WASTE MANAGEMENT IN THE SULTANATE OF OMAN

Waste management in Muscat
Waste management in the regional municipalities
Waste management in Dhofar
Recycling agricultural waste

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Waste management in the Sultanate of Oman.

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To Prof. Dr. Franz Ansprenger,
to whom I owe thanks
I can hardly express
in words

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FOREWORD

In 1995 the Sultanate of Oman celebrates the twenty-fifth anniversary of its Blessed Renaissance, which is a miracle that took the country out of the darkness of under-development, in which it had been trapped for a long time, to the light of development and modernity. The country can proudly look back to a quarter century of success and achievements in all walks of life. One of the areas to which His Majesty Sultan Qaboos, the architect of the Blessed Renaissance, has attached a great deal of importance is environmental protection, which is relevant to the topic of this book—waste management in the Sultanate of Oman. Here great success has been achieved, and preparedness for the challenges of the twenty-first century is in place.

I hope that this contribution will show how seriously environmental protection is taken in Oman and what its achievements have been in the area of waste management, which all over the world is considered one of the most important issues of environmental protection.

For the last three years, the Friedrich Ebert Foundation has been active in the GCC States, particularly in Oman in cooperation with the Muscat Municipality. The major objective during this period was to deepen and widen the relations between Arab institutions in the Gulf regions and German institutions, mainly in the field of environment. To improve our mutual understanding, it is necessary to know each other. To this end, I am pleased to briefly introduce the Foundation.

Friedrich Ebert, who was the first President of a democratic Germany, from 1919 to 1924, was the son of a shoemaker and belonged to the Social Democratic Party, which emerged as the strongest political force in Germany after the end of the First World War. Coming from a socially deprived class, Friedrich Ebert was speaking from first-hand experience when he said, "The freedom of the individual can only evolve in a public order which guarantees justice to each man and woman." And by justice he meant not only legal justice but social justice as well.

It was as his legacy that the Friedrich Ebert Stiftung was established in 1925. The Friedrich Ebert Stiftung (FES) is a non-profit, private educational and philathropic institution. It is committed to the concept and basic values of social democracy and labour welfare in Germany and worldwide. To promote the development of a humane, socially just and democratic society, particularly employment and human resources development, FES is not only engaged in Germany, but also in more than 100 countries around the world. It has offices in 74 countries, most of them developing countries. FES is funded almost completely from various public sources in Germany, meaning different federal and provincial ministries and institutions. For example, the German Foreign Ministry supports the activities of FES in other industrialized countries, and the German Federal Ministry of Economic Cooperation does the same for FES activities in developing countries.

In developing countries, FES gives assistance to governmental and non-governmental partners in the areas of labour and human resources development, science, business, education in democracy, art, environment and culture. In some countries, FES supports institutes for manpower development and the social sciences, in others, non-governmental organizations like trade unions, cooperatives or associations of small-scale industries, and again in others, mass media training institutions or civic and adult education organizations.

In this context, FES is pleased to publish this study on waste management in Oman. I would like to take this opportunity to thank Dr. Omar Osman Mohammed, whose integrity and work ethics I deeply appreciate, and whose dedication to writing this valuable study is commendable. I am sure that this book will contribute to the overall improvement of environmental protection in Oman.

Andrä Gärber
Representative
FES, Amman

PREFACE

I came upon the idea of writing about solid waste management in the Sultanate of Oman as I supervised a seminar on environmental health organized by Muscat Municipality in 1991 in cooperation with the Arab Urban Development Institute (AUDI), Riyadh, Saudi Arabia. At that time I had the opportunity of acquainting myself with solid waste management in Muscat through discussions with waste managers, visits to the landfills and studying the collection of publications I acquired on this issue. At the beginning my intention was to write a small paper about solid waste management in Muscat. However, as I began my work for Muscat Municipality as Training Consultant in April 1991, I had the opportunity of obtaining more—and more detailed—information about the subject, and this encouraged me to expand my scope to a book-length study about solid waste management in the Sultanate of Oman.

This book consists of four main parts: Waste Management in Muscat, Waste Management in the Regional Municipalities, Waste Management in Dhofar, and Recycling Agricultural Waste. On the one hand the four parts complement each other, but on the other hand each of them is an independent unit that comprehensively tackles its subject and gives recommendations on it.

Like any author of a book of such scope, I am indebted to many people, many of whom, without knowing it, encouraged and contributed to this effort. I especially want to express my gratitude to H.E. Abdullah bin Abbas, Chairman of Muscat Municipality, Mr. Hussain bin Said, Deputy Chairman of Muscat Municipality, and Mr. Hassan bin Mohammed bin Moosa, Supervisor General of Planning and Training in Muscat Municipality. Mr. Hassan has particularly enriched me with his constructive criticism and valuable suggestions, which were development-oriented. I owe him more than thanks.

I also thank Eng. Said al-Alawi, Director General for Public Health of the Ministry of Regional Municipalities and Environment, who has enabled me to make field visits to acquaint myself with solid waste

management in the regional municipalities. The many discussions I had with him on the subject were likewise very enriching.

I am indebted as well to H.E. Aqil, Chairman of Dhofar Municipality, Mr. Mohammed Amin, Technical Expert of Dhofar Municipality, who helped me to conduct field research in Dhofar. I also thank Dr. Ahmed Abdullah and Mr. David Dymond for their very useful and enriching comments on the manuscript. Besides this, Mr. Dymond corrected the manuscript linguistically.

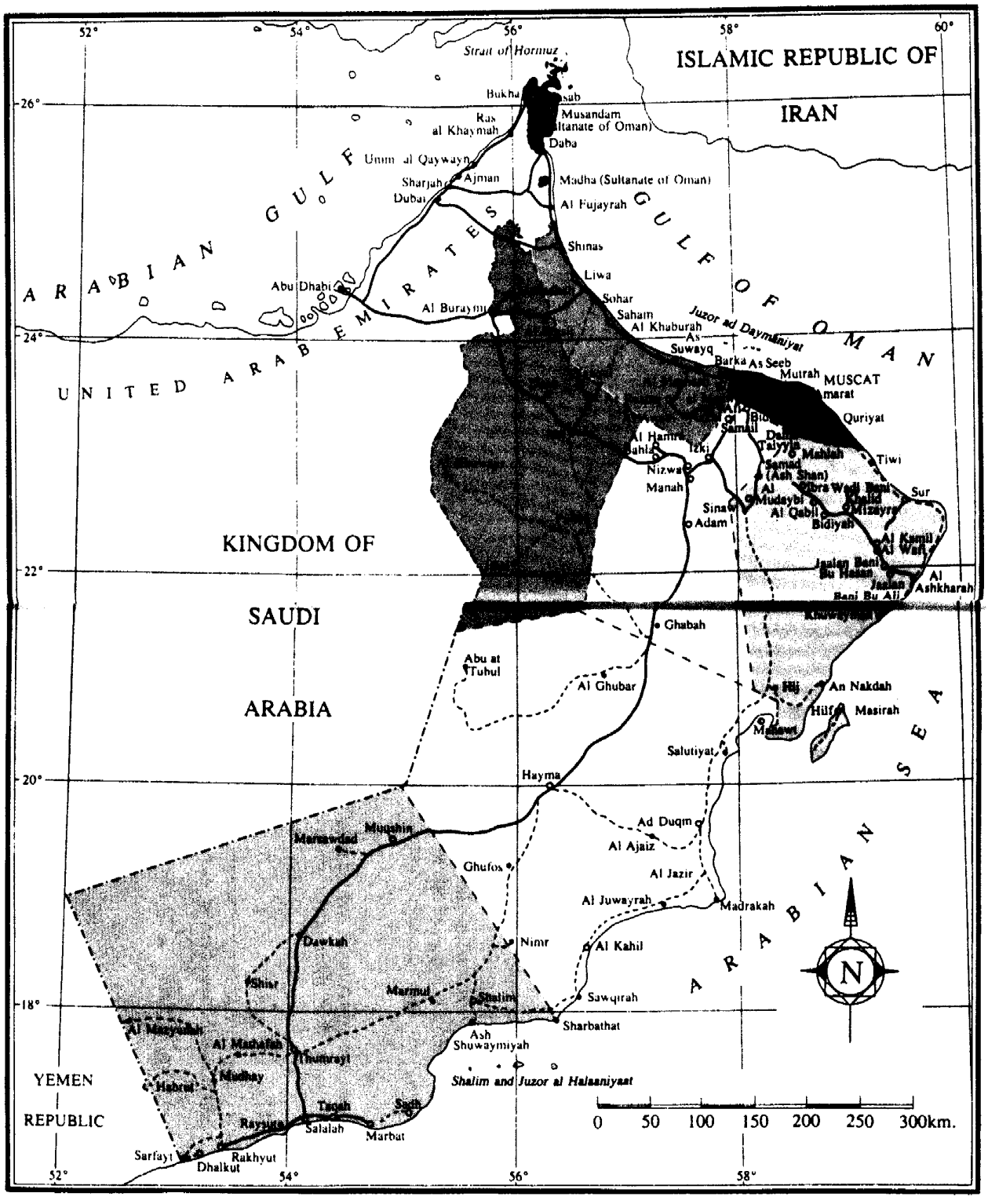
Without extending special thanks to Mrs. Kay Abbadi, this preface would be incomplete. Her very careful final editing is a great contribution, from which the book benefited much. Mrs. Lori Santrisi, who prepared the manuscript for publication, deserves my thanks as well for her unflagging attention to detail and consistency. I am also grateful to Mrs. Evelyn Abu Ayyash for her effective coordination of my contacts with Friedrich Ebert Foundation and for her useful suggestions, which enabled my work on this book to proceed in a satisfactory manner.

I owe special thanks to my wife and daughter, who always encourage me in writing what I can about Oman.

I thank Dr. Andrä Gärber, Representative of Friedrich Ebert Foundation for the Middle East and Gulf region, who arranged for the publication of this book with funds made available by the Foundation, and I thank the Foundation for its generosity. Mr. Manfred Haack, the successor of Dr. Gärber, also has my gratitude for his further support of the book and for his general encouragement.

Dr. Omar Osman Mohammed

SULTANATE OF OMAN



Produced by the Ministry of Information, September 1994

Based on National Survey Authority OR 1, edition 6 dated June 1994

This map is not an authority on international boundaries

o Wilayat

• Village / Town

Graded Road

Metalled Road

International Boundary

BACKGROUND ON OMAN*

GEOGRAPHY

A map of the Arabian peninsula rather resembles a boot with the toe pointing in a north-easterly direction. Oman, with 300,000 square kilometres of highly varied, striking terrain, occupies the south-eastern part of the peninsula, with a coastline which extends for 1,700 kilometres.

Dominated by an interior of jagged mountains called simply al-Hajr (*the Rock*), the country is a magic tapestry of different terrains. The mountains, whose king at a soaring 3,075 metres is the terraced Jabal al-Akhdar (*the green mountain*), rise straight out of the coastal plains or the seas, or soars out of the gravel plateaus and shifting dunes of the Interior.

The country ranges from the fjord-like barren majesty of the Musandam peninsula that plunges into the Strait of Hormuz in the north, to the fertile Batinah plain that inclines south-east towards Muscat, from the vast, sandy edge of the Rub' al-Khali (the Empty Quarter) through the mountains to the lush, monsoon-based, near-tropical Salalah plain in the south.

To the west Oman borders Saudi Arabia and the United Arab Emirates; to the south, Yemen; to the north the Strait of Hormuz; and to the east the Arabian Sea.

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* Extracts from *Oman '94* (Ministry of Information, 1994).

The geographical regions of Oman

Geographically, Oman can be divided into a number of distinct areas:

Muscat area
The most important features of this densely populated area are: the lovely old capital of Muscat sheltered in its picturesque bay; the larger modern port of Mutrah, which is surrounded by the old residential and trading town; and modern, busy Ruwi, which is both a commercial centre and residential extension of the capital. Beyond this, residential satellite townships and industrial estates have been spreading at a fast pace, changing the area beyond recognition for someone who has not visited Oman for a few years. Quriyat, which is situated on the coast midway between Muscat and Sur, is one of the major towns in this area.

Batinah plain
The Batinah runs from the frontier with the United Arab Emirates (UAE) for a distance of some 270 kilometres south-east almost to Muscat. It is situated between the coast and the western Hajar, varying from 10 to 30 kilometres in width. Cultivation is limited to a narrow coastal strip, seldom wider than 3 kilometres. The Batinah is one of the most populous areas of Oman. The main towns are: Barka, Masana'a, Suwayq, Khabura, Saham, Sohar, Liwa and Shinas.

Western Hajr ('Rock') mountains
Like the Batinah plain, this mountain range runs parallel to the coast from the UAE in the north to Wadi Mu'awal in the south. The highest peaks, up to 3,075 metres, lie to the south-east at Jabal al-Akhdar. There are many settlements on the Western Hajar, the most important being Rustaq, Awabi, Mu'awal and Nakhl.

The Interior (Al-Joof)
This is the central plateau that slopes from the northern base of Jabal al-Akhdar southwards to the desert. It is bounded on the west by Dhahira and on the east by Sharqiya. The area has four main valleys: Anda'm, Halfein, Bahla and Samail. The Halfein and Samail valleys together form

a natural break in the Western Hajar mountain range providing the traditional route between Muscat and the Interior. It is also one of the most populous areas of Oman, its main towns being Nizwa, Bahla, Samail, Izki, Manah, Bidbid and Adam.

Dhahira area
This is a semi-desert plain, sloping from the southern flanks of the Western Hajar into the Rub 'al-Khali (the Empty Quarter). It is bordered to the north by Yanqul, Jau and Buraimi and to the south it is divided from Oman proper by Jabal al-Koor (Deyar al-Durooa) and from the east by Deyar Bani Hinah. The major settlements are on two principal wadis, Wadi Dank and Wadi al-Ain, the towns being Dank, Ibri and Yanqul. The northern extension of the plain of Dhahira is known as Jau. In this small area between the border of the UAE and the Western Hajar, the population is concentrated around the irrigated date cultivation of Buraimi oasis.

Sharqiya area
The Sharqiya is an area of sandy plains and valleys lying on the side of the Eastern Hajar. It is bordered to the south-east by the district of Jaalan and to the south by the Wahiba Sands. The Jaalan is a sandy plain forming the southern extension of the Sharqiya and extending to the Arabian Sea. It is bordered on the northern side by the Eastern Hajar and in the south by the Wahiba Sands. The main towns are Sur, al-Qabil, Ibra, Mudairib, Samad, Mudaibi, Sinaw, Wadi Bani Khalid, al-Kamil, al-Wafi, Bilad Bani bu Hassan, Bilad Bani bu Ali, al-Ashkhara and Ras al-Hadd.

Barr al-Hekman
This is an area of approximately 650 square kilometres. Masira Island is situated to the east, separated by a channel of 14 kilometres. The Barr consists of salt flats and, on occasion, sea water covers as much as 5 kilometres of the land area. Most of the population lives on the island of Mahawt and most are fishermen.

Southern region (Dhofar)
The southern region of Oman accounts for a third of the country's total area. The coastal plain, extending from Raysut in the west past Salalah, is nowhere wider than about 8 kilometres, but the fertile alluvial soil is well watered between June and September by the monsoon. The rains also irrigate the tree-dotted hills that rise 1,500 metres above the coastal plain. To the north-west, the region's border with the Kingdom of Saudi Arabia runs through the Empty Quarter. The main towns and villages here are Salalah, Taqah, Mirbat, Sudh, Thumrait, Rakhyut, Dhalkut, Shaleem and Maqshin.

The Musandam
Separated from the rest of Oman by part of the United Arab Emirates, this is the northernmost part of the Sultanate. Its rugged mountains rise up to 1,800 metres above sea level, and the coast, which juts into the Strait of Hormuz, has a spectacular, fjord-like look. The main towns are Khasab, Bayah, Madha, Bukha, Kumzar and Lima.

The administrative regions of Oman

The Sultanate is divided into 7 planning regions, which are further divided into 59 *wilayats* (governorates), in each of which the Government is represented by a wali (governor). Muscat has its own governor with assistants in Mutrah, Seeb and Bousher, as does the Musandam, with assistants in Khasab, Bayah and Bukha. Dhofar also has its own governor and assistants.

CLIMATE

The climate varies from region to region. In the coastal areas it is hot and humid in summer. In the Interior it is hot and dry with the exception of certain higher altitude locations where it is temperate all year round. In the southern region, the climate is more benign. The country's rainfall is generally low and irregular, although heavy local rains are sometimes

experienced, with the exception of the southern region, where heavy monsoon rains regularly occur between June and September.

POPULATION

The crosscurrents of history, with its migrations and invasions, have swept Oman since time immemorial, but its people are basically of Arab origin. Omani society consists of four main categories: the people of the sea, who live by fishing, seafaring and trading; the agriculturists of the Batinah coast and the South, and those of the Interior, who employ the aflaaj system of irrigation; the mountain people of Dhofar and the Musandam; and the Bedouin of the desert areas.

The population is estimated at 2 million people.

GOVERNMENT

The administrative system of the State under His Majesty Sultan Qaboos bin Said Al Said consists of: the Diwan of the Royal Court, headed by H.E. Sayyid Saif bin Hamad bin Saud, Minister of the Diwan of the Royal Court; the Ministry of Palace Office Affairs, headed by H.E. General Ali bin Majid al-Ma'amari; the Cabinet of Ministers and Secretariat of the Cabinet; the Specialized Councils; the Governorate of Muscat; and the Majlis al-Shura.

The Cabinet of Ministers is the highest executive authority, deriving its power from His Majesty the Sultan to whom it is collectively responsible. Laws and decrees are authorized by His Majesty. International treaties, agreements and charters signed or approved by His Majesty become law from the date of their publication in the Official Gazette.

The Cabinet of Ministers consists of:

- His Highness Sayyid Thuwaini bin Shihab Al Said
  Personal Representative of His Majesty the Sultan

- His Highness Sayyid Fahr bin Taimour Al Said
  Deputy Prime Minister for Security and Defence
- His Highness Sayyid Fahd bin Mahmood Al Said
  Deputy Prime Minister for Legal Affairs
- His Excellency Qais bin Abdul Munim Al Zawawi
  Deputy Prime Minister for Financial and Economic Affairs
- His Highness Sayyid Faisal bin Ali Al Said
  Minister of National Heritage and Culture
- His Excellency Said bin Ahmed Al Shanfari
  Minister of Petroleum and Minerals
- His Excellency Hamoud bin Abdullah Al Harthi
  Minister of Justice, Awqaf and Islamic Affairs
- His Excellency Yahaya bin Mahfudh Al Manthri
  Minister of Higher Education and Vice-Chancellor of Sultan Qaboos University
- His Excellency Sayyid Badr bin Sa'oud bin Hareb
  Minister of the Interior
- His Excellency Abdul Aziz bin Mohammed Al Rowas
  Minister of Information
- His Excellency Sayyid Al Mutassim bin Hamoud Al Busaidi
  Minister of State and Governor of Muscat
- His Excellency Yousef bin Alawi bin Abdulla
  Minister of State for Foreign Affairs
- His Excellency Salim bin Abdullah Al Ghazali
  Minister of Communications

- His Excellency Ahmed bin Suwaidan Al Balushi
  Minister of Posts, Telegraphs and Telephones
- His Excellency Sheikh Mohammed bin Ali Al Qatabi
  Minister of Electricity and Water
- His Excellency Sheikh Mohammed bin Abdullah bin Zaher Al Hinai
  Minister of Agriculture and Fisheries
- His Excellency Sayyid Mussallam Al Bu Saidi
  Minister of State and Governor of Dhofar
- His Excellency Ahmed bin Abdul Nabi Macki
  Minister of Civil Service
- His Excellency Malik bin Suleiman Al Ma'amari
  Minister of Housing
- His Excellency Dr. Ali bin Mohammed bin Moosa
  Minister of Health
- His Excellency Sayyid Hamoud bin Faisal bin Said
  Secretary General to the Cabinet
- His Excellency Sheikh Amer bin Shuwain Al Hosni
  Minister of Regional Municipalities and Environment
- His Excellency Hamed bin Said Al Aufi
  Minister of Water Resources
- His Excellency Ahmed bin Mohammed Al Isae
  Minister of Social Affairs and Labour

The Secretariat of the Cabinet of Ministers is responsible for the smooth functioning of the Government machinery. One of its functions is to

ensure that Cabinet decisions are implemented within the given schedule and budget.

The Governorate of Muscat is responsible for the administration of the city. For easier administration of Oman's large land area and scattered population centres, the country has been divided into 59 *wilayats* (governorates) under the jurisdiction of the Ministry of the Interior. At the head of each *wilayat* is a wali (governor).

The office of the Deputy Prime Minister for Legal Affairs is responsible for:

- Streamlining procedures and systems for legislation and for *fatwas* for the interpretation of laws and contracts.
- Preparing and publishing volumes of laws, issued annually.
- Preparing and publishing the Official Gazette.
- Advising ministries on legal matters and drafting new legislation.

AN INTERNATIONAL OVERVIEW OF WASTE MANAGEMENT

Introduction

Pollution by waste poses one of the most critical environmental hazards today, especially in the urban areas. The production of waste is steadily increasing everywhere, to the extent that environmentalists warn of impending mountains of waste, which could cause contamination in the living world. As V.K. Dewan writes:

> In 1990, Western Europe, the USA, Canada, Japan, Australia and New Zealand produced a total of 470 million tons of household waste, 1.5 billion tons of industrial waste and 7 billion tons from activities such as energy production, agriculture, mining and sewerage disposal, or roughly 10 tons per person per year, i.e. approximately 27 kg/day.
>
> For thousands of years the human race has thrived and benefited from Earth's environment. In 1800 there were 1 billion people on the planet; the number doubled by 1975, and if the birth rate holds, the present population of 5.1 billion will double in 40 years. Proportionately waste generated will be more than double.[1]

[1] V.K. Dewan, *Making Waste Work—Recycling* (Scrapmould, Bahrain, 1991), p. 11.

In the Arab world in 1990, the population numbered about 226 million; this figure will rise to 306,889,000 in 2000 and in 2010 the figure will grow further, to reach 418,159,000.[2]

This development has implications for waste production. At present, household waste production per person is 1 kg/day. This means that the Arab world as a whole produces daily about 226,000,000 kg or 226,000 tons of household waste, with annual household waste production amounting to 82,490,000 tons. If waste production per capita remains as it is, in 2000, the Arab world will produce about 112,014,480 tons and in 2010 about 152,628,030,000 tons.[3]

In the past, before the tremendous danger inherent in waste was identified, people used to dispose of their waste in unsanitary landfills, or by burning it in the open air, with no consideration given to its negative environmental impact. This undue dumping of waste, which is still practised in some developed and many developing countries, resulted in severe environmental hazards, which were discovered only after the concerned landfills were reclaimed for other purposes. For example, in Germany, where old landfills were reclaimed and used for building purposes or as recreational sites, many of them, closed over 40 years ago, were still emitting gases and liquids which contaminate the environment, especially the groundwater. This development, which in German is called *Altlast* ("old burden"), necessitated the destruction of some buildings on the reclaimed land; also, the utilization of the unsanitary landfill sites for other purposes had to be discontinued. In

2 Muhsin A.V. Toufiq, *Al-Tanmiyat al-Mutawasila wal-Bi'a fi al-Watan al-'Arabi* (Sustainable development and the environment in the Arab world) (Tunis: Arab League Educational, Cultural and Scientific Organization [ALECSO], 1992), p. 87.

3 Ibid., pp. 88-89.

addition to this, it became imperative to reinstate the contaminated area, at very high cost.[4]

Fortunately, mankind has started to learn lessons from the damage done. Accordingly, new waste management methods and technologies are being developed which seek to take care of environmental requirements. For example, sanitary landfill has emerged as an aspect of environmental engineering. In accordance with its principles, a site should be selected to serve as a landfill only after a thorough study is carried out which shows that the site is in principle suitable. In this connection the following aspects must be considered:

- The topographical and geological nature of the site. Special attention should be paid to the porosity and permeability of the earth, which determines whether and how far liquids contained in the waste could leak to the groundwater, and whether and how far decomposition of organic materials in the waste could lead to the emission of gases such as carbon dioxide and methane, or even hydrogen sulphide and ammonia. If the gas rises to the surface, it could be released to the atmosphere, which would then be polluted. If there is a closed room near the landfill, it may become filled with inflammable gases which cannot find any outlet, creating a fire hazard.

- Avoiding establishing the landfill site upwind of a residential area.

Certain shortcomings can be eliminated by means of landfill engineering. This is done in those countries where the population density is very high and where land that can be used as landfill is scarce. To make the landfill impermeable, it is covered with a special material. In addition to this, pipes are installed in the landfill to extract any liquid effluent that

4 Karl J. Thome-Kozmiensky, "Stand und Perspektiven der Abfallentsorgung," in *Internationale Zeitschrift für Ausländische Absolventen der Technischen Universität Berlin*, No. 20/21 (September 1993), p. 25. In this article, Thome-Kozmiensky mentions that in Germany there are about 140,000 sites which are suspected of being *Altlast*.

emerges. By means of other pipes, methane can also be collected and used as fuel to generate electricity or as a fuel for incinerators.[5]

Since the early 1960s the tremendous growth in waste production and the shortage of land suitable for use as landfill have compelled the industrialized countries to emphasize waste incineration. However, this too was unsanitary because the waste gases resulting from the incineration process released chlorinated hydrocarbons and sulphur-containing compounds into the atmosphere and led to air pollution. Therefore it became imperative to equip the incineration plant with electrostatic filters and stock gas scrubbers so as to prevent the emission of anything beyond a given acceptable level of pollutants.

Although modern waste incineration plants utilize the waste heat from the incineration process to produce energy, such modern technology is very expensive. In addition, their operation requires highly qualified personnel. Hence they are still limited to highly developed and densely populated countries. However, some experts continue to reject incineration as a solution to waste management for the following reasons:

- Waste incineration cannot wholly cope with the pollutants contained in the waste. Heavy metals, e.g., lead, cadmium and mercury, and organic pollutants such as chlorinated hydrocarbons (which are highly toxic and carcinogenic) are emitted with the waste gases. Even flue gas scrubbing methods which are quite costly cannot satisfactorily eliminate all the pollutants in the gases released into the atmosphere.

- Waste incineration causes a further problem because it leads to the production of special wastes (sludge and flue dust) which again need careful disposal.

5 Kenneth Mekkanby, *Waste and Pollution: the Problem of Britain* (London: Harper Collins Publishers, 1992), p. 17. See also "Landfill Gas: Potential Source of Energy" in *Indian Express: Weekend* (14 December 1991), p. 3.

- The impact of waste incineration on consumer behaviour. Waste incineration plants are very costly but can be economical if they treat a great quantity of waste. The consumer's understanding that his waste is used to produce energy means that he has no incentive to change his behaviour. Instead of reducing the quantity of waste by consuming less and by recycling, consumers keep their conscience clean, while leaving the responsibility of dealing with the mountains of waste to the waste incineration plant.

- Waste incineration leads to the loss of raw materials and energy, since waste is actually a valuable raw material. If this raw material is incinerated, the calorific value is realized, but not all the energy which was used to produce the waste products. Waste incineration can recover only 20% of the energy contained in the waste.[6]

Another waste treatment method, which, however, is still in the process of development, is pyrolysis. This method aims at greater thermal waste utilization. The waste is burnt in a rotating heated pipe at a temperature of 400-600°C under exclusion oxygen. Whether pyrolysis is really the best solution cannot yet be said. However, it is likely to be the most expensive of the waste treatment methods. Waste may also be treated biologically or chemically; such treatments, however, are mainly concerned with special waste, which is not discussed in this study.

Finally, it should be mentioned that landfill cannot be dispensed with, whatever waste treatment is applied. Incineration, pyrolysis, chemical treatment, and biological treatment will always leave some waste that needs to be disposed of. Incineration (the most relevant waste treatment after the sanitary landfill system) does not eliminate the waste; all it does is reduce it to one third its original size and to 20% of its original weight.

6 Bund für Umwelt und Naturschutz, *Vergraben? Verbrennen? Vergessen?: Konzept für eine Umweltfreundliche Abfallwirtschaft, Arbeitskreis Abfallwirtschaft und Recycling, Bundposition* (Bonn: Bund für Umwelt und Naturschutz, 1988), p. 8.

Recent developments in waste management

Recent developments in waste management policies and strategies include the following:

1. **Avoidance and minimization of waste.** Many waste management experts are of the opinion that the industry can avoid producing a considerable proportion of waste by abandoning the exaggerated packaging methods now being practised. In addition, it is possible to use raw materials sparingly in the production process with the aim of reducing waste production. This approach is becoming more and more pertinent as the cost of raw materials continues to rise. It is also possible to develop waste-minimizing technology; a few countries have framed laws to introduce this. Waste minimization also requires changing the behaviour of consumers. Consumer environmental awareness must be heightened to the point that consumers avoid using products such as one-way bottles, as well as products with exaggerated packaging that increases waste production.

2. **Composting organic waste and recycling non-organic waste.** There are many sources that deal with composting technology. In general, it is not the technological shortcomings but the marketing difficulties which often limit waste composting. These difficulties and the possible solutions were summarized by Jon Vogler as follows:

> *Marketing of compost*
> Some municipalities have been given the idea that municipal compost is a substitute for chemical fertilizers that will be eagerly bought by local farmers at a price to give the seller a handsome profit; this is far from the truth. Compost is not a substitute for fertilizers. However, it is an excellent soil conditioner with some fertilizer value, but its weight and bulk make it expensive to transport and to spread on the fields. Farmers will only use it if it is available at low cost, close to their fields. It is therefore extremely important for any municipality that considers setting up a plant, to first research local markets for compost before equipment is considered.
>
> Sometimes, the municipal parks and gardens can use enough compost to absorb the whole production and there will be no need to sell it to farmers. In this situation, it must be clearly realized that the cost of producing good quality compost is much higher than the cost of other methods of waste disposal, such as sanitary landfill, and certainly higher than the cost of crude tipping. If no income is to be received from farmers or the public, then the municipality must be prepared to meet these extra costs as the price for having good soil in their parks, and a reduced need for space for refuse landfill. Where a city has a booming tourist trade or is seriously short of landfill sites within the city boundaries or wants to encourage tourism and/or a greener environment, these may be acceptable. This is particularly the case where the cost of transporting refuse over bad roads to landfill sites twenty or thirty kilometres outside the city will be greatly reduced. In other situations, it is not likely that any city will continue to fund an expensive operation for an indefinite time in the future just to get better roses and lawns in the parks.
>
> *The future of municipal composting*
> Provided these two matters are examined with the most careful attention, there can only be good reasons for using composting as a means of refuse disposal. Perhaps the most important argument in its favour, and it is a pity it is not easier to put a financial value to it, is that the quality of soil is one of the most important assets any country can have. Municipal composting, once the problems of technology and marketing have been overcome, offers the best possible prospect of long-term improvements and the education of

the people in the enormous long-term value of returning organic wastes to the soil.[7]

Non-organic wastes can be recycled either by reducing them once again to raw materials (industrial recycling) or by having them processed by small workshops or by craftsmen (craftsmanship recycling). While industrialized countries practice only industrial recycling, in developing countries craftsmanship recycling is the most widespread method, although industrial recycling is not excluded. In general, the recycling of waste may involve the following three stages:

- **Direct use of the waste material** for the same purposes for which it was originally made or for some other purposes. For example, old bottles and other one-way containers are used as containers for liquids (oil, water, milk, etc.).

- Many materials undergo **craftsmanship recycling** after it becomes impossible to use them directly. There are also waste objects which cannot be used directly and which undergo direct craftsmanship recycling.

- **Industrial recycling.** Some waste objects undergo direct use, then craftsmanship recycling and finally industrial recycling, as there are waste objects that cannot be used for anything other than industrial recycling.

In general, recycling in developing countries takes a longer route than it does in industrialized countries, and accordingly the lifetime of a recyclable waste object is prolonged **(figure I)**.

Although it is possible in principle to recycle almost 80-90% of waste objects, the percentage of waste actually recycled seems to be very low, especially in the industrialized and oil-rich countries. This is due to the

[7] Jon Vogler, *Work from Waste: Recycling Wastes to Create Employment* (Intermediate Technology Publications and Oxfam, Great Britain, 1983), pp. 227-228.

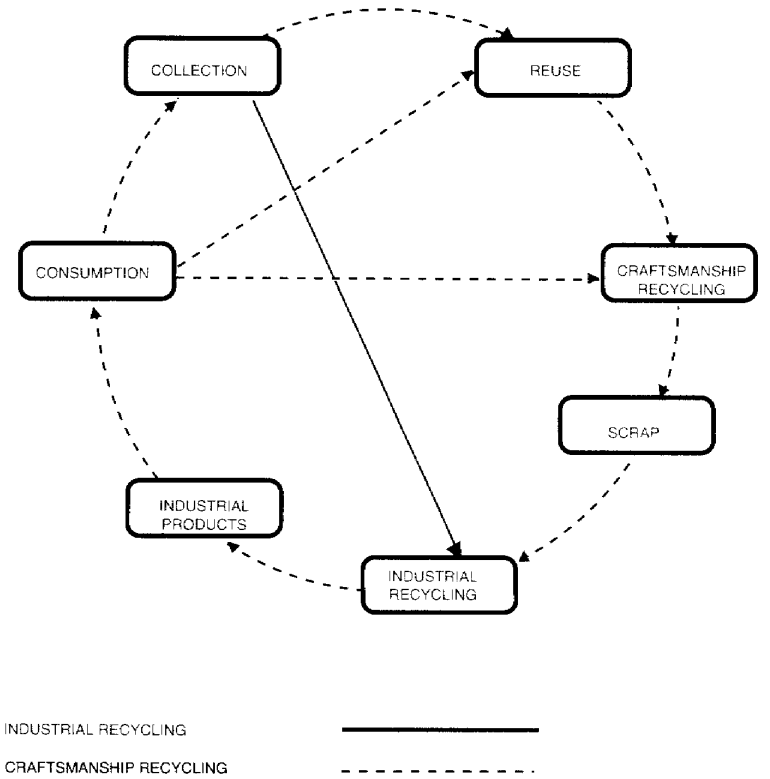


Figure I. The stages of waste recycling

Developed from Jürgen Grothues, *Aladdin Neue Lampe. Recycling in der Dritten Welt* (Munich: Trickester Verlag, 1988), p. 99.

fact that the cost of primary raw materials is comparatively low, so that industries do not think of resorting to recycling.

3. **Waste disposal.** This step includes all methods used to get rid of waste in an environmentally sound way.

The relative merits of the various waste management policies

The above-described waste management policies are relatively new, and their application is limited to certain industrialized countries which decided to undertake decisive steps to cope with the waste problem. However, disposal—especially landfill—is still the most common method even in those countries which have decided to tackle the waste problem in a better way. In many industrialized countries, sanitary waste incineration has started to compete with landfill, and in the developing countries landfill is commonly the only waste disposal method used. It is worth considering whether waste management has entered a vicious circle from which it cannot escape or whether there is a way out of this dilemma. Experts believe that a solution cannot emerge except by transition from waste disposal to a method that subjects waste management to intensive economic consideration with a view to the following:

- The costs of waste management can be minimized by improving the efficiency and performance of the concerned administrative and technical personnel.

- The recycling and composting of waste can be achieved in a better and more economical way by separate waste collection in different-type containers. This method is followed at present in many industrialized countries where the municipality or whatever institution is in charge of waste management provides different containers for each type of waste. However, it is impossible to have a separate container for every single type of waste. At present only those waste types which form a considerable percentage of the overall waste generated are collected separately, such as paper, organic waste, glass and plastic, which together

form 80-90% of domestic waste. The special waste in domestic waste (such as used batteries, expired medicine, glass, paint, etc.) is collected separately, not necessarily in order to recycle it but to prevent contamination of the organic waste meant for composting.

- Wherever there is no separate collection, waste has to be sorted, which costs time, effort and money. In addition the quality of the sorted waste objects may be inferior to that of those collected separately because there may be spoilage by other wastes. For example, waste paper may be spoiled by ashes, liquids, etc., found in the container. This can affect the quality or can even render such waste unsuitable for recycling.

- Waste avoidance is the ideal solution because it hinders the emergence of a waste problem at all. However, it can only be partially achieved and at best contributes to minimizing the waste problem.

Waste management in Germany

In general, no city follows only one method to solve its waste problems. Cities which have well-developed waste management systems diversify their strategy for dealing with waste problems. They enact laws and local orders for waste avoidance at the same time that they strive to enhance the efficiency and effectiveness of waste disposal with the aim of reducing costs and protecting the environment. They also undertake all possible steps to recycle and compost waste in order to minimize the quantity of waste to be dumped or incinerated. To illustrate a waste management system based upon **waste avoidance**, we take the German experience as an example which is summarized as follows:[8]

[8] The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, *Umweltpolitik, Guidelines on Anticipatory Environmental Protection; Guidelines of the Federal Government on Anticipatory Environmental Protection through the Avoidance and Gradual Reduction of Noxious Substances.* See also the Waste Avoidance and Waste Management Act of 27 August 1986. On the basis of this law, several laws and regulations were enacted which deal with specific types of packaging waste.

The German Federal Government considers the annual accumulation of over 100 million tons of industrial waste and around 30 million tons of household refuse in the Federal Republic of Germany to be one of the central problems of environmental protection. The 4th Amendment to the Waste Disposal Act presented by the Federal Government and approved by the *Bundestag* on 18 June 1986 prepares the ground for a movement away from waste disposal of the traditional type towards waste management.

The Waste Disposal Act in force hitherto is primarily responsible for regulating the treatment and storage of waste in a manner which is as conducive to environmental protection as possible; to date the Act has contained no provision stipulating that the production of waste must be avoided as far as possible and unavoidable waste be recycled to obtain useful materials and energy. Modern waste management is particularly designed to avoid or recycle waste containing noxious substances.

The new Waste Avoidance and Waste Management Act legally embodies these aspects and does justice to the anticipatory protection principle since all possibilities are to be used to minimize environmental damage through the depositing of waste.

In an effort to avoid or reduce waste containing noxious substances the Federal Government deems it necessary to label certain products in order to guarantee that they are returned and thus managed correctly. Waste with a high pollutant content must be disposed of separately. In accordance with the authority contained in Article 14, paragraph 1 of the Waste Avoidance and Waste Management Act, statutory ordinances can be used to determine that products containing noxious substances may only be introduced onto the market under certain conditions (mandatory deposit and acceptance of returned goods, guaranteed disposal).

In order to avoid and reduce the quantity of waste, the Federal Government will stipulate objectives which are to be drawn up in cooperation with those involved. If these objectives are not reached within an appropriate period of time, suitable measures are to be taken on the basis of statutory ordinances. This applies particularly to packagings and containers for which the duty to label, mandatory deposit and acceptance of returned goods, etc. can be prescribed by the legislator to ensure environmentally compatible management or recycling after use.

Waste recycling is to have priority over the traditional form of waste disposal insofar as technically possible and economically justifiable. The rules on the recycling of substances contained in the new Waste Avoidance and Waste Management Act apply in particular to the separate collection of useful components of household refuse (e.g. glass, paper, metals).

In order to guarantee innocuous disposal of waste, the Federal Government is working on the draft of Technical Instructions on Waste Management. As for the area of air pollution control (Technical Instructions on Air Pollution Control) and noise abatement (Technical Instructions on Noise Abatement), Technical Instructions are to be laid down for waste disposal according to uniform standards (Technical Instructions on Waste Management). These requirements must be orientated to the best available technological means.

The Technical Instructions on Waste Management must reflect the principle of anticipatory environmental protection and minimize the risks of waste disposal. The quality of disposal must be increased. Waste is to be treated, stored and deposited using technically advanced and economically justifiable methods. The conditions governing the licensing of the erection and operation of waste treatment and disposal facilities and their monitoring are to be standardized. This will, at the same time, create equal competitive conditions for waste disposal companies.

The Federal Government pursues the objective of putting an end to waste disposal at sea at the earliest point before the end of this decade. Besides national legislation, the decisive instruments to achieve this objective are the Oslo and London Conventions. It is also intended to phase out the incineration of industrial waste at sea as soon as comparable environmentally sound disposal facilities exist on land. The Conference of Environmental Ministers (UMK) called upon the Länder Working Party on Waste to present a concept by spring 1987.

Priority is clearly given to land waste disposal at a national level, i.e., in German legislation on the Oslo and London Conventions. Low-pollution production processes aimed at avoiding the production of waste and at recycling waste and residual materials within the sense of the anticipatory protection principle play an important role here.

The Federal Government thus welcomes the draft of an EC Directive on the restriction of dumping waste at sea; this draft may result in accelerating similar measures in member States. The Federal Government will support efforts to ensure that disposal on land and the principle of anticipatory protection are given priority in the new EC Directive.

The Federal Government considers the treatment of existing waste deposits to be an important and urgent task of environmental protection. Priority must be given to the treatment of acute existing waste deposits which represent a danger to the health and life of human beings. This must then be followed by the vigorous treatment of other existing waste deposits.

The Länder are responsible for treating existing waste deposits. The Federal Government gives its support to the Länder through the extensive promotion of research and development projects to compile data on, assess and treat existing waste deposits and through the granting of low-interest loans within the framework of

the Urban Development Assistance Act. Parallel to these activities, the Federal Government is cooperating with the Länder on standardized criteria to compile data on, assess and treat existing waste deposits.

In addition to these measures, the monitoring of waste deposits as stipulated in the Waste Avoidance and Waste Management Act will be extended to encompass those waste deposits which were created before the implementation of the Waste Disposal Act in 1972. This extended monitoring is intended to contribute to the scheduled compilation of data on, and the assessment of existing waste deposits.

In an attempt to solve environmental problems associated with waste oil containing PCB, waste oils will in future undergo general monitoring—irrespective of whether they constitute waste or useful materials—according to the regulations of waste disposal law. The new law will stimulate recycling to release useful energy or substances.

Since new legal regulations alone will not lead to the solution of existing problems, the Federal Government has maintained constant dialogue with the mineral oil industry and the waste disposal industry in an attempt to find solutions which will be applied at an early stage in production. These include dispensing with high chlorine content in mineral oil products. A marked reduction in additives of this kind is noticeable in metal-working oils today. The initial guide values proposed by the Federal Government for PCB in waste oil are observed today and in some cases values are even found to be well below these levels.

Now as ever, it is all important that waste oils of economic value—combustion engine and transmission oils—be accumulated separately at collection points and, during processing, not mixed with dangerous substances which would then reappear in new products thus jeopardizing the chances of their being sold.

Considerable progress has since been made in this connection in the filling-station and car trade as well as waste oil collecting and processing activities.

The implementation of the measures contained in the new Waste Avoidance and Waste Management Act will be one of the prime activities in the main area of emphasis "Waste Management" in the coming years. These measures include reduction of the quantity of waste, recycling and utilization of waste components, and elaboration of Technical Instructions on Waste Disposal. The Federal Government supports the Länder in the treatment of existing waste deposits through research and development projects.

The success of waste management is measured by:

1. The successful introduction of improved performance in each method. Regarding landfill, special attention must be paid to the transition from crude dumping to sanitary landfill. Besides environmental protection, cost effectiveness must be taken into consideration. In the case of recycling special attention has to be given to separate collection and effective sorting, as well as to improving the quality of products from waste.

Figure II shows the various possibilities which exist to recycle waste, whereby many recyclable items are reintegrated into the natural environment or reintroduced into their original life cycle once again. In addition to protecting the environment, the integrated waste management system reduces the waste management costs which the municipality has to bear by reducing the quantity of waste to be collected, transported and disposed of by the municipality. Another advantage of the integrated waste management system is the creation of new jobs.

All in all, the integrated waste management system, as shown in figure II, aims not only at finding a sustainable solution for waste, but also at integrating the waste management system into the overall economic development process in a way that helps achieve sustainable development.

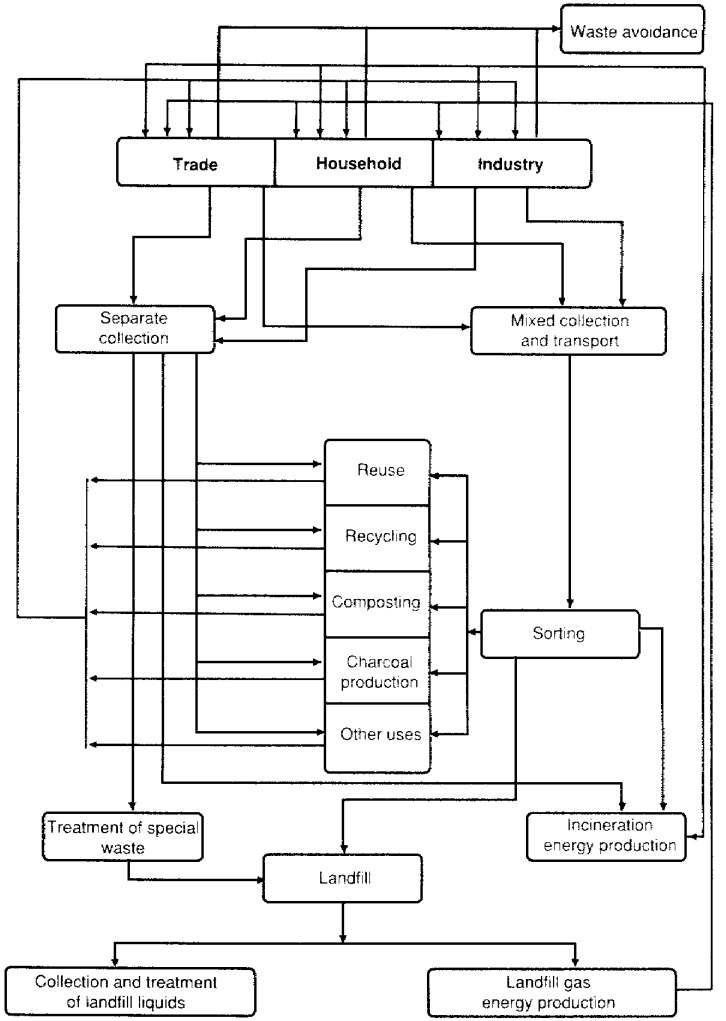


Figure II. An integrated waste management system

2. Scaling down the use of one particular method in favour of another which is better (for example, reducing waste dumping in favour of recycling and composting, or reducing recycling and composting in favour of waste avoidance). However, such a transition should be undertaken only after carrying out a feasibility study which shows that the transition is beneficial both environmentally and economically. The transition itself should not be understood as irreversible, but as a step which can be withdrawn if it proves to be unsuitable.

In general it is better to follow an integrated waste management system as illustrated in **figure II**.

WASTE MANAGEMENT IN MUSCAT

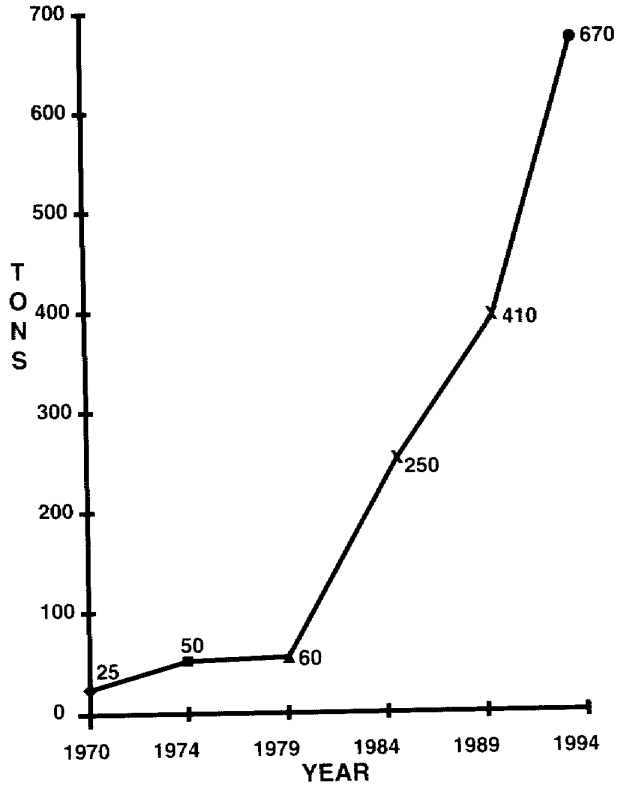


Figure III. Development of waste production in Muscat

Since 1970 household waste production per person per day, as well as total production, has witnessed continuous growth in Muscat. Daily per capita production stablized in 1989/1990 at 1 to 1.2 kg. Since then no increase or decrease has occurred. However, total production continued to grow because of continuous population increase. Further growth of total waste production can be slowed down or hindered only by reversing household waste production per person per day. Such a step could even lead to reducing total waste production. Because of this, many Western countries have embarked upon comprehensive waste avoidance strategies with the aim of reducing both total waste production and waste production per person.

Relevant issues for waste management in Muscat

On the basis of the discussion on waste management in the international arena detailed in the previous chapter, we now turn to the subject of waste management in Muscat to consider the following:

- How far do the experiences of Muscat comply with the previously mentioned modern waste management strategy?

- How far is it possible to monitor waste management in Muscat on the basis of modern waste management strategy?

- What are the particularities of the waste management system in Muscat? In this connection it should be considered that waste management is a management system that is influenced and determined by local conditions.

- How far is it possible to develop the waste management system in a way that integrates the modern with the traditional experiences of the city in this field? Perhaps what is required here is adapting and "nativizing" the modern waste management system to suit local conditions and simultaneously modernizing the traditional waste management system. Such an integration would doubtless guarantee sustainability. In this respect many cities in developing countries adopted waste management systems developed by foreign experts who did not take into consideration the particularities of the local conditions, especially the waste management system in practice. The result was that the new system was either ignored (not applied), or applied but with a resulting emergence of new problems. To avoid this kind of mistake it is necessary first of all to set about reforming waste management within the overall development of the city. Population growth and urban and economic development lead to increased production, imports and consumption and accordingly to an increase in the waste which these produce. In addition, the waste produced becomes more diversified; new waste components appear, some of which are hazardous or toxic.

If we look at Muscat and its development, we see that the population growth, economic development and industrialization since 1970 have resulted in both the increase and diversification of waste. In 1970 the population of the city was about 40,000 to 56,000, and the production of waste was limited. Municipal workers took care of street-cleaning and waste collection, using locally made hand-brooms of palm. The waste containers were made either from palm leaves or old barrels. The transport used was either wheelbarrows or animal carts.

The disposal method practised was crude dumping or open-air burning (in Arabic, *al-harq al-makshuf*), with no consideration of the environmental impact.[9] However, the detrimental environmental and health effects of crude dumping and open-air burning were limited because the quantity of waste to be disposed was very small; likewise it was void of any special waste and consisted almost exclusively of organic materials. The necessary street-cleaning and waste management work at that time was very limited.

As of 1970 the situation started to change drastically. The city, as was the case in other parts of the Sultanate, witnessed tremendous economic development including industrialization, urban sprawl, commercial activities, etc. This unprecedented development, which is known in Oman as the "Blessed Renaissance" (*al-Nahda al-Mubaraka*), started as

[9] In its third issue of 1992, the quarterly magazine *Muscat*, which is issued by Muscat Municipality, published a fascinating interview with Malik bin Ibrahim al-Sity, who has been employed by Muscat Municipality since 1945 as a sanitary-in-charge. He was responsible for supervising cleaning activities in the city. He mentions that in the past women were employed in cleaning the streets of the city. Part of their work involved bringing the waste to collection points in Muscat and Mutrah. Young boys 12 to 16 years of age were charged with the task of transporting the waste, which was either thrown in the sea or burnt. The collected waste, which was very small in amount, was put into baskets and carried by donkey to the dumping area. Thirty donkeys were employed in transporting the waste. At the end of the workday, they were taken to a certain camp where they were fed by an employee who was responsible for taking care of the donkeys and who stayed at the camp. In the early 1950s the first waste vehicle was imported—a three-wheeled vehicle that the operator could drive only while standing.

His Majesty Sultan Qaboos assumed political power in the country. His determination to develop the country in a very sound way fortunately coincided with the oil boom that endowed the country with a wealth that could translate the development philosophy of His Majesty Sultan Qaboos into a reality of which every Omani can be proud today.

Within a few years the face of the city changed drastically. The urban area expanded from 15 to about 4,000 square kilometres (1.3% of the area of the Sultanate). This was accompanied by wide-ranging economic development. The population started to grow rapidly due to urbanization and to the incoming labour force which was attracted by the prosperity in the city. In 1988 the population had grown over sevenfold to about 405,000 from only 56,000 in 1970 **(table 1)**.

Table 1. Population growth in Muscat, 1970-1993

Year	Population
1970	56,000
1977	63,000
1979	89,000
1981	230,000
1984	256,000
1989	405,000
1993	492,000

Source: Manfred Scheu, *Assessment Study on Municipal Solid Waste Management in Muscat* (Wetter, Germany: Kaltwasser-Engineering, May 1993), p. 6.

To manage the city better, administrative decentralization was introduced according to which the city was divided into five geo-administrative areas (sub-municipalities). Each sub-municipality became a directorate (in Arabic, *mudiria*, plural *mudiriat*) with a Director General as its top administrator. **Table 2** shows the growth of population in the various mudiriat.

Population density differs in the various mudiriat. Al-Amerat, which has the largest area of the mudiriat, has a low population density, while Greater Mutrah, which is the smallest mudiria, has the highest population

Table 2. Population growth in the various mudiriat of Muscat

Mudiriat	Population, 1989	Growth rate* *(percentage)*	Population, 1993
Greater Mutrah	156,180	2	169,000
Bousher	102,180	7	134,000
Seeb	103,480	7	136,000
Al-Amerat	23,230	7	30,000
Quriyat	19,000	4	23,000

Source: Manfred Scheu, *Assessment Study on Municipal Solid Waste Management in Muscat* (Wetter, Germany: Kaltwasser-Engineering, May 1993), p. 6.

* Estimated growth rate.

density. Unfortunately, population density figures for the various mudiriat are not available.[10]

[10] Population density has a great impact upon waste collection and transport. In this respect, a study carried out by Muscat Municipality in October/November 1983 showed the following:

- In the Ruwi commercial area of Greater Mutrah, where the population and commercial density is very high, a waste vehicle (Kuka) could collect 9 tons of waste after having covered only 5 km.
- In Nasi-Moja, where the population density is very high, a waste vehicle (Nissan) could collect 2 tons of waste after having completed only 2 km of its route.
- In al-Amerat, where the population density is very low, a waste vehicle (Kuka) needed to cover 25 km in order to collect 3.7 tons of waste.
- In Seeb, with a very low population density, a waste vehicle (Kuka) needed to cover 47 km in order to collect 7 tons of waste.

Such points have implications for the planning of waste collection and transport.

During this rapid development phase, several factories and commercial centres were established and new residential areas were developed. The commodities and goods available in the market (whether foodstuffs or other) became more diversified, resulting in a tremendous increase in the quantity of waste produced daily by the city.

A special factor contributing to the increase of waste production in the city is the fact that the Sultanate imports large quantities of foodstuffs and other consumer goods and commodities. In general, these goods are packaged in an exaggerated way, leaving behind great quantities of waste, a phenomenon prevalent all over the world, particularly in the industrialized nations. Goods and commodities meant for export are packaged even more extravagantly than those for internal consumption (allegedly for security), thereby contributing even more waste than other commodities and goods.

Most of the imported goods are packed in cartons, i.e., wooden and plastic boxes. These low-weight cartons are hollow and bulky and do not fully collapse, so that waste containers quickly become full without having absorbed their capacity in terms of weight.

Besides the general increase in waste production, a variety of types of waste appeared, e.g., industrial waste, construction rubble, old vehicles, tyres, plastic bags, beverage cans, etc.

At present the daily per capita production of household waste in Muscat is about 1 kg. Thus, the quantity of household waste produced daily in the city is about 500,000 kg (500 tons). The composition of waste has not yet been comprehensively studied. However, a survey carried out by Manfred Scheu in May in al-Ghubra al-Shamalia seems to be representative. **Table 3** shows the results of his survey.

Table 3. Refuse composition in al-Ghubra al-Shamalia

COMPOSITION	Wet weight (in kg)	Percentage of wet weight
Vegetable, above 50 mm	27.1	15.2
Vegetable, 10-50 mm	43.6[a]	24.4
Vegetable, below 10 mm	15.0[b]	8.4
Total vegetable	**85.7**	**48.0**
Paper, cartons	31.2	17.5
Glass	17.7	9.9
Ferrous metal	9.0	5.0
Aluminium	1.1	0.6
Plastic, soft (bags, etc.)	9.3	5.2
Plastic, hard (bottles, etc.)	6.8	3.8
Leather, rubber	0.1	0.0
Bones, meat and fish, above 10 mm	3.3	1.8
Textiles	1.7	1.0
Ceramics and stones, above 10 mm	1.1[c]	0.6
Baby nappies	11.8	6.6
Wood, above 50 mm	0.0	0.0
Inert screenings, below 10 mm	b	b
TOTAL	178.7[d]	100

Source: Manfred Scheu, *Assessment Study on Municipal Solid Waste Management in Muscat* (Wetter, Germany: Kaltwasser-Engineering, May 1993), p. 8.

a The waste sample contained some grass cuttings. Although this fraction should pass through the 10/10 mm sieve a complete sieving proved impossible. Therefore some of the vegetative fraction 10-50 mm consists of particles < 10 mm.

b The fraction < 10 mm contains vegetable material, some grass cutting and inert screenings. The inert fraction was not visible and is certainly below 10%.

c Only ceramics were observed in the sample.

d The difference in weight between the sample at source and after the analysis is about five kilograms. This seems reasonable because some moisture losses have to be expected during transport and segregation (time period between sampling and completion of the analysis about three hours, outside temperature about 40°C, sample transported in a compactor truck and removed gradually for analysis).

Waste management development since 1970

1. General strategy

There are no documents or other written materials on how waste management was traditionally practised in Muscat. However, many people who were involved in the traditional waste management system are alive, and some of them are still active in the waste management system of Muscat. We made use of this opportunity to carry out intensive discussions with them which enabled us to gain insights into the waste management system in place before 1970.

To cope with the new challenges, the city did not resort to contracting foreign companies concerned with waste management, as did the other capitals and large cities in the Gulf States such as Riyadh and Jeddah in Saudi Arabia, Doha in Qatar, and Kuwait. Oman followed a self-reliant path, by refining the long-existing system. In addition, it strove to become acquainted with new developments in the management of solid waste by sending its waste managers abroad to be trained. In this way, development of the long-existing system was combined with technology transfer. Here a positive interaction between the two emerged, leading to a considerably improved waste management system. The innovations underwent a self-adjusting process based on continuity, without which new, previously unknown disorders would have appeared. Modern vehicles and other equipment (which became indispensable) were introduced. Waste collection points (to which people had to bring their waste) were established in a balanced way in all quarters of the city. Open-air burning of waste was abolished in favour of a gradually introduced sanitary landfill system. The waste management system, which had previously operated without concrete rules and regulations, became a section of the Directorate of Public Health in each mudiria and was given a suitable managerial structure as well as rules and regulations. The development of waste management in Muscat also involved practical training of the staff of other cities in the Sultanate working in this field.

2. The legal framework for waste management

The Sultanate of Oman has not yet enacted a comprehensive waste management law. A draft exists, however, and it may soon be enacted. The absence of such legislation seems to be a common phenomenon for all developing countries: there is apparently no Arab country which has legislation of this kind. Even in the industrialized countries, waste management legislation has been enacted only in recent years, and some such countries have not yet enacted such laws (however, this does not mean that the issue has been ignored).

The Sultanate was the first Arab country to have a Ministry of Environment (now the Ministry for Regional Municipalities and Environment). In 1972 the Ministry of Environment issued Royal Decree No. 10, which dealt with environmental protection and pollution control. According to this Decree, it is prohibited for any person or governmental or non-governmental body, or any other source or workplace to use the Omani environment to dispose of pollutants, etc.

In general, waste management orders are issued by the municipalities; these are known as local orders (*awamir mahaliyah*). In Muscat, Local Order No. 2, Chapter 7 deals with waste management. The provisions contained in the local order are:

- Any owner or inhabitant of a building has to clean it regularly, including the outer parts. The owner of a building of several floors should appoint someone to clean it, including the outside of it.

- Owners of a business or industrial establishment as well as homeowners should arrange for collection of their solid waste in accordance with the procedure determined by the local authority.

- The public health authority of the municipality earmarks the places to be used for burning solid waste, and incineration should be carried out in accordance with the method prescribed by the health authority. The place where waste is burnt should be far from residential areas.

- Anyone who dumps waste or leaves waste in places other than those earmarked for such a purpose should comply with the warning he receives from the Municipality and remove the waste within the allotted period of time.

- No one is allowed to put dirty liquids or nightsoil in the places or containers which the health authority has earmarked for garbage collection.

- No one is allowed to put the carcass of any animal in the container earmarked for waste collection or in any other place near residential areas.

- No one is to defecate or urinate in any street or public place, near buildings, on the beach or on the mountains in the city.

- No one is allowed to keep droppings (dung), except if stored in a suitable way which hinders the breeding of flies.

- The health authority decides where the pens (enclosures) of animals for slaughtering should be established. It is forbidden to keep these animals in other places.

- No one is allowed to keep in his house waste that would provide a suitable breeding ground for flies and other harmful insects.

- The health authority is allowed to enter any building that is considered a source of insects and rodents and to take all to necessary steps to exterminate the pests.

In 1977, the above-mentioned order was replaced by Local Order No. 5. Chapter 5 of this law dealt with waste management in a more specific way. It emphasized the necessity of stopping the open burning of waste and of introducing a sanitary landfill system, but did not state how this should be done or give the conditions to be met.

In addition to the above-mentioned provisions, Local Order No. 5 dealt with several other matters regarding public health that are related to waste management, showing that waste management was first conceived of as a public health issue. This traditional view (which prevails in all third-world countries) is correct; however, it is not comprehensive and does not cover the environmental and economic aspects of waste management which are today determining factors in laws regarding waste management. However, Local Order No. 5 did not completely ignore the environmental aspects. It states that the Municipality decides the waste disposal method to be followed. This loose definition of responsibility is appropriate where there are no concrete concepts regarding implementation, and gives the implementing institution the opportunity to look for the right method instead of binding it with obscure and vague instructions. Charging the Municipality with the task of looking for the right waste disposal method is a challenge. It requires innovation and flexibility, which includes learning new technical and managerial methods which are then adapted as appropriate for the task at hand, so as to modernize the existing waste management method. This existing method, however, is not altered so radically that it becomes inapplicable.

In reality, the Muscat Municipality has dealt with this challenge in an innovative way, taking adequate account of the local conditions. In this regard special attention was paid to adjusting resource utilization to meeting the needs of waste management. The accumulated experience of the last 21 years is described below and can be considered a success upon which further waste management development can be based.

3. The administration of waste collection and transport

Waste management in Muscat is organized on the basis of a decentralized geo-administrative dividing of the city into five sub-municipalities of Mutrah al-Kubra, Bousher, al-Seeb, al-Amerat and Quriyat. The general administrative organization of the Municipality, including that for waste management, is divided into five sub-municipalities officially known as Directorates General. These sub-municipalities are under the administrative control of the Office of the Chairman of the Muscat

Municipality, which in turn is under the Minister of the Palace. In addition to the sub-municipalities, the Muscat Municipality also comprises the Directorate General for Administrative and Financial Affairs, the Directorate General for Technical Affairs, and the Directorate General for Transport. These three Directorates deal mainly with those matters which should be handled centrally. With respect to the Directorate of Public Health, to which waste management belongs, there is at the central level (in the Office of the Chairman) a General Supervisor, neither the duties and responsibilities nor the authority of whom is clearly defined. The directorates of public health in the sub-municipalities are directly under the Director General of the sub-municipality, with the General Supervisor having no authority over them. This official advises the Office of the Chairman on matters related to public health.

The Directorate of Public Health in each sub-municipality is divided into the following sections:

- Foodstuff Inspection
- Pest Control
- Waste Management, officially called the Section for Public Cleansing.

Waste Management is the largest of all the sections due to its wide-ranging daily activities such as street-cleaning and the collection, transport and disposal of waste in landfills. Recycling of inorganic waste is practised in a very rudimentary way. A composting plant had to be closed down within a few months of its becoming operational because of the resulting foul odours. Not only was it a nuisance to those living nearby, but the compost produced was not of good quality and could not find a market. Nevertheless, there are good prospects in the city for both recycling inorganic waste and composting organic waste.

The Head of Section for Waste Management is responsible for the overall management of the operations of street-cleaning, collection and transport of waste and the appropriate disposal of waste in the landfills. In general each sub-municipality is divided into waste management zones. A

supervisor, who reports directly to the Head of Section, takes care of the operations in each zone. He controls the street-cleaning and waste collection activities and maintains direct contact with the Head of Section by means of a walkie-talkie, which he has to carry whenever he is in the field.

The Head of Section holds regular meetings with the supervisor to discuss day-to-day problems. According to our observations, the discussions deal for the most part with minute matters such as lack of gasoline, sickness, sick leave for a worker, etc. Not dealt with are strategic issues such as how to improve efficiency and effectiveness or how the cooperation of citizens could be won or whether a better alternative to the existing system can be found. There are several reasons for this, in particular that the daily workload is so heavy that it does not leave the waste managers any time to reflect upon their work and evaluate their performance. They are rather happy if they can manage to cope with their daily routine work. This problem seems to be common all over the world.

In this respect Rushbrook and Finny write that:

> The preparation of a waste management plan to provide the foundation for an efficient collection and disposal service is frequently neglected. Senior and middle ranking staff in waste management organizations are full-time staff responsible for forward planning. Without such staff, with sufficient time to carry out their duties, it is almost impossible for an organization to assess the effectiveness and economics of current operations; analyse the options available to improve existing collection and disposal practices; design future collection services and disposal facilities; plan the smooth change-over from one collection method or disposal facility to another; and identify the staff training needs and legislative requirements to maintain efficient waste management.[11]

A very important point in the waste management system of Muscat is the fact that the vehicles, equipment and drivers are not administered by the waste management section or even by the Directorate of Public Health but by the Directorate General for Transport, which also repairs the vehicles and equipment. The Directorate General for Transport has one official in each sub-municipality who is responsible for the distribution and management of the vehicles and equipment. Such dual management sometimes creates problems. The Directorate General for Transport considers the transport needs of waste management to be within the framework of the overall transport needs of the Municipality for which it is responsible. Waste managers with whom we discussed this issue complained that the representative of the Directorate General for Transport in the waste management section does not consider himself a waste manager but simply a person whose task consists of controlling the use of the vehicles of the transport management section.

To have a single directorate general for transport for the whole Municipality seems, as far as we can tell, a wise managerial decision. This gives the city a well-manned institution with a well-equipped workshop which can benefit from economies of scale. The management of the waste transport vehicles by this directorate general is justified. However, the transport needs of the waste management section should be considered in accordance with the special work it performs. In addition, the representative of the Directorate General for Transport should be integrated within the section and should see himself as a waste manager.

[11] P.E. Rushbrook and E.E. Finny, "Planning for Future Waste Management Operations in Developing Countries" in *Waste Management and Research*, Journal of the International Solid Wastes and Public Cleansing Association (London) 6, No. 1 (1988), p. 11.

4. Methods of waste collection and transport

In all developing countries one observes that a considerable percentage of the municipal budget (25-35%) is spent on waste management and that the greatest percentage of the waste management budget (80-90%) is spent on waste collection and transport.[12] Increases in the waste management budget often become necessary, due to inefficiency in the waste collection and transport system. Thus, waste management economists pay a great deal of attention to these aspects.

In general, waste collection and transport require appropriate planning, implementation and supervision, since they require the provision of containers, vehicles and other facilities.

Street-cleaning is carried out manually or mechanically. Mechanical cleaning requires special vacuum sweepers. These vehicles may be equipped with a pipe that sprays water on the street before sweeping and sucking in order to avoid dispersal of dust and to wash the street. The sweeping is done by a thick, automatically rotating brush which leads the collected waste to the vacuum pipe to be sucked into a container on the vehicle. Manual cleaning uses hand-besom shovels and wheelbarrows.

There are various methods for collecting and transporting waste:

While the municipality takes care of street-cleaning and household waste collection and transport, for which people pay no fees, industries and large commercial establishments have to bring their waste to the landfills using their own or hired vehicles. Although special waste should be treated and disposed of separately in an appropriate manner, there is no exact classification and codification of the different types of waste. Hence it cannot be ruled out that special waste goes to the landfills along with domestic waste.

12 Werner Klinger, *Die Rolle des informellen Sektors bei der Abfallbeseitigung in städtischen Regionen von Entwicklungsländern* (Hannover: Institut für Architektur und Planungstheorie der Universität Hannover, April 1988), p. 42.

People bring their waste directly to the landfill. However, this method is used only in certain very remote, small areas and is on its way to disappearing. In fact, only industries and large commercial establishments which produce great quantities of waste can economically afford to transport their waste directly to the landfill site. This cannot apply to households because the quantity of waste produced by each household is small and does not justify its being brought directly to the landfill, especially in cities such as Muscat, where the landfills and waste treatment plants are generally far from the city (perhaps 20-25 km).

Collection technologies

There are three methods of collecting waste. Choosing among them should be done only after comparing their relative advantages and disadvantages. More than one method may be employed if it becomes apparent that the different zones of the city require the application of different methods. Bernd Kaltwasser writes about the three collection methods for solid domestic waste:

Waste collection in Sur al-Lawaliah in Greater Mutrah

(1) Households themselves are responsible for getting their waste to collection facilities. This is the cheapest method.

(2) Kerbside collection: the households are responsible for putting their solid waste at the kerbside; further steps are done by municipal (or private) workers. Since the solid waste has to be picked up at each house, this is a more costly method.

(3) Door-to-door collection: households are responsible for solid waste only inside their home. Municipal or private workers pick up the solid waste from the house and transport it to the kerbside or any collection facility. This is the most expensive method, offering the most comfortable service.

In general, any household should try to separate organic materials and non-organic valuables to reduce the amount of solid waste to be evacuated by the municipality. Certain goods should be reutilized as far as possible, such as glass, metal, paper and plastic bags (for collecting garbage for example). Organic material should either be used for animal food or should be composted for later use as fertilizer and soil conditioner. Only the non-valuable remainings should be given to the public collection system.

Within the households, garbage can be collected in any receptacles, in plastic bags, plastic buckets, metal buckets or special standardized buckets, suitable for the special loading devices of compaction vehicles.

Except for the special standardized buckets all kinds of receptacles can be used for all three collection methods. The special standardized buckets, however, are—due to their cost, size and deadweight—not suitable for transportation and emptying into larger collection facilities by the households. These buckets are designed for kerbside or door-to-door collection. A special compaction vehicle with special loading devices comes along every street and stops at every house; the standard buckets are put behind

the truck by municipal or private workers and then picked up and emptied automatically by the vehicle into its compaction chamber. After being filled, this type of collection vehicle, with either rotating or pressing compaction facilities, is driven to a transfer loading station or directly to the dumpsite to empty its collected solid waste.

All other receptacles may be placed in front of the door—either by the households themselves (kerbside collection) or by municipal or private workers (door-to-door collection)—to be emptied into a range of possible collection vehicles selected according to local conditions and which will stop at every house for garbage collection.

To save operating and investment costs by reducing the number of streets to be served by the collection vehicles and by also reducing the number of vehicle stops, domestic waste receptacles should be carried to certain collection points or to collection vehicles waiting at certain times and places for a limited time, or—in particular cases (rural settlements)—directly to acceptable dumpsites at the periphery of the settlement. This can be done either by municipal (or private) workers or—much better and cost saving—by the households themselves. Using this method, the population can be involved in the system and participate in sharing the costs by contributing with their own activities.

Collection points may be:

- Unprotected locations (to be avoided whenever possible, since waste can be scattered around by wind and animals)

- Protected locations (three- or four-sided walled masonry enclosures)

- Tons or barrels

- Small local containers
- Special standardized containers
- Set-off containers
- Roll-on containers (hook-roll system)
- 1-axle trailers
- 2-axle trailers
- Parked standard trucks

Standardized container being sprayed with insecticide

Barrel used as a container

From these collection points, solid waste has to be loaded upon collection vehicles for transportation either to a transfer station or to the sanitary landfill directly. Only trailers and parked trucks need no further loading.

Loading can by done by various methods, either manually or mechanically.

Mechanical loading from unprotected or protected locations can be done by standard trucks (tippers) equipped with an additional hydraulic shovel loader. In certain cases, when big heaps of solid waste are to be loaded, wheel loaders can also be used.

Tons, barrels or small local containers can be lifted and emptied by hydraulic cranes mounted on the standard truck chassis between cab and body.

Special hydraulic or mechanical (rope with winch) loading equipment of compaction vehicles allows automatic lifting and emptying of suitable special standardized containers.

Set-off or roll-on containers require special trucks equipped with lifting devices for hydraulic loading.[13]

The waste collection method used in Muscat should principally be whatever is most efficient and cost-effective. Households bring their waste to certain collection points distributed in a planned way within each waste management area. Collection points are no further than a five-minute walk (say 200 metres) from each household. From there waste is collected by waste compaction vehicles or lorries.

Bulky waste (such as broken furniture, parts of old refrigerators and washing machines, etc.) is collected by special large vehicles. In

[13] Bernd Kaltwasser, *Solid Waste Management* (Eschborn, Germany: Deutsche Gesellschaft für Technische Zusammenarbeit [GTZ], 1988), pp. 8-9.

principle, anyone wanting to get rid of bulky items should contact the waste management section of the sub-municipality where they reside and agree upon a specific time when the waste should be collected from their house. However, in many cases residents put such items outside without informing the waste management section. This creates a public nuisance, with the Municipality often compelled to keep a lookout for such items placed near the premises.

Using a wheelbarrow to bring waste to the container, a practice that Muscat Municipality encourages in its campaigns to promote public awareness of waste management issues.

Other items which are collected separately by lorry are tree branches and garden waste.

Both bulky waste and garden waste are brought to the landfill although they are suitable for recycling or composting. The bulky waste consists of a few items and could easily be sorted and recycled. The garden waste consists only of organic waste that is very suitable for composting. The question of how recycling and composting can be built up to become a determining factor in the waste management system of the city will be dealt with later.

How the structure of the city affects the collection and transport of waste

The districution of the collection points and the movement of local transport are both influenced by the structure of the city. If the city is spread out and the population density is low, the collection points are in general remote from each other. The collection and transport vehicles can move easily, but have to travel a long distance from one collection point to the

next and thus the overall distance from the collection points to the landfill or incineration plant will be longer. Accordingly, collection and transport costs will rise. In this case it is advisable to use high-speed vehicles. However, if the population density is higher, it is better and more economical to use low-speed vehicles. In this respect Kaltwasser states:

> Low-speed vehicles are typically used for inner-urban collection purposes. Being designed for low speeds (gear boxes, etc.), they are most suitable for collection methods which require lots of stops, like kerbside or door-to-door collection. Low-speed vehicles in general are very manoeuvrable, which allows their utilization also in areas with difficult access. To save time and number of vehicles, these vehicles should not be used for long-distance transportation. Instead, transfer stations should be used, where the solid waste is transferred to big bulk transportation units.
>
> High-speed vehicles are suitable for both collection and high-speed transportation on longer distances. Due to their high-speed gear boxes, they are less suitable for stop-and-go operations. High-speed vehicles therefore should preferably be used for collection methods with fewer stops and bigger distances between two stops (like collection point/ton/barrel/container emptying). In general these vehicles are less manoeuvrable than low-speed vehicles. Therefore high-speed vehicles are advantageous for areas with good access for trucks.[14]

A point which we have already mentioned and which cannot be emphasized enough is the planning of the collection points. If the locations are not convenient, people may throw their waste somewhere else. In planning the location of collection points, due consideration must be given to the quantity of waste produced in each zone of the city as well as to the physical limitations of the people who bring waste to collection points. Often women and children are charged with this task. Children will have difficulty throwing the waste into the collection point

[14] Kaltwasser, op. cit., pp. 46-47.

if it is too high for them. Locations should be easily accessible and within the range of accepted walking distances. It is most advantageous to change existing informal, unprotected locations, which are not well accepted by the population, into protected collection points.

The most usual locations of waste collection points are street corners of densely populated areas, meeting points of women, commercial areas, markets and public places.

However, choosing a suitable location is not always easy, especially if the population density is low and the individual settlements are scattered, with a large uninhabited area between the settlements. In such a case it may be necessary to put a container in a place where there are not more than two or three houses, in which case there will be collection points consisting of a great number of small containers which are scattered over a sizeable area. The waste-collection vehicle then has to travel a longer distance than the reasonable average between collection points, raising costs and making the whole collection enterprise uneconomical.

The same problem arises if the distance between collection points is shorter than the reasonable average, because this increases the number of required stops and the time required for collection. In addition, having a great number of stops causes a traffic problem, especially if collection takes place in daytime.

In general, waste collection and transportation becomes more economical with an increase in the number of people who use each waste collection container or in the size of the area which uses a container, and with a decrease in the number of stops the vehicle has to make. However, such an ideal combination can rarely be achieved, because the reasonable distance which a person should walk to bring waste to the collection point should not exceed five minutes (if those who bring waste to the collection point are children, one should take into consideration the small size of their steps).

Another point concerning the economy of waste collection and transport is the interval between collection times. When this interval becomes longer, costs decrease, and the enterprise becomes more economical. However, the possibility of controlling and monitoring this aspect is limited because:

- Waste production is measured against the quantity of waste which each individual produces daily. Whenever this quantity increases, the collection points have to be increased, with the distance between the collection points accordingly becoming shorter.

- To avoid health problems it is imperative to transport waste before it starts to decompose. In areas with a cold or moderate climate it is possible to transport waste once a week, but in hot climates, waste must be collected once a day or even more frequently, due to rapid decomposition of waste. This constraint raises the cost of collection and transportation. It may also lead to under-utilization of vehicle capacity because waste has to be transported daily whether the vehicle is filled to capacity or not.

The above analysis of waste collection and transport shows that there are several factors which affect the choice of the collection points, i.e., the distance between two points and the distance between collection points and the households they serve. These factors also affect the choice of the transport, i.e., high-speed vehicle or low-speed vehicle, waste compaction vehicle, lorry, animal-cart or wheelbarrow.

How the collection points should be planned and the right transport chosen can be decided only after a thorough study of the structure of the city and its population density. In almost all cases, we have various quarters within a single city which differ in population density, building density and physical structures. This has an effect upon waste production. In this respect, Kaltwasser mentions that 54% of the waste in the Yemeni city of Abe is collected from one third of the geographical area of the city. This means that there is an area in which waste production is concentrated, and this necessitates reducing the distances

between the collection points in the densely populated area compared with those in the other quarters. Such a situation is observed in Muscat, too, where waste production is concentrated in Mutrah al-Kubra, which in spite of its small size of only 100 or 110 km^2 (less than 5% of the area of the city) accommodates almost one third of the population of the city as well as most of the industrial and commercial activities, including Qaboos Port (Mina Qaboos), which is the largest and busiest port in the Sultanate. No exact statistics about waste production in Mutrah al-Kubra or the other sub-municipalities of the city are available, but some reliable estimates say that at least one third of the waste in the city is produced in Mutrah al-Kubrah.

In general if we study the organization of waste collection and transport in Muscat we see that the Municipality has excluded all collection and transport methods except the establishment of collection points to which the people bring their waste. This method is, as we have already mentioned, the most cost-effective and it is used in many industrialized and most developing countries. It can also be planned better than any other method.

According to our observation, Muscat has a suitable network of collection points. The distances between collection points and between each collection point and the households it serves are affected by the settlement pattern in each sub-municipality. In Mutrah al-Kubrah these distances are shorter than they are in the other sub-municipalities. Another point which deserves special consideration is the fact that the population and building density varies in the different areas of the sub-municipality. In general, density is high in the old parts of the city and in the commercial areas. This resulted in differences between the collection point networks in the different areas of the same sub-municipality. According to our discussions with the waste managers in all sub-municipalities, the existing distribution of the collection points is the result of a long learning process based upon trial and error and learning by doing. Those responsible for planning the collection points system have never been given any training in waste management, and the fact that they could develop such a system in spite of this is praiseworthy.

It is worth mentioning that promoting or transferring the present waste managers may result in some interruptions in the waste management system. To avoid this, a system should be created which would preserve and transmit accumulated experiences and skills, giving consideration also to developing them further. In this respect we suggest the following steps:

- Each waste manager who is transferred should train his replacement in a systematic way, according to a specific programme. Such training is not given any consideration at present. The current practice is to hand over the work to the new waste manager after giving him a short briefing.

- Accumulated experiences should be recorded in a suitable scientific way, in the form of reports, studies and handbooks to which reference can be made whenever the need arises. These documents should not only describe what exists but should be reform-oriented and should make suggestions for modern waste management approaches which can be adopted and integrated into the existing system.

Municipal collection facilities

In general, any bag or container can be used in the household as a domestic waste receptacle, and there is no household which does not make use of this possibility. However, the receptacles used in households can be divided into two types, non-standardized and standardized. Those belonging to the first type have no standardized volume and can be of any material (plastic, metal, wood, wicker, etc.). Often they have no hooks or cover and are usually low-cost.

Standardized domestic solid waste receptacles can be plastic bags made of standardized material, size, volume and shape. They are more costly than the other type. Similarly, there are standardized domestic solid-waste buckets with lifting hooks (plastic or metal) suitable for the special lifting devices of high technology compaction vehicles. These can be covered and are also more expensive. While in the industrialized countries the use of standardized domestic solid-waste receptacles prevails, the situation in the developing countries is different. Here, rural households and the poor in the city almost exclusively use non-standardized domestic solid-waste receptacles, with the middle- and high-income households often using standardized receptacles.

While the choice of domestic solid-waste receptacles solely concerns individual households, municipal collection facilities have to be chosen by the Municipality. However, the choice is not easy. Financial constraints may make it impossible to choose the most suitable or most modern facilities. Yet any collection facility, with the exception of unprotected locations, can be improved in terms of sanitation and made harmless to the environment and the health of people.

The most common municipal collection facilities are described below:[15]

1. Unprotected locations

Design and characteristics
No specific design, locations chosen by the population to be emptied and cleaned manually (using shovels, forks) or mechanically (by wheel loaders).

Dimensions
No specific dimensions, surface demand dependent on the amount of solid waste discharged.

[15] Kaltwasser, op. cit., pp. 22-45.

A masonry enclosure for a waste collection point

Upgrading
Protection of collection points by three- or four-sided masonry.

2. Protected locations

Design and characteristics
Protected locations consist of three- or four-sided masonry enclosures, with 1.0-1.5 m high walls. Four-sided enclosures offer better protection against stray animals and dispersion of wastes by wind or children at play, but are—in comparison with three-sided units—more difficult to clean. Mechanical emptying (wheel-loader) is excluded for four-sided units. In the case of four-sided enclosures the height of the walls should be adequate for children to use. The floor should be paved for easy cleaning, but should be equipped with a soakaway for infiltration of wastewater into the ground. In areas with steady rainfall, a corrugated sheet iron roof is advantageous to avoid wetting of the solid waste.

Dimensioning
Dimensioning depends on per capita waste generation, the number of people to be served by each collection point and the interval of emptying.

Location
Location of collection points should be planned carefully, taking into account the quantity of waste generation in the different areas of the city and the physical abilities of the persons responsible for solid-waste disposal. Locations should be easily accessible and within the range of accepted walking distances. It is most advantageous to change existing informal unprotected locations, which are not well accepted by the population, into protected collection points.

Typical locations
Street corners of densely populated areas; meeting points of women; commercial areas; markets.

Upgrading
- Mechanical emptying by wheel loaders.
- Stationary masonry enclosures can be upgraded by utilization of set-off or roll-on containers.

3. Standard oil tons/barrels (oil drums)

Design and characteristics
Empty standard oil tons/barrels (volume ca. 200 litres) are distributed along accessible streets at distances of 100-200 m. The population discharges their waste into the tons/barrels, which are then emptied by the Municipality every day or on alternate days.

Half-tons/barrels are more advantageous where there is high waste density, to facilitate lifting into collection vehicles.

Dimensioning
Volume of tons/barrels is fixed. The choice is between half or whole tons/barrels and in how far apart to place them. The decision for half or whole tons depends on the waste density and the lifting/emptying method. For manual lifting, the total weight of a filled drum should be less than 50 kg. For mechanical/hydraulic lifting this limit does not apply.

The distance between barrels depends on per head waste generation, the size of the population to be served by each ton and the interval of emptying.

The height of the tons should be such that children can empty waste receptacles into them (0.8-1.0 m).

Upgrading
Lifting devices on trucks to facilitate lifting of filled tons/barrels.

4. Small, locally produced containers

Design and characteristics
Ideal are locally made containers with 100-250 litre capacity, preferably rectangular box-shaped, along accessible streets placed 100-200 m apart. These should be utilized for tons/barrels.

Dimensioning
Volume should be governed by the lifting and emptying capability of workers (50 kg as a maximum for two labourers) if no mechanical/hydraulic lifting devices support lifting. Volume should be calculated according to waste density, per capita waste generation, number of people to be served by each container, interval of emptying, and acceptable walking distance from households to the containers. Spare volume has to be considered. The walls of the container should be low enough so that children can empty receptacles into it (0.8-1.0 m).

Upgrading
Lifting devices on trucks to facilitate lifting of the filled containers.

5. Special standardized containers

These should be suitable for the special lifting devices of high-technology compaction vehicles.

Design and characteristics
Design, volume, sizes and material should be standardized. Due to volume, manual lifting is not possible. These containers are therefore equipped with four small wheels and lifting facilities suitable for the special lifting devices of compaction trucks. These containers need to be pushed from their locations, to behind the container truck, where they are picked up and emptied automatically. Containers are usually covered. Loading board height should be 1.20 m.

Dimensioning
Various volumes from 1.1 to 2 m^3 are available. The volume to be used has to be chosen from among a range of standard volumes according to waste density, the population to be served by each container, acceptable walking distances and the interval of emptying.

Upgrading
Of all collection point methods, standard containers for compaction trucks offer the highest collection standard for labourers. Thus no further upgrading is possible. Further improvement can be achieved by changing the system to kerbside or door-to-door collection.

6. Set-off containers

Design and characteristics
Standard design, volumes, sizes, material. These containers should have large volumes (2-6 m^3) for mechanical/hydraulic handling. Design can be simple, open box-shaped with two slanting sides and two hooks on each side for chains by which the containers can be lifted by container trucks **(figure IV)**.

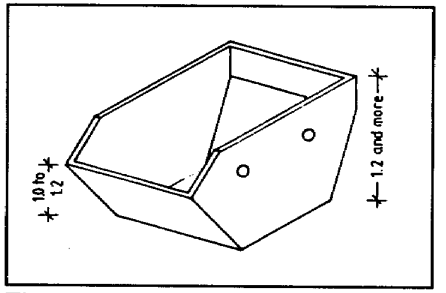


Figure IV. Set-off container

Source: Bernd Kaltwasser, *Solid Waste Management* (Eschborn, Germany: GTZ, 1988), p. 36.

Utilization as protected collection points: filled containers are simply exchanged by setting off an empty container and lifting the filled one. The filled container is then transported by the container truck to the landfill site, tipped and then transported empty to the next location where the container needs to be exchanged. No manual solid-waste handling is required here.

To facilitate the utilization of containers (high loading board), a step may be provided either behind the containers or, better, between the location for the empty and the full container **(figure V)**.

Containers specifically developed for solid waste collection have a covered top with large (sometimes sliding) doors, as for side-loaders. However advantageous the covering of solid waste may be, problems occur in handling (the doors can be difficult to open, at least for children), which means that solid waste is simply dropped on the ground.

Dimensioning
Same as for protected locations, depending on per capita waste generation, the population to be served by each container and the interval of emptying.

7. Roll-on/roll-off containers
(Hook-roll containers)

Design and characteristics
The design is exactly like that of the flatbed of tipper trucks but is removable from the truck. Lifting and setting is accomplished with one

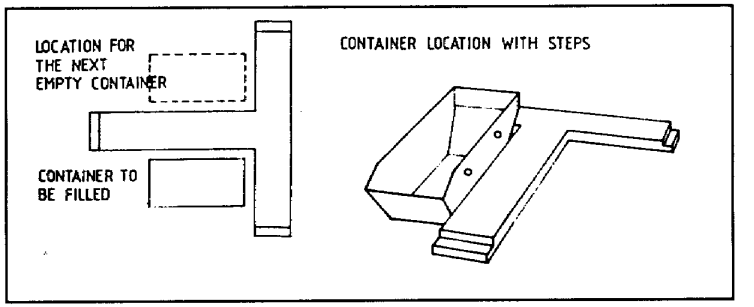


Figure V. Container location with steps

Source: Bernd Kaltwasser, *Solid Waste Management* (Eschborn, Germany: GTZ, 1988), p. 37.

central hydraulic hook picking up the container, rolling it on or off on two rollers, one attached to the truck frame, and one attached to the back end of the container **(figure VI)**. The volume and size of the container depend on the size and capacity of the container truck to be used; nearly all sizes are possible in principle. In general, volumes are greater than for set-off containers (3-6 m^3). The body is metal.

Utilization as for set-off containers: Due to the greater length of the containers' lower loading boards, which allows easy utilization by children, no steps required. No manual loading. Containers specifically developed for solid-waste collection have covered top with large (sometimes sliding) doors as for side-loaders. The covering, however, creates problems in handling (difficult to open, at least for children), which means that solid waste is dumped on the ground.

Dimensioning
As for protected locations, depends on per capita waste generation, the size of population to be served by each container and the interval of emptying.

Location
Same as for protected locations and set-off containers.

Upgrading
Similar to that of set-off containers. Change of system to kerbside or door-to-door collection or small standardized special containers with compaction trucks.

8. One-axle trailers

Design and characteristics
Standard design of low-speed one-axle trailers (e.g., agricultural trailers). The trailers are located as collection points in the city. To empty, a tractor arrives with an empty trailer, exchanges the trailers and goes off with the filled trailer either to a transfer station or directly to the landfill site and tips the trailer, which is then carried to the next location.

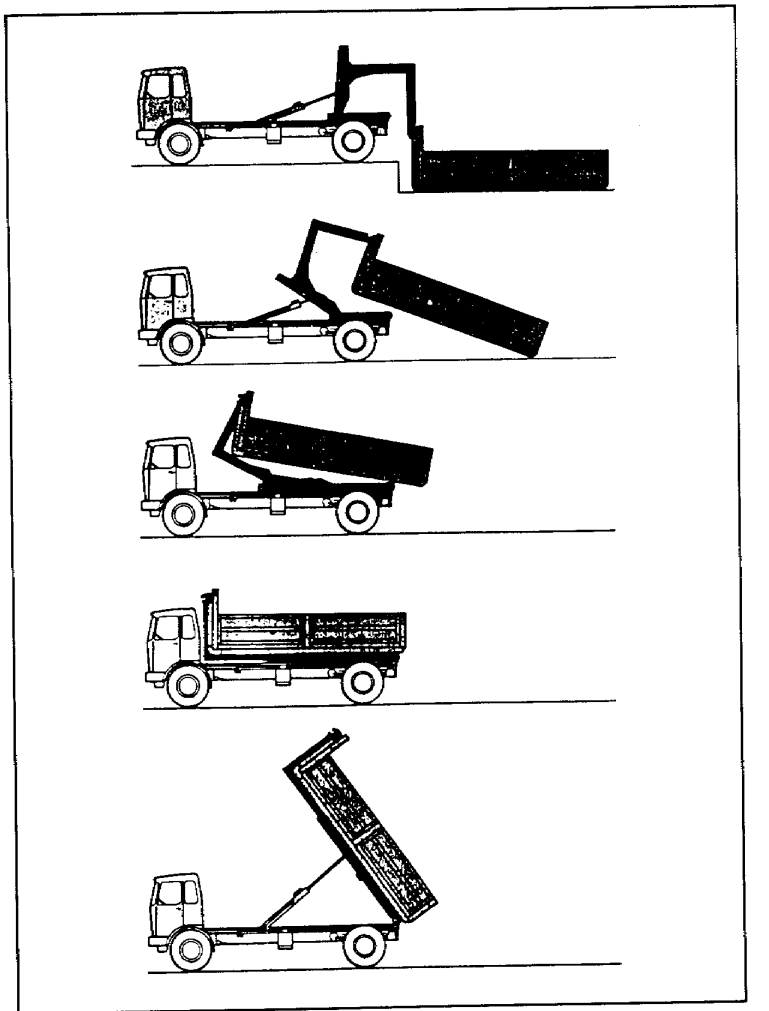


Figure VI. Roll-on container truck

Source: Bernd Kaltwasser, *Solid Waste Management* (Eschborn, Germany: GTZ, 1988), p. 38.

No manual solid waste handling required. To facilitate utilization of the trailers (high loading board), a step may be required, to be located either behind the trailer or, better, between the location for the empty and the full trailer (same system as for set-off containers).

Trailers specifically developed for solid-waste collection have a covered top with large (sometimes sliding) doors, as for side loaders. The covering, however, creates problems in handling (difficult to open, at least for children), leading to solid waste being left on the ground.

The low transportation speed makes this system suitable in combination with transfer stations, where solid waste is transferred to high-speed transportation vehicles for long-distance transportation to a treatment plant or sanitary landfill.

Dimensioning
Similar to that for protected locations; depends on per capita waste generation, the number of people to be served by each trailer and the interval of emptying. Small trailers for one-axle tractors (hand tractors) (up to 3 m^3), large trailers for two-axle tractors (3-6 m^3).

Locations
Similar to those for protected locations. Locations must be accessible for tractor/trailer combination. Space must be available for manoeuvring trailers and for second trailer.

Upgrading
Change to container system.

9. Parked standard trucks

Design and characteristics
Design similar to that of standard trucks for transportation. Standard trucks are parked as collection points and when filled are driven to a landfill site.

Dimensioning
As for protected locations.

Location
As for protected locations.

Upgrading
Change to any kind of collection point method.

In Muscat we find almost all types of domestic waste receptacles and various types of municipal collection facilities being used. However, most households use plastic shopping bags as waste receptacles.

The Municipality distributes standardized waste bags free of charge to households. However, only a limited number of these are available, and they do not amount to even 1% of the waste receptacles used.

One observes that the city makes effective use of a combination of modern and locally produced collection facilities. In the main streets and roads, as well as in the asphalted areas of the city, special standardized containers are used almost exclusively. Where the ground is unasphalted (rough or sandy) the most frequently used facilities are home-made containers made of scrap sheet iron. In general, the container is 1.5 m long, 1 m wide and 1 m high, and is open at the bottom and top. When waste is collected, the container is turned to one side and the waste is put into a cloth and the contents are then unloaded into the vehicle by two persons. Sometimes the waste collectors are compelled to collect the waste with their hands and put it into the vehicle. This is especially likely to happen if there are bulky waste pieces. After emptying, the container is placed near its original site in order to enable the previously used ground to dry.

The four-sided masonry enclosure with door is still in use in many parts of the city as a municipal waste collection facility. The floor is paved for

easy cleaning and to prevent the liquids contained in the waste from leaking to the ground. The length of enclosure is 2 m, and it is 1.5 m wide and 1.5 m high. The floor is about 0.5 m above ground level. The enclosure has no roof that would protect waste from getting wet in the rainy season.

We suggest that these enclosures be roofed, with an opening between the roof and the walls as can be seen in **figure VII.** The door should be fitted with a back, opened only when waste has to be collected. Waste should be thrown into the enclosure through the opening between the walls and the roof. A removable roof can be used, so that the floor of the enclosure can be exposed to the sun after it is cleaned and washed.

Oil barrels (oil drums) are also used as collection facilities, especially in sparsely populated and semi-rural areas as well as at some picnic sites.

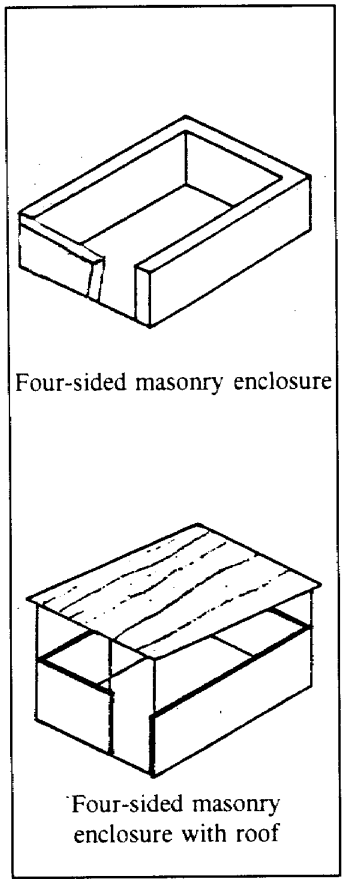


Figure VII. Four-sided masonry enclosures

According to our observations, this combination of various municipal waste collection facilities was not adopted at random but was developed in accordance with a plan that took into consideration all economic and technical possibilities of the city and its inhabitants. Each of these facilities can be developed and further improved. With respect to the home-made metal containers, craftsmen in Yemen could develop them in

cooperation with experts provided by the German Agency for Technical Cooperation (GTZ). The container could be equipped with wheels to enhance the efficiency of waste collection operations. However, although it is possible to go this route, it is perhaps better to keep the present mixture which has proved to be efficient, and at the same time to concentrate on developing a local technology for municipal waste collection facilities, with emphasis on the home-made local containers.

Developing a local technology for municipal waste collection facilities has an economic and a developmental importance. The economic importance can be understood if we consider that according to our estimation and according to the experiences of other countries with similar climatic conditions, at least 20% of the containers need to be replaced each year. If each container serves 100 persons, then 5,000 containers should be provided, considering that the population of the city of Muscat is about 500,000. On this basis the number of containers which should be replaced yearly will be (5,000 x 20)/100 = 1000.

Each container costs RO 200. The city has to spend RO 200,000 on importing containers. If home-made containers are used the costs certainly will be much lower, especially if the city makes the containers in the workshop of its directorate for transport.

The developmental importance here lies in the fact that making the municipal waste collection facilities in Oman would promote indigenous technology, since the experience and skills to be gained could be used in other areas where local technology is applied. If it is decided to develop the locally made containers further, local craftsmen would have to be trained in new skills; this would involve the transfer of knowledge, the positive impact of which does not stop at constructing municipal waste collection facilities.

A third advantage of locally made municipal waste collection facilities is that metal scrap (iron sheets) can be used to produce them, a recycling of waste that has both economic and environmental advantages.

If we view these aspects from a wider, developmental perspective, we can say that promoting locally made municipal waste collection facilities should not be limited to satisfying only the needs of Muscat, but of the whole Sultanate.

The other cities' and settlements' annual need is about 1,000-1,500 containers. This means that total annual demand in Oman is 2,000-2,500 containers. Population growth and industrial and commercial development—as well as the provision of all settlements in the country with suitable waste collection networks—will certainly increase the demand for containers. The production needed justifies establishing a workshop to produce waste containers. In addition to this, the workshop could produce other items used in waste management such as brooms, shovels, etc., as well as other products which could be marketed.

This approach shows how waste management can promote local technology. There are other aspects of waste management which can have the same impact, as will be seen in the section on recycling.

Waste disposal: landfill

Whether sanitary landfill is the best way to dispose of waste or not is a question which cannot be answered in a generalized way. Each city should study its waste problems, giving full consideration to all the factors that influence waste treatment and disposal (e.g., shortage of land and high population density, which may eliminate landfill as an alternative). Even countries with low population density and enough land available for landfills cannot always afford indefinitely to dump their waste in landfills, if landfills cannot be established in areas which are remote from the cities they serve. On the other hand, a landfill should not be more than 15 kilometres from the city it serves. This distance is very short, and urban sprawl, which occurs very rapidly in developing countries, can often cover it within a few years. This, and the fact that no one wants to have waste near his residential area, limits the landfill option, even if land is abundantly available. In addition, the area

surrounding the city may not be geologically or topographically suitable to serve as landfill.

Another factor which should always be taken into consideration is that using a piece of land as landfill means to a great extent losing it forever. At the very least, it cannot be used for a long time for building and many other gainful activities. If all the conditions regarding sanitary landfill are not followed, waste disposal may result in the contamination of a large area surrounding the landfill whereby groundwater, soil, plants and the atmosphere may be affected and the health of human beings and animals living near the landfill may be endangered. But since landfill cannot be entirely dispensed with even if other waste treatment methods are used, we can say that landfill is a necessary evil. Thus, it should be accepted, and all possible steps taken to render it less harmful to the environment. In the last two decades landfill systems have become a techno-scientific and managerial area with several dimensions. For example, the components of the waste have to be precisely analysed in order to determine the potential damage to the environment and in order to identify special and toxic waste which cannot be put in the landfill except after subjecting it to special treatments that render it less harmful. Even then, it often requires special disposal in a separate landfill site.

Furthermore, the area chosen as landfill must undergo several studies (geological, topographical, etc.) as already mentioned. It is not always necessary to do all these studies from scratch, however. Geological and topographical studies (which are the most important and the most expensive) may have already been done by a university or other institutions concerned with these issues. Thus the first step is to collect all available information and data about the area and study it carefully, after which it can be seen whether it is necessary to do additional work or not. In this respect foreign firms specialized in landfill establishment may be interested in earning as much as possible, so they may be inclined to start everything from scratch.

If we apply the above-mentioned considerations to Muscat we can see that the choice of the four landfills of the city in Bousher, al-Amerat, Seeb

and Quriyat was based upon general assumptions and not upon concrete facts derived from a study of the geological and hydrological conditions of the areas. It was assumed that the groundwater in the landfill areas was so deep that the liquids leaking from the waste could not reach it. In addition, the landfills were considered rocky, impermeable, and void of faults that might render some parts of them permeable. They were declared virtually insensitive areas, the environment of which could not be affected by waste disposal.

With respect to general conditions, the landfills are below ground level by about 2.0-2.5 m. In Bousher, al-Amerat and Quriyat, the landfills are surrounded by a chain of mountains that form a very suitable natural protective fence. This chain of mountains keeps foul odours from being blown towards the residential areas. In Seeb the land is flat and the landfill is not protected by a chain of mountains and accordingly has no natural protective fence. Here appropriate fencing of the landfill, which at present does not exist, is necessary.

All landfills are connected to the main street of the city by special roads. These roads are graded but not asphalted or paved. They are level and do not constrain waste transport. Since the landfills are in enclaves or land pockets which are relatively isolated from the rest of the city, the road leading to them is normally used by the waste transport vehicles. Thus, no traffic problems arise here.

Growth of environmental awareness and the appearance of some problems in the last few years necessitated a reconsideration of the situation of the landfills. The landfills are no longer as far from the residential areas as they were a few years ago. Tremendous urban sprawl has brought the residential areas near the landfills, and some residents in Seeb and Bousher next to the landfills have already started to complain about the bad smell and other nuisances which the landfills cause to their residential area. In addition, the landfills in al-Amerat, Bousher and Seeb will reach capacity in the first decade of the next century. Due to this fact, steps must be taken now to find new sites.

A study was carried out in May 1993 with respect to the environmental impact of the landfills. Regarding possible impact of the landfills upon the groundwater, the study stated:

> The landfill of Seeb is located in the red stripped zone of the Western Well Field area.
>
> The landfill site of al-Amerat is in the yellow protection zone of Wadi Adai Well landfills.
>
> Both well fields are primary sources of the Muscat water supply system, hence any pollution would be disastrous. Therefore, immediate action is required to assess the groundwater pollution of these sites.[16]

The study mentions further that rainfall, which is the main contribution to leachate generation, is very low in Oman. In this respect it states:

> In the temperate climates rainfall is commonly between 700 and 1,000 mm per year whereas in the Muscat area the average rainfall in the past 15 years was less than 80 mm per year. Therefore the amount of leachate generated in the Oman situation is certainly far lower than in the temperate climates.
>
> Considering the very low rainfall it is considered crucial to find out whether there is any leachate problem in the Oman situation. Some additional factors in the Muscat area contribute to a low (maybe zero?) leachate generation, namely:
>
> - Due to the hot climate the moisture content of domestic refuse is low, probably below 25% (of wet weight). Therefore the moisture absorption capacity of refuse in a landfill is high. Leachate flows usually start if the moisture content of waste in the

16 Manfred Scheu, *Assessment Study on Municipal Solid Waste Management in Muscat* (Wetter, Germany: Kaltwasser-Engineering, May 1993), p. 29.

tip exceeds 35 to 40%. Therefore a considerable amount of water will be absorbed by waste before leachate may be generated by the site.

Digging a hole in the Bousher landfill to determine how far the landfill waste has decomposed and the moisture content in the landfill.

- Evaporation rates in the Muscat area are very high. Based on data obtained at al-Seeb Airport . . . evaporation rates are about 10 mm daily on average. Therefore, a significant proportion of rainfall will evaporate before reaching the waste body in a tip.

These arguments may provide an idea about the complexity of the situation. Attempts at calculating leachate flows are considered insufficient and research is required to tackle this issue.

Assessment of pollution risks

Drilling of wells in the close vicinity of landfill sites and monitoring of water quality is standard practice in industrialized countries. Although this should be adopted in Oman whenever possible, problems may occur if the groundwater table is extremely deep. A simple method to assess pollution was employed during the mission as described below:

- An excavator was used to dig through the waste layers at al-Amerat site. The first layer of waste was expected to be more than 8 years old.

- The study aimed at obtaining a soil sample from the subsoil of the landfill (say at least 0.5 metres below the bottom of the site). An analysis of this sample (e.g., nitrate, ammonia, fatty acids) would probably allow us to find out whether any leachate has been percolating through the subsoil. In case results show no pollution, this would indicate that there may be no leachate problem.

However, the machinery used was not capable of reaching the bottom of the site and the maximum depth reached was about 3.2 metres. The layer of waste excavated was about five years old (production and expiry dates on package material). Although the main purpose of the study was not achieved, an analysis of excavated material showed some interesting features such as:

- The upper layer of waste (about 0.4 metres) was extremely dry and no biological degradation was observed. Waste from deeper areas was moist and partly decomposed (foul smells).

- The moisture content of waste increased with depth. This was visible by analysing a voluminous telephone book (depth 2.5 metres). Every single page of this book was completely wet.

These observations indicate that moisture accumulates in the tip. Hence, leachate flows may become likely after longer periods, and more comprehensive investigations have to be carried out.

It is therefore strongly recommended to drill wells in the close vicinity of landfill sites and to start regular monitoring of pollution. To obtain data regarding the behaviour and movement of leachate, the method of soil sampling and analysis should be employed. These activities have to be carried out in close cooperation with the water authorities, and specialists are required to obtain reliable results.

> The results should be used to establish appropriate standards for municipal landfill sites in the Oman situation. These standards will determine the cost of landfilling and therefore the most economic landfilling strategy (i.e., number of sites to be operated in the Muscat area).[17]

We would observe that the landfills are to a great extent free of flies and other harmful insects and that any foul odour can only be detected where there are heaps of waste not yet buried. Since arriving loads of waste are buried immediately, bad odour and flies can scarcely be detected. The fact that each two metres of waste in the landfill is covered with a 20 cm layer of sand enhances further the soundly sealed nature of the site. The waste and the covering layer above are compressed with a heavy bulldozer, and the whole area thus becomes solid and stable to the extent that any vehicle can run over it smoothly. The compression also deprives insects of any holes that could be used as breeding grounds. In general, tyres and bulky wastes are not buried, because they cannot be compressed by bulldozers. They are kept aside and often occupy a large space. No solution seems to have been found for their disposal as yet.

Two very important shortcomings we noticed were the absence of a landfill supervisor and of proper recording of the incoming waste. A well-trained waste manager to serve as landfill supervisor is indispensable. He should be knowledgeable about waste analysis and landfill economy, and should supervise and monitor all operations taking place in the landfill with the aim of guaranteeing efficiency and effectiveness, including the fulfilling of all requirements of a sanitary landfill.

With respect to proper recording, the landfill is the most appropriate place to collect and record data about the quantity (weight and size) and composition of waste. Such data are indispensable for waste management planning. At present only the number of incoming vehicles is registered (the full capacity of the vehicle) without giving any consideration to the

[17] Ibid.

actual quantity they are carrying. The best way to collect such data and information is to have a weighbridge at the entrance of the landfill, where every incoming waste vehicle is weighed. The weight of the load is obtained by subtracting the weight of the empty vehicle from the weight of the loaded vehicle. In addition to this, incoming waste should be analysed in order to identify its composition and the change that occurs to this composition. Here special waste which may be found in the domestic waste should be separated and disposed of in an appropriate way either after treating it or without treatment.

One advantage of knowing the weight of the waste which each vehicle hauls in means that the efficiency of the waste collection activities can be controlled. In general the quantity of waste collected from each area is almost the same from collection to collection. If a vehicle brings a quantity which is less or more than what it usually brings from a certain area, this means either that the vehicle did not do its job properly and accordingly there is waste which has not been collected, or that the waste produced in the area has decreased or increased. To verify the issue, the concerned area should be visited. If an increase or decrease in the waste production really occurred, the development will be observed over an extended period of time. If it becomes apparent that the decrease or increase was not an exceptional case but a permanent feature, waste collection and transport must be adapted to the new situation. If it becomes apparent that the vehicle's collection was inefficient, appropriate steps should be taken.

Other shortcomings noted regarding the Muscat landfill were lack of fire extinguishers, a first aid box, telephone and potable water for the landfill workers.

Financing waste management

Waste management is a basic municipal service that has a high cost. In the developing countries, municipalities spend one fourth or even more of their annual budget on waste management. In addition to this, waste management may require high capital investment (different types of

vehicles, bulldozers, tractors, etc.). Besides this, there are often opportunity costs which in general do not appear as costs. (For example the landfill area is often provided by the government free of charge; municipal administrators who are not directly responsible for waste management may now and then be charged with carrying out waste management activities; public participation may be encouraged.) Opportunity costs regarding these inputs do not appear in the balance sheet as expenditures; only the annual waste management budget is identified with waste management costs. Even this is too high and may cause an unbearable increase which can be covered only (if at all) at the cost of other vital services.

Budgeting for waste management is caught (like budgeting for all other services) in a vicious circle. In general the required expenditure is calculated in line with a trend analysis according to which any increase in the work to be done should be followed by an increase in the budget allocated for waste management. The main assumption here is that efficiency and performance remain as they are. This means that the resources required to tackle the increasing work are measured against a constant efficiency and performance. Innovation, improvement, etc., are not considered as resources that could replace financing.

Municipalities in both the industrialized countries and in the third world are suffering from financial shortages. Available financial resources cannot keep pace with the increasing need for services and utilities. This makes it necessary to search for possibilities other than finance to provide the services and utilities associated with waste management.

The financing of waste management (like all other services) should be considered as one among many means of providing this service without forgetting that financing will remain the most important resource for provision of waste management. In general, the other resources and means which can contribute to providing waste management services are the following:

1. Grass-roots participation in waste management. This participation consists of refraining from certain acts and doing certain others.

Refraining includes: to stop throwing waste into the streets and public places; to stop adding special waste to domestic waste; to stop dumping waste in places other than those earmarked for it; to minimize waste production; and not to have small children carry waste to waste collection points, if they are not able to do a proper job of it.

Active grass-roots participation ("doing") can take many forms. In general, each city should decide on the most appropriate type of public participation considering its local conditions. Here are some forms which are commonly used:

(a) Clean-up campaigns. These are cleaning operations which the municipality organizes in order to cover cleaning work which cannot be done by the municipality due to lack of resources. The campaigns are sometimes organized not because of any lack of resources but in order to promote citizen awareness with respect to cleaning. The aim here is to let the citizens know the importance of cleaning up and to show them that waste management is a costly service. If the aim of a campaign is awareness promotion, it is covered by the mass media, and in such cases the campaign is often organized under the sponsorship of a prominent personality in the government such as the minister of municipalities and rural affairs or the chairman of the concerned municipality. A committee comprising representatives of the municipality and private citizens is established to organize and implement the campaign.

In many Arab countries the clean-up campaign usually takes the form of a clean-up week (*osbou' al-nadafah*), which is organized once a year. According to our observations these campaigns are encumbered by the following:

- Lack of clear objectives. In general, neither the amount of work to be done nor the goal aimed at are identified. This means that the campaign is not based upon a study defining the role of the campaign in

the waste management activities. As for awareness promotion, one observes a lack of strategy and of suitable awareness promotion techniques.

- Organizational deficiencies. In general the clean-up week in Arab cities lacks planning and proper organization. The amount of work to be done is not at all known, making it difficult to design a schedule for the various activities to be undertaken. Participants are recruited according to a general mobilization without giving due consideration to the necessity of harmonizing the mobilized manpower with the size of the job to be done as well as with the equipment to be used. As experience has shown, proceeding in this way always means that more people are mobilized than are actually needed.

- Not enough equipment to enable all who come to participate in the work to actually do so. Enthusiastic participants compete with each other to get a broom (or a shovel, wheelbarrow, basket or container) which they need to participate. This competition constrains the work and minimizes efficiency because people have to invest time and effort to obtain equipment. Confusion arises, it becomes difficult to obtain a view of the situation, and no one knows how the work is proceeding. The necessity of reversing this situation and of organizing the work in a better way is recognized, but how to bring about the change is a question that can only be answered after studying the specific conditions under which the campaign is implemented. In this respect people who are experienced in organizing clean-up weeks say that a campaign which aims at mobilizing the people cannot restrict itself to manpower considerations only, since there is a psychological dimension which affects people's feelings and morale.

Taking this psychological aspect into consideration should not hinder the planning of a better campaign. It is possible to divide the participants into groups, with each group participating in the work for one day or more, as necessary. Thus, the number of hours for which each person participates in the campaign would be reduced, thus making better use of the time of those taking part. Another possibility is to lengthen the

duration of the campaign, with each group participating for one week; on the one hand this would increase the overall performance of the campaign and on the other would raise the productivity of each participant.

It is possible to plan a clean-up campaign along these lines, but it requires some kind of feasibility and cost-effectiveness study. The input needed can be determined easily by taking the input of a municipal waste management activity similar in size to the one to be implemented by the campaign. Certainly, the better organized activity of a more experienced municipal waste management department needs less input than what would be required for the campaign. Thus, an allowance of 20-25% extra input should be made.

Although such campaigns aim also at promoting awareness and utilizing a potential which otherwise would remain idle and which thus cannot be judged strictly in economic terms, it is necessary to study their cost-effectiveness because this will enable us to recognize any shortcomings and organize campaigns in a way that would make them more effective.

A very important point which should be borne in mind is that municipalities may be inclined to organize a clean-up campaign whenever a problem arises which in fact is not attributable to a shortage of resources, but to deficiencies in the waste management system. Such a practice hides the real problems, which should be tackled by efficiency measures, improvement and management reform.

(b) Self-reliance (*al-'aun al-thati*). This differs from public participation in the sense that the municipality has no role in it. Self-reliance in waste management is practised in many areas of third-world cities where such services do not reach. However, self-reliance is in general limited to cleaning and waste collection. Transport and disposal often remain the responsibility of the municipality. If they are included in the self-reliance package, this generally means that the people bring the waste to an unsanitary dumping area which is not far from their residential area.

In general, the quarters which do not receive municipal waste management services are the squatter settlements (which are excluded from such services because they are considered illegal), and the slum areas. In recent years non-governmental organizations (NGOs) active in these areas have become aware of the waste management problems that exist here and have started to help. They often offer their help as a component of a public health and environmental sanitation package which also includes the promotion of recycling activities. Also, some municipalities have started to understand the importance of this type of self-reliance and cooperate with it.

However, there are people who criticize self-reliance as unjust, because it requires the poor to provide for themselves a service which other citizens receive from the municipality. This argument can be justified if waste management is provided free of charge, but if those who receive the service are charged for it and those who are not receiving it are not, the issue must be dealt with in a different way. If the policy followed by the municipality adheres to the philosophy "The user pays for the services he enjoys," then the exclusion of those who do not pay for the services is justified on this basis, which is not to say, of course, that the philosophy itself is right. There may be people who need the service badly but who may not be able to pay for it. Thus social considerations may justify providing waste management services to them free of charge.

These problems, which we find in many cities in the developing countries, do not arise in Muscat, where waste management service of the same quality is provided to all households free of charge. Here, differences in the cleanliness of the streets, public places, etc., are due to other reasons and not to unequal treatment. People with a low educational level in general have low environmental and public health awareness. Thus, they do not maintain the cleanliness of their surroundings, resulting in lower standards of cleanliness than in the areas where people with better education live, in spite of equal treatment in the provision of waste management services.

In old quarters with narrow streets that are impassable to waste transport vehicles, street cleaning and waste collection and transport have to be done manually and with wheelbarrows. This hampers the efficiency of the work, with the result that these quarters are less clean despite equal attention.

The above shows that lack of equal treatment is not responsible for differences in the cleanliness of different parts of the city, but it does not free the Municipality from the responsibility of striving to upgrade the level of cleanliness of those quarters which are now less clean. Such upgrading requires awareness promotion, as well as urban renewal which enhances the standard and quality of the old quarters as a whole. Waste management is therefore related to urban renewal and urban planning, which are dealt with below.

A special form of self-reliance is practised in some cities such as Cairo, where people of middle and high income hire refuse collectors to take away their waste. Here self-reliance arises because people want better service and not because they are not receiving municipal waste management services. This type of self-reliance, which has proved to be efficient, relieves some of the burden on the Municipality and should be kept as it is without any municipal involvement.

2. **Waste management reform.** This includes organizational improvement and better planning, implementation, monitoring, supervision and evaluation of all operations regarding waste management; it likewise includes the training of all those who are engaged in waste management activities, particularly waste managers. Also, the enactment and enforcement of appropriate laws, rules, regulations and local orders is necessary.

3. **Recycling and composting of waste.** This aspect, with which we will deal later in detail, not only reduces the size and weight of the waste to be disposed of but also results in profitable reuse of waste and helps protect the environment.

4. **Waste avoidance.** Although it can only be partially realized in some countries, this step is the starting point of waste management. In Germany the present waste management law is called the Waste Avoidance and Waste Management Law.

Certainly the above-mentioned steps will reduce the cost of waste management; however, their contribution is still very limited. In addition, even if they are fully applied, their contribution will always remain limited, because they mainly concern cleaning. Collection and transportation (where the lion's share of the waste management budget is spent), have to be done by the Municipality or other institution to which it delegates this task. Financing will therefore remain the main factor in solving waste management problems. As already mentioned, municipalities all over the world suffer from financial shortages for the following reasons:

- While the financial resources at the disposal of the municipalities increase slowly (at best), do not increase or even decrease, the demand for their services is growing tremendously, especially in the cities of third-world countries where urbanization has led to a population explosion.

- The production of waste continuously rises, and the proportion of hazardous waste rapidly increases, both of which increase the cost of waste management.

- Inflation and price increases are making the provision of services acutely more expensive.

To solve this problem, many experts believe that the user should pay fully for all services he receives, with the aim of covering the costs through the fees collected.[18]

18 *Umweltpolitik*, op. cit., p. 24.

Since the waste produced by households differs in size and quantity, the fees to be paid should be related to these differences. Each household or group of households could be supplied with a container that can hold a certain capacity of weight. The household can, if it so desires, make optimal use of this capacity by pressing cartons and boxes before they are put into the container. More containers are provided whenever the waste production of the household or group of households increases, and conversely, a decrease in waste production (rare) means that fewer containers will be provided. This method is followed in various communities in European countries, the USA, Canada and Japan, and it has proved to be effective with respect to optimal use of containers: people cut or press cartons, boxes, cans, etc., before putting them in the containers.

In the Arab world, many cities charge fees for waste management services; however, these fees are not determined on the basis of the quantity of waste which each individual household throws out, but are set fees which each household has to pay, even though households differ in the quantity of waste they produce. In general such fees are collected along with those for water or electricity. This eliminates the need to establish a special administrative department for collecting fees for waste management. However, there are disadvantages: first, people are paying for waste management services as part of what they pay for water or electricity and accordingly they do not become aware of their contribution to financing waste management services; second, the principle of "The user pays" cannot always be applied to the extent that all the costs are covered by fees. There are always constraints which hinder the full application of this principle, such as social considerations, which means that fees are kept to a limit that can be paid by everyone. The basis on which the fees are set is in general what low-income people can afford to pay. Thus, what is achieved may be equal treatment for all, but not an equal burden for all if we take into consideration that the fees charged have different effects on the budgets of households in differing income groups.

In general, experience has proved that fees cannot be increased to cover increases in costs. In most cases fees can cover costs only partially. In Arab cities, charging fees can be problematical, considering that there are many houses which are not registered, and which therefore receive waste management services without having fees collected from them.

In Muscat and other Oman cities and villages, fees are not collected from the users of waste management services. The municipality provides this service free of charge, except in the case of industrial and large commercial waste producers, as already mentioned.

Since it is the policy of the Sultanate not to charge the household for waste management services, it is the government which has to solve the problem of financing this service. Here, no other alternative financial resources can be brought into consideration. All that can be done is to minimize the cost, by using non-financial resources which do not contradict government policy (such as grass-roots participation in cleansing and other waste management activities, waste management reform and waste avoidance).

However, the Sultanate has a special problem regarding the user paying for waste management services. Many industrial and commercial enterprises do not bring their waste to the landfills as they should. Instead, they put it in the containers meant for household waste, as was shown in a seminar on public health held in Muscat in May 1989. To solve this problem we suggest the following:

- Charge the Municipality with the task of collecting and transporting this waste against fees paid by the users of this service.

- Have the Municipality collect and transport the industrial and commercial waste for a week. This will reveal the quantity and size of waste produced by each industrial or commercial enterprise. After this period, the industrial and commercial enterprises will take care of collecting and transporting their waste to the landfills. Any landfill receiving such waste will fill out a form indicating the weight of the

waste brought to the landfill by the given enterprise and the type of vehicle used (the number of the vehicle will be recorded). The weighbridge which was suggested earlier would facilitate this work.

If a business does not bring its waste to any of the landfills in the city, this means that it is either accumulating the waste on its premises or getting rid of it in an illegal way, and this can be controlled. In addition to this, it is possible to monitor the waste collection points to ensure that no industrial or commercial waste is put into them. The fact that industrial and commercial wastes differ to a great extent from household wastes both in volume and type, and the fact that industrial and commercial wastes are more homogeneous than household wastes, facilitates control. Furthermore, if the capacities of the collection points are designed in a way that they can accommodate only the waste of the households they have to serve, there will be no room for industrial waste in them, and their misuse will mean that extra waste is left in front of the collection points (containers, etc.).

Privatization of waste management services

Privatization has become a highly discussed issue all over the world, one given further impetus by the collapse of the communist systems. It is not, however, a panacea, and there are factors which limit its application. Natural resources (oil fields, mines, etc.) upon which the whole economic development of the country depends can hardly be privatized. There are economic activities and services which are not profitable but which at the same time are indispensable infrastructures for the overall economic and socio-cultural development of the country. These activities and services have to be provided by the government at subsidy. Railway systems, urban transport, water supply and waste management often belong to these subsidized activities that are undertaken directly by the government.[19]

19 Said El-Naggar, "Privatization and Structural Adjustment: the Basic Issues" in Said El-Naggar, ed., *Privatization and Structural Adjustment in the Arab Countries* (Washington, D.C., 1989), p. 4. The articles in this book give perspectives of privatization in the Arab countries.

Privatization is no panacea, but experience all over the world has proved that the private sector is more efficient and productive than the public sector and that many enterprises function better and sometimes even become profitable after their privatization. Thus, the question to be answered is not whether privatization is better or not, but what to privatize, how to privatize, and how to supervise the privatized activities for the benefit of the whole country or community. This supervision gains special importance if the privatized activities are essential services such as waste management.

The discussion on privatizing municipal services started in Europe in the 1970s. In spite of the prevailing belief that the private sector can perform these services better and cheaper, governments and municipalities are still very reluctant to privatize basic services despite all their commitment to the principle of free enterprise. This reluctance can be attributed to the following:

- Basic services are considered core duties of municipalities. Privatization does not mean they are no longer responsible for them. The fear that the private sector may fail at a time when the municipality cannot take over the work again produces caution; if the private sector fails, the blame falls upon the municipality, from which the citizen expects immediate action to provide the required services.

- Municipalities think that they will lose power if they delegate the provision of basic services to the private sector; providing such services gives the municipality its identity.

- The private sector may not be ready to take over the workers who are already employed by the municipality to provide basic services, or it may rationalize the work in a way that renders many employees redundant, leading to unemployment and social problems, especially in the developing countries where job opportunities are very limited and unemployment through privatization is already great.

It is necessary to deal with the justifications for this reluctance on the part of the municipality before discussing the available experiences about the privatization of waste management. Whether the reluctance is justified or not is a question that cannot be answered either positively or negatively. A great deal depends upon whether the private sector has the right skills, knowledge and experience to do the work and whether it is honest; a great deal also depends also upon the ability of the municipality to exercise the right kind of supervision and control over the company charged with providing the service.

In general there are many municipalities, especially in the industrialized countries, which have already privatized some basic services such as waste management. However, privatization of this basic service, which should be provided regularly and at specific times, is not easy and has to be dealt with cautiously. The company charged with carrying out this task may fail, and in such a case the municipality must be in a position to take over the work immediately and without interruption. Due to this fact, some large cities in Europe and in the Gulf States have resorted to a strategy of diversification, the main features of which are:

- Privatizing only the provision of waste management services. This strategy is practised for example in Riyadh in Saudi Arabia and in Berlin in Germany. The company is prevented from acquiring a monopoly position which could enable it to increase fees at will. Furthermore, the municipality, which is still active in waste management, can take over the work done by the company if it fails.

- Charging several companies with providing waste management services, with each company responsible for one area of the city. This system is practised in Kuwait, where the city is divided into several waste management zones. This has resulted in positive competition among the companies responsible for the waste management system of the different zones of the city.

In August 1990 in Munich, Germany, the city council discussed the question of privatizing waste management services.[20] The strategy to be followed consisted of commissioning a private company to clean certain parts of the city for five years and then to see whether the private sector was more efficient and more cost effective. One observes that even in a country that is committed to free enterprise such as Germany, privatization of waste management is subjected to strict economic considerations and not to an ideology that believes in free enterprise as a panacea.

In Muscat, waste management services are provided exclusively by the Municipality. The possibility of involving the private sector in this activity has been raised, but it was generally agreed during the above-mentioned seminar in public health that privatization would raise costs and not reduce them. Unfortunately, we could not find further information showing why privatization would raise costs. However, we can assume that the private company which wanted to take over the waste management services believed that it should be compensated for relieving the Municipality of the waste management burden. Thus it added to the actual costs spent by the Municipality on waste management what can be called "compensation fees."

The prospects for privatization are good in Muscat only if the private sector is aware from the beginning that the Municipality can privatize the waste management service only if this step enhances efficiency and minimizes cost. Recognizing this, the private sector would carry out a feasibility study whose basic elements would be a cost-benefit study and a cost minimization analysis. However, some aspects are constrained by government policy. For example, the government may require that the private sector employ all those who are employed by the Municipality, but the private sector may come to the conclusion that it can dispense with a part of the manpower employed by the Municipality, just as it may consider it necessary to replace the present waste managers (or at least

20 "Privatization of the provision of waste management services in parts of Munich", *Süddeutsche Zeitung*, issue of August 1990.

some of them) with others who are better trained and more experienced in private business management. All these issues should be discussed carefully and objectively, and social interests should be taken into account as well.

Municipalities know that privatization cannot conjure up drastic cost reductions. Even with privatization, waste management will remain a relatively costly business. In the European cities where waste management services have been privatized and users pay fees for them, the municipality often has to subsidize the business, because the fees collected (which are fixed, so that they are bearable by all) are often not sufficient.

As already mentioned, privatization is not a panacea to which one can resort whenever problems arise. Many problems can be solved by other reforms. Privatization should not be considered an alternative to the municipal institution; otherwise it would result in the withering away of the municipality. Waste management is one of the core duties of the municipality, and privatization means that it is provided by the private sector on behalf of the municipality.

Instead of privatization the municipality could establish a municipal public enterprise to take over waste management services and run them as public enterprises, with the stipulation that the enterprise does not raise fees but concentrates on making the business more cost-effective.

RECYCLING

Recycling is not new in Oman. Direct reuse of waste materials or their reuse by craftsmen to produce utensils and other commodities has been practised for a long period of time. In the past, the recycling of waste items was widespread in the urban centres, especially in Muscat, where the consumption of recyclable items was great. People reused old one-way containers (for water, milk, butter, oil and other liquids), and some people collected and sold such items. The city contained many houses whose roofs and walls were made of old metal sheets, and in the market there were special stands where metal sheets of different types and sizes were sold (old metal barrels unfit for direct use were flattened to form sheets). Many workshops and craftsmen depended for their products on recyclable waste (e.g., soles for shoes were produced from tyres; lamps, knives, etc., from metal sheets; hammers and other tools from iron scrap; sometimes, even, jewellery was made of aluminium scrap). Products from waste were manifold and in general comprised all household articles including furniture and doors as well as construction articles, wheels for animal carts, etc.

The recycling activities in Oman were largely inspired by similar developments in India and Pakistan. Many craftsmen who recycled waste were Indians who migrated to Oman in the late nineteenth or early twentieth century. Many articles made from recycled waste (found even today in the semi-rural and rural areas and earlier widespread in Muscat) resemble those found in all developing countries. To some extent such recycling still exists in some parts of the Sultanate, but the widening distribution and ready availability of industrial goods is rapidly replacing such articles.

With the Blessed Renaissance (*Al-Nahda al-Mubarakah*) which started in the early 1970s and which found renewed material and financial support in the oil boom, the financial conditions of the country improved drastically and the standard of living rose in a way previously unknown in the history of the country. Thus the considerable growth in

consumption of consumer goods in turn produced a legacy of recyclable waste.

Ironically, this development was not a blessing but a misfortune for the craftsmen who depended upon these waste raw materials. Consumption behaviour changed, and people dispensed with products made from waste and bought industrial goods newly produced in Oman or imported from abroad. The result was on the one hand a decline in the crafts that depended upon recycling and on the other hand a massive increase in waste generation.

In general, economic development, accompanied by the change in consumption behaviour and the decline in the recycling of waste by craftsmen, resulted in the emergence of a waste production and reproduction system which, if considered independently of any waste management activities, takes the form of a circle which is continuously and forever adding waste to the environment.

Fortunately, the circle is not closed. The existence of the waste management service opens a gap in it and enables the circle to be exited so that development often takes another form. However, withdrawing from the waste production and reproduction circle is not an easy matter, due to financial and other constraints. In addition, withdrawing from the circle in itself does not always save the environment from being polluted by waste. Crude dumping, sanitary landfill and sanitary incineration still cause damage to the environment.[21] Such damage can be avoided only by fully removing the waste from the environment, and this can be done only by recycling and composting it as far as possible.

In Muscat, waste management is based mainly upon a sanitary landfill system, with the exception of Quriyat where there are still—in addition to the municipal sanitary landfill site—some unsanitary dumping areas which need to be upgraded (as already mentioned). Although the whole waste management system (street-cleaning, waste collection and transport,

21 *Vergraben? Verbrennen? Vergessen?* pp. 7-8.

and sanitary landfill system) is functioning relatively well, it is costly. Thus other possibilities must be found to minimize costs and adapt the system to environmental requirements. Recycling and composting offer suitable possibilities. The earlier practice of recycling waste by craftsmen cannot be revived, and only industrial recycling can therefore be carried out on those recyclable items used as secondary raw material. However, this does not exclude the use of waste items in craftsmanship recycling (e.g., the possibility of using metal scrap sheets to make waste containers).

On the basis of the above we will consider the recycling of non-organic waste in Muscat at present, and what steps should be undertaken to improve the situation.

Recycling: The present practice

Anyone acquainted with the development of recycling in third-world countries knows that this type of activity generally emerges sporadically and as a private initiative on the part of people who have to eke out a living where and when they can. The type of recycling which these people practise is limited to the collection and sale of waste objects, which is examined here separately.

Collection and sale of waste as a component of recycling

The above-mentioned development results in the emergence of a group of scavengers who often settle with their families near the landfill sites in squatter settlements. In general, all family members, including children, participate in recycling activities including scavenging, sorting, cleaning or washing, boiling, etc.

These scavengers are generally inclined to take whatever they deem recyclable from the landfill (or from waste containers and other places) and do the real sorting and cleaning at home. They are not allowed to scavenge in the landfills and they are often afraid of being caught. Therefore, they quickly collect whatever they can and take it home for

sorting and cleaning. The squatter/scavenger settlement often resembles an active enterprise where people (including women and children) are busy doing work related to recycling.

The scavengers sell their collected items either to middlemen (the common practice) or directly to workshops, industries, etc. This arrangement is in place because:[22]

- Workshops and industries are not prepared to buy the small quantities which scavengers can provide. They usually buy large quantities, which can be provided only by middlemen (who have stores where they accumulate the small quantities they purchase from scavengers until their stock reaches a size that can be sold to workshops and industries).

- Even if they had storage facilities, the scavengers could not afford to store their goods until they accumulate the quantities they could sell to workshops and industries; their livelihood depends upon selling daily what they collect. They have no savings to live on during the days when they only accumulate goods.

- In general, the workshops and industries which use their goods are located far from them, and in most cases the money they would earn would not cover their transport costs if they brought the waste to workshops and industries.

The above considerations resulted in scavengers selling recyclable objects almost exclusively to middlemen—a socio-economic problem. Many social reformers interested in the lot of the scavengers think that excluding middlemen from the waste trade would help improve the scavengers' standard of living. They suggested organizing the scavengers

22 Günter Meyer, "Waste Recycling as a Livelihood in the Informal Section: the Example of Refuse Collection in Cairo" in *Applied Geography and Development: Biannual Collection of Recent German Contributions*, volume 30 (Tübingen: Institute of Scientific Cooperation, 1987), pp. 78-94.

into cooperatives with the help of governmental or non-governmental organizations, with the aim of achieving an overall improvement in the quality of life of the scavengers. In this respect, help for the scavengers would take the form of community development activity with health, literacy and numeracy, and vocational training aspects.

However, the evidence from experience in this regard is not very encouraging. Problems arise not only from the helpers, who often bureaucratize cooperation with the scavengers, but also from the scavengers themselves, who are not used to being subjected to organization and discipline, and who mistrust any governmental or non-governmental interference (because in their experience, the authorities generally consider their work as criminal activity). Thus they fear that the offered help and cooperation is merely a ruse aimed at stopping their work.[23]

It is worth mentioning that recycling does not just include the work of downtrodden people who have to eke out a living where and when they can in the so-called informal sector. It can also be an activity which attracts enterprising people. In Europe there are socially organized and well-functioning companies which trade in waste paper, glass, scrap metals, old plastic and all other recyclable waste items. In the developing countries, the existence of middlemen waste traders shows that here too recycling is an activity that attracts people with initiative.

In comparing the type of waste recycling described above with the present situation in Muscat, we find both similarities and differences. In Muscat there are scavengers, for example. Near the landfill in Bausher there is even a small squatter settlement inhabited by scavengers. However, their number is very small, and considering the relatively abundant job opportunities available to them, one cannot say that they are eking out a living. The main reasons that these people scavenge waste are not known. Observation of the landfills has shown that almost all those scavenging there are women and children. We can therefore

23 Werner Klinger, op. cit., pp. 86-95.

assume that the men have other occupations. Although it is not mere subsistence that drives the scavengers, material incentive plays a role. A scavenger receives RO 0.40 for every 150 cans collected and turned in. Such incentives were learned about in discussion with some women scavengers who mainly collect cans and waste paper (which are sold to middlemen for export to Dubai).

The reaction of the Municipality to the above situation is to prohibit scavengers from entering the landfill sites. Such prohibition has not been successful and, as experience in other countries shows, cannot be successful. Need, even if secondary and not acute, will always drive people to break prohibitions. A solution can be found only in understanding the socio-economic conditions and the family life of the scavengers. Sociological study and social work (which could be conducted as part of the overall activities of the Ministry of Labour and Social Affairs or by the Muscat Municipality) is necessary here. This would certainly require female sociologists and social workers, who can make better contact with the families than their male counterparts.

The scavenging itself should not be condemned but understood as environmentally and economically useful work which, however, needs better organization. Thus, the question is not how to abolish scavenging but how to develop it into a recycling system consisting of collection, sorting, cleaning or washing, and selling, and how to organize the recyclers into cooperatives that are supported by social workers and that could help upgrade the scavengers' squatter settlement. Upgrading could also comprise establishing storage facilities as well as providing transport, etc.

How scavengers can be organized better and more efficiently as working recyclers, has been dealt with at length in a very innovative way by Jon Vogler in *Work from Waste* (see note 7). His approach inspires development in a way that upgrades the present scavenging system to well-developed recycling methods that contribute to improving the lot of the scavengers.

The collection and sale of waste paper, cans and metal scrap is undertaken also by waste collectors and street sweepers. This is a practice found everywhere in third-world cities, and it improves the income of the waste collectors and sweepers. A negative by-product of this practice (not found in Muscat, however) is that sweepers and waste collectors sort waste during working hours, causing delays in their work. Sometimes they take the waste to special places to sort it before bringing it to the landfill site. Often they do not properly clean the places used for sorting, causing new cleaning problems.

In Muscat, the refuse collectors (who are mostly expatriates from India, Pakistan and Sri Lanka) store the cans, scrap and waste paper they collect in their sheds or dormitories, creating a potential public nuisance and public health problems because the waste stored here can easily harbour insects and rodents.

The middlemen

Sorted recyclable waste is not used in Muscat but exported to Dubai by middlemen. To our knowledge these middlemen have no special registration for this type of business. Thus, their activity and that of the scavengers belongs to the informal sector, as is the case in almost all other developing countries.

The size of this business is unknown. However, in the last few years, several enterprises have appeared which are engaged in this activity. We learned that some Omanis sponsor foreigners who are engaged in waste export. The sponsor obtains from the foreigner a fixed fee or "tax" which is independent of the size of the business. The foreigner operates his business independently in the name of his sponsor. Thus, a new dimension appears in the business development found in all other economic areas and common to all Gulf States.

It seems that the waste trade is increasingly better organized. Separate collection of recyclable waste has started to gain a foothold. Restaurants, hotels and cafeterias have started to collect cans and other metal

containers separately to sell to waste traders. According to the *Oman Observer* of 27 November 1991, "The British School, Muscat has opened a community paper and beverage can recycling project. Two skips, one for paper and one for beverage cans, are now ready for service in the school's parking lot in Madinat Qaboos. All companies and interested individuals wishing to support this environmental effort are encouraged to bring their paper and beverage cans to the skips." With respect to waste paper the project observes that all sorts of paper, including newspaper, computer paper, and boxes of all sizes are recyclable.

The paper and cans collected separately by the British School are collected by Stag Enterprises, which is taking part in the project and which is engaged in waste export. Muscat Municipality became aware of this project and intends to extend it to all city schools in cooperation with the Ministry of Education.

The role of the Municipality in waste recycling

The present recycling activities certainly deserve encouragement because of their contribution to the country's socio-economic status and to environmental protection. However, they must be systematized and incorporated in a comprehensive waste management strategy for which the Municipality is responsible. The importance of such incorporation is self-evident: any recycling activity affects the waste management system and results in a reduction of the waste that has to be collected, transported and disposed of by the Municipality. But this positive development cannot be left uncontrolled because the enterprises and individuals engaged in the recycling activity may at some point find it no longer profitable and stop recycling. If this happens, the quantity of waste to be disposed of would increase, and the Municipality would have to do more work. To be able to cope with such a change the Municipality must know the percentage of waste recycled daily, as well as changes in the recycling sector. This requires the registration of all units engaged in recycling, as well as knowledge of the percentage of waste they collect and their future plans. Only then is the Municipality ready for all eventualities.

Recycling potential and development possibilities

The existing recycling activities show that this business is lucrative. However, the present practice is limited to collection and export to Dubai, which means that the recycling activity in Muscat is dependent upon the Dubai waste market and any change that occurs there will affect it. Unfortunately, we do not have a clear picture about the Dubai waste market and so we cannot judge whether there is mutual dependency, or whether the Dubai market is influenced by recycling in Muscat.

Another missing piece of information is whether the Dubai market uses the waste it imports from Muscat as secondary raw material in the country itself or (as is rumoured) adds it to other waste that is exported to India.

The waste trade is very sensitive. It is influenced by price changes in the primary raw materials for which it substitutes. As experience shows, any fall in these prices can lead to a collapse of the waste trade, for which there may no longer be a market. During the oil crisis of the early 1970s, for example, industrial recycling of plastic waste experienced a boom and accordingly the price of scrap plastic went up, but as soon as the crisis was over, trade in this item declined drastically.

Such developments led many industrialized countries to recognize that recycling cannot be left to market mechanisms, i.e., supply and demand, but should be regulated in accordance with the requirements of environmental protection (recycling being the second-best solution for the waste problem). In line with this idea, governments in some industrialized countries have issued laws requiring industries to use a certain percentage of recyclable waste (secondary raw material) in their products. In Germany a law is under consideration which aims at recycling 75% of the waste paper produced in the country. And according to the October 1991 issue (p. 14) of the U.S. magazine *Popular Science* ("Congress Wields the Hammer"):

> Congress is now reauthorizing the Resources Conservation and Recovery Act to establish goals and guidelines for the recycling of all commodities. For paper, the bill sets a goal that by 1995, 40% of all paper products will be pulled from the waste stream and recycled. This goal was established by the American Paper Institute and subsequently adopted in the legislation. Should this aggregate goal not be attained, the bill sets specific goals for the recovery of different types of paper, such as 52% for newspapers (45% is currently recovered) and 20% for mixed paper grades, including magazines.
>
> Should the objective not be met for a specific type of paper, a "hammer" comes into effect requiring a minimum amount of used fibre in paper. The minimum for newspapers is 20% in 1997, 30% in 1999 and 40% in 2001. Specific hammers for other paper grades and commodities would be developed by the EPA [Environmental Protection Agency]. The focus in this legislation on recovering waste is commendable. But legislated minimum content only indirectly addresses the problem of overflowing landfills. As long as magazines are being diverted from landfills to be recycled, it is not critical that magazines be on recycled paper.

The fact that countries which are committed to free enterprise cannot dispense with issuing laws that compel industry to use a certain percentage of recyclable waste shows how environmental considerations require that waste trade and industrial recycling not be left to market mechanisms. In Oman such a step seems at present not to be necessary, but further industrial development and further increase of consumption, leaving behind great quantities of waste, may result in the need to enact similar laws here. Encouraging recycling in a way that emphasizes the use of recyclable waste as a secondary raw material in Oman itself will enable this material to be integrated into the industrial development of the country, from the outset facilitating both the enactment and application of any law regarding the use of recyclable waste by industry.

Such encouragement in Muscat requires first of all identifying the potential of the recyclable waste that exists in the city and ascertaining how it can be recycled. Waste can be used by existing industries that add it to their primary raw materials. In general, its role is complementary, which strengthens when the price of the primary raw material goes up. In the industrialized countries, waste almost exclusively plays a complementary role, but in the developing countries we find industries that depend primarily or sometimes even exclusively upon waste. In Oman recyclable waste may be used as complementary raw material by existing industries or by those to be established in the future, as it can lead to the establishment of industry that depends primarily or exclusively upon waste.

There is no exact data covering the potential of recyclable waste. Available estimations of waste composition are given below. From these estimates we can conclude that, considering that the population of Muscat is about 500,000, the recyclable non-organic waste in its domestic waste consists of the following:

	Kilogrammes	Metric tons
Paper and cartons	105,000	105
Plastic	60,000	60
Textiles	30,000	30
Glass	25,000	25
Metal	55,000	55

No data are available for wood, rubber and leather, but our observations show that the quantities of these items are large enough to be considered in the recycling strategy. Other factors are that the main source of these items is not household waste—for leather, it is the Muscat Central Slaughterhouse, while waste rubber consists mainly of tyres, and wood comes mainly as boxes for imports of old vehicles. These do not form

part of household waste, and since Muscat Municipality is responsible for their disposal, we will consider their recycling here.

Cans and aluminium scrap

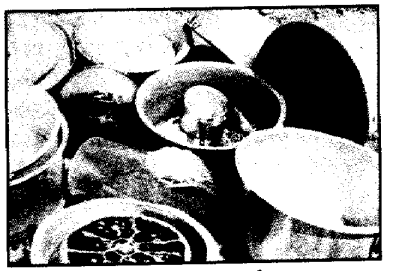
Cans are made either of steel coated with a very thin layer of tin (often coated with lacquer over the tin layer) or from aluminium. In Muscat and in the other cities and settlements of Oman we find both types. The cans in Muscat are mostly of aluminium. Cans are collected with other metals and exported to a Pakistani company in Jabal Ali in Dubai. This specialized scrap trade sends scrap collected from other Gulf cities to Pakistan. The economic gain to Muscat from this trade is unknown, and it is likewise not known how well it is organized, although effective organization of this trade can be profitable.

The present consumption of canned beverages is about 500,000 cans per day, which amounts to 5,000-6,000 kg or 5 to 6 metric tons. We ascertained that the middleman pays the collector RO 375-400 per ton. Thus, the potential daily turnover per ton yields around RO 1,875-2,400 or RO 2,250-3,600.

Since aluminium scrap has many other sources, the potential turnover could be much greater.

In this respect Jon Vogler writes:

> Aluminium is one of the most widely used metals because it is cheap to produce, lightweight and very easy to work. The main sources of scrap are:
>
> - Cook pots, saucepans, kettles.
> - Car parts.



Old aluminium pots and saucepans

- Aeroplane parts; aeroplanes are made almost entirely of aluminium alloys.
- Domestic appliances including vacuum cleaners, washing machines, dryers.
- Tubes, boxes, containers for medicines, bottle tops and other packaging.
- Camping equipment.
- Door and window frames.
- Scrap from factories manufacturing aluminium products.
- Electric cable is often made from aluminium as it is cheaper than copper—it is normally heavy gauge only.
- Trunk cans.
- Cooking foils, mainly obtainable from hotels.[24]

Many of the sources of aluminium mentioned above are found in Muscat, and their contribution, for which we do not have data, could be considerable. These sources are already exploited by collectors and traders of this type of scrap.

One noteworthy development which deserves special attention is the fact that there are people who have already undertaken to obtain a licence to manufacture aluminium ingots. This can be done easily and improves the market for aluminium scrap, as Jon Vogler writes:

> *Manufacture of ingots*
> Your market for aluminium scrap can be improved by casting your own ingots. A furnace is needed with a sloping hearth capable of reaching temperatures 200-300°C above that at which aluminium melts, i.e., 660°C. The aluminium will melt before any ferrous metals do and will run down the furnace hearth into a holding well from which it may be poured into open sand moulds. The ferrous metals remain on the hearth, avoiding the need for removing them from the scrap beforehand, but low-melting-point contraries such as plastics must be removed.[25]

[24] Jon Vogler, op. cit., p. 100.

It is also possible not only to manufacture aluminium ingots but also to cast finished products. On this issue Jon Vogler writes:

> *An aluminium foundry*
> Once you have successfully cast aluminium ingots, you may consider casting finished products. Their value will be far greater than that of the raw scrap. This is not, however, an easy process and some knowledge of foundry operations is vital. You will also need to establish that:
>
> (i) Markets exist for the product you are able to make with your skills and equipment.
>
> (ii) No other aluminium foundry in the same district is making these products or, if so, the market will support two manufacturers.
>
> (iii) You have access to equipment; fuel or power; skill in mechanical matters; some knowledge or advice on casting aluminium; and sufficient scrap material.
>
> (iv) You have the time and determination to work on a rewarding but difficult venture.
>
> (v) The product is not available locally, made from another material such as steel, stainless steel, aluminium sheet, enamelware, pottery, plastic, etc. If so, will your product be cheaper, stronger, better or more beautiful, so that you can still achieve sufficient sales?

[25] Jon Vogler, op. cit., p. 102.

Products in cast aluminium
Saucepans, lids, kettle spouts, burners for stoves, cooking pots, car parts, ladles, door and window handles and fittings, spoons and scoops, moulding boxes, ventilators, filters, knife scabbards, furniture fittings and handles.[26]

Aluminium products which can be produced locally are widely used in Oman. Thus, establishing an aluminium foundry that depends upon scrap deserves a feasibility study, and encouraging the private sector to establish such a foundry is in line with the Sultanate's determination to industrialize the country. Success in casting finished products would make possible the absorption by local production of all aluminium scrap produced in the country. Furthermore, the expansion of production might necessitate the import of aluminium (the Sultanate is exporting it at present). An encouraging development is that Ja'lan Enterprises has already applied for a licence to establish a factory that recycles aluminium scrap.

Scrap iron

Scrap iron recycling and trading have a very long tradition, dating from ancient times, when old iron was remelted to produce new items. In the developing countries, blacksmiths produce knives, spears, hammers, utensils, etc., from iron scrap, and there are workshops which use iron scrap to produce simple machines. In Oman, too, this practice still exists although it is diminishing.

In general, the scrap iron trade is a relatively large economic sector which employs many companies all over the world and which provides many scrap collectors with a livelihood. In addition, the sector uses different types of costly equipment and tools such as lorries, cranes, and electric welding machines and cutters. Even in the industrialized countries, the iron and steel industry depends upon scrap to a certain

[26] Jon Vogler, op. cit., pp. 102-103.

extent, and many third-world countries' industries and workshops could not survive without scrap iron.

While larger iron and steel industries can use iron and steel scrap by melting it to produce iron and steel ingots, small workshops and foundries rarely melt the scrap to produce ingots (since they lack the facilities to heat it to this point). Instead they use the existing scrap material, cutting and bending it to produce the required shape. Generally, these workshops can only use iron scrap that can be cut with hacksaws and metal cutters and bent without heating. They cannot recycle huge heavy scrap iron blocks; these can be recycled only by being melted down into ingots.

The amount of scrap iron in household waste is very small. Unlike the main items found in household waste, it is generally not produced continuously or in predictable quantities.

In general scrap iron is found at the following locations:

Construction sites: Offcuts of reinforcing steel rods and mesh, wire and nails.

Demolition sites: Poles, girders, joists, steel doors and windows, drain covers, pipes, railings, grills, etc.

Engineering workshops: Offcuts, swarf (turnings and chips from lathes, drills, etc.), unused parts and machinery.

Factories, mines, quarries, drilling sites, farms, technical colleges, etc.: Unused machinery, construction steel, partitioning drums and containers, pipes, tanks, carts, motors, in fact—anything!

Streets, parks and wasteland: Unused railings, manhole covers, pipes, etc.

Households: Domestic appliances (cookers, refrigerators, etc.), broken bicycles, perambulators (prams), toys, tools, furniture, etc.

Refuse dumps: Any of the above.

Unlike waste paper, scrap metal does not always arise in regular quantities; a demolition site, for example, may suddenly yield a large tonnage in a district from which only tin cans have emerged for years. So, rather than going from house to house or shop to shop regularly, scout rapidly around a district and investigate "For sale" notices, builders or shopfitters, trucks, the presence of cranes, scaffolding, air compressors and similar signs of construction and demolition.

The most profitable way of locating scrap metal is to write to and visit local factories and sources that are likely to produce scrap regularly, and to convince them that you can collect regularly, promptly and tidily in response to a telephone call.

Another source of scrap metal (to be looked at in detail later) is that of abandoned or crashed motor vehicles. Often, local traffic police will enter into an agreement or a commercial contract with a scrap metal dealer, whereby they inform him of such a vehicle, and he, in return, removes it promptly so as to avoid danger to other traffic. However, the economics of removing scrap cars, particularly in country areas, are not always profitable, so first of all work out costs and profits.

Frequently, the money from the sale of scrap goes directly to the owner, the manager or the foreman of the fabrication shop and does not pass through the firm's books. Collectors should ask themselves whether they are partners in fraud and can be prosecuted if they agree to such an arrangement. Failure to agree to it may well mean that another dealer gets the scrap! It is

difficult to be a virtuous and a successful scrap dealer, but it has been done.[27]

The quantity of scrap iron produced in Muscat is not known. However, the construction and industrial development that the Sultanate has experienced since 1970 implies that the country annually produces a considerable quantity of scrap iron, with the greatest percentage of this being produced in the Muscat area, where most of the development and construction effort has been concentrated in past years. The scrap iron trade is already established in Muscat. The material is exported, mainly to Dubai, where it is sold to the above-mentioned Pakistani company which exports it to Pakistan. Development in Oman will certainly make it possible in the near future to reuse this material in Oman itself, either in industrial recycling or recycling in foundries and workshops (already practised to some extent).

Besides scrap iron and aluminium waste Muscat has other very limited quantities of recyclable metals, such as copper, zinc and lead. Recycling of these metals cannot at present be considered separately; it is possible that they are collected and traded by those who are engaged in scrap iron and aluminium recycling.

Reclamation of motor cars and other vehicles

Reclamation of motor cars and other similar vehicles receives special attention worldwide, because of the great numbers that are disposed of yearly and that go to vehicle graveyards, spoiling and contaminating the environment if they are not otherwise handled. The best treatment is reclamation, which, besides protecting the environment, realizes a gain.

Jon Vogler states that most of the materials recovered from motor cars and similar vehicles is iron and steel. However, other materials may also

[27] Jon Vogler, op. cit., pp. 39-40.

be recovered. The reclamation of motor vehicles can be considered in three parts:[28]

1. Recovery and resale of components

The important principle here is that parts are worth much more when reused rather than scrapped. Every city in the world has dealers in second-hand car parts, and in some towns a complete commercial district is devoted to nothing else.

Here are a few principles to dismantling car spares (often known as "breaking"):

(i) It is often easier to cut or break the bodywork on which a part is mounted and then unbolt the part at a bench, instead of unbolting the part from an awkward position on the vehicle. Never use a flame-cutting torch near the petrol tank, feed pipes, carburettor, etc. The explosion could kill you.

(ii) Parts sell more quickly and for higher prices if they are:

- Kept in sets;
- Labelled by make and model of car;
- Cleaned (use paraffin);
- Made as good as new by fitting new brushes (small bronze bearings), linings (e.g., brakes and clutches), seals, electrical contacts or by repairing (e.g., radiators, motors and generators, gearboxes, etc.);

(iii) When selling used car parts it is a good idea to:

28 Jon Vogler, op. cit., pp. 54-59.

- Display them on the counter or at a stall so that buyers can easily find the part they want;
- Group all the parts of a similar type (e.g., all the brake shoes) or all the parts for a given model of car (this is more difficult, as sizes vary);
- Advertise in the local paper;
- Have a handbill printed describing the range of parts you stock and the models of the car for which you can supply parts. Placing these under the windscreen wipers of older cars of this model could bring you many customers.

2. Recovery of unsaleable parts for scrap

If parts are unsaleable, some value can be recovered by selling them for scrap. It is worth sorting them into different materials, and the following list is a guide to this. However, some parts may be made of different materials from those listed and it is useful to learn how to distinguish between them.

Cast iron. Note, however, that any of these may be made of cast steel. To tell the difference, note that steel is shinier and will not shatter under a hammer blow, whereas iron is grey, and thin sections will shatter. If in doubt, put it on the iron pile: steel castings will not spoil cast iron scrap but iron will spoil HMS.

Cast iron

Cylinder block (crank case)	Clutch housing
Cylinder head	Steering gearbox casing
Gearbox casing	Flywheel
Differential casting	Wheels
Starter and generator casings (after removal of copper)	Sump
	Brake drums

Heavy steel

Pistons and rings
Con rods
Crankshaft
Camshaft
Gears
Clutch parts
Half parts
Timing chain
Diesel injectors
Brake shoes
Steering linkage parts
Shock absorber cylinders and pistons
Transmission shaft
Brake discs
Leaf or coil springs
Lorry chassis
Generator and motor shafts (after removal of copper)

Light steel

Body
Doors
Lids
Valve cover
Fan
Bumpers
Hub caps
Headlamps
Air filter

Aluminium

Fan
Cylinder head (a few models)
Pistons
Crankcase
Starter motor and generator casing (after removal of copper)
Steering wheel

Zinc

Carburettor
Hydraulic cylinders
Door handles
Lamp sockets
Small gear boxes (e.g., windscreen wipers)

Copper

Generator armature
Generator stator
Motor armature
Motor stator
Radiator
Electric cables
Small electric motors (e.g., windscreen wipers)
Distributor points
Electrical switches
High tension coil

Bronze

Bearings from:
Crankshaft
Gearbox
Wheel hubs (but any of these may be steel [ball or roller] bearings)
Differential
Steering gearbox

Non-metallic parts such as glass, rubber and plastic are difficult to reclaim.

3. Recovery of the shell

The shell is all that remains of the car when the above parts have been removed. Shells abound in many parts of the third world, not only in cities and suburbs but also in rural areas. They are a hazard to traffic and to children, and serve as breeding areas for mosquitoes and other pests. However, their large size and low weight of metal makes them uneconomic to transport to a distant steel mill or foundry. Neither are there sufficient numbers to justify investment in huge car-crushers such as those used in the industrialized countries (the apparent large numbers are usually accumulated over many years). Because people in some third-world countries are so resourceful in repairing and obtaining used spares, their cars often run for thirty or forty years, also diminishing the scrap supply.

Where large numbers of shells are accumulating, a simple, cheap, labour-intensive method is needed to reduce them to pieces small enough for economic transport to the scrap buyers. The following system has been developed:

Equipment: 10 cm (4") brick hammer
1 kg (2-2½ lb.) hammer
Pair of leather gloves
Boots
Handcart
Wire cutters

Also useful:	Axe	Hacksaw
	Bolt croppers	Rope

A team of about six strong youths can wheel the handcart around the district and cut car shells into manageable pieces by hand. Thick pieces may need cutting with a saw or bolt croppers. The size of the piece depends on the size of the handcart and the needs of the buyer. When the cart is full it can be taken to a secure place and the contents collected regularly by lorry on a round.

Before cutting up a car shell, make sure that it doesn't belong to anybody; it may form part of a house or wall of a compound. Find out if this is the case before you touch a shell or you may be asked to pay for it. If you are considering paying for car shells remember that the average car contains about two-thirds of a ton of ferrous metal and two-thirds of this may have been stripped out, so the shell will probably not contain more than 150 to 200 kg of saleable scrap. The value of your work in breaking it down and the cost of the transport must be deducted from the sale value of the material, so do not pay too much. If you do not buy, it is most unlikely that anyone else will!

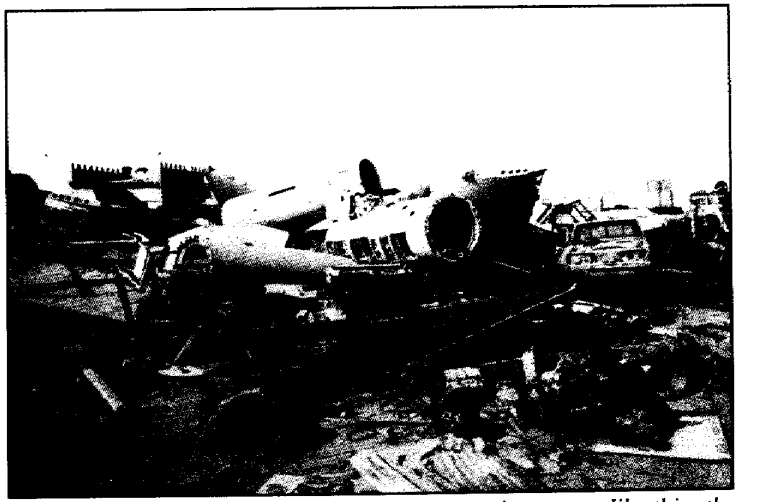
Car shells are dirty and painted, and the material is thin. If not baled, the price per ton will be low. Against this, large quantities may be available and there are good prospects for recovering components that have been missed by strippers, so the operation may well be profitable.

The author quoted here adheres to the idea that in a motor car or other vehicle, all recyclable items should be reclaimed. However, this ideal is difficult to put into practice because many recyclable items in a motor car or a vehicle form only small portions that cannot be exploited economically. In general the effort that has to be put into separating them is greater than the gain they bring. Thus the concentration is on reclaiming those parts which make up the major constitutents of the vehicle. In most cases the emphasis is on obtaining those constituents

which can be used as second-hand spare parts. This goal can be achieved if the car is dismantled in a way that avoids damaging such components.

In Muscat reclamation of motor cars and similar vehicles concentrates on acquiring spare parts and sometimes reuse of the tyres. At present there are several enterprises engaged in selling second-hand spare parts. These enterprises buy old vehicles which contain spare parts, and keep them in a fenced but open place in a very disorderly way. Cars from which all usable items have been taken are not taken to the landfill or vehicle graveyard but are left on the premises and newly arriving vehicles are simply added to them.

The fenced place (wrongly termed a garage) is an open area but has a door and a watchman, who is also the sales manager. Clients often go there when they cannot afford new spare parts or cannot find the type of spare parts they want. Generally, the "garages" are out of the way and



Unroofed store for metal scrap. In unsystematic storage like this, the scrap items are thown randomly on top of each other, making it virtually impossible to know what is available in the store and to run the scrap trade efficiently.

have no identifying sign showing what they are; it is relatively difficult to find their whereabouts and they are generally known only to those interested in second-hand spare parts. Out of 62 car drivers with relatively low incomes whom we asked about second-hand spare parts, only 5 knew of the existence of this possibility and only 2 had made use of this opportunity (1 twice and the other only once). They did this because they could not easily find the spare parts they wanted and friends introduced them to the second-hand spare parts "garages." Although they were satisfied with the second-hand spare parts they used, they were not planning to depend on them in the future.

The trade itself is set up in a haphazard way. The customer comes to the garage and specifies what he wants. He is shown the old cars in which the spare parts can be found. He selects the car from which he wants to have the spare part. The spare part is taken out in a way which often damages many otherwise useful articles. The likelihood that other useful parts will be damaged increases if the customer himself removes the spare part he wants, because to save time and trouble he may resort to breaking useful parts that could be saved by proper dismantling. The present

Unsystematic storage of scrap in Muscat.

practice is generally very uneconomical and should be replaced by proper dismantling and sales methods following these steps:

- Dismantling the whole vehicle down to its original parts with the aim of identifying those components which could be used as spare parts. If it becomes necessary to break the body covering the parts, this should be done carefully in order not to damage the components which could be used as spare parts.

- Sorting and cleaning the spare parts. This often includes oiling them.

- Repairing the spare parts. In some cases screws and other small components may be missing.

- Improving the display of spare parts.

- Sorting spare parts into the appropriate categories.

- Displaying the parts in a shop in an organized and attractive way that enables the customer to locate easily the item he wants. The store in which parts are kept must also be well organized. Experiences in some Latin American cities have shown that the number of customers increases if the display is well organized and attractive.

- In this respect it may be even better to put the spare parts in suitable boxes carrying the name of the shop.

- Preparing a list containing all available spare parts and distributing this list to petrol stations and vehicle repair workshops.

- These steps can be carried out only by reorganizing the present garages into a building that contains a protected hall for the cars, a garage for dismantling and a shop for the sale of spare parts. The customer should have the feeling that the shop does not differ in this arrangement from any other spare parts shop. Another point which may

deserve consideration is to engage the petrol stations in selling spare parts.

Motor cars and similar vehicles comprise items that cannot be used as spare parts but which can be otherwise recycled, such as the car body, which can be sold as scrap steel, and the tyres, which can be retreaded or sold to the rubber industry.

The importance of reclaiming motor cars and similar vehicles becomes apparent if we consider that about 200,000 motor vehicles are registered in Muscat. If we assume that each car or vehicle will be dispensed with after 7-10 years, then each year there will be 15,000 to 28,600 vehicles newly out of commission, which can be reclaimed in this manner. Daily this amounts to 55-78 cars and vehicles to be dismantled. Here about 100-150 people can be employed in the reclamation business, and the number rises further if we consider the business opportunity offered by other recyclable items in old motor cars and similar vehicles.[29]

Rubber

The quantity of rubber in the household waste of Muscat is very limited. According to our observations it does not amount to even 1% of total household waste. However, this does not mean that the city does not produce a considerable quantity of rubber waste that economically deserves to be recycled. In all countries, the main source of rubber waste is tyres, which in many countries alone accounts for a gainful recycling sector. As far as possible, tyres are retreaded. In India, where reclamation of the whole tyre (by retreading) plays an important role, there were in the early 1980s 12 reclaiming units which together

29 Muscat could become a centre for the reclamation of motor cars and other vehicles from other parts of the Sultanate. We were informed that the recovery of second-hand parts from old cars and vehicles has become a booming business in the United Arab Emirates. The spare parts are cleaned properly, packaged and exported to Egypt, India and Pakistan, which have shortages of spare parts and where many people cannot afford to buy new spare parts.

processed about 24,000 tons per annum. The largest processed about 8,000 tons per annum. On this issue Jon Vogler wrote in 1983: "India produces 6.5 million tyres per annum, but because of other uses for old tyres, there are not enough to reclaim, and attempts have been made to buy more from Europe, despite the very high shipping costs."[30] At present India and Pakistan are the main importers of old tyres from the Gulf area. Indian and Pakistani firms that are specialized in this business and in other sectors of the waste trade have established themselves in Saudi Arabia and other Gulf States. The short distance between the Gulf and India makes the business more profitable and lucrative. Oman, which is nearer to India than the other Gulf States, would have an advantage over the other Gulf States in terms of distance if it were to engage in waste export to India and Pakistan.

At present there is a small factory for retreading old tyres in the Rusayl Industrial Estate. This factory retreads tyres of large vehicles only and not of small cars. Although there are many old tyres that are retreadable, expansion of the factory cannot yet be undertaken because demand for retreaded tyres is very low. According to our discussions with several car drivers, the low demand is due to the "low quality of the retreaded tyres." We could not ascertain whether this was true or not, but at any rate the problem could be solved by improving the quality.

Retreading an old tyre in Rusayl Industrial Estate in Muscat

With respect to the scrapping of old tyres, there are no data. However, we can give a relative estimate concerning the approximately 150,000 cars and vehicles that are registered in Muscat. The average life span of a tyre is 70,000 km. If each car travels about 100 km daily and the

30 Jon Vogler, op. cit., p. 158.

lifetime of a tyre is 70,000 km, each tyre will last about two years. However, this rarely happens, and therefore we will assume that the life of a tyre is 18 months. The 150,000 cars and vehicles can therefore be expected to produce 400,000 scrap tyres annually.

It seems that the only possibility of reusing old tyres in Muscat is retreading, which has already been started. Success will depend here upon improving the quality, yet this by itself will not be enough. Not all tyres are retreadable, large numbers of them being rejected as unfit due to holes in the fabric-reinforced substructure or weakness in the sidewall. Because of this a recycling solution can be found only in the export of old tyres. India and Pakistan may be suitable markets, but in this respect we emphasize that the trade may not be profitable and may only cover export costs. Even if this is the case, export deserves encouragement because it helps to dispose of a large number of tyres that cannot be burned or buried and have to be stored, becoming breeding grounds for insects and rodents.

Burning rubber gives off clouds of black, polluting smoke and is prohibited in many countries. In a municipal refuse dump (or land-fill), rubber tyres cause problems because they do not rot, cannot be compressed and have a tendency to work their way to the surface if buried. Above ground they catch rainwater that cannot drain away, in which case they become breeding sites for mosquitoes. In mechanical refuse disposal plants, tyres resist baling, shredding or any other process. Also, tyres left lying around are an eyesore and spoil the environment.

Paper

Direct reuse of waste paper was widespread in Muscat and in all other settlements of Oman before 1970, and continues today, to some extent, in some remote rural areas. In the past there were people who collected waste paper to sell it to shops and foodstuff stores, which would fold it into bags in which staples such as sugar, flour or rice were put. Waste paper was used also to wrap up textile sold by shops. For hygienic

reasons the above-mentioned use of waste paper must be rejected, especially its utilization as a container for foodstuff.

In Muscat this form of waste paper reuse has disappeared altogether and has beem replaced by the use of plastic bags and specially produced wrapping paper.

The disappearance of direct reuse of waste paper coincided with a tremendous increase in waste-paper production. At present, waste paper and cartons make up about 17.5% of household waste and thus the city produces daily about 105,000 kg (105 tons) of wastepaper.

The emerging possibility of exporting waste paper meant that many people began to collect it for sale to middlemen who export it to Dubai. The Muscat Municipality does not know the exact size of this trade, although its contribution to reducing the waste to be collected and disposed of could be very high because of its high percentage in household waste.

Waste paper deserves special attention not only because it is a commodity that can be exported but also because it means that a large, profitable paper factory or several smaller paper factories could be set up in the city. The matter calls for a detailed feasibility study, since the volume of paper imports to Oman encourages the possible development of a paper-making industry in the country. Of relevance here are various detailed issues regarding waste-paper recycling, such as suitability for recycling and the appropriate types of waste-paper recycling machines. We can quote the technical aspects of the issue from a short and very impressive report by Jon Vogler and Peter Sarjeant:[31]

31 Jon Vogler and Peter Sarjeant, *Understanding Small-scale Paper-making* (Arlington, Virginia, USA: Volunteers in Technical Assistance, 1986), pp. 3-18.

Secondary pulp
Secondary or recycled pulp is made by vigorously agitating waste paper in water (usually in a hydro-pulper, a tank containing rotating blades) to separate the fibers bonded during the original paper-making process. As these bonds are weaker than those of the original cellulose plant, hydro-pulping is a more gentle process than primary wood pulping and consumes less energy. Even so, each time paper is recycled, it becomes weaker. Secondary pulp is therefore never as strong as the primary fiber from which it was made. It can be almost as good, provided pure waste paper of the same type is used. For example, pulp made by hydro-pulping clean kraft sacks will make new sacks of only slightly lower quality, particularly if mixed with a proportion of primary kraft pulp. If, however, the secondary pulp is made from materials that contain newspapers, or dirt, dust or clay, or some other weaker mechanical pulp product, it will not be strong enough to make sack paper.

Coated papers. In some cases the matted, absorbent surface of a paper is coated with a material that makes it glossy and smooth. This coated paper is better for printing. Coated papers are frequently used in magazines that are financed by the advertisements printed. In the process of hydro-pulping coated waste paper, the coating is washed out; thus, the weight of fiber obtained from a ton of coated paper is less, often by 20 percent, than that obtained from a ton of uncoated paper. As a result, the value of scrap coated paper to the paper mill, and its selling price, will be lower.

If the coating is plastic or other material that will not dissolve in water, the waste paper will require specialized machinery to recycle it and may reduce the value of more pure paper with which it is mixed. The same is true of polyethylene film, cellophane, glued paper, string, and any material that will not break down in water. Some of the various coated papers can be kept warm and wet in storage, then cooked in a hot caustic solution in order to

biodegrade and break down the coating to release the fibers. Again, these papers require special machinery and handling to recycle, and they may not be as valuable as simpler, plain paper.

Printed and coloured papers. Both printing and tinting reduce the value of paper to be recycled. They make the pulp, and the paper made from it, dull grey in colour unless bleached (which is expensive), or de-inked (which is also expensive). Tinting colours and pulp must then either be used for a limited range of similarly coloured products (or cheap grey products), or must be bleached. Therefore, white waste paper is more valuable than similar material that is coloured. Unprinted waste paper is of a greater value than the same material printed.

Structure of the paper-making industry

The manufacture and use of paper is one of the world's biggest industries; it takes place in:

1. Pulp mills, which process wood chips or other materials to make pulp.

2. Paper mills and board mills, which use pulp or waste paper to produce finished paper and board.

3. Paper converters, which use paper or board to produce boxes, tubes, rolls of tissue, boxes of blank office paper, stacks of printing paper cut to standard sizes, etc.

4. Printers, who usually buy from converters, although larger firms such as newspaper presses may buy directly from the paper mills.

5. "Integrated" mills, which make pulp and then use it themselves to make paper.

These industries are huge, highly mechanized and efficient. There are many of them, so they compete fiercely, and the available handmade and small-scale paper manufacturers find it very hard to compete. In the developing world, opportunities may be better but are rarely undertaken largely due to insufficient technology, skill, capital, and other inputs.

To put small-scale or handmade paper production into perspective, it is important to realize the vast range of production capabilities within the industry. For example, one person working out of a home workshop with minimal equipment can possibly produce as much as 45 kg of paper per day, while a partially mechanized micro factory can turn out about 225 kg daily. By contrast, the International Labour Office defines small-scale to include production capacity of up to 27 metric tons per day. And a single machine in a large modern operation can produce 270 metric tons of paper per day. It should be obvious that only in very special circumstances and for very special markets can small-scale operations compete effectively in today's paper industry.

One field in which hand and small-scale paper-makers do find a niche is in the production of the very highest quality "art" papers, or the manufacture of a variety of paper products for small local markets that are not served by large producers. Another area in which paper-making processes can be applied on a small scale is the manufacture for local markets of a variety of products such as egg cartons, flower or plant pots, rough boxes or roofing materials. These are considered in detail in later sections of this paper.

MAKING PAPER IN THE MICRO FACTORY

On a somewhat larger scale, but still in an essentially hand process, paper can be made in a micro factory capable of producing about 240 kg (1/4 ton) of paper per day; such small factories are fairly common in India, and VITA has assisted at least

one such operation in Tanzania. This process uses wastepaper or rags to make pulp, or pulp purchased from a pulp mill. It can produce good quality bond or drawing paper, card stock, school tablets, filter paper, toilet tissue, grey board, and album or blotting paper. It can also make such articles as egg cartons, flower pots, seed flats, hospital trays, etc.

In addition to an identified, reliable market, the small factory requires a steady, reliable supply of raw materials, water and power. Suggested facilities include a building of about 300 square metres for operations and shed of about 185 square metres for collecting and sorting the materials. Six administrative staff and as many as 100 labourers working in two or three shifts are needed. The United Nations Industrial Development Organization (UNIDO) estimates an investment of approximately US$26,000 for the total cost of installation. Production may be increased by installing one or two more beaters and operating the vats in three shifts. Beyond that capacity, however, economies of scale decline. For larger production, a mechanized small-scale plant should be considered. . . .

The following lists of equipment, supplies, and staffing are drawn largely from a UNIDO monograph on small-scale paper production. Moulds and presses for specialty items are not included. Production process follows the steps given at the beginning of this section.

MACHINERY AND EQUIPMENT

Vomiting type digester, 1.5 m x 1.2 m
Rag chopper, 25.5 cm blade with 3-hp motor
Beater, 61 cm x 76 cm roll size (x 2)
Electric motor for beaters of 20 hp, 960 rpm, slip-ring with oil immersed starter (x 2)
Lifting semi-automatic vats (x 6)
Hydraulic press, 102 cm x 127 cm plate size, double ram

with 5 hp motor
Screw press (91.5 cm x 107 cm or 89 cm x 1114 cm plate size for processing of sized paper, etc.)
Calender machine for paper glazing (30.5 cm x 91.5 cm roll size, complete with accessories)
Electric motor for calender machine (10 hp, 960 rpm, with starter)
Paper-cutting machine (107 cm x 122 cm blade size)
Small beater of 2 kg capacity with 1/2 hp motor for experiments
Washing machine
Chain pulley block with tripod, 2-t capacity
Platform weighing balance, 500 kg capacity
Pulp storage tanks for lifting vats (x 6)
Washing cradles for pulp washing
Press boards for calender machine, 1.2 m x 1 m (x 40)
Woollen felts (x 400)
Complete sets of carpentry tools, pipe-fitting tools, etc.
Small (2 kg) pan balance
Towel horses for keeping felts (x 6)
Sizing trays
Grinder
Dusting frame
Spare parts for moulds, etc.

ONE-TON-PER-DAY PAPER-MAKING PLANT

In India, very small (one-ton per day) "cylinder mould" machines are used to produce paper. These machines are simple to operate and can use either waste paper or agricultural wastes such as sugar cane, sisal, banana, or bamboo. Cotton rag, widely available in India, is also used.

The raw material is first passed through a chopper, then broken down to basic fibers in a "Hollander beater." This takes between one and a half and three hours. The pulp is washed and bleached

if required, then diluted with plenty of water and fed into the "cylinder mould" machine, which forms the paper.

A wire mesh covered cylinder revolves in a vat full of pulp. Water is sucked out through a drain in the cylinder, leaving a layer of pulp on the wire mesh surface. At the top of the cylinder an endless band of wool felt picks up the layer of wet pulp and conveys it to the cutting roll where an operator makes a cut parallel to the roll axis and peels off the pulp in sheets that are stacked for squeezing in a hydraulic press. Finally, the sheets are dried and calendered (squeezed between smooth rollers).

Each sheet is 86 x 56 cm. The weight of the paper ranges from 65 grams per square metre (gsm) for writing and printing papers to over 300 gsm for packaging. Among the many applications are envelopes, file covers, file cards, insulation, and filter paper.

Most of the water used in the process is recovered but there is a net consumption of about 46,000 litres in 24 hours. The plant includes a number of three-phase electric motors. It employs 12 to 16 workers per shift, plus management. According to UNIDO estimates, capital investment in a mill in this size range would be about US $100,000.

FIVE- TO THIRTY-TON-PER-DAY PAPER PLANTS

A 3-ton-per-day (TPD) machine would not be greatly different: it would have more dryers, probably a third press, and would run faster, fed with suitable stock. Capital investment for a 1- to 25-TPD machine is estimated by UNIDO to be approximately US $4 million.

A simple hydro-pulper is used for making pulp. It has a cylindrical steel tank with a rotary "impeller" (like a strongly constructed fan) in the base. The impeller swirls the water, chops the paper, then mixes the pulp. The process is performed in

batches and some contraries are physically removed at intervals. Other contraries, such as string, wires, wet-strength papers, or plastic, are continuously removed by a "rugger rope" or, occasionally a "junk trap." High-density centrifugal cleaners and pressurized or vibrating screens are also used. This is followed in some instances by low-density cleaners with up to three stages, for removing plastics and adhesives.

The output of the pulp mill requires beating or refining before it can be made into paper. This is done with a Hollander, a roll carrying heavy bars that rotates in a strong trough, at the bottom of which are more bars. The roll batters the fibers against the trough bars and also pumps the pulp around the trough. Refining strengthens the paper product, and produces a more consistent pulp.

Consistency is the percent by weight of the weight of dry pulp to the weight of the wet slurry (or semi-dried mixture of pulp and pulp plus water). For example, 6 percent consistency is about 6 kg of dry pulp plus 100 kg of water, and this is like a thick soup; 30 per cent consistency is like a wet but not dripping newspaper.

Paper-making involves the handling and processing of very thin layers of pulp, which is weak in its wet state. Maintaining the proper consistency is therefore vital. But one of the problems of small-scale paper-making is that the necessary controls for maintaining the right consistency may be omitted to reduce costs. Stock preparation also includes cleaning, screening (to remove lumps of pulp or foreign matter), and the addition of chemicals or dyes.

In more modern mills, refiners are used. In a refiner, pulp stock is fed into the centre of two flat plates with bars for brushing the fiber. One plate is fixed, the other rotating. As the fiber, at 3-4 percent consistency, moves from the centre to the edge, it is brushed by the bars.

In India (but almost nowhere else), small Fourdrinier machines are cheap and readily available. The pulp is dispensed from the "head box" into a continuous loop of fine wire mesh supported by rapidly rotating rollers that suck the water from the pulp. The roller sucks out sufficient water for the sheet, now semi-solid, to leave the mesh wire and, supported on porous felt belts, to pass through two or three sets of press-rolls. It leaves these with about 60 percent water. The excess water is removed by the dryer, an array of 16 steam-heated drying cylinders, each about 1.5 m in diameter, against which the paper is firmly held by felts and smaller rollers. A set of shiny-smooth calender rolls gives a hard, smooth surface finish to the paper, which is then wound in a continuous length into strong cardboard cylinders, to form a reel of over a metre in diameter, containing hundreds of metres of continuous paper.

The width of the small Fourdrinier machines is rarely more than 1.75 to 2.5 metres. Plants of this kind can produce papers from 50 gsm to 150 gsm in most grades, and run at over 100 metres per minute. The tonnage of paper finally produced will be around 85 percent of the weight of waste paper input, and this can be improved if the water is cleaned and recirculated, so that no fiber is lost.

Alternative products from waste paper

Fruit and egg cartons from waste-paper pulp. Another process makes egg cartons from paper pulp using a small-scale paper plant called the Super Melbourne. Waste paper is first soaked, then pulped and refined. Pulping can be done in a domestic washing machine.

The equipment includes a refiner that reduces the pulp to basic fibers. The slurry that results is poured into a sheet of mesh stretched over the forming tank of the Super Melbourne and a valve in the tank is opened. The water draining from the tank sucks moisture from the layer of pulp, which is then pulled from

the tank on its sheet of mesh. The layer of pulp is folded over once and pressed between specially shaped dies, and then it is laid to dry.

The process employs four people, but labour costs are reduced when Super Melbourne machines are batched together for greater output. Output is 60 egg trays per hour, or 60 sheets of paper measuring 84 x 66 cm. The machine requires only 300 watts of electrical power. Most of the water used is recycled. Floor space required is 2 square metres for the machinery and 5 square metres for drying.

More sophisticated machinery is available for producing from 200 to 4,000 30-egg trays or equivalent products per hour. Such a machine is made by Tomlinsons, but careful market research is essential before contemplating the heavy cost of a machine that tends to saturate any but the largest market.

Similar machinery is available or can be specially designed to produce flower pots, seed flats, hospital trays, etc. A careful market study should be made before investing in such equipment.

Asphalt roofing sheets. Low-quality, low-cost roofing sheets with a life of about five years can be made from the very lowest grades of mixed waste paper grades that would not be acceptable for paper-making due to the amount of dirt and contraries present. A factory with three moulding machines costs about US $200,000 for plant and machinery and can produce about 8,000 sheets daily, each about 1 square metre in area (over 2 million square metres annually). About 35 people are employed and 50 metric tons of paper per week are used. In India, the roofing material retails at around $0.25 per sheet, in South America, at about $0.60 per sheet. The manufacturing process consists of the following steps:

1. The waste paper is washed and pulped in a hydro-pulper. A mechanical hammer mill or a Hollander beater may be used instead.

2. The pulp is passed through a screen, to remove grit, dirt, or other impurities, and a board-forming machine (similar to that already described for a one-ton-per-day paper machine), to produce a continuous length of board that is cut to length as it comes off the machine.

3. The board is spread on the ground and dried in the open air. The edges are trimmed on a rotating slitter.

4. The board passes through an oven at the end of which are corrugating rollers. The corrugated sheets are then trimmed again and stacked in cradles.

5. Next, they are dipped in a bath of hot asphalt (asphalt is flammable, so the means of heating must be carefully chosen). The asphalt hardens rapidly at air temperature and the sheets are unloaded and stacked.

6. When quite hard, the sheets are either:

   - Taped in bundles for sale as third quality;
   - Sprinkled with mineral chips (while asphalt is soft) prior to packing as second quality;
   - Hand-painted and packed as first quality.

Which of the paper-making technologies mentioned does not suit Muscat? This is a question that should be studied carefully. Such an investigation should include visits to paper-making factories which depend upon waste paper in other Gulf cities. However, what exists in these cities should not simply be imitated: special consideration should be given to the

specific conditions of Oman in general and Muscat in particular. One consideration which, however, should be excluded from the beginning is establishing a highly mechanized paper factory, because such a factory requires more raw materials than the volume of waste paper the country can provide. We suggest starting with a factory with a production capacity of 5 tons a day, moving later to establishing another with a production capacity of 30 tons a day. It could also be decided to establish several 5-ton-per day paper factories. Establishing several factories of such a size has the advantage of giving people with relatively small capital the chance to participate in this process.

A much more important advantage of introducing small factories involves promoting the transfer of appropriate technology which can easily be absorbed into the technological infrastructure provided by society at large. It belongs to intermediate technology, whose operation resembles that of a workshop. India and Egypt are two countries that use this technology intensively. They also establish the plants at a relatively low price. Local workshops and mechanics can easily produce spare parts for them after receiving some guidance by experts acquainted with this type of technology. The introduction of small-scale plants would therefore enlarge the technological basis of society, bringing about genuine development.

Wood

The proportion of wood in household waste is very small (less than 1%), but this does not mean that waste wood production in Muscat is insignificant, since there are other sources of waste wood. Most of the commodities and goods imported from abroad come in wooden boxes that to a great extent are scrapped as waste wood. Local carpenters make use of this material, but they cannot absorb the whole production; part goes to the landfills. In late 1991, Muscat Municipality was contacted by a charcoal producing company which wanted to be allowed to collect waste wood from landfills for the production of charcoal.

The company (Oman Charcoal Establishment) informed us that it made the necessary arrangements to establish a small-scale plant to begin work in January 1994. Its daily production was to be 2 tons of charcoal, for which it would need about 8 tons of garden and agricultural waste. An annual production of 600-700 tons is anticipated, and the plant is expected to expand. The venture aims at substituting the import of charcoal with local production.

Waste wood has a higher density than garden waste and is more suitable for producing charcoal. The charcoal produced would be in briquette form and would be smokeless, meaning only 5 grams of smoke in each kilogram.

In general, waste wood could make a better contribution than it now does. Large wooden boxes are made of strong wood sheets which if dismantled carefully and without damage are suitable for making low-priced furniture and other items, resulting in wood import substitution and perhaps in the emergence of a new furniture-making industry depending mainly on waste wood.

The waste sawdust produced by carpenters is also a very useful material. It can be used as stuffing, and it can be added to organic waste for composting or to waste paper to be used for producing cheap paper.

Plastic

Plastic constitutes about 9% of the household waste in Muscat. Thus, about 50,000 kg, or 50 tons of it is produced daily in Muscat. However, the possibility of reducing this waste to a secondary raw material seems to be very low, because the Sultanate—being an oil-producing country—has plenty of cheap primary raw materials available for plastics production. If reuse of waste plastic is considered at all, it is only in order to protect the environment.

As far as we know, the export of waste plastic, unlike paper and scrap metal, is unknown, but this does not preclude the possibility of such a trade indefinitely; it may exist in the near future.

Textiles

Although the waste produced daily in Muscat contains about 5,000 kg, or 5 tons of waste textile, the possibility of recycling this material is very limited. All that can be done is to add it to the waste paper to be used in the proposed paper-making industry. Only textiles of cotton and other organic materials are suitable for such a use.

Glass

The proportion of glass in the household waste of Muscat is about 5%, with a daily production of about 50,000 kg, or 50 tons. This production is increasing steadily as the use of glassware increases. The establishment of a glass factory that recycles waste glass deserves to be considered and properly studied.

Besides its utilization as secondary raw material, waste glass can be recycled. On this Jon Vogler writes:

> *Manufacture of floor and wall tiles*
>
> Cullet, particularly from coloured bottles, can be used to make attractive and hard-wearing floor and wall tiles. The tile can be made of either:
>
> - Waste glass in resin (polyester, epoxy or urea formaldehyde resins are all suitable).
> - Waste glass in cement.
> - Waste glass in resin with a cement backing.

The waste glass should be:

- Colour sorted to enable attractive tile surfaces to be selected.
- Crushed.
- Graded into sizes: (i) coarse, + 6 to 19 mm; (ii) medium, + 1.5 to 6 mm; and (iii) fine, -1.5 mm, using sieves or screens with the above mesh sizes.
- Surface treated if possible by washing in a solution of trimethoxy silane to make a stronger tile. If it is not possible to treat the surface, then the glass must be used soon after it is crushed.
- Coloured, if desired, with dye or pigment. Dyes that are not soluble in water are best.

The operation, as seen in Mexico, is as follows:

(i) The glass is mixed thoroughly with the cement or resin. The ratio should be 1 cement: 3 fine sand with no aggregate. Colouring can be added at this point.

(ii) The mixture is then poured into a perfectly clean rectangular mould. The mould base can have a glossy, rough, or ribbed surface depending on the tile surface desired. A depth of between 14 and 20 mm is best.

(iii) It is then covered with a layer of paper and pressed.

(iv) In the case of wall tiles, a wire loop can be embedded in the back to assist fixing.

(v) The tile remains in the mould until the cement or resin has gone off (set firm enough to handle gently). Cement tiles are

cured in a waterbath for twenty-four hours, followed by drying for three days.

(vi) To make resin tiles on a cement backing, the backing (with wire loop) can be made first and placed on top of the resin glass mixture in the mould. With this process the finished tile can be removed from the mould sooner, so fewer moulds are needed.

(vii) High-gloss tiles can be obtained by polishing the surface with diamond or carborundrum paste.

These tiles sell in Mexico for about US $5 per sq m but a higher price could almost certainly be obtained elsewhere. These are an expensive wall or floor covering and should be sold in upper- and upper-middle class districts. Normally they will sell best through builders' merchants and merchants who sell bathroom and kitchen equipment and enamelware.

Other methods of making tiles

Tiles that do not use expensive cement can be made with flash from a (coal-burning) power station or other large industrial boiler furnace, with dried sewage sludge or cattle or pig manure as filler. The filler is finely-powdered, mixed 50:50 with washed cullet and pressed in moulds as described above. The tile must then be fired in a furnace at about 900°C so that the glass melts and binds the particles of filler together.

Another type of tile can be made by mixing up to 70% crushed glass, 30% mixed china and broken porcelain (from basins, lavatory bowls, etc.). These have to be dry-pressed and fired.

Building materials from glass

Bricks can be made from a mixture of 30% clay and 70% waste glass (by weight), and these have a tough outer skin that will resist

wind and rain. If the glass is powdered very finely it acts as a flux and reduces the temperature needed to fire the bricks by more than 50°C. About 30% more bricks can be made with the same amount of fuel. Another type of brick, very strong and resistant to water, is made from 31% crushed glass, 6% clay, 7% water and 56% crushed old bricks.

Strong, lightweight walls that economize on concrete or clay can be used by embedding complete bottles, in even layers, in the material.[32]

32 Jon Vogler, op. cit., pp. 196-198.

Composting organic household waste

Composting not only reduces the amount of waste to be disposed of but also has economic advantages and contributes to agricultural development, especially in arid and semi-arid zones like Oman and many other Arab countries, where the soil is poor and sandy and needs considerable soil amendment (soil conditioner) and large quantities of fertilizer.

Although the value of composting household waste is generally recognized, apparently very few people understand the function of compost; for example, in Arabic compost is called *samad*, which means fertilizer.

Consider the qualities needed if soil is to be used for agricultural purposes. In order to provide good crop yields, year after year, soil must contain the following:

(i) **Nitrates**, to give nitrogen. Normally this is provided by decaying leaves and vegetable matter or by animal droppings. If these do not arise naturally, it may be provided instead by:

- Artificial or chemical fertilizers such as sodium nitrate or ammonium sulphate (ammonia is a chemical containing nitrogen).

- Growing leguminous crops such as beans, peas or clover. These contain bacteria (minute living creatures) in their roots that convert nitrogen from the air into more nitrates than the plants themselves need. This is called green manuring.

- Manures: of animal dung (droppings), rotting vegetable matter called compost, or of mixtures of these. These are quite wrongly regarded as wastes, but they are very important to the success of agriculture! An important criterion is how quickly they release their nitrogen to the soil. Chemical fertilizers do so very

quickly (sometimes too quickly, so that the rain washes all the value away). Legumes need a growing cycle (a season). Manures depend on how well they are rotted before being put on the soil and on their make up, and these are expressed conveniently as their carbon to nitrogen (or C/N) ratio. A low C/N ratio means there is plenty of nitrogen to nourish crops. Among the best manures are animal and human excreta. They have low C/N ratios (between 5 and 20) but tend to lose nitrogen due to ammonia "volatilizing" (being given off as a gas) with the familiar sharp smell and sting to the eyes.

(ii) **Other nutrients**: Plants need other "nutrients" to feed them and help their growth. Of these, the most important are phosphorus and potassium. Like nitrogen, they may be put into the soil either by rotating certain types of crops, by adding chemical fertilizers or by adding manures. However, the amount of these substances in some manures is small and chemicals are then needed in addition.

(iii) **Soil structure** is important so that the roots of growing plants can take in air, water and the nutrients already mentioned. The water needs to be able to drain away so that the soil is not waterlogged and important nutrients are not washed away with surface drainage. The soil needs to be easy to plough. The presence of rotten fibrous matter helps provide this good structure which cannot be improved by chemical fertilizers, but only by manures.

This ability to improve and maintain good soil structure is one of the most important qualities of manures, more so than the provision of plant nutrients, in which they often need to be helped by chemical fertilizers or by crop rotation. For this reason some manures, such as town compost, should be regarded not as a fertilizer but as a soil conditioner.

> Manures also have the effects of buffering the soil against an excess of mineral salts and providing microbiological activity. These aspects are complicated and need not be discussed here, except to say that chemical fertilizers have neither of these properties.[33]

The very important role compost can play in conditioning the agricultural soil of Oman will become clear to us if we take into consideration that the share of organic substances in the soil of Oman—all of her soils in the arid and semi-arid zones—is sometimes less than 0.5% and increases in value to 2-4%.[34]

In order to avoid a drop in soil fertility, agricultural land must be continuously supplied with organic material. This can be done either by green manuring or by applying pre-decomposed organic material. The yield of humus from green manuring is mediocre, but pre-decomposed material such as farmyard manure and household waste compost have organic contents of 18% and 17% respectively.

Due to climatic influence, the soil in dry areas is more endangered than in moderate climatic zones. The irregular but strong rainfall in the arid and semi-arid climatic zones of the Orient leads to a high degree of water erosion which destroys the humus layer. This process can be counteracted to a great extent by the application of compost from household waste. The organic material enhances water permeability, which—due to the enlargement of the soil porosity—almost doubles. Great quantities of water can be absorbed by the earth (increased porosity), and this reduces the run-off of surface water, which also reduces water erosion.

[33] Jon Vogler, op. cit., pp. 107-108.

[34] Christian Eggert, Abfallwirtschaft in den Ländern Nordafrikas and Nahost unter besonderer Berücksichtigung der Kompostierung, Fachgebiet Abfallwirtschaft, Technische Universität Berlin (Berlin, 1982), p. 15.

The soil in arid and semi-arid zones, with its high share of fine sand and low organic content, is vulnerable to wind erosion. Wind erosion removes soil particles measuring between 0.1 mm and 1 mm (the size of fine sand). The best protection against wind erosion is a closed vegetation cover. The intensity of erosion stands in reciprocal relationship to the square of the moisture of the earth surface. It is possible to promote the settlement and growth of vegetation by the application of compost, which is known for its ability to retain water.[35]

The above-described advantages of composting household waste suggest that no time should be lost in embarking upon this activity. However, pure enthusiasm cannot lead to any success; on the contrary, it can end only in failure. What is needed is a clear strategy which takes into consideration all factors that influence the production and marketing of the product. In many developing countries, the experiences with composting are to a great extent negative in spite of the favourable conditions. This can be attributed to the fact that in the past the economic advantages were overestimated while the technical and organizational problems of the process were underestimated. In 1982 Eggert Kam in a study of 19 composting plants in the cities of North Africa and the Near East reached the conclusion that very few plants operate at the planned capacity, with the majority operating very much below it. Furthermore, several plants were shut down, including one in Muscat.

The marketing of compost

Besides technical and organizational difficulties, there are marketing problems which can render a plant uneconomical. The sale of compost can be ensured only if there are, right from the beginning, known compost users (agriculture, forestry, municipality, etc.) who would continuously purchase the compost. On this topic, Jon Vogler writes:

[35] Christian Eggert, op. cit., pp. 15-17.

Some municipalities have been given the idea that municipal compost is a substitute for chemical fertilizers that will be eagerly bought by local farmers at a price that gives the seller a handsome profit: this is far from the truth. Compost is not a substitute for fertilizers. However, it is an excellent soil conditioner with some fertilizer value, but its weight and bulk make it expensive to transport and to spread on the fields. Farmers will only use it if it is available at low cost, close to their fields. It is therefore extremely important for any municipality that considers setting up a plant, to first research local markets for compost before equipment is considered.

Sometimes, the municipal parks and gardens can use enough compost to absorb the whole production and there will be no need to sell it to farmers. In this situation it must be clearly realized that the cost of producing good-quality compost is much higher than the cost of other methods of waste disposal, such as sanitary landfill, and certainly higher than the cost of crude tipping. If no income is to be received from farmers or the public, then the municipality must be prepared to meet these extra costs as the price for having good soil in their parks and a reduced need for space for refuse landfill. Where a city has a booming tourist trade or is seriously short of landfill sites within the city boundaries, these may be acceptable. This is particularly the case where the cost of transporting refuse over bad roads to landfill sites 20 or 30 kilometres outside the city would be greatly reduced. In other situations, it is not likely that any city will continue to fund an expensive operation for an indefinite time into the future just to get better roses and lawns in the parks.

The future of municipal composting

Provided these two matters are examined with the most careful attention, there can be nothing but good reasons for using composting as a means of refuse disposal. Perhaps the most important argument in its favour, and it is a pity it is not easier to

put a financial value to it, is that the quality of soil is one of the most important assets any country can have. Municipal composting, once the problems of technology and marketing have been overcome, offers the best possible prospect of long-term improvement and the education of the people in the enormous long-term value of returning organic wastes to the soil.[36]

In line with this analysis we deal now with the problems and prospects of composting as part of waste management in Muscat. The idea of composting in Muscat is not new and resulted in the late 1980s in the establishment of a compost plant produced by the French company Hydromer. The following sequence of processes takes place in the Hydromer plant.[37]

The concept on which the plant operates is based upon the different "flux behaviour" of the materials under high pressure. The plant cost RO 1.3 million, of which the Hydromer pressing device was the most expensive part of the plant; it cost RO 250,000. With respect to the operations of the plant the following sequence of processes takes place.

The waste vehicles unload through three hatches in a waste store. From here the material is led to the hopper of a pressing device which is the core of the plant. In the pressing chamber the waste is subjected to the influence of two pistons operating against each other. One of them comprises a plate 10 mm in diameter. When the first piston goes down into the pressing chamber, a pressure of 300 bar is produced, and the second piston enhances the pressure to about 1,000 bar. According to the company, this high pressure forces the organic material to run through the fine channels of the second piston plate with the result that the waste is separated into two parts. On one side there is a wet fraction, the consistency of which resembles that of soil. It contains most of the water and a great share of quickly fermentable substance. On the other side

36 Jon Vogler, op. cit., pp. 227-228.

37 Christian Eggert, op. cit., pp. 77-80.

there is a dry fraction with about 15% moisture. This consists mainly of carton, plastic, textiles, glass and metal. The pressed organic material is drained through pipes and collected in containers with a C/N ratio of 20:1. The temperature rises to 60°C in less than 24 hours.

The compost produced is sieved in a sieving drum.

Due to its low water content the dry fraction can be stored for a long time and it has a density of 1-1.5/m^3. The calorific value is 10.5-12.5 kJ/kg so that it can be used to produce energy or for heating.

According to the manufacturers the Hydromer system has the following advantages over conventional composting systems:

- High content of decomposable organic substance
- High content of nitrogen and other fertilizing substances
- Low content of heavy metals
- Very fine compost
- Stabilized compost with a C/N ratio of 10-12 : 1
- Absolutely hygienized material.

The extent to which the concept described for the Hydromer process was utilized in the construction and operation of the Muscat Composting Plant is a question which we unfortunately cannot answer. The plant was closed within three months of starting operations, and we were unable to find anyone who could give an idea of how it operated and what technical and managerial/ organizational problems were encountered.

The following reasons led to the closing of the plant:

- The wind carried foul odours from the compost plant area to a nearby residential area, creating a public nuisance.

- The price of the compost was high.

- The compost was heavy and bulky, making transport costs very high. The high weight and bulk also meant that a great deal of time had to be spent in spreading the compost on the field.

- The quality of the compost was poor; it contained a relatively high proportion of inert material such as sand, glass, metal, plastic, etc.

The exact content of heavy metals and whether the compost contained other hazardous substances are questions that cannot be answered because of lack of data on this matter.

The importance of the above-mentioned points in contributing to the closing of the compost plant is beyond any doubt, yet in-depth analysis of the matter reveals that the main cause of the failure was that the plant was established without a feasibility study and without any knowledge of all the relevant factors. The plant was established in the Ghubra settlement of the Bousher area on land close to a residential area. The private sector which owned the plant thought the business would be lucrative and would return a profit easily. The French company which supplied the plant was interested solely in selling the plant and making a profit. The Ministry of Environment, which was somehow involved in the matter, saw in it an undefined environmental advantage. The role of the Municipality was limited to supplying the raw materials needed to produce the compost. The whole objective of the undertaking was largely obscure and lacked a clear identity: was it profit-making environmental protection, or promotion of industrial and agricultural development? This obscurity of objective is a typical problem observed in all cities and towns of the developing countries, as we have seen, in the analysis problems and prospects for household waste composting in the cities of third-world countries.

The questions for which we could not find an answer were: If the main problem which resulted in the closing of the plant was the unsuitability of the location, why was the problem not solved by moving the plant to a suitable place, which could easily have been found in Muscat? Why was this expensive plant kept idle?

The fact that no convincing answers can be found to these questions shows that the problem to be solved concerns more than the issues of where, when and how the plant should restart its operation. It concerns the status of composting in the waste management system of the city, which is still not defined. Waste management in Muscat, as in all other Arab cities, is disposal-centred, in the sense that sanitary landfill is still considered to be the only solution to the waste problem. Composting and recycling, which have no existence at all in the present waste management system, are raised in discussions on solving the waste problem of the city as additional possibilities and not as alternatives to landfill.

It is beyond doubt that landfill will remain the primary element of waste management. However, recycling and composting can partially take over the function of landfill and should thus be incorporated within the waste management system rather than merely being considered additional possibilities and not as alternatives to landfill. Several questions must be answered before it is possible to know how, and to what extent, recycling and composting can be put into practice.

■ **How great is the volume of the waste that can be recycled or composted?** From an economical viewpoint, waste may not deserve to be recycled or composted in a plant if the quantity is small, but this does not mean that recycling and composting are entirely ruled out. Organic waste can be recycled for gardens even at the level of the individual household. The following article appeared in *The Indian Express*, Bombay, on 22 December 1991:

> Soil Trust, a Madras-based organization set up by a group of professionals two months ago, is at present engaged in a simple venture, which is nevertheless exciting for those with gardens at home.
>
> Through an investment of less than Rs 100 [RO 1,500], an individual can recycle the vegetable and organic waste generated in his kitchen into manure for his garden. The resultant compost

is a rich organic manure which provides a high level of nutrients for plants and also conditions the soil.

Here is what you have to do: For a family of five people, a used plastic barrel of 60-litre capacity is fixed to an axle (a GI pipe about three feet long), in an upright position. The barrel can be fixed to a frame, or can be positioned in an area where two compound walls meet.

The vegetable kitchen waste is placed in the barrel (it is better to avoid bones and other non-vegetarian stuff, which takes much longer to compost, as also non-biodegradable substances like glass, paper, metals and plastic), the lid closed, and the material inside rotated twice or thrice a day by turning the axle. This rotation helps to dissipate the heat and provide sufficient aeration. A mugful of waster a day is essential to wet the matter, but care should be taken not to drench it. Addition of nitrogenous matter can speed up decomposition.

At the end of 15 days the matter should be taken out and sieved. The resultant compost is a dark brown powder with a rich aroma, and high nutrient levels. The bigger parts of the matter should be returned to the barrel.

There are four factors affecting the rate of decomposition. Water is required by the decomposing bacteria to multiply and effectively break down the organic matter. Air is needed to encourage aerobic bacteria. The temperature is very important, as the presence of millions of bacteria in the compost heap along with the breaking up of organic matter releases large quantities of heat, up to 70°C. The high temperature kills the bacteria and the decomposing slows down. But if the heat is artificially dissipated (by rotating the material in the barrel), then the composting is quicker.

Says Secretary of the soil foundation R. Venkatesh, "Composting is nature's law of return. And anyway urban waste disposal is a

major hassle confronting development authorities as well as the public. City garbage goes either in landfills or incinerators. The former affects water aquifers and the latter creates air pollution, apart from fuel consumption while being transported. And both processes give a one-way ticket to the plant nutrients which, by nature's law, should be returned to the soil. This is as important a problem as the depletion of the ozone layer."

Exnora, the civic organization in the south Indian State of Madras, which helps in keeping the city clean through paid subscription, is going to take up four streets in Madras, where bigger barrels will be used for composting and the resultant manure shared by four houses.

Also, small quantities of non-organic waste can be recycled in small workshops. Municipal composting can be done only in a plant, the operations of which will be uneconomic if there is less than a certain amount of organic waste to be composted. In such a case waste may not even pose an environmental problem.

■ **What are the constraints that must be overcome to render household waste recyclable or compostable?** The main constraint involves the fact that in general waste is a mixture, and to render it recyclable or compostable, it should be sorted. This is a time-consuming and costly process, which can never be complete. Separate collection, which is the ideal solution, is not always easy and cannot be achieved without the cooperation of the population at large. This shows that the success of recycling and composting depends on more than a technical solution.

■ **Is there any market for the compost or for the objects produced from waste?** This is a very incisive question for which a concrete answer must be found. Without a sales possibility, recycling and composting will not be feasible even if all other factors are favourable. However, a sales possibility does not always depend upon supply and demand if the selling of the item to be marketed also has environmental

advantages. Municipal parks and gardens can use enough compost to absorb the whole production; the policy may therefore be to seek to absorb the entire compost production in this fashion with the aim of avoiding marketing problems.

■ **How far can the composting of household waste be advocated?** In this respect it should be emphasized that although a feasibility study is indispensable, whether waste should be composted or recycled cannot be judged purely on an economic basis. Environmental considerations necessitate composting or recycling in spite of the uneconomic nature of this activity.

■ **To what extent is it possible to provide a suitable site for the compost plant?** As we saw in the case of Muscat, the establishment of the plant in a place where it could create a nuisance to those living in the area may lead to protests and accordingly to the closing of the plant.

Another factor which should be taken into consideration when choosing a site is economic in nature. It is advisable to establish the site near a landfill for the following reasons:

- It may be possible to use a waste vehicle to collect the raw material. This possibility is present from the beginning if the plant is municipal property, but even if the plant belongs to a private company, arrangements can be made to use the waste vehicle to supply the plant.
- It is easy to bring the non-compostable material (inert and other inorganic materials) to the landfill.
- The landfill can serve as the source for organic waste since loads consisting solely of agricultural or garden or any other organic waste are brought there.

■ **What is the most suitable technology for composting the local organic waste?** First, this technology should be adapted to the

composition of local waste. In addition a choice should be made about whether to use capital-intensive or labour-intensive technology. Modern composting technology is relatively new and has not yet reached the full development of an established technology. Inappropriate technology seems to have damaged the reputation of municipal composting over the last few years. Jon Vogler addresses this issue:

> The problem [appeared due to the fact] that the theoretical attraction of the system has been exploited by a number of industrial companies from certain rich countries as an opportunity to sell large, complex composting systems. Unfortunately, these have not been sufficiently proven in operation, and demand a standard of management far higher than that normally available to third-world municipalities. Some attempts to devise more appropriate technology have been made in India during recent years but none has so far achieved unqualified success. A municipality that is thinking of installing an industrialized refuse composting plant should first study the numerous failures that may be seen around the third world, with great care.[38]

■ **What are the contributions expected from waste composting?** They include:

- *Making a profit*. Although this is desirable, it is not always a factor whose absence means that composting should be abandoned. Composting may even require a subsidy. At least, however, cost-effectiveness should be taken into consideration.

- *Environmental protection*. Composting reduces the quantity of waste to be disposed of and accordingly contributes to environmental protection. Both the size and importance of this contribution should be identified. The environmental advantages should be measured against the subsidies which may be required.

- *Reduction of transport and disposal costs*. Such a reduction plays a role, especially if the compost plant is an independent plant and the organic waste it needs is collected separately by its own vehicles.

■ **How can composting best be integrated into the waste management system?** To answer this question we first require a definition of the status of composting in the overall waste management strategy. Integration becomes a problem when the private sector is charged with the task of composting waste. This sector may see any attempt to relate its work to the municipal waste management system as an interference that constrains the work. In actual fact, integation itself can be constrained if the waste management authority sees its task as controlling the private company instead of cooperating with it and considering it part and parcel of an overall waste management package.

Only if the questions posed here are answered and all problems related to them solved will it be possible to revive the Muscat waste composting activity in a way that would prevent the recurrence of the previous failure.

Assuming that all the factors necessary for a sound composting strategy are present, consider the compostable organic waste that exists in the city. Although the available data indicates that only 40% of household waste in Muscat consists of organic substances, our observation of the four city landfills suggests that the percentage could be higher, not less than 50%. Taking 50% as a basis, the organic substances in the household waste produced daily would be 250,000 kg, or 250 tons.[39] However, almost

[38] Jon Vogler, op. cit., pp. 226-227.

[39] The survey done by Scheu in Al-Ghubra al-Shamalia shows that 48% of household waste consists of organic material. In addition to organic household waste, Muscat produces daily over 200 tons of garden waste and a great amount of agricultural waste.

all this organic waste is mixed with other substances that render it impure. Thus, the first problem to be solved is to make sure that the organic waste is pure and compostable. The best solution is undoubtedly separate collection, which can best be implemented in the context of the overall waste collection system followed by the city. The first solution which may come to mind is to have separate containers for organic waste at all waste collection points in the city, but this solution will be successful only if the households separate their waste before it is carried out of the house. However, to involve the households in such a step requires a very high degree of environmental awareness, which is missing for the most part. Promoting such awareness is a long process and, even if it is created, comprehensive separate waste collection still cannot be achieved, as intensive awareness promotion in some Western countries shows. It is therefore necessary to follow a differentiated strategy with respect to separate waste collection, which according to our judgement should proceed as follows:

- Gradual introduction of separate waste collection at the waste collection points. This should be started in those residential areas where environmental awareness already exists or can be easily promoted. In most cases an environmental awareness higher than that required for separate collection for glass, metal and waste paper is needed, because organic waste is often wet and can be dirty as well. Collecting it separately can thus be considered a nuisance.

- Separate collection of organic waste can function well in hotels, restaurants, schools, military camps, clubs and in the foodstuff processing industry. In Muscat organic waste could be collected separately from all these sources. The Municipality could undertake steps (such as instruction on this matter) to facilitate separate collection.

- Agricultural and garden waste could be collected separately. This very useful material goes at present to the landfills and in most cases is transported separately by lorry.

Certainly, the revival of composting activities in Muscat cannot be envisaged without considering whether and how the idle compost plant could be revived. In the case of reviving it, the decision is whether the plant would remain with the private sector or be taken over by one municipality. If it is to remain with the private sector it must be decided whether a subsidy is necessary and how it should follow. In this respect, a subsidy which guarantees the company a fixed profit may make it satisfied with the status quo and thus liable to ignore any innovations that could make the subsidy unnecessary and the enterprise profitable. With respect to marketing, we think that the city greening activities of the Municipality could absorb a high percentage of the product. In principle, marketing should be aimed at absorbing as much as possible of the product—if possible the whole—by the Municipality. If this is achieved, two very important municipal services would start to complement each other.

The use of municipal sewage by the composting plant

Muscat Municipality has two large and several small sewage treatment plants. Treated wastewater is used by the Municipality for irrigation purposes. The city greening activity depends almost exclusively on this water. Unfortunately, the sludge from sewage treatment is dumped into a landfill although it is hygienically safe and would make good compost. The Municipality has always been aware of this fact, but it could not realize this advantage because the compost has a high heavy metal content. This problem could be reduced if the sludge were mixed with the compost produced from the organic household waste, which would dilute the concentration of heavy metals. The compost could even be used as a fertilizer in the city greening activities as well as on crops that would not be directly eaten either by humans or animals. Overall, future waste composting activity requires a comprehensive feasibility study and plan that also takes into consideration the possibility of integrating sludge into the composting process.

Possibilities and limitations of recycling and composting waste in Muscat

So far we have considered recycling and composting in terms of the percentage of recyclable and compostable objects and items in household waste. However, this theoretical basis can only partially be put into practice. Waste experts say that at least 50% of household waste can be recycled and composted with some effort, but this percentage more or less depends upon the effectiveness of separate collection and the will to recycle and compost waste. In Japan, where separate collection of household waste is efficiently organized and the will to recycle and compost waste is very high, only 20% of this waste goes to landfills; over 50% is recycled or composted and the rest is incinerated in a way that releases energy.[40] In Cairo, waste collected by the *zabbalin* (refuse collectors) is sorted thoroughly and all reusable material is either recycled or composted. Only inert material goes to the landfill.[41]

In general, we can say that any type of waste—except inert material—is recyclable or compostable provided that it is collected separately and is not contaminated by other substances that render it useless or minimize its usefulness.[42] It is not the recyclability and compostability of the waste but the need and will to recycle and compost it—as well as the marketability of the products—which determine the percentage of recyclable and compostable waste that is actually recycled or composted. Need is more or less identical with marketability. The need to recycle products and to compost is inversely proportionate to the extent that craftsmen and small workshops directly reuse waste or recycle it; in many cities the greatest percentage of recyclable waste is absorbed in this

40 Bureau of Public Cleansing, Tokyo Metropolitan Government, *Public Cleansing Services in Tokyo*, 1991, pp. 9-16.

41 Gunter Meyer, op. cit., pp. 78-93.

42 Even inert material can to some extent be reused; for instance, it can be ground and used to fill swamps.

way. In Pakistan and India, where industrial recycling of non-organic waste is highly developed, the need is so great that waste paper and scrap metals from Saudi Arabia and the other Gulf States are imported by Pakistani and Indian companies.

However, in may cases, especially in the industrialized and wealthy countries, there may be no perceived need to recycle waste although waste in these countries contains a large percentage of material that could easily be used directly or recycled. The huge amount of waste produced daily there causes environmental problems and a public nuisance. The will to recycle or compost waste should arise in this case from health and environmental considerations.

Both need and will are variable factors. The perceived need to recycle products declines when the standard of living rises and the society becomes richer. Even in poor countries, a correlation is observed between income and the need to recycle products. The higher the family's income, the less it consumes waste products, because families with very high income largely do not use local products whether they are made from waste or from original material.

This means that in a rich or relatively rich country, it is not need that determines how much of the recyclable waste in the city should be recycled. At issue in this case is the will to recycle or compost waste in order to protect the environment and avoid a public nuisance.

Although where there is a will there is a way, without a technology that makes recycling or composting possible, will cannot be translated into action. In spite of its being relatively new, recycling and composting technology (like any other environmental technology) has reached a standard whereby many materials which previously were simply discarded can now be recycled. Thus, technological development seems not to pose an obstacle to recycling waste.

Bearing the above in mind, we can say that two factors should be kept in mind when considering waste recycling and composting in the Muscat area:

- **The will to recycle and compost waste.** As we have already shown, the need to use recycled products is virtually nonexistent.

- **Choice of the right recycling or composting technologies.** This choice concerns not only capital-intensive versus labour-intensive technology but also choice within these technologies. Within the same technology, the choice should take into consideration its suitability for local conditions as well as the maturity of the technology itself. Technology transfer in the area of waste recycling or composting requires exact adaptation to the local conditions and cannot be done without exact knowledge of the type and quantity of waste to be processed, since the plant has to be exactly in line with the technology needed to process this waste.

With respect to how the recycling and composting of waste should proceed within Muscat, we recommend a plan which is part of the overall waste management plan for the country (with which we will deal later). The aim should be to achieve the recycling and composting of about 33% of the waste produced in the city in the five-year period starting in 1996. According to informal observations of the private sector's interest in recycling and composting, this goal could be achieved, with careful planning and with the provision of incentives to the private sector.

The plan should include the following steps:

- Analysis of the existing recycling activities, especially of the waste trade (export of scrap metal and waste paper to Dubai). This trade should be recorded and data collected and analysed.

- Organization of the scavengers in cooperatives or similar institutions and providing them with sanitary, social, organizational and administrative services related to their work. This should be done in the

context of a community development project that aims at improving their socio-economic and cultural life. After such improvements, they would attain the status of recyclers within the context of the overall waste management system.

- Identification of the main sources of certain recyclable or compostable wastes and taking all necessary steps to introduce separate collection.

- Launching a comprehensive and wide-ranging campaign for separate waste collection, which should be part of an overall waste management campaign aimed at promoting environmental awareness.

- Contacting the private sector and determining that it is prepared to undertake the task of industrial recycling and composting of waste in the context of the overall waste management system of the Municipality. It is important to make clear from the beginning that recycling and composting are part of the overall waste management system for which the Municipality is responsible. This clarification implies that at present the private sector follows a practice detrimental to the waste management strategy of the Municipality. However, it should also be clear to the Municipality that the incorporation of the recycling and composting activities undertaken by the private sector into the overall waste management system does not mean control over the private sector's activities. Such incorporation should be understood as cooperation, with each side taking into consideration the interests of the other.

- A symposium on recycling and composting should be organized within a training programme on waste management. Private individuals interested in recycling should be invited to attend. A special session should deal with the role of the private sector in recycling and composting.

- A committee of highly qualified and experienced individuals should be established to study the type of technology that Muscat should adopt in the field of waste recycling and composting. This should include study

tours to acquaint the committee with the application of recycling and composting technology in other countries, especially in cities in the Gulf States which have already accumulated experience in recycling and composting. It is also advisable to visit Egypt and India, which have a long composting and recycling tradition; they also produce recycling and composting plants which are cheaper than those made in Europe and which have proved to be effective. During this preparatory phase, composting and recycling plants could be introduced if developments allow. If there are already private individuals and institutions who have undertaken to establish such plants or are planning to do so, they must be encouraged by all possible means.

WASTE MANAGEMENT IN THE REGIONAL MUNICIPALITIES OF OMAN

A comparison with Muscat

A comparison of the waste management system in Muscat[43] with its counterparts in the regional municipalities of Oman is necessary for the following reasons:

- Waste management development in Muscat is and will remain for the regional municipalities a superior example from which they should learn but which they should not imitate blindly. In this respect it should be emphasized that learning includes avoiding the mistakes made by Muscat.

- Muscat may become in the future a centre which absorbs the recyclable waste produced in the regional municipalities. Thus, it should have knowledge of waste management development there.

- The enactment of a national waste management law, the draft of which already exists, will certainly necessitate a national waste management plan which provides the framework for waste management practices in all cities, towns and villages of the country. This plan will not start from zero, but will be based on the experiences of Muscat and the regional municipalities in this field. Its content (also comprising the experiences of the regional municipalities) will influence waste management in Muscat. It is possible that the plan will give Muscat a leading role in the development of waste management in the country; it could be charged with the task of providing training, especially on-the-job training, to the regional municipalities, but it cannot do this properly without knowing the waste management system in the regional cities.

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[43] This part of the study is based upon some reports provided by the Ministry of Regional Municipalities and Environment as well as upon several intensive discussions with Engineer Said al-Alawi, the Director General for Public Health of the Ministry of Regional Municipalities and Environment. In addition, the author carried out field research which included visits to landfills and waste collection points.

The plan will certainly aim also at homogenizing the vehicles and other equipment used in the country, as this would help to establish a central store for all spare parts and make possible a well-equipped central repair and maintenance workshop for vehicles and equipment. Muscat Municipality, which already has such a workshop, provides both a store and a workshop.

The above points justify carrying out a study on waste management in the regional municipalities.

Oman is divided into several administrative regions. While Muscat and the Southern region (Dhofar) have special status, the other regions come under the Ministry of Regional Municipalities and Environment.

Each of the regions is divided into *wilayat* (districts) as shown in **table 4**.

Table 4. Administrative regions and districts of Oman

Region	District	Administrative headquarters
Muscat	Muscat Governorate	Muscat
	Quriyat District	
Dhofar Governorate	Salalah	Salalah
	Thumrit	
	Taqah	
	Rakhyut	
	Marbat	
	Shaleem	
	Sada	
	Dhalkut	
The Interior	Nizwa	Nizwa
	Bahla	
	Adm	
	Heyma	
	Mawah	
	Sumail	Sumail
	Izka	
	Badbad	

Region	District	Administrative headquarters
Sharqiyah	Ibra, Al-Mudhaybi	Ibra
(Eastern region)	Badiyah, Al-Qabil	
	Dama Wa Dhaiyin	
	Sur	Sur
	Masira	
	Jaalan Bani Bu Ali	
	Jaalan Bani Bu Hasan	
	Wadi Bani Khalid	
	Al-Kamil, Al-Wafi	
Batinah	Sohar	Sohar
	Shanas	
	Lawi	
	Suhum	
	Al-Khaburah	
	Al-Suwaiq	
	Al-Rustaq	
	Nakhal	
	Wadi Al Maawil	
	Al-Awabi	
	Al-Masmaq	
	Barka	
Dhahira	Al Buraimi	Al Buraimi
	Mahda	
	Ibri	Ibri
	Yangul	
	Dhank	
Musandam	Khasab	Khasab
	Bakha	
	Daba	
	Madkha	

The population of the Sultanate is about 2.0 million inhabitants and has a growth rate of 4.5% per annum; the population is expected to reach 2.4 million to 2.5 million people by the end of the century. About 550,000 live in Muscat, 80,000 live in Dhofar and 30,000 in Sohar, and the rest

in the regional municipalities and districts of the country. However, it is witnessing rapid growth. According to the World Bank, by the end of this century, about two thirds of the world population will live in urban areas. If we apply this to Oman, this means that about 1.1 million to 1.2 million of the population of the region will live in urban centres. Growth of the population in general, and the disproportional growth of the urban population in the overall settlement pattern will certainly affect waste management development in the country. Growth of the urban population always entails diversification of economic activities, increases in population and building densities, increase in the built-up area, and diversification of foodstuffs consumed, with rising consumption of bottled, canned and packaged commodities, resulting in a per capita increase of waste production. These factors have to be taken into account in forward planning for waste management. However, such planning cannot be done without first understanding the present situation.

The regional municipality comes under the Ministry for Regional Municipalities and Environment. There are 37 municipalities in the areas of Batinah, Musandam, Interior, Dhahira and Sharqiyah. The municipality is responsible for street-cleaning and waste management. The work is done by the Section for Public Health Affairs in each municipality headed by a health inspector and an assistant health inspector. The Section for Public Health Affairs comes under the Director of the Municipality. The Directorate for Public Health Affairs in the Ministry exercises direct technical supervision. Waste is collected and transported to dumping areas where it is either buried or burnt. Quasi-sanitary landfill is practised in al-Buraimi, Nizwa, Ibra, Sur and Sohar. The other *wilayats* (districts) still practise open burning due to lack of equipment. The Ministry is undertaking all possible steps to introduce the sanitary landfill system into the other districts.

Due to low population density and the existence of many small settlements all over the country, the establishment of central landfills that would serve the population of all the settlements in the districts is very difficult. Villages and settlements in remote areas, especially the inaccessible mountainous areas, cannot be connected with central landfills

in the districts because of long distances and inaccessibility. In addition, the small amount of waste produced in the small settlements would make use of only a small percentage of the capacity of the collection vehicle. Both economic and managerial considerations justify the separation of these settlements from the central landfills, and to solve their problem small landfills and dumping areas were established, each serving several settlements around it. No exact data are available, however. The Ministry for Regional Municipalities and Environment gives estimates for waste brought to the landfills or dumping areas in 1989:

Type of waste	Number of loads	Estimated weight (metric tons)
Household waste	243,956	731,868
Hospital waste	11,562	34,686
Slaughterhouse waste	6,077	18,231
Waste from workshops and garages	9,893	29,679
Waste from pens, poultry farms	4,864	14,592
Furniture (bulky waste)	5,306	15,918
Rubble and debris	7,793	23,379
Metal scrap	1,414	4,242
Old vehicles	1,914	5,742

The estimates seem to be exaggerated. For example, the daily per capita production of household waste is 1 kg. This means that the daily production in the regions, with a population of 1,500,000, should be 1,500,000 kg and the annual production about 547,500,000 kg, or 547,500 tons.

This figure is far below the estimate given in the table for household waste. Such overestimation can also be found in some of the statistics on waste disposal given by the Muscat landfill. The mistake arises from assuming that each arriving vehicle brings a full load, which is rarely the case. As already mentioned, in the case of Muscat the weight of waste

brought to the landfills or dumping areas cannot be known without having a weighbridge at the entrance to each landfill or dumping area.

With respect to the waste disposal methods followed by the regional municipalities, a recent report prepared by the Ministry of Regional Municipalities and Environment reveals the following:

1. Household and slaughterhouse waste, as well as waste from poultry farms, workshops and garages, and also metal scrap and bulky waste are disposed of in a single place chosen by the municipality for this purpose, at present relatively far from the municipality (20-25 km and sometimes even further). In this place waste is either buried or burnt. As already mentioned, five districts have a sanitary landfill system and the rest practise open burning. In the small dumping places which are scattered all over the country, especially in remote areas, only open burning is practised.

2. Waste from pens and poultry farms are transported either by the owner or the concerned municipality. Since 1970, agricultural development has witnessed an increasing number of poultry farms. Municipalities face a great problem in collecting and disposing of this type of waste from the concerned farms, which are scattered over a large area.

3. Most of the agricultural waste, which consists of leaves, dry trees and branches, is collected and burned directly outside the farms; the rest is transported to the dumping area where it is burned. Since most of the regional municipalities are situated in the agricultural areas of the Sultanate, the amount of agricultural waste is considerable.

4. Hospital waste is collected and disposed of with solid waste, although this poses a health hazard. However, some large hospitals incinerate their hospital waste in special closed incinerators within their premises.

5. Rubble and debris are disposed of in a special part of the dumping area and are transported there by the contractor who constructed the building from which they originated or by the owner.

6. Old vehicles are disposed of in a special place near the landfill or dumping area. In 1992 they were sold by tender to traders dealing in scrap and second-hand spare parts for vehicles.

7. Waste from the industrial area is transported to the landfills by the producer, as in Muscat.

Problems faced by the regional municipalities: the view of the Ministry of Regional Municipalities

According to the Ministry of Regional Municipalities and Environment, waste management in the regional municipalities suffers from the following problems:[44]

1. The waste collection phase

Shortage of manpower

All regional municipalities suffer from a shortage of waste collectors and street-cleaning workers, a problem which could be solved by providing more such waste workers. Omani nationals should be encouraged to do this work. Putting this suggestion into practice requires first of all providing the financial means that would enable the municipalities to employ the necessary manpower.

[44] Said bin Darwish al-Alawi, "Solid waste disposal in the regional municipalities" (Ministry of Regional Municipalities and Environment, 1992).

Waste containers

Most containers are open barrels with a capacity of 200 litres and provided by the oil companies. There are also some metal containers with covers. Modern waste containers such as trolley bins and litter bins are available in a very limited number. This scarcity of modern containers can be attributed to a shortage of funds. However, introducing them would be helpful only if waste vehicles are provided that can use these standardized containers efficiently (i.e., waste vehicles with automatic lifting devices).

The solution to the above-mentioned problems, according to the Ministry, would involve undertaking the following steps simultaneously:

- Replacing the present containers and barrels used for waste collection with automatic waste containers.

- Providing enough plastic waste bags to be distributed to the households for carrying their waste to the containers.

- Replacing the present fleet of waste vehicles with mechanical lifting vehicles.

- Providing the necessary funds for implementing these suggestions.

The whole activity should be accompanied by a campaign to make people aware of the importance of having a sound and healthful waste management system.

2. The waste transport phase

Shortage of vehicles

The regional municipalities suffer from an acute shortage of waste vehicles, especially waste collecting compaction vehicles which can transport a large load. Also, the long distance between the places from

where waste is collected and the landfills or dumping places reduces the number of the trips which each vehicle can undertake daily, meaning that more vehicles are needed.

According to the Ministry, the problem can be solved by increasing the number of waste collection vehicles, with emphasis on replacing the present vehicles with mechanized waste compaction vehicles. In addition to this, a daily timetable for waste collection should be designed with the aim of avoiding loss of time and effort.

3. The phase of final disposal

Undoubtedly, recycling—including composting—is the best way to solve the waste problem. However, the regional municipalities have not yet embarked upon this activity because there is no market for waste products and compost in the Sultanate. The Ministry advocates a feasibility study on the recycling or composting of waste. The private sector of Oman and also of other Gulf States should be involved in promoting waste recycling.

One-way bottles

One-way bottles at present form 5% of the household waste in Oman, and this percentage is increasing steadily. One-way bottles, like cartons and plastic and wooden boxes, are hollow. Accordingly, the space they occupy in the containers is more than their weight can justify. In the case of cartons and plastic and wooden boxes, the size can be considerably reduced by pressing and squeezing them or by cutting or chopping them up. The size of glass bottles, however, can be reduced only by breaking them into small pieces. However, this is not practicable because of the resulting glass splinters. In addition, broken glass in containers or waste bags can cause injuries (especially to children, who are often charged with the task of bringing waste to the containers).

This problem can be solved to some extent by using returnable bottles (return can be guaranteed by charging a deposit on the bottle, which is

refunded when the bottle is returned to the shop) and by recycling old glass.

Disposal of old tyres

The problem of the disposal of old vehicles in landfills and dumping grounds is growing. Earlier, they were neither burned nor buried but were dumped somewhere within the landfill or dumping area, where they could harbour rodents and insects attracted by the discarded food found in the waste.

However, the Ministry recognized this problem and took positive steps to solve it; a special place in the landfill or dumping area was earmarked for this purpose.

Likewise, interest in recycling old tyres started to grow. The retreading plant in Muscat began to enlarge its activities and to receive old tyres from the regional municipalities. The aim here is not only environmental protection but also import substitution of tyres. The government has begun offering the private enterprise which owns the retreading plant preferential treatment so that it can proceed apace with the retreading of old tyres.

Another positive development is the export of old tyres to India and Pakistan. It is noteworthy that these two countries are interested not only in retreadable old tyres but in any old tyres that can be recycled otherwise or reduced into raw material. This makes it more likely that the problem of the accumulation of old tyres can be solved. However, translating this possibility into practical action needs proper management.

Hospital waste

At present most of this waste is collected by the municipality and burned or buried along with household waste. The Ministry recognizes that hospital waste should be classified as special and hazardous waste, and

it recommends that the Ministry of Health establish suitable incineration plants for it in the hospitals.

It is worth mentioning here that the report of the Ministry recommends a modern incineration system even for household waste. This, however, is not acceptable, not only because it is very expensive, but also because it is based on sophisticated technology that requires highly qualified specialists to operate it. Even in the industrialized countries, waste incineration is limited to a few countries and within these to a few cities.

Waste management problems in the regional municipalities: a critical analysis

A consideration of the problems raised and suggestions made in the report of the Ministry for Regional Municipalities and Environment shows that although the report seems to have covered everything, there is room for further analysis which goes beyond the traditional considerations with respect to waste management reform.

The first point that one observes is the belief that a shortage of funds is the main factor behind the problems faced by waste management. This thinking is based on trend analysis, according to which any increase in the work to be done and services to be provided should be followed by a commensurate increase in the financial means to cover the costs of the additional work and services. Government institutions all over the world still adhere totally or in great measure to this conventional solution. However, in recent years it has become apparent that financial resources cannot be provided in proportion to the increase in work and services. A breakthrough is therefore necessary to find other ways and means which require less money and at the same time identify methods that could replace financing.

Specifically, in regard to the waste management problems in the regional municipalities, we must reject trend analysis for the following reasons:

1. It is not always possible to provide financial resources proportionate to the increases in the work to be done and the services to be provided.

2. Even if providing financial resources in this fashion is feasible, it often hides administrative, organizational and technical weaknesses that impede efficiency and effectiveness.

With these two points in mind the Ministry should study whether it really makes efficient use of the financial and material resources as well as the manpower at its disposal and should see how they could be utilized more efficiently.

These two points are interrelated: the second forms the causes (deficiencies) and the first one the effect (inefficient use of resources).

Although the report of the Ministry does not address the problems of waste management in the regional municipalities or indicate whether there is inefficient use of resources, we can assume the existence of such problems, as these are found (as we have already seen) even in Muscat, where the standard of waste management is much higher than in the regional municipalities. We therefore recommend that before thinking of providing additional funds (which are limited) the following steps be undertaken:

1. Ascertain whether the capacity of the waste vehicles is underutilized, and take all necessary steps to achieve full utilization of this capacity. In this respect we strongly believe that the waste vehicles are underutilized.

2. Ascertain whether the waste transport plan followed at present could be improved, to shorten the distance travelled by vehicles collecting and transporting waste to landfills or dumping areas. This would save time and increase the daily number of trips made by each vehicle.

3. Ascertain whether the capacity of the containers is underutilized, and undertake all necessary steps to achieve full utilization of this capacity.

If these three points are combined, a considerable improvement in waste collection and transport could be achieved.

With respect to improving vehicles and containers, we recommend the adoption of the strategy proposed for Muscat. Furthermore, it should be noted that not only the financial constraints but also the existence of many small settlements scattered all over the district, the mountainous topography of the country and the prevalence of narrow roads with many ups and downs put limitations on the introduction of modern waste vehicles and containers.

4. Ascertain whether waste management manpower is fully utilized or not. Regarding street cleaning and waste collection, we would note that the deployment strategy for Muscat is necessary also for the regional municipalities. There, where the organizational and managerial capabilities are below those in Muscat, the need for a deployment strategy is even more pressing; introducing one would certainly minimize the manpower needed for street-cleaning and waste collection.

5. Identify any recycling activities such as the utilization of recyclable scrap metal, etc., by craftsmen and small workshops, as well as waste trade, including scavenging, which have emerged spontaneously and without the knowledge of the municipalities. Recall here that the waste traders who export waste paper and scrap metal (such as beverage cans) collect their material from all parts of the Sultanate.

Here, we suggest that our recommendations for Muscat be followed and that the recycling activities in Muscat strive as far as possible to absorb recyclable material produced in the regional municipalities.

6. Study how far and in what way organic waste can be composted. Such research should pay attention to traditional waste composting, which

may still be practised by rural people. Agricultural waste, including waste from livestock pens and poultry farms, is a valuable material that can easily be composted, since it consists solely of compostable organic material. Thus, there is no need for sorting or even for separate collection. Household waste, which in the rural and semi-rural areas contains a greater organic percentage than that found in Muscat, also deserves composting. However, the composting strategy to be followed here must be differentiated and should take into consideration the fact that the regional municipalities are in agricultural areas that can easily absorb the compost. It should also take into consideration the fact that the regional municipalities comprise (besides the administrative centre) many small settlements scattered over a sizeable area. We therefore recommend the following procedures:

(a) Where traditional composting of organic waste is carried out, the aim should not be to replace the traditional method with a modern compost plant, but to strengthen and modernize the traditional system so as to render it more effective and productive. At present the compost consists almost solely of easily digestible matter. Trees, leaves and branches are now burned, but simple shredders could turn them into easily compostable material. In general, composting processes are similar and anyone acquainted with traditional composting methods could easily be taught modern composting ideas, techniques and skills.

(b) Composting plants of suitable size should be established in the administrative headquarters. These plants should compost the waste of the administrative centre and its immediate surroundings; they should be established near the landfills and dumping areas, as recommended for Muscat. The aim should be to compost and recycle as much of the waste as possible.

7. Identify the problems of the present waste disposal system with the aim of eventually introducing a sanitary landfill system. High-tech disposal systems such as modern incineration should be avoided not only because they are expensive, but also because they require highly

specialized experts to operate and maintain them. The aim should be to eliminate open burning of waste. Another point which should always be taken into consideration is that the landfill site should fulfil all conditions regarding environmental protection.

8. A suitable solution must be found for hospital and other hazardous wastes. Incineration of hospital waste on hospital premises as is the practice now in large hospitals may be the best solution, but cannot be applied in small clinics and hospitals. A solution may be found in cooperation between the large hospitals that have or can afford incineration plants and the clinics and small hospitals, in which the large hospitals would incinerate the waste of their small counterparts against fees. This waste should be brought to the incineration plant by special vehicles in hermetically-sealed containers. Such vehicles should carry a special sign showing that they are hauling dangerous hospital waste, as well as documents that show all the types of waste being transported. Expired medicines should not be incinerated along with such waste; like many other hazardous wastes, they need special disposal and should be disposed of or treated in one centre that deals with all hazardous wastes in the country.

The case of Nizwa District

Nizwa District has a population of about 80,000 and covers 3,600 square kilometres. The district is divided into 43 subdistricts. Waste management in the district is carried out by the Public Health Section in a decentralized way in accordance with the requirements of the settlement pattern in the district; the Public Health Section established two units for supervising waste management activities, one in Jabal al-Akhdar (Green Mountain) and the other in Barkat al-Nowz. Street-cleaning, waste collection and transportation are carried out once a day in the residential and commercial areas of the district. The working hours are divided into morning and afternoon shifts. The morning shift starts at 6 a.m. and continues till 1 p.m.; the afternoon shift goes from 4 p.m. to 7 p.m. The vehicles used include a number of waste compaction vehicles, dump

trucks and lorries. Repair and maintenance are done either in the government workshop or in privately owned workshops.

The waste collection points consist mainly of oil drums. There are also home-made metal containers and three-sided masonry enclosures used as temporary waste stores. The district possesses very few modern containers.

The daily cleaning and waste collection work involves the following:

1. Waste collectors collect the waste by vehicle from the collection points. In each vehicle there should be four waste collectors and one supervisor.

The waste produced in Nizwa District is not all disposed of in the central landfill. The district comprises several scattered settlements, many of them far from the centre, and some in remote, mountainous and inaccessible areas. These small settlements transport their waste by animal cart and dump it in small nearby dumping areas, where either open burning or crude dumping are still practised. Agricultural waste prevails, and part of this is composted by the peasants using a traditional method. Dry trees, branches and leaves, although they are valuable and compostable material, are burned. Such waste, however, could be shredded and added to the other compostable waste. The composting method could easily be improved by acquainting the peasants with new composting techniques that could be integrated with the traditional method they are following at present. The waste to be disposed of could be considerably reduced in this way.

2. Waste from the administrative centre and surrounding area is brought to the landfill, which is surrounded by a chain of mountains that isolates it from residential areas and prevents the residential areas from being affected by any bad odours, etc., emitted by the landfill. A natural opening leading to the landfill serves as a gate.

3. The vehicles unload the waste in the landfill, which consists of several natural cavities. Every 2 metres' depth of waste is covered with 20 centimetres of earth and compacted with a heavy compactor. In this way the compressed waste and earth become stable and hard to the extent that they cannot be distinguished from the surrounding surface area.

4. The landfill is sprayed with insecticides twice a week to keep insects from breeding.

5. The containers, etc., at the collecting points are disinfected with insecticide to prevent the multiplication of insects and the emission of foul odours.

6. The narrow streets in the administrative centre and its surroundings are swept by hand and the waste is transported to the containers in wheelbarrows.

Nizwa District sees constraints to waste management development in the following:

1. Shortage of waste transport vehicles and waste disposal equipment such as tractors, compactors, etc.

2. Shortage of manpower.

3. Low environmental awareness of the population with respect to waste management. People put their waste in front of the containers instead of inside. Pressing or tearing cartons and plastic boxes before putting them into the container to reduce their volume is unknown.

4. Cats and goats get into the containers and feed on the waste, which they often scatter around.

It is generally assumed that the above problems could largely be solved if funds were provided to buy vehicles and equipment and to hire more manpower. However, the solution should not be seen as based on trend

analysis, according to which funds should be increased in proportion to the increase in the workload, since it would never be possible to provide funding of this magnitude. In addition, eliminating managerial, organizational and other deficiencies in the waste management system would certainly result in considerable improvement in performance. Resources other than money should also be utilized to improve the level of the service rendered, first of all public participation.

All in all, the waste management problem in Nizwa (as in other parts of the country) requires a thorough study that would consider the issues previously mentioned in connection with solving the waste management problems in Muscat.

The differences between the waste management system of Muscat and that of the regional municipalities are not fundamental; differences can be attributed only to the fact that the development standard of Muscat is higher than that of the regional municipalities. Waste management development in Muscat was previously similar to what is now found in the regional municipalities. The open burning of waste once prevailed in Muscat, but since 1970 the situation improved gradually and systematically, with a sanitary landfill system being introduced in all landfills of the city with the exception of a few in the remote areas of Quriyat, which became part of Muscat only in 1991. The strategy followed by Muscat was to improve and modernize what existed and not to replace it completely.

In practice the regional municipalities are following this same route. Gradual improvement, which takes available resources into consideration, is taking place. Central landfills have already been established in five districts and the other districts are following. Here we can speak of a common experience between Muscat and the regional municipalities, with Muscat playing a pioneering role. Any waste management plan for the Sultanate should take this common experience into consideration, while at the same time allowing each district or locality to consider its specific conditions; experience has shown that specific conditions finally

determine how successfully the aims of the plan can be realized at local level.

Issues in waste management reform

Waste management experts emphasize that in any human settlement (except in new towns which have to start everything from scratch) there is always some sort of waste management system in effect. They also emphasize that it is better to develop the existing system instead of fully replacing it with a new one. In other words, they recommend waste management reform, which means development from within. Such reform was undertaken in Muscat. This was favoured by the following factors:

1. The Sultanate's development strategy, based upon the socio-political thinking of His Majesty Sultan Qaboos, emphasizes self-reliance and mobilizing all Omani development resources before looking for the cooperation of others.

2. The oil boom in the Sultanate was not as overwhelming as it was in the other Gulf States (where it questioned the whole traditional waste management system and rendered it inoperative). Despite its importance, the oil-based boom in Oman was able to be integrated within the existing waste management system. The traditional waste management system was developed in such a way that the practice is today based upon the sanitary landfill system. Further development can follow, by adjusting modernization to the needs as well as the dynamics of the present waste management system. Muscat Municipality avoided undiscriminating enthusiasm for everything modern, including the blind introduction of modern waste management equipment. It resorted instead to the modernization and improvement of available equipment, especially containers. Large metal containers were also made locally using scrap metal sheets; these containers could be further improved.

There is no comprehensive waste management law. Local orders (*awamir mahaliyah*) enacted by the Municipal Council (*Al-Majlis al-Baladia*) regulate matters regarding cleaning and waste management and

are purely public-health oriented. They do not deal with environmental protection and do not say what disposal system is to be followed; rather, they concentrate solely on street and public cleansing. The removal of waste (both collection and transport) from the city is emphasized more than the waste disposal practice. It is only stated in the relevant Local Orders that the waste management section should dispose of waste in an appropriate way. Despite this shortcoming, waste disposal improved in line with the requirements of sanitary landfill. This occurred due to the following:

1. The nuisance as well as the health hazards created by the dumping area could not be avoided without introducing a sanitary landfill system that took environmental requirements into consideration.

2. The Municipality had been exposed to world practices in waste management development. It sent participants to international and Arab seminars dealing with waste management development, and these individuals returned with new ideas and skills that were integrated within ongoing operations in an innovative way which dynamized waste management development in the city.

3. The city does not lack empty areas that could be used as landfills. There are large areas that can be considered insensitive because the groundwater within them is very deep and is not used either for drinking or irrigation. These areas are surrounded by unbroken chains of mountains that form not only a natural fence but also prevent the wind from spreading foul odours from the landfill to residential areas.

However, it should be remembered that the urban expansion which the city is experiencing and which will continue will one day make the present landfills inadequate (as happened with the closed landfill in Wadi al-Kabir, which had been outside city limits). This means that any implications that landfills may have for the future must be taken into account now. It is necessary to include landfill requirements in land-use planning practices as well as in the master plan of the city.

The present landfills were established without a thorough geological study of the sites involved. Although almost certainly the choices were

right, it would be better to conduct a follow-up geological study to see whether any remedies or adjustments are necessary.

4. A landfill can be compared to any other consumer goods which leave waste behind. A closed landfill may not only be a useless wasteland but can be positively harmful if steps are not taken to render it harmless or even recycle it. Recycling (the best way to solve the problem) requires on the one hand avoiding landfill contamination and on the other reclaiming the land in an appropriate way to make it usable.

5. The recycling of waste by craftsmen and in workshops has almost completely disappeared from Muscat. Revival of this practice is impossible, although available recyclable waste has grown quantitatively and qualitatively. The welfare State that has emerged since 1970 has also led to a consumer society in which people consume more than they really need (over-consumption) and label as waste items which could still be used, at least after some simple repairs. This should result in the qualitative improvement of waste that could be recycled by craftsmen and small workshops, but such waste simply does not become available. The only way open is either export of recyclable waste or industrial recycling of waste in Muscat. This possibility should be addressed at length. We recommend industrial recycling as far as possible. If about half the recyclable waste were recycled, this would help protect the environment, reduce the need for waste collection and transport, and also create job opportunities. In our view, 3,000 to 5,000 jobs could be created in this manner. Assuming that each job would support a family of 5 persons, the jobs created would support 15,000 to 25,000 people, each of whom is a consumer, thus contributing to growth of the economy.

6. If we compare the stage which the present waste management system has reached against **figure II** on the integrated waste management system we see the following:

- The waste management system is landfill-centred.

- Separate waste collection is almost unknown, although there are encouraging signs in this direction. The export of waste paper and scrap metals has resulted in the appearance of scavengers and entrepreneurs who collect these materials separately. Recycling cannot be successful without well-organized separate collection, and this should be devised and introduced.

- The sorting of waste is carried out to some extent in the landfills by illegal scavengers.

- The recycling of waste exists but in a very limited way that has no economic or environmental significance. However, there is a growing trade in waste paper and scrap metal exported to Dubai.

- Bio-gas production from organic waste is unknown and can hardly be introduced in light of the low local price of petroleum and natural gas sources of energy and fuel.

- Use of landfill gas as a source of energy is absent and cannot be introduced because its production would be very costly. In addition, the quantity of gas available may be so small that it does not warrant collection.

- Waste avoidance and waste minimization are absent but there are some attempts to introduce this concept into the waste management strategy of the city.

Comparison of the above-mentioned points with the figure shows that waste management in Muscat is very far from an integrated waste management system. However, elements of this system are increasingly being introduced in the waste management activities of the city.

With respect to the applicability of **figure II**, we can say that it is primarily an ideal model which can be used as a guide but which should not be dogmatically followed. Its objectives consist of the following:

- Environmental protection by means of waste avoidance (waste minimization) as well as recycling and composting and the reuse of landfill gas.

- Upgrading the efficiency and effectiveness of the waste management machinery.

- Reduction of waste management costs.

- Developing recycling and composting into a profitable economic sector to the greatest extent possible. However, profitability should not be a determining factor. Environmental protection can sometimes justify recycling even if there is an economic loss.

In principle, the long-term waste management objective of Muscat Municipality is to achieve a sustainable integrated waste management system in line with the substance of **figure II** as far as this is feasible. Recent developments show that Muscat is moving towards such a system. The Municipality has increased its awareness-promotion activities with the aim of making people avoid waste production as far as possible. The sanitary landfill system followed in the city is witnessing continuous improvement. The interest of the private sector in the recycling and composting of waste is growing; there are already several enterprises which have taken steps to establish plants which recycle or compost waste. In fact, all components of the integrated waste management system that are included in **figure II** can be applied in Muscat with the exception of landfill gas collection for the production of energy as well as collection and treatment of landfill liquids. Due to the fact that rainfall in Muscat is only 80 mm per year as compared to 1000 to 1200 mm rainfall in the temperate zones of Europe (Germany, the Netherlands, the Scandinavian countries) and the fact that a considerable percentage of the moisture in the waste evaporates in the hot sun before it is disposed of, anaerobic decomposition of organic waste, which depends upon the moisture content of the waste, is very slow, as samples of waste show which were buried five to seven years ago. Accordingly, there is no leachate which would justify the collection of landfill liquids, as the

amount of landfill gas is so small that collecting it for energy production is uneconomic.

The legal framework for non-hazardous waste management in the regional municipalities

Non-hazardous waste management in the regional municipalities is regulated by Ministerial Decision No. 17/93, which was enacted on 2 February 1993. Paragraph 4 of Article 1 of this Decision defines non-hazardous waste management as follows:

> Any solid or semi-solid material which does not pose any danger to the environment or to human health if it is dealt with in a scientific way, including:
>
> • Household waste.
>
> • Solid or semi-solid materials discarded or produced from residential, commercial, industrial, agricultural and other activities.
>
> • Construction and demolition debris.
>
> • Metal scrap, including discarded motor vehicles.
>
> • Dewatered sludge from domestic, industrial or agricultural wastewater treatment, providing that such sludge contains no toxic components in concentrations exceeding the acceptable limits of the wastewater regulations.
>
> • Slag and ashes from incineration processes, provided that these materials have an available toxic content within the criteria applied to the characterization of dewatered sludge from wastewater treatment.

The Ministerial Decision puts the emphasis on safe waste disposal:

(a) Treatment of non-hazardous solid waste, with the aim of reducing its adverse impact on the environment or rendering it more suitable for reuse.

(b) Following the sanitary landfill system.

Although the Ministry does not specifically require the avoidance of waste production or the recycling of waste, the Ministry of Regional Municipalities and Environment has recognized the importance of these two aspects of waste management and has begun to promote them. The Ministry's activities to promote environmental awareness give special emphasis to waste avoidance. In addition, the Ministry encourages individuals and businesses who want to recycle waste or export recyclable waste materials.

With respect to waste collection and transport, the municipalities are charged with the task of providing these services to households (i.e., residential areas) free of charge. However, industrial and commercial establishments are required to bring their waste to the landfills.

To achieve effective waste collection and transport, the municipalities are required to establish waste collection points to which private citizens can bring their waste.

To be able to introduce sustainable waste management planning, the Ministerial Decision requires that the "concerned authority" (the municipality) prepare a comprehensive 15-year master plan for the collection, storage, transport, treatment and disposal of non-hazardous waste.

However, applying this very ambitious law is not easy, as experiences in the industrialized Western countries show, where there are still many open dumpsites in spite of the enactment of comprehensive waste management laws and the preparation of master plans. In Oman, the shortage of waste management specialists is a constraint that must be overcome if the provisions of the law are to be fully applied. The best

strategy is to implement the law step by step in line with improvements made by the waste management system. It is noteworthy that waste disposal in Oman, particularly in the regional municipalities, is not as complex as it is in the industrialized Western countries, where there are large landfills that often have to accommodate the waste of a large city or of several cities and towns. Muscat, with its 550,000 inhabitants, has four landfills, and no single landfill accommodates the waste of more than 200,000 inhabitants. In the regional municipalities, the situation is even more straightforward. None of the districts into which the regions of the regional municipalities are divided has more than 40,000 inhabitants. In addition, each town in a district has its own dumpsite or landfill, with some districts having over 10 landfills. This is the case especially in the mountainous areas where the topographical structure does not allow for easy transport of waste far from the town or village, as well as in the sparsely populated areas, where waste production is low and distances are great between towns and villages, with no paved roads.

For the regional municipalities, the following steps would generally be sufficient:

1. In the major towns, waste in the landfills should be compressed by compactor and covered with soil.

2. In smaller towns and villages it would at present be sufficient to improve the existing dumpsites. A favourable factor here is that smaller towns and villages use their kitchen waste as fodder for their animals, so that most of the waste brought to the dumpsites consists of non-organic waste and inert material (ashes, sand and small stones). If recyclable items were collected separately, the dumpsite would primarily accommodate materials which do not cause environmental or health problems.

However, the introduction of a waste management system based upon the Ministerial Decision requires first of all a thorough understanding of the present situation of waste management.

Conclusions and recommendations

1. Waste management law

A comprehensive waste management law should be enacted, with waste avoidance the principle upon which the entire waste management philosophy is based. The second principle should be recycling and composting of waste, and next should come appropriate waste disposal and treatment. Application of the law should not be dogmatic but should follow a flexible approach that recognizes that avoidance, recycling and appropriate disposal should complement each other. The waste that cannot be avoided should be recycled or composted and appropriately disposed of. The three aspects will always coexist, but the law should include clear provisions on waste avoidance, waste recycling or composting, and appropriate waste disposal or treatment. It should require that imported goods and commodities be packaged only to the extent necessary. Industries should minimize their waste production as far as possible. Further, the law should fix for each recyclable waste or compostable waste a certain percentage that should be recycled or composted. There should also be concrete provisions on sanitary waste disposal in which the choice and preparation of appropriate sites should be given special attention.

The law should be supported by regulations specifying how its provisions should be applied. In addition, each region or area should issue local orders in a way that adapts the provisions of the law to specific local conditions. This adaptation is the factor that would finally decide how easily the law could be put into practice.

For hospital waste, special and toxic waste, etc., there must be special laws which clearly define how they should be treated or disposed of, as dangerous wastes differ in their nature, toxicity, durability, etc. Radioactive wastes cannot be destroyed, and there are other special wastes with a similar nature. Some special wastes are less dangerous

than others. All this has to be taken into consideration. As Kazuo Akita writes:[45]

> As a category, dangerous goods are determined by examining the substances themselves to see in what measure they are dangerous. But danger is continuous and it is not possible to establish categories within which substances are uniformly dangerous or uniformly safe.
>
> With progress in service and technology, numerous substances have been spawned and have come into liberal use in both the industrial and domestic sphere. Also, as economic research developed for markets overseas, how dangerous goods are traded, since regulations differ from one place to place, arises as a question; this question interferes with the free flow of goods.

The worldwide free flow of goods has increased the exposure to dangerous substances appearing either as goods or as waste. Export of hazardous waste from industrialized countries to the third world is well known. The international dimension of hazardous waste led to demands for the international standardization of dangerous goods regulations, eventually giving rise to the United Nations Committee of Experts on the Transport of Dangerous Goods, which was established in 1957 under the auspices of the Economic and Social Council. Again, Akita writes:

> It is currently composed of 17 voting member nations, other nations with speaking rights only, and various organizations related to the EC. The Committee's principal tasks are to provide guidelines for classifying products and substances as dangerous goods and to standardize the criteria for restricting or setting cautionary measures for transporting them. Items approved by the Committee are listed in a United Nations publication called the

[45] Kazuo Akita, "On the Safe Side: Dangerous Substances—Handle with Care", in *Look Japan* (Tokyo) (October 1991), pp. 30-31.

> orange book (the colour of its cover). This has undergone numerous revisions and is currently in its seventh edition.
>
> The United Nations Committee has played a large role but its most important contributions have been a nine-class categorization system for dangerous goods and experimental procedures for objectively rating the danger of substances in each class. The classification system is used throughout the world as a basis for regulations in respect of transportation and other actions involving dangerous goods. The experimental procedures have not yet been perfected, but even if they had, it would be impossible, for reasons mentioned above, to finally specify all dangerous goods. Still, these procedures are important in that they indicate a course to be followed in the future.
>
> The United Nations recommendations have been taken up by such organization subgroups as the International Maritime Organization (IMO), the International Civil Aviation Organization (ICAO), and the International Atomic Energy Agency (IAEA), and have been incorporated into sea and air treaties. In Europe these recommendations have also been invoked as a basis for land transport regulations (e.g., the International Regulations concerning the Carriage of Dangerous Goods by Rail, and the European Agreement concerning the International Carriage of Dangerous Goods by Road.[46]

Since regulations for dangerous goods cover such a broad range of areas, from manufacturing and storage to transportation and consumption, the United Nations recommendations cannot be incorporated as they stand. In such an internationalized society as today's, however, domestic regulations cannot but be made to conform with international regulations.

Although the above quotations deal with dangerous goods and their transport, we consider them significant to the present topic. Accordingly,

[46] Kazuo Akita, op. cit., p. 31.

all precautions that should be taken with respect to hazardous goods have to be considered also in the case of hazardous waste. The standardization of dangerous goods is valid also for dangerous wastes.

Although dangerous wastes are produced today in Oman only in small quantities and do not pose a serious problem, the country is in need of laws and regulations to deal with such waste, because the country's growing industrialization will inevitably increase these small quantities. In addition the internationalization of Omani society in terms of economic development will increase the country's exposure to international trade in dangerous goods. Available international experience can be of great help, and domestic regulations have to conform to international regulations, yet it should always be borne in mind that not only objective scientific criteria but also the attitude of society determine whether a certain type of waste should be considered dangerous. In this conjunction, Kazuo Akita writes, "Dangerous goods are those which the members of a particular society at a particular time deem necessary to dispose of or to restrict in some way because these goods, with their flammable, explosive, poisonous, corrosive, or radioactive nature, inflict direct harm."[47] This means that laws and regulations on the disposal or treatment of dangerous wastes often differ from one country to another. In Oman, matters regarding hazardous waste are regulated in Ministerial Decision No. 18/93, which was issued on 2 February 1993. This Decision defines hazardous waste (in Article 1, Paragraph 3) as follows:

> Any waste arising from commercial, industrial, agricultural or any other activities which, due to its nature, composition, quantity or other reason is hazardous or potentially hazardous to human health, to plants or animals, or to air, soil or water. This applies to explosive, radioactive or flammable substances which may cause disease and which would be included in a Decision issued by the Minister.

[47] Kazuo Akita, op. cit.

The Decision requires the treatment or disposal of hazardous waste in a site licensed by the Ministry, whereby the final disposal should be without risk to health or the environment. According to Article 2 of the Decision, waste generators should "apply the best available technology relevant to [their] production and operational practices to minimize the generation of hazardous waste . . ." Article 7 states that hazardous waste may be recycled, with the recycler required to obtain a licence for this purpose and to comply with the provisions of the Decision. In general, the Ministerial Decision tackles all aspects of hazardous waste management. It requires a licence from the Ministry to store, transport, treat and dispose of hazardous waste. The mixing of hazardous waste with any other type of waste and bringing it to landfills for domestic waste or discharging it into the sewer system is strictly forbidden. Further, generators of hazardous waste should keep a record of their hazardous waste production, and before the hazardous waste is transported from their premises, a consignment note—a document listing the category and quantity of hazardous waste—should be submitted to the Ministry. A copy of the list should go to the Royal Oman Police Force (Traffic Control Police). Here it is also required to give the type and target of the vehicle used.

Enforcement of the Ministerial Decision is going on relatively well. However, a shortage of specialists trained in environmental impact assessment and environmental auditing, as well as a shortage of facilities for treating or disposing of hazardous waste, poses constraints. To overcome this problem, the Ministry embarked upon a programme which includes the following:

(a) Training its personnel who are responsible for the application of the law, in environmental impact assessment and environmental auditing.

(b) Recruiting specialists in the area of hazardous waste management.

(c) Offering training opportunities to personnel of other ministries and other government institutions who practise any form of hazardous waste

management or whose work requires an acquaintance with hazardous waste management.

(d) Establishing facilities and landfills specialized in the treatment and disposal of hazardous waste.

In order to introduce effective and efficient hazardous waste management, the Ministry intends to hire a specialized consulting firm to do the following:

(a) Inventory the hazardous waste.

(b) Categorize and codify hazardous waste.

(c) Recommend how each type of hazardous waste should be treated or disposed of.

(d) Recommend the hazardous waste treatment and disposal facilities which should be introduced, giving due consideration to their suitability for conditions in Oman.

(e) Design training programmes for the Omani specialists in hazardous waste management who are employed by the Ministry.

(f) Develop any Ministerial Decisions necessary.

By carrying out all these steps, the Ministry aims to develop a comprehensive hazardous waste management system and apply it efficiently.

2. Research

The available information about waste production and waste composition is based on rough estimates. It is therefore necessary to conduct a study on waste production and waste composition with the aim of obtaining a clear picture of this matter. This would make it possible to reform the

waste management system with respect to collection, transport, disposal, recycling, etc., in an appropriate way.

The present organizational set-up for waste management has proved to be relatively effective. However, it needs some amendments to cope with the steadily growing environmental challenges which waste has started to pose. Central guidance and control should be strengthened. In this respect, the general supervisor for hygiene in the Office of the Chairman must be given powers to guide and control waste management activities. To achieve this, his office must be provided with two experts, one in waste management economics and another in waste analysis.

3. Management of waste vehicles and equipment

Waste vehicles and equipment as well as drivers are not managed by the Waste Management Section in each sub-municipality, but by the Directorate General for Transport. This Directorate General has in each sub-municipality someone who is responsible for the supervision of the vehicles, equipment and drivers, and who answers directly to the Directorate General for Transport. When there are differences of opinion between the Waste Management Section and the Directorate General, he sides with his employer, whose interest he represents and upon whom his career development depends. The Directorate General considers the needs of waste management for vehicles and equipment in the context of its overall responsibility for transport in the municipality. However, waste transport has specific needs and problems, and it is thus better for it to be dealt with directly within the waste management system, by the general supervisor, whose power should be upgraded.

4. Cooperation

Cooperation should be promoted between the State (government institutions) and society in matters concerning waste management. Such cooperation is an indispensable element in ensuring successful waste management. Cooperation demands fair play between all State and social forces in the opinion-forming and decision-making process as well as in

realizing the objectives of the waste management strategy as foreseen by waste management laws.

> This improves the degree to which those involved are informed as well as the acceptance, and thus efficacy, of environmental policy decisions. It also reduces or avoids unnecessary conflicts, administrative effort and costs. Admittedly, cooperation between State and public bodies also has its limits. For instance, the State is not able to dispense with competencies vested upon it by the Constitution or legislature. It can, however, give social groups and the individual citizens responsibilities in managing the environment.[48]

The necessary cooperation involves the following:

> The behaviour of each individual citizen contributes to the nature and extent of environmental stress. However, by purchasing environmentally compatible and low-pollution products as well as behaving in a manner conducive to the environment, he can contribute towards the environment being burdened as little as possible.
>
> A high level of environmental awareness on the part of the population is an all-important prerequisite in obtaining the objectives of the best improvement of the environment.[49]

The present low environmental awareness in Oman (as in all other Arab countries) hinders sound waste management. Thus, comprehensive awareness promotion is indispensable. Besides the mass media, all social institutions in the city (schools, institutes, universities, sports clubs, mosques, etc.) should be used as a forum for environmental education

[48] *Umweltpolitik*, pp. 20-21.

[49] *Umweltpolitik*, p. 21.

with the aim of inducing the population to behave in a manner that would help improve the environment.

(a) Cooperation with industry

Industry and commerce, trade, agriculture and transport, as well as other sectors of industry, are potential polluters of the environment. As manufacturers and users of substances, companies and their trade associations know better than anyone else the possibilities of and methods for reducing and avoiding the introduction of substances into the environment. Industry therefore should be involved at an early stage in the opinion-forming and decision-making process associated with environmental policy. The government should always be open to suitable proposals by industry. In addition, industry should take the initiative in using environmentally compatible technologies.

(b) Cooperation with science and technology

The development of waste management policy concepts, objectives and measures must be based upon the findings and results of scientific and technological research activities. Preparing waste management measures that aim both at environmental protection and economic use of waste may require a comprehensive interdisciplinary investigation. It is therefore necessary to involve all relevant university faculties, the government bodies dealing with science and technology, and individuals who are considered experts in social sciences, administration and management, economics, public health, hygiene, etc., in the preparation of the measures.

(c) Cooperation with the Gulf States

Since 1970 waste production in the Gulf States has witnessed a rapid and steady increase. This increase covers both per capita waste production and waste produced by industry and other economic sectors. Furthermore, the composition of the waste has become more diversified, and the proportion of hazardous waste in overall waste has increased

considerably. Also, hazardous wastes previously unknown have appeared in our society. This development has caused the Gulf Cooperation Council (GCC) and its specialized organs to pay great attention to waste management, with the aim of finding appropriate solutions to the waste problem in the Gulf States. In line with this commitment, the Association of Chambers of Commerce of the Gulf States organized a seminar in November 1981 aimed at the exchange of waste management expertise among the Gulf States. Since then, several activities on cooperation in the field of waste management have been undertaken by the GCC. Oman has taken a very active part in these; cooperation with the Gulf States in the field of waste management is very important for Oman, because the growing economic integration of the region means that the flow of goods among the Gulf States is steadily increasing. This certainly has an effect upon waste production in the individual States. Recognizing this fact, the GCC is conducting a study that aims to introduce a common waste management strategy including regulations at the Gulf level, whereby waste management laws in individual States would have to be based upon the Gulf regulations. Oman's participation in these activities is indispensable, and the Sultanate should try to ensure that the relevant Oman experience goes into the formulation of a common waste management strategy and body of regulations.

(d) Cooperation with all Arab States

Cooperation at the Arab level in the field of waste management is relatively limited. However, some years ago the Arab Urban Development Institute (AUDI) began organizing Arab seminars on waste management with the aim of enabling Arab cities to exchange experiences and to supply Arab waste managers with up-to-date, relevant knowledge, skills, etc., in their field of specialization and work. In addition, in 1983 AUDI prepared a comprehensive survey of waste management in the Arab world. Muscat and other Omani cities take an active part in the activities of AUDI.

(e) International cooperation

International cooperation in the field of environmental protection is growing steadily. Waste management enjoys special attention in this context because of the growing exports of hazardous waste, especially to third-world countries. The dangers resulting from such exports (often an illegal activity) spurred the United Nations to organize in 1988 an international congress on hazardous waste exports, at which industrial countries promised that their industries would not undertake such exports.

The above-mentioned dangers from the export of hazardous waste and the increasing international flow of goods to which Oman is exposed necessitate that international cooperation become an important aspect of the waste management strategy of the country.

(f) Bilateral cooperation

Cooperation with individual countries on the basis of bilateral agreements is increasingly important. One type of cooperation is cooperation between two cities in different countries. Muscat Municipality has already started such cooperation with several cities in Europe and in the Arab world.

(g) Cooperation between Muscat and the regional municipalities

To our knowledge, this kind of cooperation is at present almost non-existent. However, some steps have been taken recently to establish cooperation in the field of training, especially in matters regarding hygiene and public health. Training in waste management was emphasized during a meeting between the regional municipalities and Muscat Municipality. Certainly this step could lead to further joint activities regarding waste management, such as research, exchange of expertise, etc. Such cooperation is indispensable for designing a sound national waste management plan. In fact the plan should be based upon it, and designed in a way that makes cooperation imperative. This objective could be much better realized if comprehensive cooperation

between Muscat and the regional municipalities were established and cooperation in the field of waste management became part and parcel thereof.

(h) Fees for waste collection and disposal

The policy of the Sultanate is that waste management services should be provided free of charge to households. It is also a policy that factories and commercial establishments must bring their waste directly to the landfills or hire someone else to do this work for them. Unfortunately, factories and commercial establishments do not always comply with this provision, instead putting their waste into containers meant for household waste. In addition they do not press the cartons, plastic, boxes, etc., which they put in the containers, meaning that the containers fill up long before their weight capacity is reached. In the commercial areas, it is common to see containers filled with a few empty cartons, boxes, etc., with other waste lying in front of the container. This misuse of containers happens because commercial establishments are not punished for these illegal practices; a solution can be achieved only if the regulations stipulating that commercial and industrial establishments bring their waste to the landfills are enforced. This is in line with the principle "The polluter pays," which is increasingly applied in all industrialized countries. This principle asserts that anyone responsible for causing a burden on the environment must bear the cost arising from avoiding or eliminating this burden. The instruments used in polluter-oriented environmental policy range in practice from rules and prohibitions, to compensatory arrangements, to environment charges. The principle of "The polluter pays" is primarily based on the idea that each producer and consumer remains responsible for the burden on the environment caused by him and that he is capable of developing his own measures to protect the environment.

Introducing the collection of fees for waste management in a selective way (i.e., which includes an exemption for households and small shops) would reduce the waste to be collected and raise revenue, especially if the fees were fixed in accordance with the size of the waste container

regardless of whether its full capacity were used. In order to pay as little as possible, polluters would press or tear boxes to reduce their size, making better use of the container. This would also result in the collection of more waste from fewer containers and would reduce the distance run by the waste vehicles and the time required to empty containers into the vehicle.

5. Establishing a weighbridge

To weigh the waste deposited in the landfills, a weighbridge should be established at the gate of each landfill to weigh the load of each incoming vehicle.[50] The vehicle is weighed with the load, and the vehicle weight is deducted from the total weight to obtain the weight of the load.

Installing the weighbridge would have the following advantages:

- It would be possible to determine whether the full capacity of the vehicle were used or not, since the weight of the load would be known. If the load were less than the capacity of the vehicle, this would indicate organizational or managerial problems that would have to be solved to achieve optimum use of vehicle capacity.

- The weighbridge would enable the Municipality to record the development of waste production in the city. A more comprehensive picture could be gained about this if waste brought to the composting and recycling plant were also weighed.

- The weighbridge would make it possible to identify the quantity of waste disposed of daily in the landfills. This would enable better planning of landfill use and would give a clearer idea of how long it could be used.

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50 In January 1993 the first weighbridge was established in al-Amerat landfill, enabling us to know the exact weight of waste brought to the landfill as well as the fluctuation in the weight of waste collected daily by the Municipality.

6. Urban renewal

Waste management is an indispensable aspect of urban planning and urban renewal. Urban planning ignored waste management for a long period of time, and even today urban planners in most cases pay no more than lip service to waste management. Urban planning in Muscat seems to be no exception to this; here, too, waste management is dealt with in complete isolation from urban planning. The Directorate General for Technical Affairs, which deals with all matters regarding urban development, is in no way responsible for waste management, which is dealt with at the sub-municipal level by the Directorate for Public Health Affairs. We are not suggesting here to make waste management a department in the Directorate General for Technical Affairs, since waste management is a service that has to be provided daily. In addition, the technical aspect is just one of many other components that together make up the field of waste management. Due to this fact, waste management is currently carried out under the central supervision of the general supervisor for hygiene. The Directorate General for Technical Affairs considers waste management as an indispensable dimension of all its urban development activities.

Concerning the relationship between waste management and urban renewal, it is first important to know that the quarters in the Muscat area which need urban renewal suffer from severe waste management problems. These old quarters were built at a time when the present waste management problems were unknown. They lack modern sanitation facilities, their streets are narrow and to a great extent unpaved, and here one observes dilapidated buildings into which some people throw waste, and which become breeding grounds for insects and rodents.[51] Here

[51] In the narrow streets of these old quarters, waste is collected with wheelbarrows that bring it to collection points. Medium-sized Nissan vehicles (2-ton capacity) collect the waste from the collection points and bring it to the landfill, which is far removed from the collection area—30 to 40 kilometres. The vehicles have great difficulty moving in the narrow streets, many of which are so narrow that they are impassable, meaning that the vehicles must make detours that prolong the time needed for waste collection and transport.

also are some historic buildings which symbolize the cultural heritage of the Sultanate. In short, these quarters consist of a mixture of buildings, most of which lack modern sanitation facilities and others which are dilapidated, along with historic buildings. Urban renewal has to take these factors into consideration, and the fact that the quarter as a whole represents an architectural and urban development heritage that to a large extent deserves preservation. Indiscriminate demolition of the quarter must therefore be excluded from the outset. What is required is a well-thought-out urban renewal strategy that takes the following into consideration:

- Preservation of the national architectural heritage. This includes the declaration of historically and architecturally important buildings and their preservation as historical monuments.

- Restoration of some buildings and the installation of domestic sanitation facilities (modern toilets, sewage system, etc.).

- Demolition of dilapidated buildings used by some as waste dumping areas.

- Demolition of selected buildings with the aim of creating open spaces for recreational purposes. In this respect it should be ascertained whether it would be possible to widen the service roads leading to the main streets to ensure that waste collection vehicles could enter the quarter.

7. Rethinking the role of scavengers

Scavengers should stop being viewed as antisocial elements and be considered instead as people who have understood that they can make a living by sorting waste and selling the recyclable items found in it. Their recycling practice should be improved, and this should happen in the context of improving their overall quality of life. Scavenging, which is already providing some livelihood, could be upgraded by establishing supported cooperatives for the scavengers.

8. Preparation of a waste management plan

Present waste management practice in Muscat is based upon a long experience which emphasizes how to clean streets and public places and collect and transport waste. The sanitary landfill system was introduced not because there was a plan that foresaw its introduction, but because the people in charge of waste management learned by doing that it was a better way to dispose of waste and that this method was feasible. With respect to the cleanliness of the city and how waste is disposed of, one can only be satisfied. However, this does not mean that the waste management system is efficient in terms of cost-effectiveness. The capacity of waste vehicles as well as the time of the workers is underutilized. The vacuum sweeper used seems to be inefficient, as it has to be shut off for at least 30 minutes after it has been in operation for one hour. The sub-municipalities justify the underutilization of the capacity of the waste vehicles by arguing that collected waste has to be landfilled in a short, fixed period of time which is not enough to allow a vehicle to be loaded to its full or almost-full capacity. All in all, the present waste management system suffers from severe managerial and technical problems that minimize its cost-effectiveness. Reform and a sound plan are badly needed, but this cannot be done by the present waste managers, who are not qualified for such a job and who are fully occupied in resolving daily crises and complaints.

In general the waste management problems existing in the Muscat waste management plan are similar to those found in all developing countries. Thus, the solution required is comprised in the following quotation:

> The preparation of a waste management plan to provide the foundation for an efficient collection and disposal service is frequently neglected. Senior and middle-ranking staff in waste management organizations are commonly fully occupied resolving daily crises and complaints. Very few organizations have full-time staff responsible for forward planning. Without such staff with sufficient time to carry out their duties, it is almost impossible for an organization to assess the effectiveness and economies of current

operations; analyse the options available to improve existing collection and disposal practices; design future collection services and disposal facilities; plan the smooth change-over from one collection method or disposal facility to another; and identify the staff training needs and legislative requirements to maintain efficient waste management.

Cointreau (1982) has commented that these activities require specialist expertise. Consequently, a waste management organization could benefit from a specialist forward-planning department, separate from supervisory and operations staff, but with the same status in the organization structure. Planning is vitally important. Without planning, waste management lurches from one crisis to another, with little control of the direction taken. It should be the principal function of the forward-planning department to advise senior management on appropriate ways to avoid these situations in the future.

Improvements in waste storage, collection, treatment or disposal operations may also require some change in the habits of householders and waste management staff. In the successful implementation of a plan, these are probably more difficult to effect than organizational improvements. Waste-planning staff must be aware of this because even the most well-thought-out waste management plan will fail if it does not have the collaboration and support of the general public and staff in other departments. Considerable skill is required of waste planners and senior managers to educate the public and manual waste management labour about the improvements to their lives that will follow from planned changes. Considerable humility is also required. Many good ideas on ways to improve waste storage and collection can come from the public, and many good ideas for improving waste handling, vehicle utilization and disposal practices can come from all grades of waste management staff. The waste management plan can benefit considerably from their views. The

planner is well advised to listen to and learn from the public and staff in other departments.

Cooperation is essential and cannot be obtained easily; but with perseverance it is possible. Cooperation cannot be aroused by an insensitive attitude by a waste management organization. Pickford (1984) summarizes a situation he has found in some developing countries:

It is easy to fall into a trap. Whether expatriate or local, experts can be tempted to say: We are providing you with a wonderful collection system with fine new tractors, trailers and handcarts; all you have to do is carry your rubbish to a nice new concreted collection place two blocks away. Then the streets will be tidy and you will be free from flies, smell and disease. If the words are not spoken, the thought may be there. The zeal of the reformer telling people what they ought to do is seldom effective.[52]

9. Training

The present waste managers in Muscat have, to a great extent, gained their skills through learning by doing. They did not enjoy pre-service training before being charged with the responsibility of waste management. Transfer to or from the Waste Management Section often happens suddenly by administrative order. Neither the one transferred to the section nor the one transferred out of it to somewhere else are given enough time to discuss everything properly. Thus, the newcomer is not systematically introduced to his work in a way that would properly acquaint him with how it is done or with the problems and constraints that exist. What takes place is nothing more than a quick hand-over. In addition, none of the waste management sections in the city has a reliable filing system. The available file information is often nothing more than how many loads of waste were transported daily, and even this is not systematically recorded. This occurs because:

[52] Rushbrook and Finny, op. cit., pp. 11-12.

- The educational level of the Head of Section is low (maximum six years of education). This does not enable him to write reports or to analyse performance and problems in writing.

- The Section is not equipped with a secretary or typists who could help to prepare and type reports.

- The Head of Section has very little decision-making power. His work consists of a daily supervisory routine in the field, which requires almost no written work. He reports orally to the Director of Public Health Affairs. In general the Head of Section settles administrative and managerial matters with his subordinates orally in a daily meeting after work. In addition, both the Head of Section and his subordinates are equipped with walkie-talkie radio through which they constantly communicate. Operational problems arising are discussed and often even settled by walkie-talkie. The Director for Public Health Affairs and the Director General of the sub-municipality are also connected with the Head of Section and the supervisors by walkie-talkie. This apparently perfect system of communication enables better supervision and immediate decision-making, but its negative aspect is that it encourages chatter and hinders record-keeping. Thus, much valuable information regarding problem-solving is lost. A particular problem (for which a highly suitable solution was previously found) may arise again, but the precedent (which was not recorded) is forgotten, and a new solution is sought which may not be as successful as the precedent. This situation does not create an atmosphere conducive to dynamic learning and self-training. The newcomer learns very little from his predecessor. However, he can easily find his way in his new place of work, because the waste management operations (which are highly routine) function automatically and need little intervention or creativity to cope with them.

It is worth mentioning that without changing the above-mentioned management practices, training will not be able to bring about the desired improvement. Thus, training has to be considered within a strategy of overall waste management reform that comprises the following:

- Making the whole waste management system sensitive to problem-solving and cost-effectiveness.

- Identifying existing managerial problems, including gaps that could be filled by training.

- Introducing organizational reform.

- Identifying the training needs of the present waste management staff, taking into consideration their low educational level and the fact that their capacity for training is relatively limited. This means that a managerial gap (requiring employment of qualified manpower) will exist even after they have been given the maximum level of training they can absorb. Thus the question to be solved not only concerns training but also the recruitment of qualified people who can do the work better.

WASTE MANAGEMENT IN DHOFAR

The geographical set-up and settlement pattern, and the effect of these upon waste production

The Governorate of Dhofar has an area of 102,300 square kilometres and occupies about a third of the territory of the Sultanate of Oman. It is bordered by Saudi Arabia in the north and by Yemen in the west. The extensive desert area of central Oman separates the Governorate of Dhofar from the north of the country and the capital area. On its southern border, the region has a coastline of over 500 kilometres along the Arabian Sea.

The population of the region numbers about 120,000, with about 5% of the inhabitants living in urban areas, mainly Salalah and its suburbs. The coastal plain has a fertile alluvial soil and is well-watered between June and September by the monsoon. The rains also irrigate the tree-dotted hills that rise 1,500 metres above the coastal plain.

The governorate is divided into four subregions: the Western Jabal (mountain) subregion, the Nejd subregion, the Eastern subregion and Salalah subregion.

The Western Jabal subregion (Jabal al-Qamr) is a pastoral area accommodating 27,000 inhabitants. Most of the cattle of the region, which number 110,000 to 130,000 head, are reared in the jabal areas. In addition to this the Jabalis (the mountain dwellers) raise a considerable number of camels and some goats and sheep.

The Nejd subregion, which comprises about half of the entire territory of Dhofar, is populated only by 12,000 bedouin and their livestock (camels and goats).

The Eastern subregion, which occupies about 36,000 square kilometres of low plateau and plains, contains some of the currently exploited southern oilfields.

Salalah subregion is the smallest subregion in Dhofar; however, it accommodates about 90% of the population of the Governorate. It also possesses the greatest environmental diversity and economic activity. It contains the eastern and central jabals (Jabal Samheen and Jabal al-Qara).

Dhofar produces approximately 40-45% of the national oil production, and about 12% of national development expenditure is allocated for it. Industrial activity is very limited; it is confined to a small number of large, capital-intensive industries involved in such activities as fish processing, cement production, soft drinks, animal feed and mud engineering (for the oil industry). In addition to these large industries are small ones, employing an average of six people. These industries are mainly involved in fabricating components for the building industry.

Major economic activities are agriculture, which is mainly concentrated in Salalah and its surroundings, and livestock rearing, which is mainly concentrated in the jabal areas. Salalah, which is the second largest city in Oman after Muscat, is not only the capital of Dhofar but also its commercial centre.

The above-mentioned settlement and production pattern affects the distribution of waste production, which has the following features.

1. Waste production is concentrated mainly in Salalah, where over 65% of the population of the Governorate lives and where agricultural and industrial production is concentrated.

2. The second largest quantity of waste is produced in the Jabal area, where 27,000 people reside and which has about 110,000-130,000 head of cattle and a considerable number of camels and goats; this area amounts to about 2,000 square kilometres.

3. The Governorate, like all other regions of the Sultanate, not only depends upon local production but also consumes large quantities of foodstuffs and other consumer goods from abroad. This considerably increases the quantity of waste produced there; the increase is the greatest

in Salalah, with not only over 65% of the population, but also with a large concentration of foreigners and urbanized Omanis who prefer imported foodstuffs and other consumer goods that often leave behind large quantities of packaging material as waste.

4. Industrial waste has almost no importance except in the oilfields around Rima and Marmul. However, this study does not cover industrial waste related to oil production. The oil industry has its own waste disposal system, which includes a plant for the treatment of special and toxic wastes at Fahud. At present Muscat Municipality is exploring how to reach an agreement with Petroleum Development Oman (PDO) with the aim of making use of the facility in Fahud for disposing of or treating special and toxic wastes produced in Muscat.

5. In Salalah, agricultural waste is generated in great quantities and disposing of it poses a great problem. Actually, Salalah is a green "agro city" with 120,000 coconut trees and an area of 750 feddans planted with 375,000 banana trees. In addition to this there are considerable numbers of papaya, mango and sugar-cane plantations as well as farms that grow tomato, watermelon, cabbage, fodder grass, alfalfa, eggplant and rhodes grass.

6. In the jabal area, waste from the livestock sector is produced in great quantities. This waste consists mainly of dung, which is partly used as fertilizer, and carcasses, which can be considered special waste, the disposal of which poses a great problem.

Agricultural waste and waste from the livestock sector (dung) are recyclable and compostable, and will be dealt with separately in the present volume in the context of overall agricultural waste management in the Sultanate. Our concern here is household waste management.

Central and local governmental organizations

In Oman, government practices at the local level are characterized by dual functionalism. On the one hand are the Governorates (sing. *Muhafada*, pl. *Muhafadat*) and Districts (sing. *Walaya*, pl. *Walayat*). The Governor and Wali carry out government activities on behalf of the Ministry of Interior in their respective geo-administrative areas. On the other hand, in each locality is a municipality which carries out local administration activities that involve providing municipal services and utilities as well as some local public order functions related to municipal work.

The highest government authority in Dhofar is the Minister of State and Governor of Dhofar. He acts on behalf of His Majesty the Sultan of Oman in the Governorate. The Governorate is divided into six geo-administrative *Walayat*. Local government activities in each district are carried out by the *Wali*, who answers to the Governor.

The Governor and the *Wali*, each in their own territory, deal with all matters regarding development in the Governorate or District, as they coordinate all government activities in the area and act as a linkage between the traditional Omani administrative system and modern government institutions. In this respect it should be mentioned that modernization in Oman has not considered traditional Omani society as an obsolete or archaic phenomenon that cannot be reconciled with modern development and that should be eliminated. Tribal structure, which is the core of traditional society, has not been perceived as a constraint to development but as an agent of development. Tribal chieftaincy was not only retained but improved in a way that made it a dynamic force that interacted positively with the modern government administration for the benefit of the country's progress. Tribal chiefs, who are the centre of the traditional administrative system, are responsible for several activities of a community-development nature as well as for certain local administration work concerning the community in which they live and all members of their tribe. Birth certificates, death certificates, etc., can be issued only after citizens submit documentation issued by the tribal chief

and attested by the governor or *wali*. The tribal chief settles disputes between individuals and groups who belong to his tribe. If the dispute concerns people who belong to different tribes, chiefs of these tribes may come together to achieve a settlement. Traditional law is often applied here to achieve reconciliation. In this way, the activities of the modern government administration fulfil very important roles. Their scope of action could be expanded to include some municipal activities concerning waste management, especially in remote villages and settlements, as will be discussed later.

Government activities at the local level are carried out also by the municipalities, which have to provide basic services such as pest control, foodstuff inspection, waste management, etc., to the populations of their respective territories.

Whereas in the other regions of the Sultanate the municipalities come under the Ministry for Regional Municipalities and Environment, Dhofar Municipality answers to the Governor of Dhofar. It was established in 1983 by a Royal Decree and is responsible for providing municipal services and utilities as well as for overall human settlements development in the whole Governorate. However, its activities have to comply with the requirements of urban planning and the regulatory functions of the Ministry of Housing as well as with the standards for the reuse of treated effluents, solid waste management, septic tanks, protection of the natural environment and wildlife, etc., established by the Ministry for Regional Municipalities and Environment. Close cooperation between these two ministries is indispensable, and although such cooperation does exist, it is not always problem-free. The Ministry for the Regional Municipalities and Environment (which is of great concern for our topic) often establishes standards which are either impracticable or very stringent *vis-à-vis* international experience, as, for example, in the case of standards for the reuse of effluent from sewage treatment plants.[53]

[53] B.H. Dieterich, *The Environmental Health Programme for Muscat Municipality* (Geneva: World Health Organization, 1992), p. 22.

The Municipality levies fees and taxes on certain areas and activities. However, income from these sources is very small and accounts for less than 5% of the Municipality's expenditure. Both the ordinary and the development budget are provided by the central government.

Waste management is an area which claims a large proportion of the annual budget of the Municipality, as it employs over half of the Municipal employees; the great majority of these are waste collectors and street-cleaning workers. Although no exact figure is available for expenditure on waste management, according to our judgement and confirmation by the administrative leadership, not less than 30-35% of the Municipality's budget is spent on waste management. In addition, waste management requires several types of capital-intensive items such as vehicles, tractors, compactors, cranes, etc.

Further, mechanization of the cleaning work as well as of waste transport and disposal, at which Dhofar Municipality is aiming, would certainly require a considerable increase in the budget in this area. Budget limitations, which may become more severe in the future, leave no doubt that there is no alternative to enhancing the efficiency of the waste management machinery. The following remarks on waste management in Muscat can be applied here too.

The administration must not only be concerned with the effectiveness of operations but also with costs, especially in the light of ever-increasing demand. Balancing costs against effectiveness is deemed timely, but the high standard of cleanliness (in Muscat) should be a yardstick for ruling out compromises which would jeopardize the achievements of the past. Thus, the question boils down to reviewing whether or not the available resources can be managed more efficiently in day-to-day operations, and this in turn, boils down to the management and supervisory skills of the technical staff at the Mudiriat. The Directors of Health Departments at the Mudiriat and the Heads of Section and their Supervisors are the *managers* in the day-to-day application of the resources of the (Muscat) Municipality, yet whatever their experience in technical matters, most of them have not had the opportunity of training in management.

Even an experienced manager is prone to make mistakes if he lacks clearly stated objectives, a plan for the future, and full knowledge and understanding of the budget and of the way it is prepared. Obviously, the objectives are well-known in the Mudiriat, but the staff have no plan for the future, no information or an appreciation of the budget or of what is involved in budgeting for the coming year. It should not come as a surprise, therefore, that the senior staff of the Mudiriat tend to work in isolation, and on the basis of "business as usual," rather than with the aim of managing their resources for maximum efficiency. This matter is a major challenge to the headquarters of Muscat Municipality, though the headquarters does not seem to be fully prepared to meet it.

It would not be fair to end these observations at this point. Efficiency in the Mudiriat is closely linked with an important external constraint: the expectations, behaviour and participation of the people served by the Mudiriat. It is sufficient to note at this juncture that the Mudiriat could be considerably more efficient if the people would play their role in keeping their city clean. This matter too is a major challenge to the headquarters.

The legal framework of waste management

The Sultanate has not yet framed a national law for waste management. Work on such a law is under way, however. In Dhofar, waste management issues are at present regulated by Local Orders, the substance of which has been considerably improved in the last decade. Administratively, waste management is considered a component of public health, which consists of waste management, food safety and pest control. At present, two Local Orders govern waste management in Dhofar, Local Order No. 8/87 of 27 October 1987 and another Local Order issued 29 December 1987.

The first Local Order, which is more comprehensive than the second, concerns not only waste management but also the other aspects of public health and is entitled "Public Health Prevention Order." Chapter 7 of

this Order, which deals with waste management, contains the following provisions:

Article 60: The owner or occupant of a building should clean all parts of it regularly, including the outer yard of the building. Any owner of a multi-storey building which is rented out should appoint a worker to clean the house, including the outer yard.

Article 61: Any owner or occupant of commercial or industrial premises, as well as any owner or occupant of a house, should dispose of his waste in the way that the Municipality decides upon.

Article 62: The Municipality determines the waste collection points for residential, commercial and industrial premises, as well as for public places and streets. It is prohibited to store waste in places and containers other than those earmarked for this purpose by the Municipality. It is also prohibited to throw waste and garbage on the streets and in public places.

Article 63: The Municipality decides where waste should be dumped. These places must be far from the residential areas.

Article 64: Anyone who dumps waste in a way or place that violates this Local Order must comply with the municipal directives in the notification he receives from the Municipality and accordingly remove the waste and dump it in the place earmarked for this purpose as is required, within the period fixed in the notice.

Article 65: It is prohibited to put harmful liquids or excrement in the places or containers that the Municipality provides for waste collection.

Article 66: It is prohibited to put any animal carcass in places other than those provided by the Municipality for this purpose.

Article 67: It is prohibited to urinate or defecate in any street or public place, near a water source, on the beach, or in the mountains near the city.

Article 68: It is prohibited to keep animal droppings (dung) in a way that would allow the multiplication of insects.

Article 69: The Municipality earmarks pens for the animals that await slaughtering in the slaughterhouse. It is prohibited to keep the aforesaid animals in pens other than those earmarked by the Municipality for this purpose.

Article 70: It is prohibited to keep animals in the house except in those places which the Municipality earmarks for them.

Article 71: (a) Without prejudice to the stringent punishment stipulated by the laws in force in the country, anyone who violates the provisions of this Order and its executive decisions will be punished by being fined not more than RO 100 for the first and second violations and by a fine of not more than RO 300 for the third violation or by imprisonment for a period not exceeding three months or by both punishments for any violation that may follow.

(b) Anyone who continues to violate this Order or its executive decisions after having received notification about the violation from the Municipality will be fined not more than RO 50 per day for each day the violation continues, with the total amount not to exceed RO 1,000.

(c) In addition to the two punishments described in (a) and (b), anyone who does not comply with the directives of the notification will pay any costs the Municipality bears in order to undertake the work that he fails to do.

The second Order differs from the first as it deals exclusively with waste management:

Article 3: (a) It is prohibited to dump waste or garbage from residential premises or farms in public places.

(b) It is prohibited for workshops, factories, commercial establishments and restaurants to dump or keep waste or waste-water in public places.

(c) The prohibitions foreseen in (a) and (b) do not prevent the aforementioned materials from being put in containers provided by the Municipality or by the producer of the waste or waste-water for this purpose.

Article 4: Farm owners should carry their waste to the dumping places provided by the Municipality or get rid of it (destroy it) locally in any way that does not cause any health or environmental problems. It is prohibited to keep or throw old items such as old furniture, old vehicles, etc., as well as construction waste (rubble and debris, etc.) in public places.

Article 5: Anyone who keeps waste of any kind, old cars or construction waste, including rubble and debris, in public places must comply with the directives of any notification he receives from the Municipality and remove the waste within the period required in the notification.

Article 6: The driver of a car is considered to have violated the Local Order if waste or malodorous items fall from his car onto the streets or in public places, except if this occurs unexpectedly and the driver removes the waste or materials immediately.

Article 7: The driver of a vehicle that carries stones, sand, earth or cement should cover the load in a way that prevents the load or parts of it from falling.

Article 8: It is prohibited to distribute or post advertisements in a public place without obtaining the approval of the Municipality.

Article 9: It is prohibited to keep animals or to establish a pen for keeping animals in a public place in the city or near a public street.

Article 10: It is prohibited to leave animals unattended in streets or public places without tying them up.

Article 11: It is prohibited to drive a vehicle or motorcycle or ride an animal or animal cart in public places where this is not allowed.

Article 12: It is prohibited to block any street, road or lane that is used by pedestrians by storing or leaving materials, goods or animals in it, and it is likewise prohibited in such places to display goods and commodities meant for sale. This prohibition also includes leaving boxes and commodities outside of any shop.

Article 13: (a) Anyone violating this law will be fined RO 50 for the first and second violations; a third or subsequent violation will be punished by a fine of not more than RO 100 or imprisonment of not more than two months or both punishments.

(b) In addition to the above-mentioned punishments, anyone who does not comply with the directives of a notification received from the Municipality will pay the cost the Municipality bears to do the work that he fails to do.

The second Local Order was enacted only 63 days after the enactment of the first one, and was aimed at amending the first one and clarifying certain ambiguous points.

The second Order did not abolish the first one, which contains provisions that are not found in the second. Today both Orders are applied, and although they do not contradict each other, it would have been better had they been integrated into one Local Order.

Conceptually both Local Orders view waste management as if it pertains only to public health and public cleaning and order. This is the case both

in Muscat and in the regional municipalities. This concept is not wrong, but it is far from being comprehensive. The shortcomings from which it suffers include the following:

1. Neither Local Order says who is responsible for street-cleaning and collection and transport of waste. Although it is known that household waste management is the responsibility of the Municipality, it cannot be taken for granted and left unmentioned in the Local Order. The Orders should have started by stating the overall responsibility of the Municipality for waste management and specifying the waste management activities for which the Municipality is directly responsible. They should also have mentioned that commercial and industrial establishments of a certain size have to bring their waste directly to the landfills. This regulation, which is not included in the Local Order, is assumed and it is expected that the concerned establishments will follow it. But if it is not included in the Local Order, there cannot be any provisions that punish those who violate it. It is important to specify which types (and sizes) of industrial and commercial establishments should bring their waste directly to the landfills.

2. The Local Orders do not specify how waste should be disposed of or what conditions would have to be met by any site that is presently used as a landfill or that will be used as a landfill in the future.

3. Recycling, composting and waste avoidance are not taken into consideration at all in the Local Orders.

The present organizational set-up for waste management

Waste management in Dhofar has no uniform organizational structure. While Salalah has a full-fledged Directorate for Waste Management as shown in **figure VIII**, waste management in the other districts of the Governorate is dealt with by the Directorate for the Branches of the Municipality in the Rural Districts. Within the municipal administration,

this Directorate takes care of all municipal matters regarding the rural districts. This clarification is important because:

- Most of the available reports about waste management in Salalah are presented as if they deal with the whole governorate.

- The managerial reform needs of the other districts are different from the needs of Salalah. This results not only from differences in the organizational structure of present waste management but also from differences in economic structure and development between Salalah and the other districts.

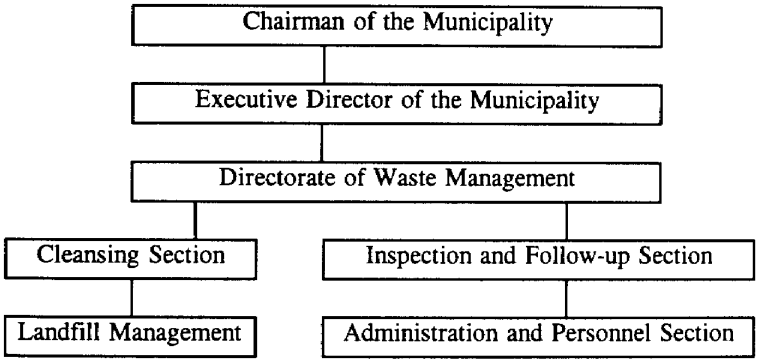


Figure VIII. The administration of waste management in Salalah.

While Salalah is to a great extent an "agro city" which possesses almost all urban ingredients, the other districts are rural areas with small semi-urban centres that are considered capitals of the districts and provide some urban services to the inhabitants of the district.

In Salalah the responsibilities of the Directorate for Waste Management include:[54]

1. Implementation of all Local Orders and administrative directives regarding waste management.

2. Design of necessary plans for waste management including cleaning work, waste collection and transport, and waste disposal.

3. Supervision of the cleaning and waste collection work with the aim of ensuring that the plans are implemented properly.

4. Supervision of the waste collection fleet, including follow-up of maintenance and repair as well as the fleet's distribution according to the plan.

5. Supervision of the equipment, machines, etc., used in waste management, and seeing to their proper use and distribution.

6. Transport of solid waste to the landfills.

7. Arranging for proper disposal of the waste.

8. Organization of cleaning campaigns in cooperation with the public and government institutions whenever such a need arises.

9. Educating the public so that they comply with cleaning and waste management regulations and orders.

10. Monitoring violations regarding cleaning and waste collection and seeing to the punishment of those who commit violations, in accordance with the provisions of the Local Order.

[54] Annual Report of the Directorate for Waste Management in Salalah, 1992 (in Arabic).

11. Promoting the further development of the waste management system by introducing modern waste management technology and methods in accordance with the available resources, and modernizing the local waste management technology used at present to make it more efficient.

12. Preparation of the budget.

In line with the overall responsibilities of the Directorate for Waste Management, job descriptions for each section of the Directorate are formulated.

Job descriptions for the Cleansing Section include:

1. Preparing the work plan for the Section and implementing the plan after it is approved by the Director for Waste Management.

2. Supervising the implementation of the cleaning work in accordance with the duties of the Section and the work plan as approved by the Director.

3. Implementing the Local Orders regarding public cleanliness.

4. Designing a programme for the transport of waste to the landfill and supervising the implementation of the plan.

5. Supervising the waste vehicles and seeing to their proper use, maintenance and repair.

6. Organizing clean-up campaigns whenever the need arises, in cooperation with public and government institutions.

7. Developing the cleaning system and arranging for the introduction of modern technology and management systems in accordance with the available financial and other resources.

8. Preparing reports about the development of the work and submitting them to the Director.

9. Preparing the annual budget for the Cleansing Section.

The job description of the Head of the Inspection and Follow-up Section includes:

1. Preparing the work plan for the Section and implementing the plan after it is approved by the Director for Waste Management.

2. Supervising the cleaning work and inspecting the Municipal waste collection points and containers, to ensure that waste is collected and transported on time.

3. Supervising the movements of the waste collection vehicles to ensure that the movements are in line with the time schedule for waste transport.

4. Receiving and analysing complaints and comments from the public.

5. Punishing those who violate the Local Order on waste management in accordance with the provisions concerning the type of violation committed.

6. Coordinating the work of the Inspection and Follow-up Section with that of the other sections.

7. Enhancing inspection and follow-up activities by introducing modern management techniques related to inspection and follow-up.

8. Preparing the work of the Section for the Director for Waste Management.

9. Preparing the annual budget of the Section.

The job description of the Head of the Landfill Management Section includes:

1. Supervising the implementation of the landfill work in accordance with the duties of the Section and the work plan as approved by the Director.

2. Ensuring that waste is disposed of in accordance with environmental requirements.

3. Guaranteeing systematic and optimal landfill use. (Systematic landfill use includes dividing the landfill area into units and moving from one unit to the other only after the first has been fully used. Optimal landfill use includes spreading the waste on the landfill properly and evenly and compacting it to reduce its bulk and integrate it into the earth.)

4. Classifying waste into types and identifying the toxic and special waste that is not to be disposed of in the landfill.

5. Making suggestions regarding the improvement of the landfill such as modern landfill management and modern landfill engineering.

6. Preparing reports and submitting them to the Director.

7. Preparing the annual budget of the Section.

The Administration and Personnel Section does not deal with matters directly regarding waste management. Rather, its role is supportive, and the job description of the Head of Section includes:[55]

1. Preparing the general work plan of the Section and implementing it as approved by the Director of Waste Management.

55 Annual Report of the Directorate for Waste Management in Salalah, 1991 (in Arabic).

2. Taking care of the personnel management of the entire Directorate, such as employment, annual leave, sick leave, absence, termination, manpower development and training.

3. Preparing general reports about the Directorate after collecting information, data, etc., from the sections.

4. Preparing letters and memos regarding the activities of the Directorate. In this respect the Head of the Administration and Personnel Section functions as secretary of the Director.

5. Registering and filing the correspondence and documents of the Directorate.

6. Procuring stationery and other needs of the Directorate.

7. Preparing the annual budget of the Section as well as of the whole Directorate.

The above-given duties and responsibilities of the Directorate for Waste Management and the job descriptions of its sections show that, conceptually, the needs of waste management have been well perceived. However, with respect to translating the concepts into practice, several shortcomings that hinder efficiency are observed. These shortcomings include a shortage of employees with training and experience that match the duties outlined in the job descriptions: some people are given work which does not belong to their description because it is assumed that they will do better than others. Thus it becomes difficult to know who is doing what and to follow the channels through which the different activities are proceeding.

WASTE MANAGEMENT IN PRACTICE

Waste management consist of several steps that employ different types of vehicles and machines, and it also requires a large number of cleaning and waste collection workers. To do the work properly and efficiently,

these steps have to follow each other systematically and should be carried out with the same degree of efficiency. In the following section, we will deal with the various steps of waste management, giving consideration to the sequence they should follow, as well as to the waste management differences between Salalah and other parts of Dhofar.

Salalah

Cleansing

Cleaning is understood in Salalah and in the other parts of Dhofar as sweeping the streets and public places as well as collecting waste put in the containers found at the municipal waste collection points.

The cleaning manpower consists of 200 sweepers, 36 drivers, 2 field supervisors, 1 foreman and the Head of the Cleansing Section. Most of the sweepers are engaged in cleaning streets and public places.[56] Since the overall area to be cleaned is unknown, it is impossible to take the area each sweeper cleans as a basis to determine the productivity of one individual. However, we can measure this productivity by taking the population of the city or the daily waste production in the city as a basis.

The population of Salalah is about 80,000. Accordingly, each of the 200 sweepers serves 400 persons.

The daily waste production in Salalah is about 120,000 kilograms, and accordingly each sweeper collects about 600 kg of waste daily.

However, the above-given productivity of each worker ignores the distance the worker has to cover to collect the waste. The time that the sweeper spends covering the distance is unproductive, and the longer it is the shorter the time that remains for collection (productive work). Here effective time management that takes into consideration how to

[56] Information provided by the Directorate for Waste Management.

reduce the walking distance would be of great use. However, it can only be introduced to a certain extent. For example, the organization of the collection points could be improved in a way that reduces the time necessary to collect the waste. In this respect, all collection points that can be dispensed with should be omitted. In Salalah we observe such points in many parts of the city. In several places, collection points are very close to each other—only 10 to 20 metres.[57] In our judgement, there is no reason that justifies such a dense network of collection points. On average, only one fifth of the capacity of each container is utilized to store the daily waste. This means that three fourths of the collection points could be dispensed with, and yet the distance each household would have to cover to bring waste to the collection point would still be reasonable (50 to 100 metres). However, we were informed that residents were not satisfied even with this dense network and wanted to have more waste collection points. This shows that the introduction of an efficient collection system that would reduce the time required by the Municipality to do its work cannot be achieved without the cooperation of the people. It also shows that careful study, analysis and planning are necessary to design an efficient and effective network.

With respect to street-cleaning, the time management required is somehow different. Here the area to be covered cannot be reduced. Thus, the emphasis can be only to increase the speed with which the work is done and/or reduce the cleaning frequency. Until now, Salalah has concentrated on increasing the speed of work. It introduced technology that serves this purpose, the most important of which is the motorized tricycle. These relatively fast three-wheeled motorcycles are fitted with a high-level tipping body of about 2 cubic metres. They are used in cleaning the long streets outside the city centre that up to mid-1988 were cleaned by sweepers using wheelbarrows. The new technology raised the speed of the cleaning work considerably. With the wheelbarrow, the sweeper was able to clean only 2 to 3 kilometres of the street in seven hours. The introduction of the three-wheeled vehicle raised his production to 12 to 15 kilometres in the same number of hours.

57 This observation was made during two field trips in June 1991 and July 1992.

This means that the use of these vehicles in principle saved 75% to 80% of the manpower utilized to clean the streets outside the city centre. At present the city employs 12 such vehicles, which can help to clean daily (seven hours) a total street length of 180 kilometres. With a wheelbarrow this would require 90 sweepers, since the maximum a sweeper can clean daily is 3 kilometres. With a tricycle, the required manpower is only 12 sweepers. Thus, the manpower saving would amount to 48-78 sweepers. The three-wheeled vehicles are imported from India and cost RO 800 apiece. The average monthly salary of each sweeper is RO 100. In addition to this, he receives lodging, free medical care and a round-trip ticket to his country every two years. This raises the total amount the Municipality spends on him for salary and benefits to about RO 140 per month, or about RO 1,680 per year. This shows that the use of motorized tricycles in street-cleaning would result in a considerable financial saving. However, we could not determine the real saving in manpower the Municipality made by using tricycles against the costs of running, repairing and maintaining the tricycles. Discussions with the Director of Waste Management and the Head of the Cleansing Section showed us that the management of the small tricycle fleet suffers from several problems, including lack of spare parts, maintenance and repair problems, and lack of skilled drivers. These problems, especially lack of spare parts, resulted in the the fact that in June 1992 only 6 of the 12 vehicles were in operation. The others were in workshops awaiting spare parts that had to be imported from India. These problems could easily be solved by keeping enough of these items in the store at all times and by agreeing with the supplying repair establishment to provide spare parts quickly whenever it receives an order from the Municipality.[58]

In general, the use of motorized tricycles could be increased, to include not only other streets outside the city centre but also streets in the old city, as is the practice in several cities in Asia and West Africa. Here the length of the road-sweeping work done by one worker is only 1 kilometre

58 Personal communication from the Director for Waste Management during a discussion on 18 June 1991.

if wheelbarrows are used, but this could be raised to 10 kilometres if motorized tricycles were employed. In this respect, Frank Flintoff writes:

> [The motorized tricycle] is in common use in several cities in Asia and West Africa, particularly in old city centres where the streets are too narrow to admit larger vehicles. Its relatively high speed gives it an operating radius of about 10 kilometres, but it does not operate well on the rough roads of a sanitary landfill. Thus, unless a refuse disposal plant is available it should discharge at a transfer facility.[59]

The use of motorized tricycles and small trucks for waste collection is not limited to developing countries or countries that are on the threshold of industrialization. Japan, which is a highly developed country, of course, makes extensive use of small trucks in waste collection. In this respect a report on waste management in Tokyo says, "A total of 3,462 waste collection vehicles collect waste. Given the existence of many narrow streets in Tokyo, 90% of them are small waste collection trucks with a capacity of 4 cubic metres or less."[60]

In Salalah, where the road leading to the landfill is not rough but asphalted, direct transport of waste to the landfill or use of transfer facilities are possible. Both possibilities should be studied and compared to see which of them is more advantageous.

At present these motorized tricycles which clean streets that are near the landfill bring the waste directly to the landfill, while those charged with cleaning streets at some distance from the landfill use transfer facilities. This seems to be a sound practice from an economical viewpoint.

59 Frank Flintoff, *Management of Solid Waste in Developing Countries* (New Delhi, India: World Health Organization, Regional Office for South-East Asia, 1984), p. 39.

60 Bureau of Public Cleansing, Tokyo Metropolitan Government, *Public Cleansing Services in Tokyo*, 1991, p. 6.

However, it should be kept in mind that a wider introduction of motorized vehicles would require a considerable increase in the number of transfer facilities if efficiency and cost minimization are taken into consideration. In this regard we mention that most of the waste in Salalah is generated in the city centre and the old city, which are relatively far from the landfill. Here reloading dictates that only a few large vehicles transport waste to the landfill instead of a fleet of motorized tricycles; this enhances transport efficiency and has economic advantages. An increase in the number of transfer facilities requires the design and introduction of a suitable network of collection points as well as efficient management of the vehicles' movements within this network and from it to the landfill. In this respect the activities of the tricycles must be synchronized with those of the large trucks. To manage this, it is necessary to study the topography and the physical construction of the city with the objective of establishing facilities at the most suitable locations. In general, the organization for street sweeping should provide "a transfer facility within reasonable distance of each beat. The ideal arrangement is for this to be located in the district depot where it is under continuous supervision. It can take many different forms, but it must not be a dump on the ground which would be unhygienic and costly in manpower for reloading."[61]

An alternative to the motorized tricycle used at present is an exchange-bin system:

> The depot would hold a supply of bins similar to those on the [motorized tricycle], so that a sweeper could exchange his full bins for empty ones at each visit to the depot. At suitable intervals throughout the day the depot would be visited by a vehicle into which the full bins would be emptied. The advantage of the exchange-bin system consists in the fact that the possibility of dumping waste on the ground does not arise at all.[62]

61 Flintoff, op. cit., p. 90.

62 Flintoff, op. cit., p. 86.

Salalah's use of motorized tricycles in street-cleaning is a unique experience in the Sultanate and has attracted the attention of Muscat Municipality, which sent an expert to Salalah to study the system. The report submitted by the expert was encouraging, and Muscat Municipality decided to acquire three tricycles to be introduced in street-cleaning as an experimental phase. If Muscat decides to introduce motorized tricycles on a large-scale basis, this would have a positive impact upon Salalah's use of tricycles. Muscat would require a relatively large fleet of tricycles (100 or more). Muscat, Salalah and other cities in the Sultanate which may decide to adopt the system could negotiate as a group with a producer of such vehicles to obtain terms favourable to them, including reduced prices, timely provision of spare parts, and custom changes in the design of the tricycle body in line with the requirements of the buyer.

Sources of street waste

Waste that accumulates on the street includes:

(a) **Natural waste**, which consist of dust and sand that the wind blows from unpaved terrain in the city and its suburbs, and leaves, blossoms, etc., from trees and plants in the city. The generation of these wastes cannot be prevented but can to some extent be controlled by selecting for city greening plants and trees that produce less natural waste and by afforesting or otherwise planting up unpaved terrain. This would reduce wind-blown dust and sand on the streets.

(b) **Road traffic waste**: "Motor vehicles deposit oil, rubber and mud. In addition, there is sometimes accidental spillage of vehicle loads. Animal-drawn vehicles deposit excreta on the road surface. At large construction sites mud is often carried out by motor vehicles and deposited on adjacent roads; in wet weather this can cause danger to traffic via skidding. Traffic wastes are largely unavoidable but some legislative control is possible in the cases of load spillage and construction sites."[63]

63 Flintoff, op. cit., p. 89.

(c) **Behavioural waste**: These wastes are generated mainly by pedestrians who litter, as well as by households and shops which sweep or throw waste out of private premises instead of putting it in the containers provided by the Municipality. Animal excrement left on the streets can also be considered behavioural waste. Behavioural waste can be avoided to a great extent by: an efficient waste collection system that provides litter bins for the use of pedestrians; and a continuous public education programme that is supported with legislation, and with speedy enforcement procedures against those who violate the waste management law, especially those provisions which concern cleaning and waste collection.

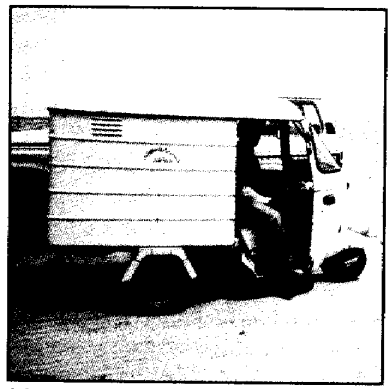
In Salalah natural waste, road traffic waste and behavioural waste are concentrated mainly in the city centre and residential areas. The city greening activities as well as the many planted areas found in the city generate natural wastes in the form of leaves, branches, blossoms, seeds, etc., and the above-mentioned types of road traffic waste is significant. However, the great part of the waste found on the streets here is of a behavioural nature. The present Local Order on Cleaning and Waste Management gives the Municipality suitable legal steps to handle the problems arising from road traffic waste and behavioural waste. However, comprehensive enforcement of such steps is almost impossible because it would require a large team of inspectors in all streets and public places from early morning till late evening. In addition, enforcing the law is not always easy and can involve the police and the office of the Governor of Dhofar. Cases may even go to court. Thus, the emphasis here should be on public education backed by prompt enforcement of the law, including prompt collection of fines by the inspector.

With respect to natural waste, it can be assumed that in the city centre and residential areas, tree planting and city greening will minimize dust and sand blown by the wind but that decaying vegetation such as fallen leaves, blossoms and seeds will increase. However, here too, careful selection of the types of trees planted in the city may help minimize natural wastes of plant origin. In the streets outside the city centre, the amount of natural waste is relatively small and consists mostly of sand

and dust blown by the wind. The fact that the streets here are in most cases bounded by vast unpaved areas increases the dust and sand blown onto the streets by the wind.

The behavioural waste found outside the city centre is small in quantity and consists mainly of empty cans and bottles thrown by car drivers. It is scattered over a large area and found mostly in the unpaved areas close to the roads. Sometimes wastes accumulate in narrow gullies between the asphalted street and the unpaved areas adjacent to the street. These gullies are caused by the wind that blows loose sand in the areas adjacent to the street, as well as by rainfall that sometimes washes the sand away. However, the sweepers too play a role in deepening and widening these gullies, since whenever they collect waste from them they also remove quantities of sand. Thus the gullies become big catchments in which light waste blown around by the wind accumulates.

In general, waste collected from streets outside the city centre is small in quantity, so that a motorized tricycle with a body of about two cubic metres' capacity can collect not more than 500 to 750 kilograms of waste from a street 15 kilometres long. This fact raises the question of whether it is necessary to collect this small amount of waste daily from these streets, or if it is instead possible to sweep these streets only two or three times a week. If we consider that the wastes found here consist of non-organic items (bottles, cans, paper, etc.) which do not decay and rot, reduction of the frequency of sweeping to two or three times a week is possible without allowing wastes to accumulate to the extent that they cause a public nuisance and mar the visual appearance of the streets and their surroundings.



Motorized tricycle used as waste vehicle in Salalah

The above-described situation is also found in Muscat and the other main cities of the Sultanate, where natural waste, road traffic waste and behavioural waste are relatively concentrated in the city centre and residential areas and where the streets outside the city centre have relatively small quantities of waste (mainly non-organic waste) that are scattered over a broad expanse, making street-cleaning time-consuming relative to the quantity of waste to be collected and the areas to be cleaned.

A point that should be born in mind is the fact that "the cost of removing wastes which have been scattered in the streets is very much higher than the cost of collecting similar wastes which have been placed in containers such as domestic wastes, bins or litter containers."[64]

Thus, street-cleaning policies should have the following objectives:

- The provision of services to collect wastes from the source, i.e., efficient refuse collection.
- Reduction of street litter through public education.
- The use of systems which achieve high labour productivity.
- The design and use of effective tools and equipment.

The objectives of street-cleaning policies in Salalah are not far removed from the ones listed here. However, no concrete strategy exists to implement them. Learning by doing seems more or less to determine the present street-cleaning practice. The necessity was recognized to collect waste at the source to the greatest extent possible, and steps were taken to achieve this; the concentration is on increasing the number of collection points rather than optimizing the capacity of the containers. Also, public education is under way, with the aim of educating people to put waste in containers and litter bins instead of throwing it on the street.

64 Flintoff, op. cit., p. 85.

With respect to productivity enhancement, motorized tricycles were introduced as described above. In addition, some tools were adopted for street-cleaning. Where manual street-cleaning is practised, shovels and brooms are used. The brooms are of two main types: those formed from a bunch of long fibres and those made with a wooden stock into which are inserted numerous date-palm or coconut-palm fronds. Where mechanical sweeping is applied, mechanical sweepers are used. These are suction machines assisted by one or more revolving "scarifying" brushes for dislodging adhering matter.

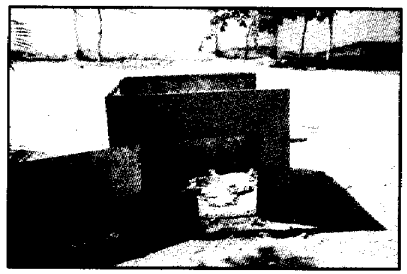
In general street-cleaning is a relatively successful endeavour. However, the work lacks a conceptual framework which harmonizes the individual activities and provides the basis of a well-thought-out street-cleaning plan implemented on the basis of cost-effectiveness. This shortcoming is, as we will see, found also in all other aspects of waste management.

Collection and transport of waste

It has already been mentioned that it is cheaper to collect refuse directly from houses or specific collection points where it is kept in containers than to sweep it up from the streets. However, collection and transport can be expensive if they are not well organized and if appropriate vehicles, containers, litter bins, etc., are not used.

Collection points

In Salalah, waste is collected from communal storage sites distributed all over the city. At present there are 3,000 such sites. About 500 containers are the modern type. Some of them are set-off containers and the others are special standardized containers suitable for the special lifting devices of high-



Old metal water container converted for use as a waste container, Salalah

tech compaction vehicles. The rest consist of barrels and locally-made containers. The Municipality has a small workshop which produces 7 to 10 containers daily, each one having a capacity of about 2 cubic metres. The containers have a frontal door that can be opened to collect the waste, as well as a lid, four legs about 30 centimetres long, and four handles that enable them to be moved easily from one place to another.

The barrels are to be provided with four short legs (about 30 centimetres), a lid and a door which can be opened to collect the waste.

While the Municipality receives the barrels gratis from the oil company, the other containers cost about R0 25 apiece to produce. The average lifetime of about three years could be prolonged by improving the maintenance of the containers.[65]

A comparison of the locally produced containers with the modern imported containers reveals the following picture:

- The cost of each imported modern container is R0 750-800 with an average lifetime of five years. The cost of producing a locally made container is only R0 25. This means that the cost of an imported container is equivalent to the total cost of 30 to 32 locally made containers, which together have an average lifetime of 90 to 96 years.

- The imported containers are more convenient than the locally made ones. However, the locally produced containers have undergone improvements in recent years.

- The locally made containers are provided with four short legs. The modern containers, on the other hand, have wheels that allow them to be pushed. Furthermore, they can be emptied automatically into the vehicles, in contrast to the local ones. Equipping the local containers with suitable wheels is possible, and automatic emptying into the vehicle may be possible.

[65] Personal communication from the Director of Waste Management, 18 June 1991.

- The four-wheeled modern containers are more advantageous in the paved areas of the city where they can be pushed easily, but in unpaved areas they do not enjoy such an advantage.

- Where high-tech compaction vehicles with special lifting devices are used, modern containers have a great advantage.

In addition to the above-mentioned types of containers, four-sided masonry enclosures are used as communal waste collection stores. The height of the walls is 1 to 1.5 metres. The floor is paved for easy cleaning. This type of waste collection point is found mainly in remote areas where the production of waste is not high.

Most of the masonry enclosures are old; we were informed that no new ones have been constructed since 1989. It seems that the Municipality intends to phase out this type of collection point. In this respect we were told by the Head of the Public Cleansing Section that the enclosures limit the flexibility of rearranging the collection points, because they are fixed and cannot be moved from one place to another like the mobile containers.

In general, the present composition of the containers is suitable, as their distribution is relatively appropriate. Locally made containers are placed where the ground is unpaved and rough and where wheeled containers are of no use. Modern wheeled containers are used mainly in the city centre and residential areas with paved streets.

The containers are generally not used to their full capacity. Such a container has a capacity of about 2 cubic metres and serves only about 27 inhabitants who produce at most 50 kilograms of waste. The fact that despite this, many containers quickly become full can be attributed only to bulky and hollow waste items such as cartons, crates, etc., being put into them. If torn or pressed, these items would not occupy more than one fifth of the space they now take up. This misuse of containers considerably increases the cost of waste collection and transport by lengthening the time taken for these operations since the vehicle must stop

When bulky, hollow items are put into containers without being pressed or torn, the containers quickly become full and waste is then dumped on the ground around them.

frequently. And besides lengthening the time required for collecting waste, the frequent vehicle stops also cause traffic problems.

Waste transport

The efficiency of waste transport depends upon several factors, including:

- Type of refuse collection vehicles
- Physical structure of the city
- Width of the roads as well as the general condition of the roads
- Traffic density
- Population and building density
- Organization of vehicle route
- Organization of the network of collection points

The physical structure of the city, the width of the roads, traffic density, and population and building density are to a great extent invariable factors, the situation and development of which cannot be influenced or changed by waste management practices. On the contrary, they influence the management of waste collection and transport, which has to be adjusted to them. However, here too, waste collection and transport do not always need to react to what we have termed invariable factors. Urban renewal, which can include destruction of certain buildings with the aim of creating space for communal utilities and infrastructure, can also meet the needs of waste collection and transport by providing suitable sites for waste storage and collection and by widening some streets to give waste collection vehicles easy access to the collection sites.

In addition to the above-mentioned points, the planning of new settlements can take into consideration the needs of waste collection and transport from the beginning.

Unfortunately, urban planning and urban renewal as now practised pay little attention to the needs of waste collection and transport. Thus, the main concern remains how to render the variable factors (selection of waste collection vehicles, organization of the vehicle routes) more efficient and suitable. Vehicles should be chosen on the basis of the functions they are expected to perform and the road conditions they will encounter. With respect to organizing vehicle routes, this can be simple in the case of small settlements with very few collection points, but the problem of route selection becomes more complex as the number of points to be served and the number of processing and disposal sites to be fed increase. Three approaches are generally available for use depending on the complexity of the problem:

(1) Heuristic: In this method, the old system of assigning routes based on experience and intuition is systematized by the formulation of some simple rules. However, the reliability of the results depends upon the experience of the user, and the solution obtained will only be "reasonable" but may not be optimum.

(2) Deterministic: In this method a model is developed, and by using a digital computer an optimum solution can be obtained. Models for use in developed countries having "house-to-house" collection systems are available. However, in the majority of developing countries the "community bin system" is commonly used and hence these models cannot be directly applied. Modification of such models is needed to suit the community bin system.

(3) Heuristic-deterministic: In this method, a number of possible alternatives are first identified and then, for the existing constraints, the most possible solution is identified.[66]

In comparing the above conceptual consideration of waste collection and transport with the practice in Salalah the following points are observed:

- The city uses a fleet of vehicles consisting of:
  - 18 automatic compaction vehicles with special lifting devices (5-ton capacity) and 4 automatic compaction vehicles into which lifting is done manually (4-ton capacity).
  - Four tipper vehicles (3-ton capacity).
  - Two Nissan vehicles (3-ton capacity).
  - Two large street sweepers. These are mechanical sweepers equipped with suction machines and revolving (scarifying) brushes.
  - Four small street sweepers. These are mechanical sweepers equipped with suction machines and revolving (scarifying) brushes.
  - 12 motorized tricycles (2 m^3 capacity).
  - 2 vehicles (2-ton capacity) for collecting stones from the streets.
  - 2 vehicles for transporting carcasses (3-ton capacity).
- The total capacity of all vehicles is 163 tons. Since the daily production of waste per inhabitant is about 1.5 kilograms and the population of the city is 80,000, the city produces daily about 120,000 kilograms of waste. This means that over one third of the total capacity

66 Flintoff, op. cit., pp. 80-81.

of the vehicles is not used. In spite of this fact, the Directorate for Waste Management complains of a shortage of waste vehicles. This occurs due to the following reasons:

- The vehicles are often broken down and seem to be misused.
- The vehicles do not receive proper maintenance.
- Spare parts are not always available.
- The workshop in which the vehicles are repaired is not well-equipped or well-manned. It belongs to the Governorate and is responsible for repairs and maintenance of all government vehicles. In general each vehicle remains there 10-15 days for repair.[67]

Solving the above-mentioned problems would increase the availability of the vehicles. If, in addition, effective waste collection and transport were achieved, it would be possible to keep some vehicles aside as a reserve that could be used in case defects were found in an operating vehicle.

Whether the present composition of the waste vehicle fleet is suitable or needs to be changed is a question that should be studied. The Directorate of Waste Management advocates a change in the fleet composition with the eventual aim of having only modern waste vehicles, with an emphasis on automatic compaction vehicles. In this connection, it is also advocated to reduce the number of locally made containers in favour of modern containers that suit modern vehicles with lifting devices. However, this opinion is not based upon any analysis that takes into consideration what types of vehicles and containers best suit the physical structure of the city and can achieve efficient waste collection and transport; rather, it is based upon a general belief that modern is always better and can work wonders. Development most certainly cannot dispense with modernization, but modernization should be subjected to scrutiny, relevance and comparative advantage for the situation at hand. In Salalah, modern automatic

[67] Personal communication from the Director of Waste Management, 18 June 1991.

compaction vehicles are suitable only for the city centre where the streets are relatively wide and a relatively large quantity of waste is generated, the volume of which could be considerably reduced by compaction. Further, this type of vehicle could be used in a transfer station where waste is reloaded from small vehicles to the large compaction vehicles that transport it to the landfill.

As mentioned, motorized tricycles, which are already being used successfully in the streets outside the city centre, may also be suitable for the old city and wherever the streets are narrow. Their successful introduction on a large scale would require the adoption of a waste collection and transport system based to a large extent on a network of suitable transfer stations. The organizational and managerial steps to be undertaken include the choice of site for the transfer stations, and reorganization of vehicle routes in line with the requirements of the transfer stations. The reorganization should take into consideration that collection and transport of waste to the transfer stations must be coordinated with the transport of waste by the large vehicles from the transfer stations to the landfill.

Introducing motorized tricycles on a large scale would mean, of course, that the Municipality would have a relatively large fleet of this type of vehicle. The management and operation of this fleet would require development and reorganization of the present set-up for waste management.

Another point which supports the introduction of motorized tricycles is the fact that modern waste vehicles are capital-intensive. An automatic compaction vehicle with a lifting device costs RO 200,000 to 250,000, and its average lifetime in the hot and humid climate of Salalah cannot be more than eight years. Accordingly, the yearly depreciation would be RO 25,000 to 30,000. In addition, the price of spare parts is high. This means that introducing modern waste vehicles and the accompanying modern containers on a large scale would considerably increase overall waste management costs.

Waste disposal

The composition of household waste in Salalah resembles that of Muscat. Hazardous waste is generated only in small quantities and consists of hospital waste, old batteries, empty insecticide containers, etc. At present these types of wastes are disposed of with household waste, a practice which should soon be stopped. A special problem arises, however, from carcasses, which in actual fact are special waste and which should be disposed of separately. At present this waste goes to the household landfill, but this is not an acceptable procedure. Disposal of carcasses seems to be a problem in all districts of Dhofar, and it requires a special solution which we will deal with separately.

In general, disposal of household waste in Salalah has improved considerably since the beginning of 1988. Prior to this date, waste was dumped in an unsanitary landfill, where it was burned at the end of each day. Such disposal can be described as crude dumping plus open-air burning of waste. The burning was never complete; it covered only part of the waste, hardly reaching the lower parts. The pollution it caused consisted of the smoke it emitted, which contained dust and gaseous compounds containing fluorine, carbon monoxide, sulphur dioxide and nitrogen oxides. These harmful emissions not only polluted the air but also exacerbated pollution at the landfill site, because part of the smoke remained in the landfill, where moisture enabled the harmful compounds in the smoke to dissolve and combine with the ashes. In this way the landfill became a dumping area containing special and poisonous waste.

In addition, the above-mentioned unsanitary landfill became a breeding-ground for rodents and harmful insects. Thus, the landfill posed ever-increasing environmental and health problems because of the continuous growth of the waste being deposited. To solve this problem the Municipality closed the landfill and reclaimed the site so that the landscape of its surface cannot now be distinguished from that of the surrounding area. However, the internal pollution (old burden) left by the crude dumping and open-air burning of waste in the site is unknown. It is not known to what extent and in what way the soil of the site is

polluted and how far this has affected the groundwater. Here, it is necessary to subject the site to serious techno-scientific research with the objective of identifying the damage caused by the old burden and looking for suitable, effective remedies.

A new landfill was established to the north of Raysut where the old one had also been established. It is about 20 kilometres from the city, and no residential or commercial buildings are close to it. It is about 3 kilometres from the main road, with a smooth but unpaved road leading to it. The surface of this road is solid and stable so that the waste vehicles can move on it without any problem.

The landfill covers 120 hectares. The ground consists of two different layers, an upper layer of stones and sand that could easily be moved to create large holes 1.5 metres deep where the waste could be tipped, and a lower layer of solid and rocky impermeable ground. The landfill area contains shallow valleys that are considered natural waste-dumping areas. The dumping method practised here is relatively sanitary. Each layer of waste of about 2 metres' height is covered with a layer of sand about 20 centimetres high and the whole is compacted with a special compactor.[68]

The estimated lifetime of the landfill is 15 to 20 years.[69] Since urban sprawl in Salalah shows a clear expansion towards Raysut, it cannot be ruled out that the landfill will become engulfed by the city before its lifetime comes to an end. This is a development that can be observed in Muscat and the other large cities of the Sultanate too, and it poses a serious problem concerning the choice of landfill sites. The widespread argument in almost all Arab countries that land is available in abundance and accordingly there is no problem in finding suitable sites for landfill is far from true. The availability of sites that can be used as landfills is

68 Observation made during field research in June 1991 and July 1992.

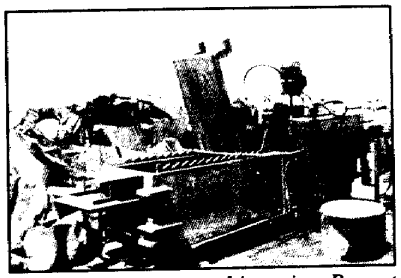
69 Personal communication from the Director of Waste Management, 20 July 1992. However, this information is not based upon a study made by the Directorate but is simply a guess.

not determined by the general availability of land but by the possibility of finding an area that is relatively close to the city and which can be used as landfill. This relative closeness is important; otherwise the cost of waste transport will be very high. Experiences in many Arab cities have shown that landfills that started out outside the cities yet relatively close to them ended up after a few years within the city's boundary because of urban sprawl. In Muscat the landfill in Wadi al-Kabir, which in the early 1970s was outside the city, was by the early 1980s within the city and had to be closed. The current landfills in Bousher, al-Amrath and Seeb which replaced the landfill closed in Wadi al-Kabir are now facing the same problem. In Bousher and Seeb the distance between the landfills and the residential areas is not more than 5 kilometres and urban sprawl is extending in the direction of the landfills.

Shortage of land (which compels many densely populated industrialized countries to resort to other methods of waste disposal, such as recycling, composting and incineration as far as possible) is not acute in Salalah and the other cities in Oman, but here too the necessity of siting the landfill relatively close to the city, combined with rapid urban sprawl which soon can bring the landfill within a city's boundary, amounts to a land-shortage problem. Neither Salalah nor the other cities in Oman can resort to incineration; state-of-the-art incineration is a highly sophisticated technology. It generates residues which normally have to be landfilled and gases which have to be cleaned before they are discharged into the atmosphere. However, composting as already practised to a small extent could help solve the waste disposal problem of Salalah. Its effective introduction would minimize the quantity of waste to be disposed of and thus reduce the landfill requirement. Here the transport cost would be reduced even if the landfill were established in an area relatively far from the city, since the amount of waste to be brought to the landfill would be smaller and accordingly the number of trips that the waste vehicles would have to make would be reduced.

Recycling

Recycling and composting are not included in the present waste management strategy and practice of Salalah. However, this does not mean that they are completely unknown. Recycling exists in the form of the collection and export of scrap metal and paper. This is practised by several private enterprises which export the material to Dubai, where it is either utilized locally or shipped (together with other recyclable material collected from the Emirates) to India or Pakistan.



Scrap-pressing machine in Raysut landfill in Salalah

Scrap metal and paper to be exported to Dubai are collected in Salalah either directly from the source or from the landfill near Raysut. The practice is separate collection if the material is received directly from the source, but in the case of collection from the landfill, sorting is necessary. In both cases the enterprises which trade in the waste have to pay for the material they get. The sources are paid in accordance with the quantity and quality of the material they deliver. The price fluctuates and is determined on the basis of demand and supply. The collection of scrap metal and paper from the landfill is done on the basis of a monthly fee paid to the Municipality which entitles the concerned enterprise to collect materials from the landfill. In June 1992 we were told that the Municipality received a monthly fee of R0 700 from the enterprise. The enterprise deploys workers who sort the material systematically and put the useless waste in the dumping place; it has a machine to process scrap metal and vehicles to transport the recyclable material in it. The costs arising from these inputs, including the wages of the workers, the machine that processes the scrap metal, etc., enhance the monthly investment of the enterprise in this business to about R0 1,000-1,200.

It is worth mentioning that the Municipality does not interfere in the enterprise's activity at the landfill. It is concerned only that waste be returned properly to the dumping place after the recyclable items have been sorted out. Furthermore, the Municipality knows neither the quantity nor the composition of the recyclable material collected by the enterprise; such knowledge is important, however, not only from the viewpoint of setting or resetting the monthly fee to be paid by the enterprise but also from the viewpoint of understanding the quantity and composition of recyclable waste brought to the landfill. Such understanding would shed light on the possibility of collecting the recyclable waste separately at source or at the Municipal collection points in some form of separate collection. In this respect we should mention that Muscat Municipality, which intends to lease its landfills to an enterprise trading with waste (as did Salalah), requires the enterprise to submit monthly reports regarding the quantity and composition of waste collected by it.

Composting

Salalah is an "agro city" producing a great quantity of agricultural waste that causes disposal problems. The composting of this material together with organic household waste could be introduced here on a large scale and in an economical way that would also support agricultural development. In addition to this, the type of agricultural waste produced in Salalah can also be utilized to produce wood-based industrial products, fodder for animals, charcoal and cord.

Due to its importance for industrial and agricultural development, we prefer to deal with the recycling and composting of agricultural waste in a separate study that deals also with agricultural waste in other parts of the Sultanate.

Waste avoidance

Waste avoidance has appeared only recently as a component of waste management strategy and practice. It was introduced and developed in

industrialized countries such as the USA, Japan and Germany, where waste generated started to amount to tens of millions of tons each year. It is apparent that disposal, recycling and composting cannot eliminate these huge amounts of waste and that if waste production continues at the same pace, the world will sooner or later suffocate in the waste it produces. Thus, waste avoidance has become not a matter of choice but a must. In line with this necessity, several industrialized countries started to consider waste avoidance as the core of their waste management policy. The German law on waste management which was enacted in 1986 is named the Waste Avoidance and Waste Management Act. This law specifies how the production of waste should be avoided in principle and how it should be minimized as far as possible where it cannot be avoided. The law concerns mainly industry, which is the main producer of waste, in the sense that in the industrialized Western countries and in the oil-rich Gulf countries, a great portion of household waste is due to the exaggerated packaging practices of industry.

Avoidance-oriented waste management policy should not ignore the role of the individual consumer, who can contribute to waste avoidance and waste minimization by undertaking the following steps:

- Not disposing of consumer goods that can still be used. He should use them further or give them to someone else (by selling or otherwise) who can use them. This practice is not new: collecting old clothes, furniture, etc., to sell or to give to needy people is practised all over the world. However, experience has unfortunately shown that prosperity often makes people throw away things that can still be used.

- Avoiding buying items that after a short period become waste.

- Avoiding one-way bottles and disposable containers, plates, tableware, etc.

- Avoiding buying items with exaggerated (i.e., unnecessary) packaging.

- Avoiding extravagant use of consumer goods of all types.

In Salalah, waste avoidance has not yet emerged as a component of the waste management system of the city. However, awareness of the fact that waste is in many cases produced unnecessarily is growing. This is paving the way for the introduction of a suitable waste avoidance policy that would differ from that adopted in the industrialized countries, since the factors influencing waste production in Salalah are somewhat different from those found in the industrialized world. Industrial production that generates great quantities of waste does not exist here. However, the great dependency upon imported consumer goods (including foodstuffs), generates household waste, a great percentage of which consists of packaging material and empty cans, bottles and other one-way containers.

Since export goods are packaged in more layers than those consumed locally, Oman has more packaging waste from the same amount of goods consumed in the industrialized countries. The minimizing of packaging as provided for by waste avoidance laws in some industrialized countries tend not to be applied to export goods. Any search for a solution to this "imported waste" should involve the following two steps:

- Study whether the present amount of packaging for imported goods is necessary or can be reduced.

- Agree with the enterprises from which the Sultanate imports goods to use only the amount of packaging material that is indispensable, and introduce all necessary technical and organizational steps that would make possible a reduction of the amount of packaging material.

Waste management outside of Salalah

Besides Salalah, the Governorate of Dhofar comprises six other districts which consist of rural areas with small semi-urban centres that are the district capitals and administrative centres. Each district has a landfill provided and supervised by the local municipality as is the case in Salalah. However, waste management practices here are different from

those of Salalah. The prevailing practice is crude dumping with open-air burning. The landfills are not supervised at all. The vehicles empty their loads in the landfill site wherever they want. In most cases they select the most convenient place, which of course is nearest to the access. This behaviour means that the remote parts of the landfill site remain relatively empty while the areas nearest the access are filled with heaps of waste that are dumped randomly here and there, often blocking the way to the more remote areas of the landfill.

The situation is worsened further by the fact that carcasses are also dumped there together with household waste, amidst which they are often found. Half-burned and half-decayed carcasses can generally be found in the landfills. Carcass disposal is a very serious problem, especially in the mountainous area, where the inhabitants, who number 12,000 people, raise 120,000-140,000 head of cattle and several thousand head of camels and goats.

Although carcasses dumped here are "livestock-breeding-related special waste," they are dealt with as if they are household waste. The Municipality is responsible for their collection, transportation and disposal.

Data about household waste production (weight, volume and composition) are not available. However, waste generation here is relatively small, even if we assume that the daily per capita production of waste is 1.5 kilograms. The population of Dhofar is approximately 120,000, of which about 80,000 live in Salalah. Thus, the other six districts of the Governorate have a collective population of about 40,000 people, with each district having an average population of about 6,700; accordingly the daily waste production of each district is about 10,000 kilograms, or 10 tons. In addition, this small quantity of waste is not produced in one settlement, but in many tiny settlements which are dispersed over a large area, often separated from each other by hills and valleys. In most cases the daily waste production of a settlement does not exceed 100 to 120 kilograms. Even in the semi-urban areas (the district capitals) the quantity cannot be more than 1,000 kilograms.

However, the various municipalities here are responsible for overall waste management, including carcass disposal. The waste management situation outside of Salalah has the following features:

- Consumption habits in the *jabals* (mountains) differ considerably from those of Salalah. Here people depend on rice, meat and tea. Consumption of canned or packaged foodstuff is very limited. This limits the quantities of waste consisting of packaging material as well as of one-way bottles and containers.

- In general, household waste is collected in barrels at waste collection points not far from the settlements.

- The amount of behavioural waste thrown on the streets by the people is very limited and does not require considerable street cleaning.

- There are few paved streets, and these are concentrated in the district capitals; the paved streets in each district amount to no more than a few kilometres.

- Some parts of the mountain roads are confined from both sides, or perhaps one side slopes, and waste is thrown here. The waste found here consists almost exclusively of empty cans, bottles, one-way containers, paper and cartons. In general, these items are tossed out by residents of Salalah who picnic in the mountains, consuming packaged food and canned beverages and using disposable plates, knives, forks, napkins, etc.

- Leaves and branches that fall from trees rot relatively quickly in their places and become fertilizer that conditions the soil.

- Animal droppings are found in great quantities both in pens and grazing areas. If they fall in the grazing areas they fertilize the soil, but if they fall in the pens they cause some environmental and health problems. They become mixed with the urine of the animals and become sludge that contains a great quantity of fluid. This type of waste has to be removed continuously from the pens. However, in the past 10 years

the cattle breeders have started to collect and dry it out somewhat to reduce it to manure that is sold to middlemen who market it in all regions of the Sultanate.

The main problem facing waste management concerns disposal of carcasses. As already mentioned, carcasses are disposed of with household waste in a very crude way. However, the problems caused by this type of waste add up to more than the problem of unsanitary and crude dumping. The various municipalities do not have enough vehicles to transport the carcasses. In many cases people do not have transport facilities to bring carcasses to the landfill, and so they throw them in nearby bushes and slopes of the mountains where they decay and become a breeding ground for flies and other harmful insects. The settlements near these places are affected by the foul odour of the rotting carcasses.

Although the above-mentioned features are generally found in all districts, there are certain differences. The following examples will serve to illustrate these differences:

Taqah

Taqah is the second largest district in Dhofar, after Salalah. The district capital by the same name has a population of about 2,000 inhabitants and is about 50 kilometres from Salalah. The town has a few paved streets, the total length of which does not exceed 100 kilometres. However, it is connected with Salalah and most of the other districts in the Governorate with new, wide roads that can be considered highways. Street-cleaning is not a separate activity as is the case in Salalah.

Economic activities in Taqah town consist mainly of trade and services such as vehicle repair, plumbing, masonry, etc. In addition to this, people also raise some cattle. In 1992, some people began to grow vegetables and some types of fruits on relatively small plots which resemble house gardens. The town also provides urban and governmental services to the rural areas with which it forms an economic unit.

Waste is collected daily in the town—twice a day in some areas. In the other settlements, waste is collected only once or twice a week, and there are areas that are not covered at all by the waste management activities provided by the Municipality.

Waste is disposed of in an unsanitary landfill in the form of crude dumping. It is neither spread nor covered with sand and compacted as is the case in Salalah. It is kept in heaps that are separated from each other. Each vehicle unloads the waste wherever the driver considers it convenient. Carcasses too are dumped and burned with the household waste. Since the landfill is not fenced in and has no watchman, animals often enter to eat any edible matter they find in the waste.

The situation requires immediate action, including:

1. Fencing the landfill.

2. Appointing a watchman who sees that the vehicles empty their loads in appropriate places that are agreed upon. Furthermore he should register the incoming vehicles and make sure that only household waste (and not carcasses) is disposed of in the landfill.

3. Waste should be spread and compacted.

4. Disposal of carcasses in the landfill should be stopped immediately.

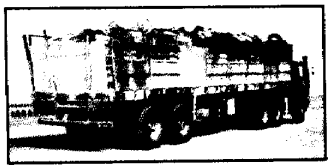
5. Animals should not be allowed to enter the landfill. Fencing would help to achieve this goal.

Sun-drying sardines to be used as animal feed

6. The area that is adjacent to the landfill is used now to dry sardines that are used as animal feed. The sardines are spread directly on the earth, which could be contaminated because of its proximity to the landfill. This practice should be stopped.

Thumrait

Thumrait is a district in the desert. Its proximity to the oilfields in Dhofar enabled the district capital which carries the same name to become a centre with some relevant urban ingredients. In general, the rural areas of the district are populated by nomads who mainly breed camels and depend on milk, meat and dates as foodstuff.



A cargo of scrap, Thumrait. This cargo is from the oil fields, which produce great quantities of scrap.

The city, which consists of several hundred buildings, is a trade and service centre with very few asphalted streets. However, a modern road that goes through the desert and mountains connects it with Salalah.

The landfill of the district is about 10 kilometres from the town. It is sited in an unpopulated area, on a low piece of land. And although it is fenced and has a gate, there is no watchman, and its situation is no better than that of Taqah. Here too, only crude dumping and open-air burning is practised. The difference can be attributed to the fact that the nomads here mainly raise camels, which are hardier and die less frequently than cattle. During our visit in June 1992, waste in the landfill contained mainly burned cans and containers and a considerable quantity of scrap. We were informed that this type of scrap stems mainly from the oil company. Existence of some animal skeletons and skulls showed that the landfill is used also to dispose of carcasses, which, however, are fewer in number than in the Taqah landfill. It seems that the open-air burning here is more effective and relatively complete. The whole landfill looks like a burned area, and there are fewer flies and less foul odours. However, it must be improved, and the present waste disposal practice should be replaced by a sanitary landfill system.

Bales of scrap, Thumrait.

Rakhyut

Most of the area of the district of Rakhyut is actually on the Jabal. Only the district capital which carries the same name is situated on a very narrow coastal plain. The capital's population does not exceed 300 people. It has only one paved street, which runs for only a few kilometres.

The district has only one Nissan truck for waste collection and transport. In the capital, street-cleaning and waste collection are carried out daily, but in the other settlements this is done only once or twice a week. There are settlements which do not receive cleaning or waste collection services at all.

The landfill in Rakhyut is on the coastal plain, about 1 kilometre from the town. It is only a few metres from the sea; the site is on rock and surrounded by mountains, and it has a fence and a gate. The household waste disposed of here daily does not exceed 300 to 400 kilograms. However, carcass disposal is a problem. We were informed during a visit to the landfill in June 1992 that at least two carcasses (mainly of cows) are brought to the landfill daily. However, the statement seems to be an exaggeration, because during our visit we did not observe any carcasses, only some skeletons and skulls which were relatively clean, indicating that they had been brought to the landfill at least 20 days ago.

The Municipality does not have enough transport facilities to bring the carcasses from the mountains to the landfill, and the inhabitants do not make the effort to bring the heavy carcasses from the mountains by rough roads to the landfill; instead, they throw them into the nearby bushes and slopes of the mountains, as already mentioned.

If the problem of carcass disposal is resolved, the landfill will not have any serious problem, because the other waste arrives in such small quantities that even open-air burning does not cause any pollution worthy of mention.

Dhalkut

Dhalkut to a great extent resembles Rakhyut. Most of the area of the district is on the Jabal. Only the capital, which carries the same name, is on a narrow coastal plain. It has an area of about 3 square kilometres, and there is only one paved street which goes through the city, the length of which is about 3 kilometres. The city has a population of not more than 350 inhabitants. However, the daytime population reaches 750 or even more, because almost all the schools of the district are here, and over 200 children come from the Jabal to attend school. Further, inhabitants of the Jabal come to town often to receive government and other services and to buy goods and commodities.

The district has only one waste vehicle, with a capacity of 2 tons, and four workers who are often used in other activities such as city greening, etc. In Dhalkut, street-cleaning and waste collection are carried out daily while in the other settlements this practice is reduced to only once a week. There are many settlements which do not enjoy waste collection service at all.

Household waste production in the town cannot be more than 750 kilograms. This means that the maximum amount of household waste brought daily to the landfill is about 1.25 tons. At least 60% of this consists of organic material with a considerable percentage of bones. Inert materials too, such as ash, small stones and soil, form a good amount of the waste.

In contrast to Salalah, Taqah, Thumrait and Rakhyut, there is no sanitary landfill in Dhalkut, only a crude dumping area. Waste is brought to a place that is only about 500 metres from the town, where it is dumped into the sea. First, waste falls onto rock with a surface of about 10 square metres and it remains there till the waves—which are very strong when there is flood—draw it out to the sea. It often happens that waves throw the waste onto the town's beach. Since carcasses are also disposed of in the same way, they too are thrown back onto the beach by the action of the waves. This creates a significant environmental and health

problem, and the Municipality has decided to put an end to it. As an alternative, the introduction of modern waste incineration or moving the dumping area to a more suitable site is being considered, but this new site can only be in the Jabal, because the coastal plain has an area of only 3 square kilometres and is very narrow (about 50 metres wide). On one side it is confined by the sea and on the other by a high and steep chain of mountains.

The two alternatives have considerable constraints. Modern incineration is a highly sophisticated technology which is expensive. Its operation requires highly trained expertise. Furthermore, small incinerators which would suit Dhalkut exist, but only for hospital and other waste, and they are more expensive and more complicated than those for household waste. Thus, in our judgement, modern waste incineration is not an alternative.

Moving the landfill, however, is possible, and in fact the Municipality has chosen a site that is about 30 kilometres from the town and situated in the Jabal. During our visit to the proposed landfill site, we made the following observations:

- The main road that leads to the proposed site is rough. The vehicle therefore has to slow down. This road took about 45 minutes to traverse with a Landrover.

- There is a 3-kilometre side road connecting the main road with the landfill site, but it is so rough that even a four-wheel- drive vehicle can only move very slowly over it. This road would have to be reclaimed and paved, and this would not be cheap.

- The distance between the proposed landfill site and the place from where waste has to be collected is an average of 60 to 70 kilometres.

- The site is at a low area in the Jabal. On the north side it is confined by a deep valley and the other sides by land that is about 4 metres higher than the landfill area.

- The ground at the proposed landfill site is rocky and in general seems to be suitable for waste disposal. However, it contains some brittle areas and cracks which may be permeable.

- Another point which should be taken into consideration is the fact that heavy rains may draw the waste from the landfill down to the valley.

- Also, the time needed to collect and transport the waste poses another problem which can be summarized as follows:

Collection from the town of Dhalkut

- Waste collection takes about 90 to 120 minutes.

- Transport of waste to the landfill takes about 45 minutes.

- Unloading of the vehicles takes about 15 to 20 minutes (on the basis of the time needed to unload the vehicle at present).

- Return from the landfill to the city takes about 45 minutes.

- Total time for one trip of waste collection and transport is 3 hours, 15 minutes to 3 hours, 45 minutes.

Collection of waste from the other settlements

- Collection from the tiny and scattered settlements in the Jabal takes 3 hours. The roads between the settlements which the vehicle has to cover are rough and uneven. The quantity of waste collected from each settlement is very small. In general each settlement produces only 75 to 150 kilograms of waste.

- Due to the rough roads, transport of the waste to the landfill takes about 90 to 120 minutes (This is also the time needed

to transport waste from the Jabal to the present dumping area).

- Unloading of the waste takes about 15 to 20 minutes. The time required can rise to 30 to 60 minutes if the load contains carcasses.

- Return of the vehicle from the landfill to Dhalkut town is about 45 minutes.

- Total time needed to collect and transport waste is 5 1/2 hours to 6 hours, 45 minutes.

If it is decided to establish the landfill in the above-described site, it will be necessary to do the following:

- A wall should be established between the landfill and the valley that confines it on the north side, with the aim of preventing heavy rains from drawing the waste down into the valley.

- The side road that leads to the landfill must be reclaimed and paved.

- The main road that leads to the landfill needs to be improved.

- Revision is needed of the structure of the network of waste collection points as well as the routes of the vehicle, with the aim of making waste collection and transport more efficient and reducing the time it takes to collect and transport waste.

The above-given examples of waste management in the districts outside Salalah show that the existence of many tiny settlements mean that centralizing waste collection and transport, with all waste being brought to a single landfill, is a very costly and time-consuming operation. In addition to this, there will always be settlements that cannot be covered

by the waste collection and transport system. This problem is not limited to Dhofar but is found in all other regions of Oman, where each district contains, besides an urban centre that is the district's capital, many tiny settlements and villages that are scattered over a large area and separated from each other by valleys and mountains. The roads between them are rough and uneven, and there are villages and settlements that are not accessible by any vehicle, whatever its size.

In Dhofar, as well as in other regions of Oman, the topography severely limits centralized waste management and makes it very expensive and time-consuming. Thus, one must look here for other alternatives that are more suitable and more cost-effective. Adopting a decentralized waste management system for the scattered tiny rural settlements may be a good solution. Such a system is already practised in some regions of Oman, where every small settlement or every group of small settlements that are relatively close to each other has a small dumping area (*mardam*). Since open-air burning of waste is practised here as well, the dumping area is also called a *mahraqa* (place for open-air burning of waste). Environmental damage assessment regarding this practice has not been undertaken. However, since the quantity of waste to be disposed of daily is small, the damage cannot be great. This decentralized waste disposal system, for which no alternative seems to exist, is also suitable for the rural settlements of Dhofar. The system could be improved and made more efficient, more cost-effective and environmentally sound by doing the following:

1. Establishing the landfill in a site that is relatively far from the settlement(s) that use it (about 5 to 7 kilometres).

2. Avoiding establishing the landfill in an area upwind of the settlements.

3. Levelling the wastes in layers that do not exceed 2 metres or so in thickness.

4. Covering the surface of the levelled waste with soil or other suitable material to a depth of 15 to 25 centimetres on the same day that the waste is delivered to the site.

5. Fencing the site to prevent animals from coming in and eating the rubbish.

6. Establishing a waste collection point for every settlement and keeping a container there, the size of which can accommodate all wastes until they are transported to the site.

7. Training the people to put waste into the container and not in front of it.

8. Training the people to press or tear their hollow waste items in order to reduce the space they occupy in the container.

9. Achieving the aim of keeping the container closed at all times.

10. At present waste is collected from the rural settlements of Dhofar once a week. This interval seems to be suitable and should be kept.

11. At present, waste is transported to landfills that are about 60 to 75 kilometres from the rural settlements of Dhofar. Decentralization would reduce this distance to 5 to 7 kilometres. This would make possible the use of carts drawn by animals (e.g., donkeys) to collect waste from the settlements. Animal carts have these advantages:[70]

- No consumption of fossil fuels
- Very low cost compared with motor vehicles
- Almost silent in operation
- The driver can leave the vehicle and assist in loading.

[70] Flintoff, op. cit., p. 39.

With respect to the design of animal carts, "they should be low loading steel bodies mounted on pneumatic tyres, and fitted with sliding shutters and manually operated tipping gear."[71] Animal carts which are suited to Dhofar are already in operation in many Asian countries. They can be adapted and even produced in the Municipality's workshop, which has already shown creativity in designing and constructing suitable containers.

The system could be further improved by combining it with recycling and composting activities. Anaerobic composting, which can easily be undertaken on a small-scale basis, is a cheap solution to the disposal of organic household wastes. "These materials are placed in alternate layers in small trenches which are sealed and left undisturbed for many months; the contents are then dug out and used as compost."[72]

Aerobic composting can also be introduced. It is characterized by rapid decomposition, normally completed within two to four weeks. As long as aerobic conditions are kept, offensive odours do not arise. However, aerobic composting may require spraying the waste with water in order to give it the moisture content that is indispensable for the decomposition of the organic material, and it also requires that the waste be turned several times, to bring the outer layers of the waste inside so that they receive exposure to the higher temperatures that are present inside the heap.

With respect to recycling, it is possible to collect all recyclable items separately and sell them to the middlemen who trade in such materials. In this regard, we were informed that some Indian and Pakistani drivers who bring goods to the rural settlements collect cans, scrap, cartons, etc., and take them away with them.

Composting and recycling would considerably reduce the amount of household waste to be landfilled. There are several possibilities for

[71] Ibid.

[72] Flintoff, op. cit., pp. 151-152.

utilizing animal droppings in an economical way that could also have positive developmental effects. We will deal with this issue extensively in our consideration of the recycling of agricultural waste.

Disposal of carcasses

Carcasses pose a serious problem in Salalah, especially in the Jabal, where most of the animals, especially cattle, are reared. Deaths of animals occur almost daily. During our tour in the Jabal there was no district which did not emphasize the problem of carcass disposal. How many animals die daily is unknown. Often there are epidemics during which the animal death rate rises to a high level. In such cases the problem becomes more complicated and serious, not only because of the high death rate but also because of the diseases that kill the animals and make the carcasses more dangerous. In this respect we were informed that birds, especially crows, which fed on the carcasses of animals that had died of rabies became infected and began to attack people.

As already mentioned, carcass disposal is carried out at present in a very unsanitary and dangerous way. Carcasses are either thrown into the brush or onto the slopes of the mountains, or are disposed together with household waste in a very crude manner. The means used to transport the carcasses to the landfill are open vehicles. The carcasses are put on the vehicle without being covered or put in a box. Often they have started to rot. Those that are collected from the streets are generally in a state of advanced decomposition.

The workers who collect the carcasses for transportation to the landfill wear neither gloves nor masks to protect themselves and touch the carcasses with their bare hands. Facilities for washing do not exist in the landfill. During our visit to the landfill in Taqah we noticed that the workers who transport carcasses are not at all aware of the danger to which they expose themselves. Thus, it cannot be confirmed whether they wash their hands when they return home. Since they interact with society (they visit restaurants, shops, barbers, etc.), they can transmit disease to others. Protection for them means protection for society.

Preliminary steps

This problem requires an immediate solution. Dhofar Municipality recognized this and began to introduce the following measures:

1. Stop disposing of carcasses in the household landfills and throwing them in the brush; select special sites for carcass disposal.

2. Provide suitable closed vehicles for the transport of carcasses.

3. Provide the workers who transport the carcasses with clothes, gloves and masks to protect themselves from infection.

4. Wash and disinfect the transporting vehicle properly every day.

5. Wash the work clothes of the workers every day. Gloves and masks should be disinfected, or they should be disposable.

6. Give the workers medical check-ups every three months.

7. Vaccinate the workers against rabies and tetanus.

8. Oblige the animal breeders to report to the municipality any deaths of animals, giving also the possible cause of death.

9. Have every carcass checked before its disposal by a veterinary surgeon, with the aim of identifying the cause of death. Such a step would help in ascertaining whether the cause was a disease of an epidemic nature which could easily spread.

10. Spray the landfill where carcasses are disposed of with insecticides, etc.

11. Supervise closely the process of carcass collection, transport and disposal.

12. Monitor the landfill continuously for early detection of problems, so that solutions can be found for them.

In addition to putting these immediate measures into practice, a strategic solution should be developed as follows.

Strategic solution

At present carcasses are considered more or less normal waste (household waste), the disposal of which is the responsibility of Dhofar Municipality. Certainly the Municipality cannot be excluded from any institution that may be responsible for carcass disposal, for the following reasons:

- The Municipality has experience in collecting and transporting carcasses.

- The cleaning activities of the Municipality are carried out everywhere. This enables it to know better than any other institution where carcasses are found.

The collection and transport of carcasses can be more efficient and effective if these activities are coordinated with the collection and transport of waste. In this respect it would be very helpful if the drivers of waste vehicles were equipped with walkie-talkies so that they could communicate with the centre whenever they discover a carcass that should be transported to the landfill. At present the person who wants to remove a carcass has to come to the Municipality and ask for transport. This takes time, especially if the person is coming from a remote settlement. The person may not have the time required and may instead decide to put the carcass in nearby brush or on a mountain slope. If he comes to the Municipality there will always be delay, and the carcass will start to decay. To enhance efficiency, the walkie-talkie should be supplemented by an on-call team that receives the message and immediately take steps to collect and transport the carcass.

Since carcasses are special waste, the institution that is responsible for their disposal should possess expertise regarding the nature of this type of waste, including the environmental and health damage it can cause. Thus, the unit that takes care of carcass disposal has to be multi-institutional and should include:

- The Ministry of Agriculture, which should provide a veterinary surgeon who would be responsible for checking the carcasses and taking samples to be analysed in the laboratory of the Ministry.

- The Ministry of Health, which should be responsible for the health aspects of carcass disposal.

- The Ministry of Regional Municipalities and Environment, which should take care of the environmental aspect of carcass disposal.

- Dhofar Municipality, which should be responsible for the collection and disposal of the carcasses.

The above-mentioned government institutions should establish a standing committee which meets at least once a month. Organizationally, the work of carcass disposal should remain with the Municipality. However, a separate unit should be established to oversee this work, with a veterinary surgeon as its head. The activities of the unit should be coordinated with activities of the animal health sectors and laboratories of the Ministry of Agriculture.

The above-mentioned activities should be accompanied by the enactment of a detailed law on carcass disposal at the national level. However, since the enactment of this law could take some time, Dhofar Municipality could issue a Local Order regulating all issues concerning carcass disposal.

Since epidemics that result in the death of a great number of animals occur relatively often, it is also necessary to establish an emergency or disaster preparedness committee consisting of representatives of the

Ministry of Health, the Directorate General for Animal Husbandry and Livestock (within the Ministry of Agriculture and Fisheries), the Ministry of Regional Municipalities and Environment, Dhofar Municipality and the Royal Oman Police Force in the Governorate.

Summary and recommendations

Some of the recommendations made here have already been raised in the exposition and analysis of waste management in Dhofar. If repetitions are discovered here and there, this occurs due to the necessity of bringing all recommendations under one umbrella and emphasizing their importance. Before listing the recommendations, we would like to emphasize that Dhofar Municipality has shown remarkable creativity in tackling the waste management problems of the Governorate. The work done by the Governorate is commendable. It could to a great extent optimize utilization of the resources at its disposal. This fact should not only be recognized but also be considered as the basis of any improvements to be introduced.

In general the issues to be tackled here concern environmental protection and improvement as well as enhancing efficiency and effectiveness.

Environmental protection

Steps to undertake here include:

1. Waste avoidance, with the aim of minimizing the quantity of waste to be recycled or disposed.

2. Reuse of waste. Certain waste items can be reused several times, such as one-way bottles which could be reused a number of times either for the original purpose or for other purposes.

3. Recycling and composting of the waste that cannot be avoided and that cannot be reused directly.

4. Disposal of the waste whose production cannot be avoided and which cannot be reused directly or recycled in sanitary landfills.

5. Appropriate treatment of hazardous and special waste before disposing of it.

6. Separate and special arrangements for the treatment and disposal of carcasses.

7. Research on waste production and waste disposal and treatment methods in the Governorate.

8. Enactment of a comprehensive Local Order on waste management.

Taking action on these points should not wait until a national law on waste management is enacted. However, the Local Order should be adjusted to the national law and should contain all items and provisions that would be included in the law in the future.

Effectiveness and efficiency

Effectiveness deals with how well work is carried out and with the extent to which cleanliness and environmentally sound waste disposal (including reuse of waste and recycling) are actually achieved. Although effectiveness is the measure against which success is measured, it says little if it is considered in isolation of efficiency, because it is possible that the success achieved does not justify the costs incurred. Unfortunately, little attention is paid to this very important point in Salalah and the other municipalities in Oman. Any increase in the work to be done is countered by demands for more money, with present expenditure taken as a basis. This means that if there is a 20% increase in work, an additional 20% of the present expenditure is demanded. Input/ output analysis, which measures optimal use of resources and determines how further optimization can be achieved, is unknown. Also, analytical techniques that compare the cost-effectiveness of the present practice with possible alternatives are unknown. If any alternative is

introduced in the present practice, this is done as an isolated intervention that is adopted without prior study and not related to the overall waste management system.

Although the overall costs of waste management are not known, all people in the Municipality with whom we discussed the issue emphasized that it is too high and amounts to 30-35% of the Municipality's annual budget. To make the waste management system more efficient and more cost-effective it is necessary first of all to obtain a clear picture of all costs of this system, with an unambiguous statement of the budget allocation for each item. This would enable planners to relate the budget allocations of the different items to each other so as to identify whether the budget allocations are so disproportional that the overall performance of the waste management system is negatively affected. In this respect it should be mentioned that both in Dhofar and in the other regions and cities of Oman, over 90% of the budget is allocated to street-cleaning and waste collection and transport. Waste disposal and treatment receive scant attention in terms of budget allocation and provision of manpower and equipment. This disproportionate budget allocation means that waste collection and transport is carried out with a reasonable level of effectiveness that cannot be matched in the case of waste disposal.

Tackling the above-mentioned problem requires a review of the present budget allocation practices and the allocation of a budget to landfill operations and waste disposal that would enable the waste brought to the landfills to be disposed of sanitarily. The provision of more money to landfill management could be effected by allocating any additional money in the waste management budget to this item and by drawing off some funds from waste collection and transport and allocating them to landfill management. As mentioned, greater efficiency in waste collection is possible, meaning that the budget for this item could be cut without impairing effectiveness in this area. This means that resource reallocation (that is, adjustment in resource allocation) should take into consideration the possibility of enhancing the efficiency of this activity, the budget of which has to be cut for the benefit of another activity in the waste management system.

Enhancing efficiency would first require:

- Developing a comprehensive waste management plan; assessing whether resources are being delivered and used in accordance with the plan's provisions and timetable and whether the intended work is done in a timely and cost-effective manner; and monitoring the efficiency with which the work is implemented.

- Evaluating the extent to which the intended target has been reached and comparing the present practice with possible alternatives.

One point that should be kept in mind is that even the most carefully planned work undergoes substantial modifications during the process of implementation. Timely, appropriate decisions on work modification can only be made if rapid feedback is provided throughout the implementation process.

A well-designed monitoring, assessment and evaluation system is indispensable for any efficiency enhancement programme. It provides most of the basic information required for efficient and cost-effective implementation of the work.

Since efficiency deals with input/output relations, especially with maximizing the output from each item or unit used as input, it is necessary to look at the various inputs of the waste management system and see what should be done to render them more efficient and productive.

Manpower

The manpower engaged in waste management consists of cleaning and collection workers as well as technical and administrative personnel responsible for organizing and supervising waste management and for planning and implementing the work. The cleaning and waste collection workers in any waste management system make up the greatest

proportion of manpower. Manpower needs in the area of street-cleaning and waste collection are determined on the basis of the following factors:

- The number of inhabitants and housing units as well as commercial and industrial units whose waste has to be collected.

- The area from which waste has to be collected, taking into consideration the natural topography and the structure of the built-up area.

Although these factors are important, there is no fixed rule according to which manpower requirements can be determined. In general, manpower requirements are affected by the efficiency of the workers, which depends upon the following factors:

- The health and general physical condition of the worker, which may determine his productivity.

- Psychological readiness to do the work.

- The equipment and tools used in the work.

- The organization and supervision of the work.

Taking into account these factors, which determine the efficiency and productivity of the worker, we recommend the following:

- Taking the physical and psychological readiness of the workers into consideration and giving the workers medical check-ups both before their employment and periodically thereafter. In addition to this, they should be vaccinated against tetanus and rabies, and the proposed periodical medical exam should pay special attention to communicable diseases.

- Proper and timely maintenance and repair of the vehicles, equipment and tools. This requires having sufficient quantities of all necessary spare parts in the store.

- Efficient, appropriate supervision of the workers and their performance.

- Provision of first-aid facilities, as well as fresh water, soap and towels at the landfill sites.

- Redistribution of the workers for Salalah and the other districts of the Governorate. At present Salalah has enough workers. Thus, any additional workers provided to waste management should be allocated to the other districts. Furthermore, steps should be undertaken to make street-cleaning and waste collection work in Salalah more efficient, with the aim of completing the work with fewer workers and providing workers to the other districts that need more workers.

The waste management system suffers from an acute shortage of administrative and technical personnel. Furthermore, the available manpower that has gained some expertise through learning by doing needs to be trained and exposed to modern waste management systems.

Since efficiency cannot be enhanced without proper management and supervision, it is necessary to focus on this issue and recruit three or four waste management experts and administrators from abroad; at the same time Omanis should be trained in this field.

Vehicles and equipment

Salalah does not suffer from any shortage of waste vehicles, and if any problem arises here it is due to lack of maintenance or to delay in repair. With proper and efficient management, Salalah may even be able to dispense with some of its vehicles, which could be given to the districts which lack vehicles.

One should consider also introducing animal carts to transport waste from rural and mountainous areas where the roads are rough and where modern vehicles can hardly be used. Wheelbarrows too should not be

excluded; they may be practical and even necessary in the narrow roads that are not accessible to other means of transport.

In general, a comprehensive strategy for waste transport should be developed which takes into consideration all transport means that can be used and which determines the role of each type in the waste transport system.

Equipment needed for sanitary disposal of waste such as tractors and cranes is in short supply and needs to be provided.

Collection points and containers

At present the Municipality uses different types of waste containers. Some of them are modern and standardized, while others are made locally in a Municipal workshop. In addition to this, masonry closures, old barrels and old water tanks are used as containers. The present composition seems to be adequate. All that is needed is to standardize the capacity of the locally-made containers and to develop them further.

The distribution of the collection points was arranged on the basis of experience gained in work. To a great extent, this distribution is suitable. However, in some areas of Salalah the density of the collection points is so high that only 25% of the capacity of the containers is used. Here the number of collection points should be reduced to a level that ensures that the available containers can accommodate all of the waste generated in the area.

The spacing of containers needs careful monitoring. In principle the distances between the containers should be 150 to 200 metres (a five-minute walk), but the distance can be made longer or shorter in accordance with the population and building density and the quantity of waste to be removed. Effective organization of the collection points should also include the proper use, maintenance and repair of the containers and should address the problem of cats and goats feeding on

garbage containers; these points could be included in public education and information activities.

Waste disposal

To a considerable extent, waste disposal in Salalah follows a sanitary landfill system, which should be upgraded. This requires providing earth movers, tractors and other equipment.

In the other districts of the Governorate, only open-air burning and crude dumping are known. The dumping areas are close to the district capitals—about 5 kilometres away. However, the distance between them and the other settlements of the districts is great (60 to 80 kilometres). In addition to this, the roads are rough and the quantities of waste transported are often small. Although no information about the transport cost per ton of waste is available, the great distances to be covered and the roughness of the roads suggest that this cost is high not only in terms of current expenditure but also in terms of capital investment, because the poor roads damage the waste vehicles and shorten their life.

Outside of Salalah we recommend that a decentralized waste disposal system be followed. The district capital and its surrounding area should be served by the present landfill. More remote settlements should have their own landfills. Since waste production in these settlements is small, disposal does not pose a problem, especially if it is combined with recycling, composting and biogas production as was suggested. For each settlement or group of settlements near each other, it is possible to establish a small, suitable landfill in which only waste that can be neither recycled nor composted is disposed.

Disposal of carcasses

The problem of carcasses cannot be solved in the context of the organizational framework for waste management. For this problem, we recommend a separate and multi-institutional department comprising the Ministry of Agriculture, the Ministry of Health, and Dhofar Municipality.

Disposal should take place far from the landfills used for the disposal of household waste. Modern equipment should be used to achieve sanitary disposal of the carcasses.

Since carcasses are special waste and can even be toxic if the animals are diseased, the following sanitary and preventive steps should be taken in disposing of them:

- Identify the sources of the carcasses.

- Have a veterinarian check each carcass before it is disposed of to determine the cause of death.

- If the cause of death is a communicable disease, the necessary steps should be taken to combat this disease.

- Carcasses should be transported by a special closed vehicle that is not to be used for any other purpose. The vehicle should be disinfected at the end of each working day.

- Gloves, masks and special clothes should be provided for the transport and disposal workers. They should wear these items only when they are on duty. The items should be washed and disinfected daily. Disposable gloves and masks are preferred.

- The transport and disposal workers should have medical check-ups every three months, and more often if any doubt arises.

- Transport and disposal workers should be vaccinated against rabies and tetanus.

- Soap, water and towels should be provided to the transport and disposal workers. Since these workers are uneducated, one must assume that they go to restaurants and grocery stores before having washed themselves properly and disinfected their hands.

- Since epidemics that cause mass death of animals are not rare, the administrative set-up for carcass disposal should establish a disaster preparedness unit to tackle the problem whenever it occurs.

Enactment of a comprehensive waste management law

A comprehensive national waste management law should be enacted. However, since this could take some time, the present Local Order on waste management should be elaborated further and made more comprehensive in the following way:

1. *Waste avoidance*: Production of waste should be avoided as far as possible. A Municipal administrative order or even a special Local Order should be issued for this purpose.

2. *Reuse of waste items*: Waste items whose production cannot be avoided should be reused as far as possible. Throw-away containers and one-way bottles should be reused as far as possible, and where it is possible such containers should be banned.

3. *Recycling waste*: When it is impossible to avoid waste or to reuse it, the waste should be recycled or composted or used for biogas production as far as possible. When this is not possible, it should be disposed of properly, with special and hazardous waste being disposed of separately or being disposed of with household waste only after it has undergone a special treatment that makes it similar to household waste.

Organizational framework

The present organizational framework for waste management in Salalah is suitable and should be retained. However, it should be better staffed. The efficiency of the present administrative and supervisory staff should be upgraded by training. New specialized administrative and supervisory staff should be recruited.

Waste management planning

The present waste management system in Dhofar has been developed more or less on the basis of trial and error and learning by doing. However, it has not been the object of systematic planning. Improvements have been introduced on an ad hoc basis and as individual acts and not on the basis of a systematic study that identifies needs and solutions. This continues to happen because the present staff has neither the educational (training) background nor any practical experience in waste management planning. In addition to this, in general, personnel are fully occupied in resolving daily crises and complaints. Forward planning requires full-time staff responsible for the work. As was stated earlier, "Without such staff, with sufficient time to carry out their duties, it is almost impossible for an organization to assess the effectiveness and economics of current operations; analyse the options available to improve existing collection and disposal practices; design future collection services and disposal facilities; plan the smooth change-over from one collection method or disposal facility to another; and identify the staff training needs and legislative requirements to maintain efficient waste management."[73]

The vital importance of planning cannot be emphasized enough. "Without planning, waste management lurches from one crisis to another, with little control of the direction taken. It should be the principal function of the forward-planning department to advise senior management on appropriate ways to avoid these situations in the future."[74]

Changing the habits of private citizens and waste management staff

Improvements in street-cleaning, waste storage, collection and disposal definitely require changes in the habits of both private citizens and waste management staff. Even the most well-thought-out waste management plan is doomed to failure if it does not enjoy the support and

[73] Rushbrook and Finny, op. cit., p. 11.

[74] Ibid.

collaboration of the general public and the waste management staff. The change in habits required here is probably more difficult to bring about than organizational improvements. Considerable skill is required of waste planners and senior managers to educate the public and the waste management manual labourers who often adhere to their preconceived ideas and habits. It is worthwhile to mention here that public education should not be understood as one-way communication that aims at indoctrinating the public and waste management labourers and imposing behavioural patterns upon them from which they must not deviate; rather, it involves two-way or even multi-lateral communication. This means that ideas can emerge at all levels and in all groups and be communicated to all other levels vertically and horizontally in an effective way that enables the emergence of a fruitful dialogue and "multilogue." In this sense P.E. Rushbrook and E.E. Finney write:

> Many good ideas on ways to improve waste storage and collection can come from the public, and many good ideas for improving waste handling, vehicle utilization and disposal practices can come from all grades of waste management staff. The waste management plan can benefit from their views. The planner is well advised to listen to and learn from the public and staff in other departments. Cooperation is essential and cannot be obtained easily; with perseverance it is possible. Cooperation cannot be aroused by an insensitive attitude by a waste management organization.[75]

In the long run, it may be unavoidable to request the people to pay, at least in part, for waste management services. This step needs to be carefully considered in the light of traditions and expectations. Through public education and environmental awareness promotion, the ground must be prepared for the eventual introduction of such charges. With respect to the collection of commercial waste, charges must be introduced in principle if the collection is undertaken by the Municipality; otherwise,

[75] Rushbrook and Finney, op. cit., pp. 11-12.

the commercial establishment should bring the waste to the landfill or hire a private company to carry out this task.

Finally, we conclude with the observation that it is important to recognize waste management as a field that needs specialization and expertise on the one hand, and on the other appreciation as a problem that concerns everybody and that requires public participation.

RECYCLING AGRICULTURAL WASTE

PRESENT SITUATION AND FUTURE PROSPECTS

Overview

Agricultural waste in Oman derives mainly from date-palm and coconut palm, as well as from banana, mango and papaya plantations. In addition to these, vegetable and fruit farms in some areas of the countries produce considerable agricultural waste.

Agricultural waste in Oman is not concentrated in the rural areas, as is the case in other developing countries, and the reason lies in the nature of the plants grown in the country. Date-palm trees, which constitute more than 90% of all agricultural plants in the country, are widespread even in the cities, to the extent that many of the best-cultivated large date-palm plantations are found in Muscat Governorate and in the other large cities of the country.

In Dhofar, or Garden City, as it is sometimes called, coconut palm plantations as well as banana, mango and papaya farms are concentrated in Salalah, which actually is an agro city. In the past, agricultural waste was considered a useful by-product. Fronds, fibres and trunks of date-palm trees were used in making a wide range of products important in the life of the people at that time. Fronds and fibres were used to make mats, baskets, cords and several other items. Trunks were used to make furniture, doors and many other wood items. Similar products were woven or produced from the fronds, fibres and trunks of the coconut tree. The use of agricultural by-products as fodder was common; people even used to grind date pits and give them to their animals. Agricultural waste that could not otherwise be recycled was used as fuel. However, the fast change-over of the economy from agriculture to oil production meant that these recycling activities diminished to the extent that what was yesterday a useful by-product has today become a harmful material that pollutes the environment, as it is disposed of by burning it in the open air, with the smoke and all the pollutants released by the burning

going into the atmosphere. Although the air pollution caused by burning the agricultural waste has not been measured, the people residing near the places where such waste is burned complain of respiratory problems due to this pollution.

If the development that the Sultanate has been witnessing has rendered past recycling methods unsuitable, this does not mean that agricultural by-products have lost their value and cannot be recycled in an economical and profitable way that is suitable for the Sultanate's development. Not only is there the possibility of profitable recycling but there is also demand for products made from the available agricultural by-products.

With this in mind, we consider in the following paragraphs how the various types of available agricultural waste can be recycled.

Recycling date-palm by-products

Availability of by-products

Date production is the most important agricultural sector in the Sultanate. There are about 8.5 million date-palms. Production is concentrated mainly on the Batinah coast, in Sharqiyah and in the Interior. About 60% of the total plantation is found on the Batinah coast. Most of the trees there are old, with low productivity. The relatively high humidity in the region has a negative effect upon the production and quality of the fruit.

In the Interior we have a situation that differs considerably from that of the Batinah coast. The low humidity results in good fruit ripening. About 25% of date-palms in the country—including some of the best date varieties—are found in this area. However, water shortages hinder any expansion in date-palm cultivation here. Some of the trees are very old and unproductive and many of the date varieties are of poor quality. Both old trees and low- quality varieties have to be replaced.

In the Sharqiyah region, where about 15% of the total date-palms in the country are grown, there are some good date varieties. The other varieties grown here resemble those that are common in the Batinah coast. Here, too, water shortage is considered the main constraint to the expansion of date-palm cultivation.

In general the present plantations contain a considerable percentage of unproductive trees as well as palm trees of undesirable varieties. Rehabilitating plantations by replacing old trees and undesirable varieties of palms increases the by-products in two ways:

- It not only increases the production of date fruit but also of such by-products as fronds, fibres, leaves, bunches and pits.

- It results in cutting down and replacing old trees, which increases the number of trunks felled.

These date-palm by-products are useful and renewable materials which can be recycled and processed in different ways. Factors that justify their recycling include:

1. Environmental protection. At present, date-palm by-products are considered agricultural waste whose disposal poses an environmental problem, as has already been mentioned.

2. Minimizing expenditure by avoiding the costs associated with the appropriate sanitary disposal of date-palm wastes.

3. Development contribution. Date-palm by-products can be recycled to substitute several items which the country is importing at present in great quantities, such as wood-based industrial products, manure and fertilizer. In addition, charcoal, which the Sultanate imports in not negligible quantities,[76] can be produced by recycling date-palm by-

[76] The Sultanate imports 600 to 700 tonnes of charcoal annually, according to the Ministry of Commerce and Industry (1992).

products; this would help promote profitable economic activities in the country and would create employment. Another very important point that deserves special attention here is the fact that date-palm by-products are renewable and reliable natural resources. All that is needed is to preserve and develop the environment in which they can flourish.

4. The availability of the by-products, which determines whether it is economically feasible to recycle the date-palm by-products. Mohammad bin Husin writes:

> There are about 8 million date-palm trees, consisting of about 250 varieties now planted in the Sultanate of Oman. If a rehabilitation programme is to be carried out, the estimated annual availability of date-palm lignocellulosic by-products are as follows:
>
> A. Trunk
> In general, the old date-palms are very tall and straight with small tapering towards the top. There are some variations in the palms' characteristics and these are believed to be due to age and varietal differences. These palms range in height from about 6 to over 13 metres with diameters between 35 and 45 centimetres and with age sometimes exceeding 100 years old. However, for the purpose of this estimate, the palm height is taken as 9 metres and trunk diameter is 38 centimetres, based on average measurement made during the course of an experiment carried out to determine the use of the date-palm by-products. The average specific gravity of the trunk was found to be about 0.45. The trunks can be made available for wood-based industries when they are felled during the rehabilitation process. Assuming the replanting is done on only 4 million palms, or 50% of the total 8 million palms within a span of 30 years, the annual availability of date-palm trunk is estimated to be around 61,500 tons annually. This involves the felling of about 133,250 palms per year. In the next 30 years, the remaining 4 million date-palms may have grown too tall and unproductive and therefore due for replanting. Toward the end of the second 30 years, those replanted palms, especially in the beginning of the first

> 30- year replanting period, will attain the age of 60 years and may also be considered for replanting. Meanwhile, palms in new planted areas may also have reached their replanting age after the first and second 30-year replanting programme. This will add to the amount of by-products yield to support the wood-based industries.
>
> B. Fronds
> The production of fronds per palm per year in northern Oman had been cited to be in the range between 10 to 20, and 15 fronds per year had also been adopted. Ideally, in a mature palm, the number of old fronds to be pruned should be equal to the number of young fronds produced. The number of fronds remaining on the palm should be just enough to provide for the physiological needs of the palm, while conserving the energy and other resources, for maximum fruit production. However, the current practice is that every year, 4 to 10 fronds are pruned per palm, depending on the localities of the palm. In Batinah coast, 4 to 6 fronds and in the interior and surrounding areas, 6 to 10 fronds are pruned per year. The frond count on a few felled palms indicated that there were 90 to 100 mature fronds pruned per year per palm depending on the severity of pruning and age of the palm when it was felled.
>
> The fronds are available for utilization in two forms, pruned fronds and felled fronds. The pruned fronds are obtained during the pruning of old fronds and the felled fronds during the replanting process when the old or unwanted palms are felled. To estimate the amount of fronds available annually, samples were taken from Nizwa and the average weight per frond was calculated on an oven-dry weight basis. The calculated figures were then used to estimate the availability of fronds. On average, about 75,000 tons of frond biomass are available yearly, of which about 80% is obtained as pruned fronds and the remainder as felled fronds during the replanting process. It is also estimated that out of the 75,000 tons available annually, 62% is in the form of petiole and

rachis. The remaining 30% is in the form of leaflets consisting of lamina and midribs.

C. Empty bunches

The estimate of the availability of empty bunches from date-palms is based on samples obtained from Nizwa and the estimated production of dates annually. The estimated annual availability of empty fruit bunches is calculated to be in the range of 2,200 to 3,000 tonnes with an average of 2,600 tonnes. It is expected that with improved agronomic practices the amount of available empty bunches will increase following an increase in yield of date fruits.[77]

The Government of His Majesty recognized the existence of all conditions that favour recycling date-palm by-products and embarked upon research projects aimed not at seeing whether recycling is possible but at finding out the best and most profitable ways of recycling these by-products. The Ministry of Agriculture, which is in charge of these research activities, established two projects, one dealing with the processing of date-palm lignocellulosic by-products into wood-based industrial products and the other with evaluating the feeding value of date-palm by-products (leaves and pits) supplemented with sardines in a pelleted diet for growing goats.

Processing wood-based products from date-palm by-products

The results of both of the above-mentioned projects are encouraging. With respect to the processing of wood-based products from date-palm by-products, Mohammad bin Husin researched the physical, mechanical and dimensional stability properties of date-palm by-products:

77 Mohammad bin Husin, *Availability, Properties and Processing of Date-Palm Lignocellulosic By-products into Wood-based Industrial Products* (Muscat: Ministry of Agriculture and Fisheries, 1991), pp. 2-4.

Based on the physical, mechanical and dimensional stability properties discussed above, it appears that date-palm woods have similar characteristic trends as those of oil-palm wood, although the absolute values of some of the properties differ. Also there was a wider range in data values in the date-palm wood as compared to oil-palm wood. These may be due to the variation in the date-palm variety, which is not accounted for in this experiment.

From the information obtained thus far and the experience in the processing of oil-palm wood, wood-based products are expected to be technically possible for processing from date-palm by-products. However, based on the needs of the country as depicted from the data on import of wood-based products discussed earlier, the following strategies are recommended. It is hoped that maximum benefit can be obtained from the optimal use of the by-products.

If a systematic replanting programme is adopted, the date-palm trunk can be utilized as raw material for the manufacture of blockboard. . . . The main purpose is to substitute for the demand for plywood, fibreboard and veneer. Blockboard can also be used for knock-down furniture for export or for local consumption. The frond, rachis, empty fruit bunches and wastes from the trunk from the manufacture of blockboard can be chipped and used as raw materials for the manufacture of moulded particle board as furniture or furniture parts or any moulded products for other purposes. . . . The parenchyma cells which are produced from the chipping of the by-products in large quantity should be collected and together with the frond leaflets may be ground and used in animal feed formulation. All of the above products . . . have been successfully tested at industrial level using oil-palm by-products as raw materials. Since many of the properties of date-palm in general are similar to oil-palm, such a strategy will have a good chance of being successful.

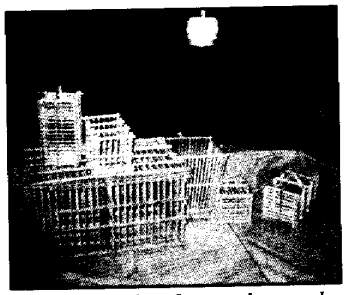
> The products proposed above are not without limitation. Block-board manufactured from date-palm, as reflected from the physical and mechanical properties of the wood, may not be suitable for load-bearing applications if it is to be manufactured in accordance with generally acceptable standards such as the British Standard (BS) or Malaysian Standard (SIRIM). This kind of product is most suitable for wall panelling, partitioning or furniture manufacturing as it is light and uniform with good workability. The dimensional stability can be improved if a thicker laminating veneer or waterproof adhesive such as phenol formaldehyde is used with a small addition of wax. For sintering purposes, the blockboard needs to be manufactured thicker than standard board, and cross-laminated with a thicker veneer. The surface of the blockboard in touch with cement can preferably be coated with phenolic film so that the board can be used over and over again before ending its service life.[78]

It is worth mentioning here that the processing of date-palm by-products into wood-based industrial products has great economic significance in terms of import substitution, promotion of industrial development and creation of employment and entrepreneurial opportunities, as Husin shows:

> The average value of wood-based products imported into the Sultanate of Oman based on the years 1987 to 1989 is RO 21.3 million weighing about 84,300 tons per year. . . . The biggest consumption is wood furniture followed by panel products. . . . Various type[s] of wooden furniture [are] imported into the Sultanate of Oman. . . . The import of wooden furniture on the average was RO 8.72 million or 40.10% of the total value of wood-based products imported, although the amount of material was only 22.24% of the total volume. This value also represents about 60% of the value of the total amount of furniture (including metal, plastic and others) imported into the country. This indicated

[78] Husin, op. cit., pp. 6-7.

> the preference of the local consumer for wooden furniture as compared to furniture from other materials such as metal, plastic, etc.
>
> As mentioned earlier, the import of panel products came second in terms of monetary value. Volume-wise it was one of the highest, consisting of over 37% of the total wood products consumed within the particular period of time. . . . The average consumption for the period in question was 28,800 tons per annum valued at RO 5.8 million. The import of various kinds of plywood appears to be the highest compared to other panel products. The average consumption was 26,000 tons per year or 90% of the total panel products. The increase in consumption of fibreboard and veneer may indicate that they are used as a substitute for plywood in applications where strength properties are not essential. This was done probably to reduce cost, as plywood is more expensive than any other wood-based panel product available in the market today.



Cages made from date-palm branches

The imports of paper and paper products in the Sultanate of Oman for the years 1987 to 1989 were valued at RO 13.68 million, 15.89 million and 16.25 million, respectively. In terms of weight, the amount was 20,300, 24,300 and 29,400 tons, respectively. The highest amount of paper products used is sanitary-type paper products. Sanitary paper products include facial tissue, napkins and towels. The demand for these products was rather steady. However, the manufacturing of pulp and paper requires an extremely high capital investment and a large amount of fresh

water. The intensive and large amount of chemicals used also results in heavy pollution discharge to the environment.[79]

Processing date-palm by-products into feed

Regarding the nutrition value of date-palm leaves and pits supplemented with sardines for animals, M.G. el-Hag, who has conducted valuable research on this issue, writes the following:

> The shortage in animal feeds in the Sultanate and the dependence on imported costly concentrate feed ingredients dictated a continuous search for locally available and cheap animal foodstuffs. The strategy for local production of animal feeds will depend largely on either horizontal expansion and an increase in cultivation and production of irrigated forages, or promoting the use and exploitation of the existing cheap and potential agro-industrial by-products in the Sultanate, in addition to the current full use of the dwindling natural pasture and range resource. Due to the shortage in underground water, drought conditions and low soil fertility, horizontal expansion in the production of irrigated forages seems to be very expensive, impracticable and less feasible. Thus the only remaining cheap and logical alternative for decreasing the gap in animal feed shortage is to promote utilization of the existing potential for agro-industrial by-products in the Sultanate.
>
> Date production and fisheries are the most important sectors of agriculture in the Sultanate and they both contribute significantly to the gross national income.
>
> By-products of dates (leaves and pits) and sardines are the most available potential animal foodstuffs in the Sultanate. Accordingly we considered date by-products to be evaluated as ruminant feeds in this study.

[79] Husin, op. cit., pp. 4-5.

> Laboratory analysis . . . indicated that the nutrient composition of date by-products is superior to Rhodes grass hay except for the relatively low CP content. Sardine was thought of as a locally available and cheap protein-mineral supplement to be used with the date by-products.
>
> The results obtained in this study clearly demonstrated the potential of date by-products when supplemented with sardines as a replacement for the conventional roughage component in whole-pelleted growing and finishing ruminant diets in the Sultanate. This was supported by the higher rate of average daily gain, higher intake of DM, superior feed conversion efficiency and nutritive value for the (DBP - fish) test diet as compared with the control diet. DM-intake was increased by 14.4% for the test diet in this study. Increase in DM-intake was shown to decrease DM-digestibility; Riewe and Lippke (1969) reported that a 1% increase in intake per 100 kg of body weight lowered the apparent digestibility of DM by 1.0% to 6.5% depending on the quality of the forage. The decrease in DM-digestibility, observed in this study, for the test diet could be explained by the increase in the intakes of those fractions. The digestibility of the crude fibre fraction (CF), cell wall content (NDF), cellulose and hemicellulose was substantially improved in the test diet.
>
> Fish meals were reported to have an enhanced nutritional value because of their content of growth factors known collectively as Animal Protein Factor (APF) (McDonald et al., 1981). Nitrogen supplementation of low quality roughages was reported to have a stimulatory effect on the cellulolytic microflora of the rumen with a resultant increase in the rate of passage of feed residues along the intestinal tract (Campling et al., 1962; Campling and Murdoch, 1966). The improvement in DM-intake and digestibility of the crude fibre fraction observed in this study for the test diet was in agreement with the findings of Campling et al. (1962) and Campling and Murdoch (1966).

The apparent partial degradation of lignin observed in this study was likely an artifact of differential analytical characteristics of feed versus faecal "lignin." The results obtained in this study for lignin degradation were in agreement with the results obtained by Brown and Johnson (1985) for wheat straw diets using goats and sheep.

Date leaves used in this study were obtained free of charge and are not yet known as a marketable animal feed in the Sultanate, the price charged for date pits was nominal, and sardines are locally available and relatively cheap as a rich protein supplement. The price of the (DBP-fish) test diet was expected to be at least 30% cheaper than the control commercial concentrate diet. Furthermore the improved feed conversion efficiency coupled with the excellent growth rate obtained with the test diet substantially reduced the feeding expenses of kids fed on the (DBP-fish) test diet.

The data obtained from this study add to previously published data showing that many by-product foodstuffs have potential for extensive use in ruminant diets if cost and availability make them economical.[80]

In addition to the above-mentioned, date-palm by-products can be processed to make compost or charcoal. Although these two possibilities have not yet been systematically researched, our awareness of available practices which were common in the past suggests that they are practicable. In the past, the composting of date-palm leaves and fronds was practised on farms. In addition to this, leaves and fronds which were not collected but left on the farm slowly decomposed and went into the earth as useful compost.

[80] M.G. el-Hag, "Evaluation of the Feeding Value of Date-Palm By-products (Leaves and Pits) Supplemented with Fish Sardines in a Pelleted Diet for Growing Goats," (Muscat: Ministry of Agriculture and Fisheries, 1991), pp. 6-8.

Composting date-palm by-products

The composting of date-palm by-products can be introduced on a large-scale industrial basis using modern plants, or plants based on intermediate technology. Small-scale production on individual farms is also possible; this requires little technology and only some basic knowledge that can be easily acquired. Literacy is helpful, but it is also possible to transfer this knowledge to illiterate people through practical demonstration.

Composing agricultural waste in Salalah. The composted waste consists mainly of banana-tree waste.

Date-palm leaves, fronds and bunches can be composted on a small-scale basis in the same manner in which coconut leaves and fronds, banana leaves and bunches, etc., are composted in Salalah on some farms. The process takes place in two underground pits 2 metres deep with cement floors and walls.

The raw material is kept in the first pit for about 45 days. Some ammonium sulphate is added to it to accelerate the composting process. Water is sprayed on the material to give it the necessary moisture. The material is occasionally turned, so that the surface layers are buried inside and those inside are brought to the surface. This is done because the inside temperature is higher, and accordingly the material here decomposes quicker than in the outside layers. Turning the materials enables all constituents to reach decomposition maturity at the same time.

After 45 days the material is moved to the second pit where it stays for another 45 days at which point the compost is mature. Further information and data about this aerobic composting method is not available. However, some farmers confirmed that the quality of the

compost is not inferior to manure and fertilizer imported from outside. The problem that farmers complained of was that they could only compost leaves and other small pieces of material. This problem can be overcome by shredding the big pieces. Small, moveable shredders are available on the world market at reasonable prices.

Application of the Salahah system to date-palm by-products should follow in an innovative way that introduces improvements into the system, which should include composting of kitchen waste and other vegetable and fruit wastes. In this way it will be possible to avoid the landfill disposal of organic material in household waste.

In the large cities and towns of the country (Muscat, Salalah, Nizwa, Sur, etc.) it may be better to use large processing plants that process date-palm by-products along with organic household waste. Here the compost could replace the soil conditioner (manure) and fertilizer which the municipalities import in large quantities for city greening activities. In Muscat it seems that the Governorate will be able to utilize at least the greater part of the compost, as shown by the information in **table 5**.

Furthermore, in many of the big cities in the world, STP sludge and household compost are the principal organic manures used for the maintenance of municipal gardens. Utilizing these two items in Muscat could result in good savings in foreign exchange. Some precautions should, however, be kept in mind: the STP sludge used should be dry, free of foul smell and lead-free, and there should be some arrangement for properly decomposing the household compost properly, before it can be used; otherwise it creates weed infestation in the gardens.

In either a large- or small-scale processing plant, the decomposition of organic waste to compost will remain a natural process that can be either anaerobic or aerobic. In case of anaerobic composting, the process is brought about by anaerobic bacteria which perform their work in the absence of oxygen. For the aerobic method, the decomposition process is carried out by aerobic bacteria, which require oxygen. Flintoff writes:

Table 5. Organic manure purchased during 1990 and 1991 by Muscat Municipality

		Number of bags	RO
1990			
1.	Peat moss, 300 l/bag	3,200	6,500
2.	Oil cake, 50 kg/bag	1,300	4,000
3.	Oman organic, 25 kg/bag	13,000	1,000
4.	Potting compost, 80 l/bag	1,300	4,000
1991			
1.	Peat moss, 300 l/bag	7,720	8,000
2.	Oil cake, 50 kg/bag	2,700	4,000
3.	Oman organic, 25 kg/bag	25,000	1,000
4.	Potting compost, 80 l/bag	6,000	4,000

Source: Landscaping and Public Parks Department of Muscat Municipality.

Two alternative natural processes are available as bases for composting plants. The main characteristics of anaerobic composting are:

1. The process is a lengthy one, extending over a period of 4 to 12 months.

2. It is a low-temperature process and the destruction of pathogens is accomplished by their exposure to an unfavourable environment over a long period.

3. The gaseous products of reduction are methane, hydrogen sulphide and other gases with offensive odours.

The main use of anaerobic composting has been in India, where for many years it has provided, usually on a small scale, a cheap solution to the combined disposal of solid wastes and nightsoil. These materials are placed in alternate layers in small trenches which are sealed and left undisturbed for many months; the contents are then dug out and used as compost. This, the Bangalore system, is now being abandoned in favour of aerobic methods because of the very large land area required owing to the long retention period. In other respects, however, it is a low-cost system, as the amount of material handling required is much less than for aerobic methods.

Aerobic composting is characterized by:

1. Rapid decomposition, normally completed within two to four weeks.

2. During this period high temperatures are attained which achieve speedy destruction of pathogens, insect eggs, and weed seeds.

3. So long as aerobic conditions are maintained, no offensive odours are produced.

All current composting systems aim to maintain aerobic conditions throughout the process. Many types of organisms assist bacteria,

which predominate at all stages; fungi, which often appear after the first week; and actinomycetes which assist during the final stages.

The process begins at ambient temperature by the activity of mesophilic bacteria, which oxidize carbon to CO^2, thus liberating large amounts of heat. Usually the temperature of the wastes reaches 45 degrees centigrade within two days, and this represents the limit of temperature tolerance of the mesophilic organisms. At this point the process is taken over by thermophilic bacteria and the temperature continues to rise. Most of the thermophilic phase, which lasts about two weeks, takes place in the temperature range 55 to 70 degrees centigrade; should the temperature increase beyond 70 degrees activity temporarily declines. This process is dependent, of course, on the provision of a suitable environment for the bacteria; in addition to the nutrients provided by the wastes the main requirements are adequate supplies of air and moisture.

Moisture content is a critical factor in aerobic composting; for the type of wastes now being considered the following are the main requirements:

1. If water content falls below 40% the speed of the process declines.

2. If it falls below about 20% decomposition ceases.

3. If it exceeds 55% water begins to fill the interstices between the particles of waste, reducing intersticial oxygen and causing anaerobic conditions; this results in a rapid fall in temperature and the production of offensive odours.

Indian wastes of the types given earlier probably fall within the optimum range of initial moisture content and are unlikely to require the addition of moisture during the first few days. During the thermophilic stage, however, the high temperature causes rapid loss of water and this must be replaced from time to time until the

final fall in temperature. At this point it is desirable to allow the moisture content to decline to 25% in order to minimize the weight of material to be transported to the farm.

Should the moisture content accidentally exceed the maximum required level, for example, as a result of continuous heavy rain on exposed waste, it is necessary to provide conditions under which the excess moisture will evaporate rapidly, and to aerate the wastes more frequently. This can be achieved by more frequent turning.

In general, it would appear that the use of sludge in Indian composting is unlikely to confer any measurable advantage, and may give rise to some undesirable consequences.

Although a vast amount of research has been carried out to determine the quantity of air required by decomposing solid wastes, little of practical value has emerged. It has been demonstrated that oxygen demand is greatest at the beginning and declines as the process nears completion, and that an increase in moisture content imposes a need for more oxygen. But attempts to quantify oxygen requirements have provided such diverse results as to suggest that there is a wide range of oxygen need depending upon such factors as the detailed composition of the wastes and the average particle size.

Thus in most composting plants it is necessary to rely upon the experience of the operator, rather than any form of scientific monitoring, to determine the adequacy of aeration. Perhaps it is fortunate that the onset of anaerobic conditions is immediately signalled by offensive odour; should they appear remedial action is seldom difficult.[81]

Not only composting but the use of date-palm by-products as fuel was common in the past, to the extent that dependency upon them as fuel was

[81] Flintoff, op. cit., pp. 151-152.

exclusive or almost exclusive in the rural areas of the country and even in some urban centres. Processing date-palm by-products, especially trunks, into charcoal was practised to some extent on a commercial basis. It is reported that in some remote rural areas this practice still exists: some people prefer cooking with this kind of charcoal, saying that it gives the food a better taste.

Although the predominant cooking fuel used at present is natural gas, followed by electricity, the use of charcoal has not completely disappeared. On the contrary, it is experiencing a certain degree of revival in urban centres, where it is used for barbecuing as well as for burning incense (*bukhur*) and sweet-smelling pieces of wood (*'uud*). In addition to this, there are people who occasionally cook with charcoal that is now imported from abroad, especially from the USA. In Muscat the Oman Coal Establishment became aware of the possibility of processing woody waste, including agricultural waste, into charcoal and has already made all necessary arrangements to establish a small plant that should start working soon. However, detailed information is not available about this plant or about charcoal consumption in the country.

Although processing date-palm by-products into charcoal is possible in principle and could be profitable, its introduction as an effective instance of waste-recycling requires research on the properties of the material to be charred and on suitable technology; it also requires a feasibility study that looks at economic profitability.

Development strategy

The information now available about date-palm by-products is far from adequate for purposes of designing a concrete development strategy with respect to their recycling in the four above-mentioned ways. Yet availability of the material and the possibility of recycling it in these ways—as well as the country's development needs regarding import substitution, the promotion of economic development and the creation of jobs—justify thinking about a comprehensive development strategy for

recycling date-palm waste. The points upon which this strategy should be based include the following:

1. General survey and data collection regarding the availability of date-palm by-products. Factors that should be taken into consideration here include:

- The effect of seasonal change upon the availability of the material.
- The effect of rehabilitation (replacement and replanting) of date-palms on the availability of the material.

2. Studying which sectors of the Omani market could absorb the products made by recycling date-palm waste.

3. Studying markets in other Gulf States that could accommodate the products made from recycled date-palm waste.

4. Incorporating the recycling of date-palm waste into the overall planning of date-palm plantation development. Here it should be appreciated that successful implementation of the plan would not only increase production but would also generate renewable natural resources which could support various wood-based and some agro-based industries for the Sultanate of Oman, very similar to forestry land in other countries.

5. Choice of appropriate technology and production methods. Composting and recycling technology should be carefully adapted to the material they process, as well as to the local climatic and socio-cultural conditions. Available technological alternatives include higher technology, intermediate technology and traditional technology.

6. Geographical distribution of date-palm plantations. This should not only take into consideration regional and subregional divisions but also

differences in the size of the plantations, distances between them, accessibility to the plantation sites and closeness to the main roads.

7. Establishment in the Ministry of Agriculture of a research unit which deals with the recycling of agricultural waste.

8. Choosing the appropriate size for the production units. This choice also includes considering whether the production should be centralized or decentralized. Centralization favours large-scale production. This choice is influenced by different considerations including:

(a) Transport costs: Transport of the material, which is characterized by great bulk, is one of the most expensive operations involved, and all possible steps should be undertaken to minimize transport costs and accordingly overall costs. They may include reducing the distance that the waste has to be transported by establishing the production unit (plant) near the place where the waste emerges, compacting the material as far as possible (thereby allowing maximum loading of vehicles), and use of animal-drawn transport if this is cheaper than motor-driven vehicles.

(b) Use of return loads: "Return loads are those put on a vehicle that is returning empty from delivering another load. It has to make the return journey so the extra cost of carrying a load is less than the cost of a special journey. The skill is to find a vehicle or fleet of vehicles that make regular empty return journeys and negotiate with the operator on this basis."[82]

(c) Nature of the production unit: Processing wood-based products from date-palm by-products can take place economically and profitably in relatively large industrial plants. These plants often have to be established in urban centres that are far from the rural areas where most of the date-palm by-products emerge, as all the infrastructures that support industrial production are concentrated in the urban centres. This

82 Vogler, op. cit., p. 317.

means that the industrial processing of date-palm by-products requires relatively long transport of the raw materials which raises the transport costs. However, this can be compensated for by the relatively high price of the wood produced.

The situation is different with respect to compost. Production can take place on a small-scale basis and even at the level of individual farms. There are no technological or other constraints that hinder small-scale production. Production on a large-scale basis encounters some constraints if the plant is far from the place where the waste emerges and the raw material has to be transported a relatively long distance; in this case, transport costs will be higher in relation to the value of the raw material. The low price of the compost cannot compensate for the high cost of the transport of raw material. A second constraint arises from the transport costs of the compost. Compost is bulky, and if it has to be transported a relatively long distance, the price rises and it may not find a market. Small-scale production at the farm or village level makes it unnecessary to transport either the raw material or the compost long distances from a large-scale plant to the village or farm where it is consumed. This minimizes costs and makes the enterprise more economical.

However, in the cities of Oman with date-palm plantations, there are considerations that justify large-scale composting. Here, the large amounts of organic domestic wastes should be composted instead of being disposed of by landfilling or burning, which cause environmental pollution.

Such household waste is not delivered as pure organic waste. It is mixed with inorganic materials that have to be removed by sorting. Sorting, however, cannot be perfect, and inorganic materials will always remain, even in mainly organic waste, reducing the quality of the compost to a relatively low level, depending on the quantity of the remaining inorganic materials.

Composting agricultural (i.e., pure organic) waste together with domestic waste reduces the percentage of inorganic waste in the material to be

composted. This makes for a high-quality compost. If, as we recommend, the Municipality uses the compost in its city greening activities, the problem of high transport costs does not arise. The transport of compost then simply replaces the transport of the manure which the various Omani municipalities use at present in their city greening activities.

Processing date-palm waste into fodder can take place on a small scale as well as a large scale. Small-scale production may be practised by farmers who rear considerable numbers of animals or by farmers whose farms are situated in areas where livestock are bred as an economic activity. Large-scale commercial production can also be justified. At present the Sultanate imports feed, but locally-produced animal feed could replace the lucrative fodder import business. Export of the feed to other Gulf States may also be possible.

Small-scale charring of date-palm waste is possible at the farm or village level, using traditional charring technology. However, this cannot produce the type and quality of charcoal that is demanded by urban consumers. In general the charcoal pieces produced in this way are not of a high, even quality because some have a heavy density and provide a high degree of heat for a long period, while others may have a very low density and burn into ash after only a short time. Other pieces are not properly charred, being half raw material and half charcoal, which makes them produce clouds of smoke.

Thus, the charring of date-palm waste should take place in a modern plant that is able to char the whole material properly and form the charcoal into small equal-size balls like those now imported in 2.5 kilogram bags. Such charcoal may be produced not only to satisfy local needs but also for export.

Recycling coconut palm and other agricultural by-products

Besides coconut palm by-products, other agricultural by-products that could be recycled include those of banana, mango and papaya plantations. These by-products play an important role only in the Dhofar region. Coconuts are cultivated almost exclusively in the coastal area of Salalah, where there are about 140,000 coconut trees.

The Sultanate's production of bananas, mangoes and papayas is also very largely concentrated in this coastal area, which covers 12,000 hectares. Bananas, which are the second most important agricultural product in Dhofar Governorate after coconuts, are cultivated in an area of 750 feddans, each feddan accommodating 500 trees. Data about papaya and mango cultivation are not available. Small-scale cultivation of these plants is, however, widespread throughout Salalah. In the last ten years, the cultivation of vegetables and other fruits has expanded. The fact that the production of agricultural waste in Dhofar is mainly concentrated in Salalah, whose area amounts to only 12,000 hectares, deserves special attention. On the one hand, it means that agricultural waste is available in the area, and on the other that the availability of great quantities of recyclable agricultural by-products within a relatively small area makes collection and transportation much easier and cheaper.

At present, agricultural waste is causing a headache in Salalah; for most of the year plantations and farms become congested with such waste, which is disposed of mainly by open-air burning within the farms and plantations. This causes air pollution as well as fire hazards. Only a small proportion of such waste is collected by the Municipality and hauled to the landfill site for disposal.

The importance of recycling agricultural waste has been recognized, but no concrete steps have yet been taken to achieve this. Available data about the issue is very limited, but nevertheless can be used when considering the possibilities and limitations of recycling agricultural waste in Salalah.

Coconut palm by-products

Coconut palm by-products consist of trunks, fronds and leaves, as well as the shell of the coconut fruit. The shell consists of a hard round cover which contains the edible parts (coconut meat and coconut milk). The hard cover is embedded in rough layers of thick fibre (coir) that ends with a smooth and very thin outer surface. The fresh fruit with all its contents weighs about 3.5 kilograms. After removing and consuming the edible part, the shell (which is considered waste) weighs 3 kilograms when fresh (wet), but when dried the weight is reduced to only 0.5 kilograms. This means that about five sixths of the shell's weight consists of water contained in the layers of fibre.[83]

Each tree annually produces 80-100 fruits. This means that the 140,000 coconut trees in Salalah produce annually between 11,200,000 and 14,000,000 fruits.[84] After their edible parts are consumed, these fruits leave behind agricultural waste, the total weight of which is between 33,600,000 and 42,000,000 kilograms (33,600 to 42,000 tons). When dry, this is reduced to one sixth of the original weight (the waste decreases to only 5,600 to 7,000 tons). However, the size of this waste is barely reduced; when the shell becomes dry the fibrous layers (coir), which consist of relatively long fibres, become loosened and can easily be worked loose and removed with the hand. They can be processed into cord, and in fact this was done in the past in Salalah using very simple methods. The coconut husk was put into water for some time, which enabled the fibres to be disconnected and made them tender and flexible. The disconnected fibres were dried once again and interwoven by hand into strong, long cords of different thicknesses. However, this handicraft

[83] This information is based upon research which the author carried out in June 1992 in Salalah. A sample size of 185 coconuts from different sites were weighed while they were full, empty, wet, and finally after they were dry.

[84] Information provided by the Agricultural Department of the Ministry of Agriculture and Fisheries, 1992.

disappeared in the last two decades and today the country imports cords similar to the ones earlier produced locally.

Revival of the past methods to produce cords from coir seems to be impossible. However, it would be possible to establish a small factory that produces such cords; suitable, tested technology that could be imported to achieve this goal exists in India, Pakistan and other Asian countries. The technology is simple and labour-intensive. Not only the technology but also skilled workers who are well-versed in this technology could be recruited from India or other Asian countries if necessary.

Trunks emerge as waste when old trees are cut down. According to the Ministry of Agriculture and Fisheries replanting and rehabilitation plan for coconut plantations, each year 5% of the existing trees should be replanted and rehabilitated, besides expanding the cultivation of coconut plants. The replanting programme will result in cutting down about 7,000 trees every year. Assuming that each trunk weighs 100 to 120 kilograms, the total weight of the 7,000 trunks would be 700,000 to 840,000 kilograms, or 700 to 840 tons.

The trunks and fronds have the same properties as their counterparts from date-palm plantations. Accordingly, they can be recycled to produce wood-based products, as well as charcoal. The fronds can be processed into fodder or can be composted. While processing the by-products into wood-based products or into charcoal requires the establishment of relatively large-scale or medium-scale plants, composting can be done either on a small-scale basis at the farm/village level, or at the municipal level.

Composting the by-products

The leaves of the coconut palm fall in great quantities all year round and cause the greatest problem to the plantation owners, especially in the rainy season when they become wet and slippery. Their collection and transport to the landfill site requires a great deal of work. They are thus

disposed of by burning them together with other coconut plantation waste such as trunks and shells. Composting, which is already practised on a very negligible scale, is an environmentally sound and economically profitable alternative to unsanitary burning or disposal. It can be carried out on a small or large scale.

In the latter case, the composting is done in a plant which can be large-scale or medium-scale depending upon the quantity to be composted. The advantages of small-scale composting at the farm level are that both raw material and transport costs can be avoided because the compost is consumed in the place where it is produced. In addition, it enables the agricultural waste to be effectively reintegrated into the production process.

Large-scale or medium-scale composting at the city level requires transport of the raw material as well as of the compost, increasing the production costs. However, here too we have some advantages, in that coconut plantation waste can be composted with household waste as well as with waste from banana, mango and papaya plantations, which are suited more to composting than coconut plantation waste, which has less moisture and is more fibrous.

This composting at the city level compensates for the disadvantages of some materials with the advantages of their counterparts. Since Muscat Municipality has embarked upon large-scale city greening, it could be the main consumer of the compost that is produced in large-scale plants, as is the case in the United Arab Emirates.

Banana, mango and papaya plantation by-products

It is worth mentioning that by-products from banana, papaya and mango plantations can also be composted at the farm level.

Here, banana by-products deserve special attention. About 375,000 banana trees have been planted. Each tree has annual by-products

weighing about 30 to 40 kilograms,[85] which consist of trunk, leaves and branches. In general, these by-products have a high moisture content. Even the trunk—which in date and coconut palms is a solid block—is, in the case of bananas trees, tender; it contains a large amount of moisture and can easily be shredded.

In general the prevailing conditions in Salalah are conducive to composting agricultural by-products. Such by-products are available in large quantities. The area within which the by-products are generated is not very large, and thus the transport costs of the material cannot be very high. Salalah is an agro city that is experiencing considerable agricultural development in terms of expansion of the area cultivated. The small-farm area expanded from 1,400 to almost 1,700 hectares between 1985 and 1990, but further expansion within Salalah is restricted by the demand for housing and other urban land. The Salalah structure plan (1983) and the subregional land use plans (WSAI, 1990) proposed a possible reduction of about 300 hectares in the agricultural area and their conversion to urban uses. See also Dames & Moore (Water and wastewater) Master Plan for Salalah, Basis of Planning Report (1991). In addition to this, a wide-ranging city greening is going on. This means that the city's need for compost is high and growing steadily. And yet the Municipality, although it has the facilities for composting, is not practising it! As a soil conditioner, compost would enable marginal land suffering from organic deficiency to be brought into cultivation. Such areas are quite common in Oman, where the hot sunshine tends to destroy the organic content of the soil. Furthermore, other climatic influences endanger the soil in hot areas more than in temperate zones. The irregular but very heavy rain of semi-arid climatic zones like Dhofar or any other place in Oman leads to severe water erosion which carries away the humus layer of the soil. The use of compost considerably decelerates this process: organic material enhances water permeability, which redoubles due to an increase in soil porosity, enabling the soil to absorb great quantities of water; this reduces both the outward flow of surface water and water erosion.

[85] Information provided by the Agricultural Directorate of the Ministry of Agriculture and Fisheries, 1992.

Not only does water erosion drag away the fine portion of the soil, but loss of nutrients is also high. Here, too, the use of compost can limit the process. In addition, if composting is operated successfully, it enables the following highly desirable results to be achieved.

1. Conservation of resources by recycling.

2. Support for nature's cycle by returning to the earth organic household waste and agricultural by-products.

3. Reduction of the landfill space requirement.

Utilization of dung

Availability of dung

The use of dung as a fertilizer and soil conditioner is practised all over the world, especially in third-world countries. In Dhofar too this practice is widely known; the region today exports great quantities of dung to the other regions of Oman. To understand the utilization and commercialization of dung we first highlight livestock breeding and its economic importance in Dhofar.

Cattle—apart from the few thousand maintained on the coastal plain, which benefit from the use of irrigated fodder—are confined to the grassy plateaux of Jabal al-Qara and Jabal al-Qamr. Some stockbreeders on both jabals also keep camels and goats. Camels and goats traditionally browse on shrubs, which are more predominant on the periphery of the jabals. Both on the Salalah plain and on the Nejd, camels and goats are maintained on the desert scrub under pastoral nomadic systems.

Although all types of animal dung are suitable for use as soil conditioners and fertilizers, the practice is limited to cattle dung, the commercialization of which has started to provide additional income to the livestock breeders. Data about the extent of the present animal dung commercialization are not available. However, the development seems to

be limited and could probably be further promoted. Dung is available in considerable quantities, and the need for it as a soil conditioner and manure is great in all parts of the country. The fact that cattle breeding is concentrated in the jabal zones within an area of 2,000 square kilometres is a factor that makes the collection of the dung easier.

Production of dung depends upon the number of the cattle and the quantity of droppings that each animal produces daily; it also depends upon the quantity of food eaten by the animal. In the past, as the animals depended almost solely on pasture, the fodder available to them varied considerably from season to season. In the *khareef* (monsoon) season of July-September the jabals in general enjoy considerable rainfall. In addition heavy clouds, which in this season constantly cover the sky, create conditions resembling those in a tropical rain forest, i.e., high humidity, low light levels and temperatures in the upper 20 degree centigrade range. Evaporation rates are of course reduced, lowering irrigation requirements.

These climatic conditions make the pasture in the jabals rich, and give the animals good grazing possibilities. They eat great quantities of soft pasture and their droppings increase. In the dry season, the available pasture is limited and their droppings decrease. In the past this had a considerable effect on the growth and productivity of the animals. They lost weight and the quantity of milk and droppings they produced decreased. If the dry season took on the dimensions of a drought, many animals died and the majority of the others became more of a burden than a useful asset.

However, since 1970 dependency upon pasture has declined. This occurred due to the deterioration of the rangeland as well as to the fact that the livestock breeders, for reasons of economy, feed their animals imported fodder and other nutrients with dried sardines. The rich fish stocks of the Omani coasts and especially those of Dhofar, combined with the decline of rangeland productivity, give special importance to the use of sardines for feeding animals; on the one hand, it compensates for the shortage caused by the decline of rangeland productivity and, on the

other, enables utilization of the surplus production of fish, which was previously disposed of in crude dumping areas.

In the last ten years, the dependency upon imported fodder and other nutrients for animals has increased a great deal. This limited the movement of the animals, which no longer needed to find grazing in relatively far-away areas. Furthermore, cattle breeders, who were now able to feed their animals other than by moving around with their cattle in search of pasture, became to a great extent sedentary cattle breeders, and this led to overgrazing of the pasture areas around the settlements. Feeding the animals with other food did not mean that the practice of grazing withered away entirely, but only that dependency upon it declined and that the distances which the animals needed to travel for grazing were reduced.

These developments have had the following effects:

1. The areas in which the cattle droppings fall have become smaller due to the reduction of the grazing areas.

2. The variation in the quantity of droppings which each animal produces daily in the different seasons has become insignificant since the decline in the grazing possibility for the animals is now compensated for by supplementary animal feed. The percentage of feed in the animals' diet has increased to the extent that in the semi-urban areas of the jabals and in Salalah, what used to be supplementary food has now become the main food.[86]

According to present estimations, each animal produces daily about 2 to 3 kilograms of dung. The production occurs 2 to 3 times per day. In the *khareef* season the animals may defecate 4 times daily, and produce a greater quantity. In addition, in the *khareef* season the dung is better than in the dry season when the direct and indirect water intake of the animals is less. Half of the droppings fall on the rangeland where the

[86] Observations made during field studies in June and October 1992.

animals are grazing. Thus the other half falls during the period when the animals are in their pens. This can cause serious health and environmental problems. The muddy dung that is mixed with urine and trampled by the animals is a breeding ground for flies, mosquitoes and other harmful insects. Many cattle breeders collect the dung that falls in the pens, and dry and sell it. However, a great proportion of the dung is not so used but is disposed of in crude dumping areas.

This dumping occurs because, although demand exists, the marketing facilities (especially transport and storage) are limited. What is needed at this time is the development of a fully fledged business system for the product, keeping in mind the potentially available quantity. There have been recent inquiries and proposals concerning the collection, transport, storage, processing and packaging of animal manure in a factory (industrial) plant.

The present situation is characterized by the fact that each animal produces almost the same quantity of dung daily. However, in the *khareef*, when the rangeland is in good condition and the animals consume more soft grass, the dung produced is wetter. This is advantageous if the dung is left in the rangeland where it supplies the soil with moisture and where it easily falls apart and is accordingly integrated into the soil. However, if the wetter droppings are produced in the pens this causes some inconvenience. Since the product is diluted by the urine of the animals and since the pens are unroofed, rain further dilutes the material so that it sometimes resembles porridge. If the material is meant for sale, it should be dried to reduce its moisture content to the required level, but if the material is to be used to fertilize the surrounding rangeland or a field near the settlement, the high moisture content may be advantageous because the dung also supplies the soil with water. However, the application of dung with a very high moisture content to the surrounding rangeland and fields near the settlements is very limited.

A rough estimate of the daily dung production can be calculated easily. If the number of cattle reared in Dhofar is 120,000 head and if each

animal produces 2 kg of dung daily, then there is a daily production of 240,000 kg or 24 tons. Half of this amount falls on open rangeland, fertilizing it, and the other half falls in the pens, where it can be collected and sold.

As already mentioned, the commercialization of dung exists today to some extent. Dung from Dhofar is sold in all regions of the Sultanate by middlemen who buy it from the cattle breeder. The price is 500 baisas for each bag containing 25 kg of dung. Thus, if the whole material were collected and sold, the cattle breeders would have an additional daily income of about RO 2400. From this amount would be deducted the cost of the bags, which is RO 7 per 100 bags (4800 bags would be needed, costing RO 336). Thus the net daily additional income would be RO 2064 and the additional annual income would amount to 2064 x 365, or RO 753,360. The middlemen sell each bag for RO 1 to 1.2, and their daily business volume would be RO 4800 to 5760. Annual volume would be 4800 to 5760 multiplied by 365, or RO 1,752,000 to 2,102,400.

The above-described possibility shows that the commercialization of dung could result in the emergence of a small-business sector that, besides generating income for the cattle breeders and middlemen, would create employment opportunities for a good number of people in the area of transport, storage and sale.

The following steps should be taken to promote this business:

1. A survey should be conducted regarding manure and fertilizer consumption in the Sultanate, taking into account the fact that the municipalities use great amounts of manure and fertilizer in their city greening activities.

2. A survey should be conducted on the production of droppings, taking into account the distribution of the production.

3. Suitable stores for the material should be built. At present the cattle dung intended for sale is heaped near pens and houses. The heaps attract flies and other insects, for which they become breeding grounds. Establishing a suitable store for every producer may be feasible, but it is better to establish a few central stores, whereby each store serves a group of adjacent settlements. This would not only provide a better storage system but would also reduce transport costs. At present the middleman collects the material from each settlement, or each settlement brings it to his central store in Salalah. Avoiding such collection and transport would certainly reduce the transport cost.

4. Storage and sales cooperatives should be established, with cattle breeders whose settlements are near each other and who live in the same grazing area forming a cooperative. The cooperative, which should have its own administration, would strengthen the bargaining position of the cattle breeders with the middlemen. If deemed necessary, the cooperative could even be used as an instrument to bypass the middlemen. To achieve this goal it is necessary that all cooperatives in the jabals establish an umbrella organization with headquarters and large storage facilities in Salalah. The individual cooperatives would supply the umbrella organization in Salalah with dung, and it would market the product.

An ideal development would be to expand the activities of the cooperative so that it collectively purchased supplementary animal feed as well as other materials for the livestock breeders. This kind of expansion of the activities of the umbrella organization would also minimize transport costs. The vehicles which the umbrella organization owned or rented would haul the purchases made through the organization to the Jabal and return to Salalah loaded with bags of dung.

Biogas production

Biogas production from dung is another promising possibility. Such production is widely practised in China, India, Pakistan and other south-east Asian countries. Production systems used here involve intermediate technology. The production process is based upon

fermentation. As is well known, in the presence of air, organic materials rot so as to produce heat and give off carbon dioxide and nitrogen, provided the C/N ratio is low enough. The rotting is caused by minute creatures called bacteria and the kind of bacteria that need plenty of air are called *aerobic*. If only limited quantities of air are present, different, *anaerobic* bacteria digest the material, as long as the temperature is high enough (above 28° centigrade) and the C/N ratio is not too high (preferably between 10 and 30, but never more than 35). Under these conditions, the rotting process gives off a mixture of about 35% carbon dioxide, a small amount of carbon monoxide (a poisonous, flammable gas) and 60-65% methane, a non-poisonous inflammable gas with the familiar smell of rotting vegetation. This mixture is called biogas and is a safe and useful fuel for cooking, heating and lighting the home.

Human and animal dung (faeces or excreta) diluted with water in a ratio of 1:1 or 1:2 has a low C/N ratio, and its availability determines whether a digester will be economic to operate. If a substantial quantity of dung is available, vegetable waste can be added, but lignocellulosic materials such as straw and wood wastes are not satisfactory. Any materials used should not be strongly acidic or basic (i.e., they should be approximately neutral or slightly alkaline). If they are, they must be "neutralized" by other materials to give a Ph of between 6.0 and 8.0. At the start, a biogas plant must be seeded with bacteria, either from fresh dung from a ruminant (e.g., a cow) or a sample of slurry from a working digester.[87] Jon Vogler writes:

> Two different types of digester have been widely used in the third world: the Indian and the Chinese. The important difference is that the Indian type uses a loose steel cap that floats up and down on the cushion of gas, maintaining a fairly constant pressure. The Chinese uses a fixed cap, constructed from reinforced concrete as part of the digester tank. The gas pressure is allowed to build up and a safety valve fitted in case it should rise too much. The Chinese design is quite a lot cheaper to build. However, it

[87] Vogler, op. cit., p. 210.

requires yearly opening for maintenance and cleaning. The Indian design runs continuously. There are many variations on this very basic design: single and double stage, batch and continuous, heated and unheated, agitated and non-agitated.[88]

In general, biogas is produced in small-scale plants with the aim of satisfying the fuel and energy needs of a rural family that often consists of 10 to 15 members. Plants of a larger size are rare, but their construction is feasible. Some experts even believe that relatively large biogas plants could cover the energy and fuel needs of small rural or urban communities and could be operated in an even better and more economical way, because the possibility of introducing technological improvements becomes greater.

In Dhofar, especially, in the jabals, where dung is available in abundance, the introduction of biogas production is generally possible. However, the low price of natural gas that is now used as fuel poses a hindrance to some extent. Despite this, there are strong reasons which justify the introduction of biogas production:

1. Biogas can be used to produce electricity that can be used for cooking, for raising water from wells, for lighting, and for operating machines. This means that biogas can supply workshops and small factories with the necessary electricity for their work.

2. Biogas production provides the people with skills that promote development in the area.

3. Biogas is a renewable resource which is more dependable in the long run than natural gas, which is a non-renewable resource.

4. Biogas production enables organic household waste to be disposed of in a productive way by adding it to the other material to be processed into biogas.

[88] Vogler, op. cit., p. 112.

5. An important benefit from the production of biogas is that the sludge which remains after consuming the biogas is a valuable compost that can be sold. The digestion that it undergoes kills any harmful bacteria that may be in the raw material. Thus, biogas production does not greatly affect the sale of dung as compost.

Finally, we would like to mention that in India and China the dung of at most five cows is used to produce a quantity of biogas that can supply a family of seven to ten people with cooking and lighting energy. In the Jabal, where the ratio between the human population and cattle population is 1:14, almost all families possess enough cattle to provide sufficient dung to produce biogas to cover all the energy and fuel needs of the family.

It would be possible to establish relatively large biogas plants in the urban and semi-urban centres of the Jabal that could provide them with a great proportion of their electric power needs.

These possibilities suggest that the Jabal has all the prerequisites to satisfy a great part of its energy needs through biogas production, that is, through an alternative energy source. This issue deserves serious consideration and study as well as the establishment of a research and administrative unit that would be responsible for developing a strategy for alternative energy use in the Jabal, and in Dhofar in general.

Other dung utilization methods

Besides being utilized in biogas production and as fertilizer and soil conditioner, dung can be recycled in other ways; however, these are of no importance for Oman. Dried dung is used as fuel for cooking in the rural areas of Egypt and Ethiopia and many other developing countries. In many African countries, the walls of the round rural huts that provide housing to the majority of the population are constructed of tree branches covered with a construction material consisting of dung mixed with slaked lime or sand. This use of dung as a construction material has a special protective and environmental importance. Huts built with dung are

cooler inside than a stone or concrete house. In addition to this, termites keep away from such a house. However, the disadvantage is that dung, which contains fibrous material, does not allow walls constructed with it to be highly compacted and thus impermeable. When rain falls the walls become wet and they can easily fall apart.

Conclusions

The agricultural and livestock sectors in Oman generate great quantities of by-products which are at present not utilized except in a very few and negligible cases. In general, they are considered as waste and pose environmental and health problems because they are disposed of in a crude and unsanitary way. Discussions at the municipal level concentrate on how this "waste" can best be disposed of in an economical way. Composting and recycling are not given any serious attention in these discussions. The two projects mentioned previously on recycling agricultural waste are unknown to the municipalities. They consider recycling purely in economic terms; their findings will be subordinated to an economic feasibility study. This means they will enter into a production phase only if such projects are judged to be profitable. Environmental protection through agricultural waste avoidance and through the introduction of agricultural by-products in the form of compost into the soil with the aim of improving its productivity are matters which are not given the attention they deserve.

What is missing here is not just coordination, but also the concept that would link economic activities (economic development) with environmental protection (environmental management), in the sense that economic activities would become factors that also contribute to environmental protection. Environmental protection could therefore be carried out in a way that promotes economic development. The introduction of such a concept is not a matter of choice but a must. In the case of agricultural waste recycling, the concept on which this activity is based should take the following into consideration:

1. In most cases it depends on man's viewpoint whether an item is waste or a useful by-product. Simply renaming an object can give it another identity.

Leftovers from agricultural production are understood by the municipalities as waste, the disposal of which is a problem, whereas conversely and very importantly, the two projects launched by the Ministry of Agriculture define them as by-products that have economic value.

Although it is correct to conceive of the leftovers as objects of economic value, this does not reflect the whole truth, because it ignores the fact that the leftovers are at present wastes, the disposal of which poses great economic and environmental problems. This second identity is as important as the first and any attempt to recycle agricultural by-products should take it into consideration, because the municipalities in Oman (as well as in all other Arab countries) are professionally socialized in a way that causes them to see the only solution for waste management as disposal.

Emphasis on disposal means allocating ever-increasing sums of money. Such a development, however, will not lead to any solution but will only enlarge it and make it more complicated. Recycling and composting are the best alternatives to disposal if waste generation cannot be avoided.

Due to this fact, they should be embodied in the waste-management strategy as decisive components. In this manner, leftovers that are now considered waste will appear as useful by-products. The transformation from waste to by-products should be first of all a change of attitude within the waste management system. If this does not happen, recycling will be divorced from the system. However, this does not mean that recycling will not be of any use. Recycling may indeed reduce the waste to be disposed of, but waste management from which it is isolated cannot rely upon it and may even follow a strategy that is detrimental to recycling and its requirements. Waste management may become efficient

in collecting and disposing of waste that is considered by the recycling lobby to be useful by-products and raw materials.

2. Agricultural waste differs from industrial, household and commercial wastes, which are man-made wastes and whose production depends upon man's behaviour. The generation of agricultural waste depends upon natural processes. These processes determine when it emerges and how great the quantity will be. Man can minimize industrial waste by the optimal use of raw materials and can reduce commercial waste by reducing packaging material and using refillable containers. He can also reduce household waste by avoiding the consumption of waste-generating products. Agricultural waste, on the other hand, can be reduced only by cutting production, and this is not the policy of the Sultanate, whose objective is the expansion of agricultural production with the aim of realizing self-sufficiency in foodstuffs, particularly agricultural products. Thus, in this case there is no alternative but to recycle or dispose of wastes.

Recycling agricultural by-products should not only be a component of an overall waste management strategy but also an element that is integrated into the planning and development of the agricultural sector. In this respect it should be possible to reintroduce recycling in the form of soil-conditioning and fertilizing compost or to consider it as a source of raw material for agro-based industrial production.

3. Recycling agricultural waste requires reliable data about its generation. The basic facts which affect this generation and which should be recognized are:

(a) Waste generally depends upon overall agricultural production, with the ratio between yield and by-products remaining relatively constant.

(b) Crop failure can be due to a lack of plant growth. In such a case both the yield and its by-products will suffer. However, sometimes crop failure occurs at a stage when the plants have not yet

produced any crop. In this case the whole crop becomes a by-product, meaning that crop failure results in an increase of by-products.