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Islamic Republic of Iran  
Ministry of Energy

in cooperation with

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

SF/IRA/92/001

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**Industrial & Domestic Water  
& Wastewater Management**

Contract SF / IRA / 92 / 001

**DOMESTIC & INDUSTRIAL  
WASTEWATER SUBCONTRACT  
Final Report**

May 1995



**MONTGOMERY WATSON**

with Iranian counterpart



**RAYAB CONSULTING ENGINEERS**

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**Islamic Republic of Iran**

**Industrial & Domestic Water & Wastewater Management**

**DOMESTIC & INDUSTRIAL WASTEWATER SUBCONTRACT**

**Final Report**

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May 1995

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**MONTGOMERY WATSON**

*Serving the World's Environmental Needs*

**INDUSTRIAL AND DOMESTIC  
WATER AND WASTEWATER MANAGEMENT  
CONTRACT No. SF/IRA/92/001  
DOMESTIC & INDUSTRIAL WASTEWATER SUBCONTRACT  
FINAL DRAFT REPORT**

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## LIST OF ABBREVIATIONS

AC	Asbestos Cement
AS	Activated Sludge
ASP	Activated Sludge Plant
BAF	Biological Aerated Filter
BOD	Biochemical Oxygen Demand
BOT/BOO	Build Own Transfer/Build Own Operate
CW	Constructed Wetlands
DO	Dissolved Oxygen
ds	Dry Solids
EA	Extended Aeration
EPA	Environmental Protection Agency
EU	European Union
FST	Final Settlement Tank
GBH	Gravel Bed Hydroponics
GRP	Glass Reinforced Plastic
HC	House Connection
IC	Inspection Chamber
IEPA	Iranian Environmental Protection Agency
MLSS	Mixed Liquor Suspended Solids
MOA	Ministry of Agriculture
MOE	Ministry of Energy
MOI	Ministry of Industry
N	Nitrogen
NCS	Non-conventional Sewerage
NWVEC	National Water and Wastewater Engineering Company
O&M	Operation and Maintenance
P	Phosphorous
pa	Per Annum
pe	Population Equivalent
PLC	Private Limited Company
PST	Primary Settlement Tank
RBC	Rotating Biological Contactor
RQO	River Quality Objectives
RWVEC	Regional and Wastewater Engineering Company
SO <sub>4</sub>	Sulphate
STW	Sewage Treatment Works
TDS	Total Dissolved Solids
tpa	Tonnes Per Annum
tph	Tonnes Per Hour
TSS	Total Suspended Solids
UNEP	United Nations Environment Program
UNIDO	United Nations Industrial Development Organisation
WHO	World Health Organisation
WM	Waste Minimisation
WSP	Waste Stabilisation Pond
WWTP	Wastewater Treatment Plant

## SECTION 1 SUMMARY

### 1.1 OVERVIEW OF PROJECT

The overall aim of the co-operation project with UNIDO is to develop a *National Strategy For Water and Wastewater Management* and for the local *Manufacture of Pipes*. This Stage I consultancy has been conducted by Montgomery Watson with RayAb as its nominated Iranian counterpart. The Terms of Reference recognise the complexity of the overall task; this consultancy is limited to small inputs and is intended to summarise current circumstances and to define further larger studies and demonstration projects to be conducted under Stage II.

For this *Domestic and Industrial Wastewater* sub-contract the specific duties required are to:

1. collect and review available data within the country
2. check the effectiveness of existing government policies:
  - towards wastewater management in terms of waste minimisation in industries
  - towards treatment objectives (standards) and methods for the smaller communities
3. develop recommendations for further studies to determine more accurately the present status
4. develop recommendations for development of comprehensive strategies and policies aimed at improving the present situation.

This report summarises the activities listed above, the preliminary conclusions drawn and the recommendations for Stage II.

### 1.2 OVERALL OBJECTIVES

Iran has taken steps towards the study and implementation of wastewater management for some of the larger cities in the country but very few wastewater collection and treatment schemes are operational. The most advanced wastewater management system in the country is at the City of *Esfahan* which has a comprehensive sewerage network and three operational sewage treatment plants. Elsewhere pilot schemes and plants serving selected communities are operational in some of the main centres (*Tehran* has a number of pilot WWTPs; *Mashad* has a significant WWTP serving initially the Holy Harem Area).

The Rio Summit led to the development of AGENDA 21 which has encouraged a global interest in the need to develop National policies for the reduction of environmental degradation. UNIDO is at the forefront of development of waste minimisation strategies for industry. Iran has not yet developed a clear strategy towards waste minimisation although some industries visited appeared to be taking steps towards environmental policies.

The overall output of the whole project is to be a comprehensive *National Policy on Domestic and Industrial Waste Water Management*. This study is the first step towards such goal. This document reports the activities and analysis for the first stage towards this national policy.



The particular areas of water and wastewater management that are addressed in this study are:

- (i) appropriate domestic wastewater treatment technologies for small communities of less than 50,000 population
- (ii) promotion of waste minimisation and water conservation in industry through the use of demonstration factories.

The objectives of this preparatory study were to:

- (i) visit and assess existing WWTPs in Iran with a view to assessing existing experience and expertise.
- (ii) review the available technologies for waste water treatment and recommend those most suited to the needs of the smaller communities of up to 50,000 people in the different regions of Iran.

The project will ultimately address:

- local capabilities in both construction and operation
  - local capabilities to manufacture process equipment
  - environmental conditions
  - local financing capability for both capital and operation and maintenance costs
  - opportunities for exporting technologies developed as part of the project recommendations
- (iii) assess the industrial base of Iran and categorise industries into those potentially the most polluting, particularly those producing wastewaters.
  - (iv) visit selected industries to review their attention to environmental protection and make recommendations for industries to be used as demonstration facilities for the principles of waste minimisation.
  - (v) review the existing Institutional arrangements and legislation controlling the discharge of treated and untreated wastewaters and make preliminary recommendations on the development of a *National Strategy for Wastewater Management*.

This study has been limited to short specialist inputs and is necessarily at a reconnaissance level. Some of the information presented is subject to further data collection/analysis, but a good overview has been achieved enabling recommendations to be made for Stage II additional studies and pilot schemes.

### 1.3 OVERVIEW - OUR APPROACH

A flow of activities has involved the resident team from Rayab consulting engineers in collecting data over a period approaching twelve months. The most intense period of activity was from October to December 1994 when Montgomery Watson's Project Manager was resident in Tehran and supported by specialist visits of varying duration

The stages comprised the following key activities:

***Definition of National Water and Wastewater Projects*** - allied to the parallel project to define the pipe manufacturing needs of the country data was collected from the Ministries and Iranian consultants on projects in the water and wastewater sectors for the next two to three decades. The data was collated and summarised has given a good overview of domestic wastewater treatment needs of the country.

***Existing WWTP Site Visits*** - during the periods when specialists were in Iran visits were made to a number of existing WWTP installations to assess performance, O&M capability and acceptance of the technologies installed

***Existing Design and Construction Capabilities*** - information was collected from each of the consultants on the Iranian design and construction capabilities, standards, specification and criteria used for various processes proposed for different climatic and geographic regions. In this regard, information on industrial waste treatment processes used was also collected.

***Institutional and Legislative Review*** - through discussions with representatives of some of the key bodies responsible for the development and management of wastewater projects an overview has been obtained and a preliminary assessment made of the needs for development of existing legislation and control mechanisms.

***Industrial Base Review*** - collection of information on the range of industries active in Iran has led to an assessment of the main water users and a categorisation into industries which might benefit most from waste minimisation programmes.

***Visits to Selected Industries*** - have been undertaken to industries selected as accessible examples from a cross section of major polluters. Discussions with the management and tours of factories led to an understanding of some of the main sources of environmental degradation and has led to recommendations of industries to be used as demonstration facilities.

***National Standards and Specifications Review*** - the standards of the IEPA have been reviewed and compared to standards adopted in other countries in the Middle East and elsewhere. International trends have been identified and the need for a comprehensive review discussed.

***National Policy on Small Communities Wastewater Treatment*** - the need for a rational approach to the adoption of appropriate treatment technologies is recognised. Preliminary suggestions are made for appropriate treatment methods for various climatic and geographic regions. Suggestions are made for information to be collected and steps to be taken to develop a national standard policy on design and construction of sewer collection system and treatment process design for small communities.

***National Policy on Industrial Water Conservation and Waste Minimisation*** - the need for a rational approach to industrial waste minimisation and water conservation is realised. The results of the programs implemented in the demonstration factories are to be expanded to remaining industrial sectors. Plan on development of a national policy in this respect is proposed.

## 1.4 PRELIMINARY WASTEWATER MANAGEMENT POLICY

At the conclusion of Stage I a number of indicators have been developed towards a *National Strategy for Wastewater Management* in the two elements covered by this study:

### 1.4.1 Small Community Wastewater Treatment

Discussion with operators has indicated a number of preferences:

- the need to recognise the difficulties of extreme cold on mechanical plant (icing of wheel tracks for scraper mechanisms was cited as an example)
- a strong preference by the manager of the Esfahan WWTP for natural systems such as Wastewater Stabilisation Ponds - already selected for the extension plants for Esfahan
- satisfactory performance of pilot extended aeration plants operating in built up areas of Tehran with no noticeable odour
- concern about sludge disposal and the problems of managing sludge lagoons and beds at Esfahan led to a keen interest in the potential for conversion of some of the existing beds to sludge reed beds and literature has been forwarded to the manager about this technology
- problems in the local manufacture of plant such as aerators
- need for a review of the IEPA Standards to develop appropriate standards for the different forms of discharge; to rivers, wadis, sea, or to re-use in different climatic and ground conditions, has been discussed in the IEPA office in Esfahan
- note that energy costs, which were very low, are currently increasing rapidly.

Iran has a number of distinct climatic regions with different needs; some areas are very short of water and re-use of effluent must be considered a priority - this is less of a concern in the more temperate regions of the Caspian Sea region but still has relevance.

We have reviewed the latest technological developments in wastewater treatment and include a comprehensive review in Appendix D of this report.

Many of the latest technologies developed in Europe and the USA are designed to meet new legislative restrictions on wastewater constituents, in particular nutrients (N and P) which can lead to eutrophication of receiving waters. Dense urban populations and limitations on siting from existing sewerage networks has also led to small footprint processes. Deep shaft sewage treatment, "Vertech" sludge treatment, biological aerated filters (BAF) plants are all examples of small footprint processes which are, in consequence, high in energy consumption and complex in operation and are not considered suitable for Iran.

Modern developments of processes which are favoured for the small communities of Iran are:

- new developments in Wastewater Stabilisation Pond processes involving wind powered mixing and low mechanical aeration systems
- well-proven extended aeration activated sludge processes

- in some circumstances and where maintenance and spares can be provided, compact packaged systems involving rotating bio-contactors (RBCs) which are readily covered over for temperature control and protection from sand ingress
- constructed wetland configurations, particularly where related to rice-use and cash cropping
- reed bed sludge dewatering and composting methods.

These are discussed in relation to other conventional treatment processes in the text.

It is recommended that carefully engineered and managed schemes are developed in a range of appropriate technologies in order to assist in the development of sound principles on which a National Strategy can be developed

Table 1.1 overleaf gives recommendations for selection of wastewater treatment processes in each of the four geographic divisions of Iran discussed in this report. It also categorises the towns by population ranges. Temperature, land slope, soil type, wastewater quality and discharge arrangements and legislation are the main factors that affect the process selection.

Economies of scale play an important role in selection of a process based on population and processes such as enclosed biological filters and RBCs which can only be implemented economically for smaller populations.

#### 1.4.2 Industrial Waste Minimisation

This study has enabled an overview to be gained of the types of industry throughout Iran. These cover a very broad spectrum of activities and visits were made to 21 factories or factory complexes representing a reasonable cross-section.

These were:

Iron Smelters  
 Steel Rolling Mill  
 Leather Tannery  
 Textile Dyeing  
 Paper Mill  
 Abattoir  
 Sugar Refinery  
 Confectionery  
 Pharmaceutical  
 Tyre Products  
 Concrete AC, GRP and Ductile Iron Pipe Factories

Based on these visits a number of factories were considered potential candidates for Demonstration Waste Minimisation Programmes. The criteria used in selection were:

- proliferation of wet wastes
- range of processes and materials
- observations of potential improvements
- interest and enthusiasm of management

## CLIMATE

**Table 1.1 - Recommended WWTP Processes for Small Communities**

POPULATION BAND	MOUNTAINS	CENTRAL PLATEAU	CASPIAN SEA REGION	PERSIAN GULF REGION
12,000 - 50,000	EA (Diffused Air ,Closed Tank)	EA	EA (with PST plus Iron or anoxic zone)	EA (with PST plus Iron or anoxic zone)
		WSP	Oxidation Ditch plus FST	Oxidation Ditch plus FST
2,000 - 12,000	EA (Diffused Air , Closed Tank)	EA	WSP Variation	WSP Variation
		Biofilter plus PST & FST or CW	"AcroFac"	"AcroFac"
		RBC & FST or CW	Pasveer Ditch plus FST	Pasveer Ditch plus FST
		WSP		
< 5,000	EA (Diffused Air , Closed Tank)	EA	Acrated Lagoon	Acrated Lagoon
		Biofilter plus PST & FST		
	Enclosed Biological Filter plus PST/FST	RBC + FST or CW	WSP	Facultative Lagoon/WSP
	RBC and PST/FST or CW	CW	CW	CW

**Key:**

EA: Extended Aeration, PST: Primary Settlement Tank; FST: Final Settlement Tank; WSP: Waste Stabilisation Ponds;  
RBC: Rotating Biological Contactor; CW: Constructed Wetlands

A broad classification of industry types for waste minimisation prioritisation has been prepared and other factories might be considered for minimisation programme demonstrations.

Waste minimisation is essentially a process of rational review within the factory systems with a view to identifying the weak points. Often quite simple and obvious procedures and changes can make significant impacts to waste generation. It has been the experience in other countries that industries who have embarked on serious waste minimisation programmes have found significant cost benefits have resulted from the recycling and raw material reductions which have resulted.

Most of the industries visited showed a reasonably positive attitude to environmental improvements and with government direction and incentives a national improvement should be possible.

## **1.5 RECOMMENDATIONS FOR STAGE II**

The following are the actions considered necessary as stages in development of a *Domestic and Industrial Wastewater Management Policy*:

### **Review of Standards**

- to evaluate the international trends in setting standards for treated wastewater discharge and to consider the different discharge scenarios applicable to the various communities and regions of Iran.
- to ensure due regard is given to different requirements for the protection of aquifers, rivers and marine environments
- to give appropriate attention to the safe re-use of treated wastewaters and sludges wherever appropriate and to define permitted disposal options where re-use is not practical.
- to develop a "polluter pays" policy towards industry to encourage waste minimisation and recycling and avoidance of harmful chemicals entering sewerage systems and limiting the re-use potential for sludges.

### **Review of Institutions**

- to review the existing IEPA organisation and its operation and assess the needs for any reorganisation, training and procedural development.
- to review the role of the IEPA in relation to the NWWEC and the regional RWWECs - define relationships and responsibilities and consider possible changes
- to consider "privatisation" BOT/BOO option towards the water and wastewater industry in Iran, both for construction and for ownership.

### **Demonstration WWTPs**

- to establish a number of WWTP technologies appropriate to the variety of circumstances in Iran and to engineer them carefully as models for the country. A suggested listing is presented in Section 3.
- development of ongoing monitoring programmes of the selected treatment processes in order to record and assess performance.

### **Waste Minimisation**

- to establish demonstration waste minimisation projects in the following industries:
  1. Esfahan Steel Mill
  2. Chuka Paper Mill
  3. Tehran Charm Shahr Tannery Complex

Alternative industries are also discussed.

### **Wastes Inventory**

- to assist the IEPA in the development of a computerised data base of waste dischargers to terrestrial, atmospheric and aquatic environments and to train operatives in its use to monitor and control the discharges.

### **Policy and Guidelines**

- to propose a *National Policy on Domestic and Industrial Wastewater Management* with attention to the wide range of smaller communities some of which are close to each other, others being remote and to develop guidelines for the Regional Water and Wastewater Engineering Companies and their consultants.

### **Technical Study Tours**

The UNIDO agreement includes an allowance for a Technical Study Tour and it is recommended that key decisionmakers from the Ministry of Energy make visits to view selected technologies and management systems in other countries. These might include the following:

- **Sultanate of Oman** - to view the Ministry of Environment's Database of Discharges to the Environment and to discuss the changing legislation and policy towards environmental discharge.
- **Egypt** - to view the research programme into constructed wetland systems funded by the UK government. The systems are given the terminology "Gravel Bed Hydroponics" and include research into "cash cropping" and industrial waste treatment by natural methods.
- **Saudi Arabia** has a number of oxidation ditch, aerated lagoon and extended aeration plants operational.
- **France** has some examples of constructed wetland enhancement to wastewater stabilisation pond systems, which have resulted in

enhanced performance for populations up to about 3000 people. France has numerous WSP systems in operation.

- Greece - Montgomery Watson has managed the design and construction of one of the largest vertical flow constructed wetland systems to serve villages of a total of 3500 population. This system should be commissioned early in 1995.
- UK - at the forefront of the privatised water industry, discussions with UK operating companies and regulatory authorities could be beneficial to review approaches to legislation and control of industries and tariff structures.

Severn Trent Water PLC is one of the largest privatised companies with numerous small communities served by RBCs and Constructed Wetlands.

- USA - visits could be arranged to one of the most successful *Aer-o-Fac* installations at Crawley, Louisiana, to sludge reed bed installations and to the EPA.
- Waste Minimisation in industries could be viewed at the following industries which have undertaken successful WM programmes:

British Steel has undertaken very large projects in waste minimisation and Montgomery Watson could assist in arranging visits through contacts. This visit would be particularly relevant to the Esfahan Steel Mill.

UK New Paper Mill - visits could be arranged to a new mill designed to produce virgin pulp from 100% post consumer waste paper. Montgomery Watson used a Best Practicable Environmental Option analysis of alternative disposal options for sludges following successful pilot trials: full scale production is about to commence on the conversion of sludges to construction materials.

Other visits could be arranged to:

Tanneries: a variety of companies

ICI: where MW waste audits assisted in the objective of world-wide reduction of wastes by 50%

Various Private Companies: where waste minimisation has been undertaken for a variety of wastes

## 1.6 REPORT CONTENTS

The remainder of this report describes the individual study stages identified in our approach in the following sections:



- Section 2**      **Institutions and Policies** presents a summary of the Iranian institutions responsible for the management of industrial and domestic wastewater and of the current legislation. A brief assessment of other international and national trends is presented to illustrate the need for Iran to develop its own rationale with the benefit of experience elsewhere. Emphasis is placed on effluent reuse in relation to the development of effective treatment methods and standards for Iran. Existing Standards are summarised in Tables in Appendix C.
- Section 3**      **Small Communities Wastewater Management** includes an analysis of the existing experience in Iran of Wastewater Treatment and a summary of the WWTPs visited which are reported in Appendix A.
- Section 4**      **Industrial Waste Minimisation** begins with a review of the principles of industrial waste minimisation and goes on to summarise the industrial base of Iran and to categorise the industries for which wastewater minimisation is a key issue. Reference is made to the industries visited for which visit reports are included as Appendix B.
- Appendix A**    **WWTP Visit Reports** gives notes on the WWTPs visited during the specialists visits to Iran and comments on the performance and the operational experience of the works management
- Appendix B**    **Industrial Visit Reports** gives notes on each of the factory visits made during the study
- Appendix C**    **Summary Tables from IEPA Standards**
- Appendix D**    **Options for Sewerage, Sewage Treatment and Effluent Reuse** is a comprehensive review of available options for wastewater collection, treatment and reuse.

## 1.7 ACKNOWLEDGEMENTS

Preparation of this report has involved the collection and assimilation of a large amount of data in a relatively short period of time. This would not have been possible without the co-operation of a large number of individuals from the public and private sector too numerous to mention.

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- Mr Kuchechian, Managing Director and the appointed UNIDO project team of RayAb Consultancy Engineers.
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- Management of Industrial Factories and Sewage Treatment Plant Managers throughout Iran.

## SECTION 2 INSTITUTIONS AND POLICIES

### 2.1 IRANIAN WASTEWATER MANAGEMENT OVERVIEW

#### 2.1.1 The Operating Institutions

As a developing nation, Iran is moving forward and strengthening its industrial base, founded on oil economy. This move towards industrialisation has brought about adverse effects to the environment due to industrial air and water pollution. The high rate of population increase during the last 15 years has also caused concern over domestic waste disposal in the major cities, as well as in the smaller communities which have less complex socio-economic establishments.

The water industry in Iran is generally managed under the auspices of Ministry of Energy (MOE), which is responsible for water supply, distribution, wastewater collection, treatment and disposal. In some cases water supply to the agricultural sector is managed by the Ministry of Agriculture (MOA), and that for the industrial sector is managed by the Ministry of Industry (MOI). All of these Ministries collaborate in their programs and plans, where necessary.

The Ministry of Energy (MOE) has traditionally been in charge of water supply, distribution, and sewerage programmes, through the Regional Water Boards. Out of concern about the domestic and industrial waste, and to strengthen the technical, economic, and political support for the sewerage projects, the MOE established the National Water and Wastewater Engineering Company (NWWEC) in 1368 AH (1989). This company, which is directly managed by the Deputy Minister of Energy in water and wastewater, is responsible for planning all present and future water distribution and sewerage projects, as well as, supervising all the design and construction of projects at the national level. At the same time, the Regional Water and Waste water Engineering Companies (RWVEC) were formed to supervise the planning, design and construction of projects at the regional level, but more importantly, the RWVECs operate the water distribution and sewerage networks.

Under the NWWEC program and during the period 1373-1378 AH (1994-1999 AD), over 1.5 million cubic meters per day of water will be supplied to newly served towns and villages. This will increase the population served by potable water from 92.5% to 98%. The NWWEC is also planning to study and implement sewage collection and treatment system in over 150 cities, including major cities such as Tehran (population of over 8 million), Shiraz (population of over 2.5 million) and Mashad (population of over 1.1 million), as well as smaller cities in various parts of the country. This latter program is part of the long-term plan for the next 25 years.

#### 2.1.2 Legislation and Control

In addition to NWWEC, Iran has established the Iranian Environmental Protection Agency (IEPA) to formulate and implement standards for drinking water, and domestic and industrial waste disposal, as well as, other environmental issues. The IEPA has now set standards for both drinking water quality, domestic waste and industrial waste disposal. These are summarised in Tables C1 and C2 in Appendix C. Due to economic constraints, and the fact that Iran is recovering from the effects of an eight year war with its neighbouring country, Iraq, increased industrial production has had a high priority without proper attention to the environmental issues and often without compliance with the IEPA standards.

In order to control the present adverse environmental effects from industrial and domestic sectors, as well as plan for future environmentally safe operations, Iran needs to implement strict policies for enforcement of IEPA regulations. Recent legislature in the 1373 AH (1994) Budget Law is a major positive step in this respect. Section v of article 25 in the 1373 Budget Law states that

*"The Regional Water and Wastewater Engineering Companies (RWVEC) are obliged to fine the industrial units which cause surface water and/or groundwater contamination, in relation to the extent of contamination. The fine which should be suggested by the Ministry of Energy (MOE) and approved by the government, will not be more than 10,000,000,000 Rls. in total and will be deposited to the national treasury. Of this fine 50% is available to the RWVEC for their funding local projects".*

The RWVEC is now in the process of detailing this law and industrial waste minimisation is high on their agenda.

It is also appropriate that Iran reviews and develops its institutional structure, its environmental legislation and its methods of enforcement. It is important to learn from the experiences of other countries and to refine the international and other national standards to suit the socio-economic, cultural, climatic and physical conditions of Iran.

## 2.2 TRENDS IN OTHER COUNTRIES

Throughout the world there are many forms of institutional management of the water industries. Common to most countries, however, is a recognition of the rights of the people to safe drinking water at reasonable cost, and to the development of sanitary and environmentally sound methods of collecting, treating and dispersing of wastewater.

It is a fact that the US and Europe have led the development of institutional structures and the accompanying legislation. Many countries of the Middle East have adopted US and European standards and some are now in the process of reviewing them. Many countries of the Gulf, for instance, initially adopted very stringent standards for wastewater treatment, some based on the California Standards for Unrestricted Reuse. Some of these countries (e.g. Oman) are now in the process of relaxing these standards to more realistic and achievable levels appropriate to the real needs for reusing effluents and recognising the recent recommendations of WHO.

Other trends are towards privatised schemes for the development and operation of the water industry. BOT/BOO is an increasingly common mechanism for funding major water and sanitation schemes throughout the world, with privatised companies responsible for producing water and/or effluent to the stipulated standards. Such privatised bodies require enforcement agencies and the UK, which has led the world in privatising its water industry, is currently considering restructuring its current National River Authority to an independent Environmental Protection Agency, such as exists in the US and embryonically in Iran.

## 2.3 CURRENT EUROPEAN TRENDS

The 1991 Urban Wastewater Directive (91/271/EEC) of the EU has applied fixed emission standards to all wastewater discharges throughout the member states in order to create a "level playing field". In theory the competitiveness of factories will not be affected by environmental constraints irrespective of their location.

Prior to this Directive the UK had adopted a system of meeting River Quality Objectives (RQO's). In this system which permitted some account to be taken of sensible economics, the desired quality of each particular river system was considered on its merits. For example it may have been required for the river to provide:

- (a) A game fishery (salmonoid fish)
- (b) A coarse fishery (cyprinoid fish)
- (c) A raw source of abstraction for drinking water
- (d) An environment for immersion sports, e.g. swimming competitions
- (e) Only a means of carrying domestic and industrial wastewater to the sea without causing a nuisance or hazard to public health

These criteria led to widely different consent standards for WWTPs throughout the UK.

Similar considerations were applied to WWTP discharges into other surface waters such as lakes, estuaries and the sea. RQO's were determined to be compatible with the desired quality of the rivers or surface waters and inputs of domestic and industrial effluents were controlled with respect to volume and quality to ensure that the desired objectives were achieved and maintained.

The present EU Wastewater Directive does not allow for individual RQOs to be assessed and is currently the subject of considerable debate. There is a wide range of responses within the member countries and it is unlikely that many will be able to achieve the Directive requirements by the stipulated deadlines, particularly in Southern Europe.

## 2.4 PRIORITIES FOR IRAN

Iran is currently striving to improve its environment from a relatively poor situation as at present to an acceptable state as soon as possible, whilst obtaining the best possible value for money. It is therefore appropriate that Iran should adopt and enforce standards which are achievable and based on the real needs for the different environments to which discharges are made. In those regions with rivers, standards based on river quality objectives might avoid spending capital and revenue on meeting very high standards in locations where commensurate benefits cannot be derived.

It must be said, however, that the system based on RQO's is more complicated to set up and in its ultimate will require river quality modelling to ensure the optimum input standards are derived. In the initial stages, however, more simplistic techniques can be used to set discharge limits on effluent inputs.

In the Middle East generally and in certain regions of Iran, underground water resources are extremely precious and need to be protected at all costs. If a river becomes polluted, normal water quality (if not organisms living in it) will be restored within days of the source of the pollution being eliminated. In the case of an aquifer, however, it may take decades, or even centuries, for the situation to return to normal.

Considering the current prevalence in Iran of using boreholes or wells to dispose of wastes, and in particular, industrial wastes, it is almost certain that many underground potential water resources will already be almost irretrievably polluted. It is therefore essential that rapid steps must be taken to protect those still remaining unpolluted.

It is relevant to point out that the limits in Table C2 make no reference to chlorinated hydrocarbons or to pesticides which are two of the most persistent and frequent pollutants of underground waters.

Iran must also recognise the potential for effluent and sludge reuse in setting standards and in recommending appropriate methods for the treatment of wastes.

## 2.5 GLOBAL PRACTICE AND CONSTRAINTS FOR EFFLUENT REUSE

### 2.5.1 Basic Criteria for Assessment

Around the world there exists a wide range of standards and an even wider range of practice associated with the reuse of treated wastewater products.

The development of appropriate standards to be applied for the quality of effluent must take into account a number of factors and methods of assessment and evaluation of risks to health:

- **Microbiological criteria** can be used to assess the survival patterns of excreted pathogens and of the removal of those pathogens in wastewater treatment processes. If this method alone is used, then pathogen removal is required to eliminate "potential" risk to health.
- **Epidemiological evidence** can be used to focus on the chances of any individual developing a disease or a reduction in health status over a period as a result of exposure. The epidemiologist will take into account factors such as:
  - pathogen survival
  - minimum infective doses
  - host immunity
  - human behavioural patterns
- **Religious and philosophical objections** exist in many communities, both to contact with human waste products or the concept of re-using human waste products in human food production. Many communities will accept the principle of using the nutrients of sewage wastes to produce animal fodder crops ensuring at least one stage removal in the food chain.

The above factors have to be viewed in relation to the overall sociological, economic, climatic and physical constraints of a country to arrive at a set of standards which is appropriate, safe (within certain rules or reuse application) and acceptable to the religious, philosophical and human feelings and constraints of the community.

The above three factors represent totally different approaches to setting standards. The first two, scientific, approaches require a mechanism of measurement and the most common indicator is the faecal coliform bacteria count. These bacteria exist in the human gut without causing disease. It does not therefore represent a threat to the health of a community, but is relatively easy to measure. It is, therefore, taken as an indicator of the degree of removal of micro-organisms including those which are pathogenic.

## 2.5.2 Current Practice

In the more temperate climates of the world, the common practice is to return treated effluent to rivers, lakes or oceans. The high dilution factors, natural die-off of pathogens and inactivation by ultra-violet irradiation lead to a relaxed attitude to microbiological quality of effluents, except where the receiving waters are used for recreational purposes. In such temperate and wetter zones, sewage effluents are rarely used directly for crop irrigation. Microbiological criteria are applied, not to the effluents themselves, but to designated bathing zones where stipulated sampling of the actual bathing waters throughout the summer season has to show compliance. Typical examples of these mandatory limits are:

Mediterranean Pollution	1 000 E coli per 100 ml
EU	2 000 E coli per 100 ml

These limits are set on the basis of epidemiological evidence and are under constant review and considerable international discussion.

In arid climates, where effluent is a more valuable resource for essential agriculture, a range of standards has been developed. Over the last fifty years standards have tended to be very strict and have been based on theoretical microbiological criteria rather than epidemiological evidence. The "zero risk" concept in most countries (China excluded) has led to the aim of achieving an "antiseptic", pathogen-free environment. The preferred treatment systems, judged by coliform removal, has been secondary treatment followed by chlorination.

The standards set by the California State Department of Public Health permit only 2.2 coliform per 100 ml for "unrestricted" reuse applications (i.e. public recreation areas) and for certain crops.

In 1971 the WHO Meeting of Experts on the Reuse of Effluents concluded that the epidemiological evidence did not support such strict guidelines and recommended 100 total coliforms per 100 ml for irrigation of vegetables eaten cooked.

Since 1971 extensive reviews have taken place of epidemiological evidence by a number of leading world public health experts and scientists. The broad conclusions are summarised in the WHO 1989 guidelines which recommend less stringent standards for faecal coliforms, but much higher standards for numbers of helminth eggs which are recognised as the greatest public health risk associated with wastewater irrigation. Helminths include *hookworms*, *trichuris* and *Ascaris* which can exist in concentrations up to about 1 000 per litre in some communities. The report recommends that helminth eggs are reduced by appropriate means to no more than 1 per litre where public exposure is likely, and comes down heavily in favour of stabilisation ponds as the method of treatment to achieve such reductions.

Chlorination, as a method of disinfection, is increasingly questioned because of growing concerns over the carcinogenic effects of chlorinated hydrocarbons which can form under certain conditions.

The 1989 WHO recommendations are summarised in Table 2.1.

The WHO includes the statements that:

"The guideline values given in the above table, however, must be carefully interpreted and, if necessary, modified in the light of local epidemiological, socio-cultural, and environmental

factors. Greater caution may be justified where there are significant exposed groups that are more susceptible to infection than the population at large.....”.

“..... Where members of the public have direct access to lawns and parks which are irrigated with treated wastewater, the potential public health risk, particularly to children, may then be greater than that associated with the irrigation of vegetables eaten raw ..... an effluent standard for park lawn irrigation of 200 faecal coliforms per 100 ml was recommended in the report of a study at Colorado Springs and the WHO Scientific Group thought it prudent to adopt this guideline figure.”

**Table 2.1**  
**Recommended Microbiological Quality Guidelines for Wastewater in Agriculture**

Cat	Reuse Conditions	Exposed Group	Intestinal nematodes (b) (arithmetic mean no. of eggs per litre (c))	Faecal coliforms (geometric mean no. per 100 ml (c))	Wastewater treatment expected to achieve the required microbiological quality
A	Irrigation of crops likely to be eaten uncooked, sports fields, public parks (d)	Works consumers, public	<1	<1000	A series of stabilisation ponds designed to achieve the microbiological quality indicated, or equivalent treatment
B	Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees (e)	Workers	<1	No standard recommended	Retention in stabilisation ponds for 8-10 days or equivalent helminth and faecal coliform removal
C	Localised irrigation of crops in category B if exposure of workers and the public does not occur	None	Not applicable	Not applicable	Pre-treatment as required by the irrigation technology, but not less than primary sedimentation

**Notes:**

- (a) In specific cases, local epidemiological, sociocultural and environmental factors should be taken into account, and the guidelines modified accordingly.
- (b) *Ascaris* and *Trichuris* species and hookworms
- (c) During the irrigation period
- (d) A more stringent guideline (< 200 faecal coliforms per 100 ml) is appropriate for public lawns, such as hotel lawns, with which the public may come into direct contact.
- (e) In the case of fruit trees, irrigation should cease two weeks before fruit is picked, and no fruit should be picked off the ground. Sprinkler irrigation should not be used.

**2.6 SUMMARY OF INSTITUTIONAL/REGULATORY NEEDS**

This study concerns, primarily, the treatment of wastewaters from small communities and the minimisation of wastes from industries. These cannot be considered independently of a wider,

**national approach to wastewater management and the following are considered necessary development stages for Iran:**

- (i) National Guidelines on Wastewater Management Practice for all communities with recommendation on suitable treatment processes for:**
  - **different community**
  - **different regions**
  - **different discharge arrangements**
- (ii) Review of the IEPA Standards and National Legislation for both Industrial and Domestic Wastes. This should take into account international trends and should finish with a set of standards based on latest international consideration of environmental protection.**
- (iii) A National Inventory of Discharges to assist the IEPA in monitoring and controlling all discharges to the environment from inception through to implementation of projects.**
- (iv) A review of the IEPA and its structure with a view to establishing a regulating authority with the structure and capability to:**
  - **set standards**
  - **generate "consent agreements" for industries and RWWECS within the limitations of the standards**
  - **undertake regular sampling and analysis regimes for enforcing compliance with the standards and individual consent agreements.**



## SECTION 3

# SMALL COMMUNITIES WASTEWATER MANAGEMENT

### 3.1 DEFINITION AND SCOPE

#### 3.1.1 Overview

Iran has proceeded to plan, design and install wastewater collection and treatment facilities for the larger and medium sized urban centres. One of the principle objectives of this current project is to address the wastewater management for the 'small communities' defined as collection systems serving communities of up to 50,000 persons (or equivalent).

The selection of collection and treatment systems to be adopted will be greatly influenced by such factors as:

- climate
- terrain
- the actual population served. e.g. 2 000 or 20 000
- type of community; industrial-based, farming, tourism-oriented

since smaller systems are more sensitive than larger systems to variations.

In this section an overview is given of the smaller communities of Iran and of the current experience in wastewater treatment and reference is made to Appendix D which reviews viable options for sewage collection and treatment and for effluent reuse.

#### 3.1.2 Population Grouping

In order to permit the matching of appropriate technologies to overall plant capacities, the main grouping of "populations up to 50 000 persons" has been divided into three sub-groups, viz:

- (a) Up to 5 000 persons
- (b) Between 2 000 and 12 000 persons
- (c) From 12 000 up to 50 000 persons

The philosophy underlying this subdivision is illustrated by the use of say Constructed Wetlands (CW) which might be appropriate for populations up to 5 000 persons, but would involve the use of larger areas of land than other technologies and may, therefore, be less attractive for populations in the higher bracket.

At the lower end it is difficult to justify continuous supervision or even daily visits. The systems adopted therefore need to be simple, robust and only require routine visiting no more than three times a week. (e.g. Sat, Mon, Wed). At the top end of the scale (12-50,000 pe) daily visits or resident operation and management teams may be advisable, depending on the technology in use.

#### 3.1.3 Climatic Zoning

Iran comprises a series of distinct and different climatic zones which will impact on the selection of treatment processes:

- The relatively temperate, wet Caspian Sea region
- The Mountain regions with long periods of freezing conditions - but sparsely populated
- The Central Plateau with classic desert conditions - extreme hot and cold conditions
- The Persian Gulf region with humidity and consistently warm to hot conditions throughout the year

Temperature has a marked effect on the effectiveness of biological treatment processes and freezing conditions can influence the choice of mechanical process. The manager of the Esfahan works, for instance, commented on the difficulties of operating the rotating scrapers during freezing conditions when they have to apply salt to the wheel tracks.

The selection of treatment technology for use in a particular area will need to take account of the prevailing climate of that area. For instance, in the mountainous areas the use of some constructed wetland configuration, or shallow lagoons may be inadvisable due to the prolonged periods of freezing conditions which are experienced. Even biofilters may prove unsuitable unless they are fitted with covers and controlled ventilation. In other areas where the climate is hot and humid consideration may need to be given to malodours arising from septic sewage.

### 3.1.4 Terrain

In some areas such as the Caspian Sea coastal strip and the Gulf coast the very shallow gradient of sewers and warmer temperature could result in septic sewage arriving at the treatment works which will require special provision to avoid nuisance due to malodours and possible treatment difficulties.

### 3.1.5 Summary of Small Communities in Iran

Information supplied in Iran on the small towns within Iran is summarised in Table 3.1 This information is obtained from the JarmAb Database on Urban and Rural Water Use. The international De Martin climatologic classification has been used. These do not relate directly to our Iranian classification (Caspian Sea, Mountain Regions, Central Plateau - desert, Persian Gulf) but are indicative of the numbers of towns to be considered. NB: The data in this table needs verification. We particularly suspect the quoted numbers of very small communities, which are likely to be numerous, but which may not appear in the listings used to generate this table.

Table 3.1

De Martin Climatologic Classification	0-2000	2,000-10,000	10,000-20,000	20,000-50,000
A1.1, A1.2 (Arid)	2	20	42	141
A2 (semi-Arid)	2	15	27	117
A3, A4 (Mediterranean)	1	11	12	42
A5, A6 (Wet)	0	4	17	44
<b>Totals</b>	<b>5</b>	<b>50</b>	<b>98</b>	<b>344</b>

## 3.2 IRANIAN EXPERIENCE IN WASTEWATER MANAGEMENT

### 3.2.1 Overview

Iranian wastewater disposal methods used to date include:

- Local cesspits with collection
- Septic tanks
- Deep well disposal
- Wastewater Stabilisation Ponds
- Aerated Lagoons
- Biological Filters
- Extended aeration activated sludge
- Conventional activated sludge

Deep Well Disposal which is widely practised throughout Tehran and other cities can no longer be considered satisfactory in the view of the risk of further contamination to groundwater and should be phased out as soon as practicable. Local cesspits and septic tanks can be viable systems for small communities, provided they are designed and constructed to recognised guidelines and served and maintained in good condition. They can also be incorporated into small-bore sewerage systems for economy. The concern is that they are poorly constructed and allow seepage of contaminated water into groundwater systems and as such their continued use needs to be questioned. Provided there is control over quality of construction, then continued use may be valid as discussed in later sections.

For this study inspection visits were made to a number of sewage treatment plants (see works visits reports in Appendix A) and Plates 1 to 4.

These included:

- (a) Large WWTPs:
  - Esfahan South (the largest WWTP in Iran) - Biological Filters and Activated Sludge (serving 800,000 pe)
  - Holy Harem WWTP, Mashad (serving approx 200,000 pe)
- (b) Small Community WWTPs
  - 2 extended aeration plants in Tehran (60,000 and 15,000 pe)
  - Esfahan Steel Mill Domestic WWTP
  - Ghahderigan WWTP (uncommissioned)
- (c) Industrial Complex WWTP
  - Kaveh Industrial Complex, Tehran for Industrial and Domestic waste (uncommissioned)

The following paragraphs summarise these plants:

### 3.2.2 Large WWTPs

#### Esfahan South WWTP

The Esfahan South WWTP (Plate 4) is the largest and oldest WWTP in Iran and is understood to serve in excess of 800 000 pe. The plant was constructed in three stages, the first, completed 26 years ago, was a biological filter plant and the second two stages, commissioned in the last decade, are both conventional Activated Sludge.

The plant is hydraulically and biologically overloaded and surplus flows are passed untreated to the River (Zayandeh Rud). Local abattoirs and textile industries produce shock loadings which upset routine operations.

The plant is well managed by a competent team and under the overloading conditions is producing a good quality effluent. The Manager has a great sludge management problem and was very interested in the potential for converting sludge drying beds to sludge reed beds to alleviate the sludge handling operations. Literature has been forwarded to the Manager on this method of treating sludges.

The Manager expressed his preference for simple wastewater stabilisation pond systems which, he believes, are proved to work in Iran with a minimal operation and maintenance requirement. A wastewater stabilisation pond (WSP) plant is currently under construction 25 km distant to relieve the overloading of this plant.

### **Mashad, Holy Harem WWTP**

The Mashad WWTP (Plate 3) receives municipal sewage from the Holy Harem area through a 9km (1.4m to 2.0m diameter) gravity concrete sewer. The sewage arriving at the treatment works is grey in colour and appears to be septic. The sewer capacity is 2,500 l/s and is designed to serve planned future capacity at the treatment plant.

The treatment plant consists of three sets of lagoons. The first pair are planned to be aerated but are currently anaerobic. The second stage is a series of three lagoons which are also, currently, anaerobic. It is further intended to disinfect the effluent between the facultative lagoons and the maturation lagoon. A chlorine contact channel is in place but no chlorination is yet provided.

The contents of the maturation pond are currently pink in colour and therefore probably anaerobic. The single point inlet and outlet facilities also probably mean that short circuiting is taking place.

The strength of the incoming sewage is unknown whilst the effluent BOD is 100 to 150 mg/l and still dark grey.

The management are experimenting with locally made "Simon Hartley" type surface aerators, but they are currently experiencing problems with the shaft and gearbox. The construction of the treatment works appeared to be quite good except for unfilled expansion joints in the concrete work.

### **3.2.3 Small Community WWTPs**

#### **Tehran Pilot Extended Aeration Plants**

Two pilot extended aeration plants were visited, *Gheytaarieh WWTP* (Plate 1) in the north east, *Shooshi WWTP* (Plate 2) in the south of the City. The former was constructed in very restricted space surrounded by offices and housing. Screened and degrittied sewage is fed directly to the extended aeration plant. An effluent of very high quality is produced and no complaints of odours have been made by nearby residents. At the time of the visit (November) there was no significant odour detectable. The plant is designed in a very small "footprint" and is very compact which leads to some safety concerns in access, but is, however, effective.

The Shoosh WWTP to the South of Tehran treats 3000 m<sup>3</sup> of sewage per day using a similar process, extended aeration without primary settlement. A major benefit of omitting primary settlement is the avoidance of major odour problems. Final effluent following chlorination was discharged to river via a 5 km outfall sewer. This river was used as a source of water for agricultural irrigation.

The operational managers of these two treatment plants clearly had a good understanding of the processes involved and were very enthusiastic about their work.

These plants demonstrated the benefits of the extended aeration process, where space is limited, in relative simplicity of operation and in minimising odour by eliminating primary settlement. Both plants had some poor concrete with signs of deterioration in quality.

### **Esfahan Iron and Steel WWTP**

The sewage treatment plant visited at Esfahan was owned and operated by the Esfahan Iron and Steel Co for the purpose of treating the domestic wastewater from the small community which houses the Company's employees.

The primary settlement stage of this plant comprised an "Imhoff Tank". This is a vertical flow sedimentation tank below which is a sludge storage tank ('digester') into which settled solids automatically fall through slots in the base of the settlement tank. Thus some compaction and stabilisation of sludge is achieved in the dual purpose installation without giving rise to septicity in the settled sewage. This system is common in some countries in Southern Europe and the Far East and may be suited for use in small communities in Iran - especially in colder areas (where the tank can be easily covered; this being facilities by the elimination of the sludge scraper mechanism essential for other types of settling tank).

Secondary treatment at this works was provided by four 4m deep trickling (biological) filter beds. These were not operating when visited due to the failure of the rotating sewage distributors to rotate. Closer examination showed this failure to be caused by a design fault which indicated a fundamental lack of understanding by the designer about how the distributors are intended to be driven. Advice was given to the operators. Imhoff tank sludge is passed directly to sludge lagoons for dewatering and maturation.

Despite the shortcomings at this particular installation, the trickling biological filter still remains a simple and reliable method of treating sewage from small communities where only a minimum level of supervision is available.

The steel works effluent is passed to very large evaporation lagoons adjacent to the WWTP. These are lined lagoons and are, therefore, not threatening groundwater quality, but the land areas are very large and it is possible that waste minimisation studies could recommend greater recycling of water and recovery of chemicals (see Section 4).

### **Ghahderigan (near Esfahan)**

This sewage treatment plant consists of a pumping station and two parallel aerobic lagoons. Although the construction of this plant is fully completed, it was still not operating at the time of the visit. This was due to excessive infiltration of groundwater into the main sewer caused by poorly jointed sewer pipes. As a result, the lift pumps were unable to empty the sewer sufficiently for foul sewage to flow into the main treatment plant from the town.

It was observed that spare pipes remaining near the plant had very poorly formed spigot joints, as had been observed during earlier visits to one pipe manufacturers. This situation highlights dramatically the need for improved manufacturing standards and guidelines on the installation of pipework. One potential remedy for this now difficult problem might be the application of some form of in-situ lining of the sewer.

### 3.2.4 Industrial Complex WWTP

#### Kaveh Industrial Complex

A conventional activated sludge treatment plant is under construction and is designed to treat the domestic and industrial wastewaters discharged by the 420 factories on the estate. A mixing and balancing tank and primary settlement are included in this scheme. The treatment plant is *not* in any close proximity to residential areas.

The final effluent from the plant will be chlorinated prior to its use for agricultural irrigation. Since the plant is not yet completed, it was not possible to discuss operational experience or understanding. However it was evident from limited discussion that the designers were well versed in this technology.

The treatment plant was much larger than would be required for the "small communities" under consideration. Nevertheless, the principle from which this type of system has evolved during the last 40 years, the "Pasveer oxidation ditch" which is based on very simple technology may be very appropriate for use in many of the "small communities" (for which Pasveer ditches were originally intended).

### 3.2.5 Overall Conclusions

In relation to a National Strategy for Wastewater Management, the visits have revealed the following:

- there is limited expertise in WWTP design and management
- operational capabilities are varied, ranging from highly competent and knowledgeable to relatively poor
- where local manufacturers have copied designs of plant (surface aerators and bio-filter distributors) failures have occurred due to fundamental lack of understanding of principles or materials
- there is a preference for simple, non-mechanical processes where land permits, particularly where freezing conditions are common
- with long term affordability in mind, energy costs need to be considered and reviewed
- extended aeration is an effective process for built up areas where odours would lead to complaints and problems
- construction quality is variable

## 3.3 WASTEWATER COLLECTION SYSTEMS

Appendix D2 includes a description and technical discussion of the options for sewage collection in small communities, namely:

- conventional sewerage
- tanker collection

- septic tanks and holding tanks
- non-conventional (small bore) sewerage

### 3.3.1 Conventional Centralised Sewerage

In some cases where dwellings and other premises are built relatively close together, as in some towns, the most attractive option will be to install a centralised sewerage system, draining all foul discharge to the communal treatment works. Separate drainage should be installed to take surface water drainage directly to the nearest watercourse. This might be piped or a development of existing surface systems as exist in Tehran. Where gradients are shallow, pumping stations and rising mains may be required.

### 3.3.2 Conventional Local Sewerage

Where funds are not available to construct a complete town or regional sewerage system, local sewerage may be provided for groups of new or existing housing feeding either to small collection tanks or to small localised sewage treatment facilities.

A policy in rural areas could be to adopt localised sewage treatment and effluent reuse, utilising packaged plants or natural constructed wetland or lagoon systems.

Localised sewerage can also be adopted as a first stage towards an ultimate conventional centralised sewerage system by adopting tankerage in the interim.

### 3.3.3 Non-Conventional Sewerage

For smaller and more spread out communities the relatively new concept of small bore sewerage might become applicable. In this system sewage from small groups of properties is first settled in a septic tank and the resulting low solids effluent is transferred to a centralised full treatment facility, using small bore pipework - either gravity or rising main. Accumulated sludge is tankered out periodically. The relative merits are discussed in Appendix D1.

Other non-conventional sewerage systems include vacuum sewerage, a system through which foul sewage is drawn to a treatment plant, or main sewer, by vacuum. These systems have been installed in Europe to a limited extent, but involve relatively complex plant, very precise pipelaying, skilled operation and maintenance, high operating costs, and the system is considered too risky for small communities in Iran.

## 3.4 APPROPRIATE WASTEWATER TREATMENT TECHNOLOGIES

### 3.4.1 Preamble

Appendix D3 includes a thorough review of the main options available. Preferences for sewage treatment are discussed in this section.

The main considerations in selecting from the panoply of *Available Technology* those which are appropriate to the Iranian situation are:

- (i) Climate
- (ii) Population served
- (iii) Simplicity of operation and maintenance, spares availability

- (iv) Capital and operating costs and the availability of capital and operating budgets
- (v) Reliability and local expertise
- (vi) The choice between effluent/sludge reuse or disposal

For small communities both cost and simplicity of operation might favour dispensing with primary sedimentation where possible, as when adopting extended aeration, wastewater stabilisation ponds and some constructed wetland configurations.

The following paragraphs summarise the systems of treatment which are discussed in Appendix D3.

### 3.4.2 Preliminary Treatment

#### Screening

Of the screening methods discussed, simple hand-raked screens for smaller works and mechanical screens for larger works are the most appropriate options for Iran.

- maintenance of hand-raked screens is minimal, although an operative must carry out daily raking;
- mechanical screens have less operational input, but regular maintenance of motor and mechanised elements is required;

Automated fine screens and associated screen presses and comminutors are not considered suitable alternatives to conventional screens for the smaller communities, since:

- they have high operation and maintenance requirements
- they are expensive in terms of capital and running costs
- increased removal of organic material by fine screens is disadvantageous in hot climates since safe and odourless screening disposal is difficult
- grit and sand can damage a comminutor's cutting teeth
- shredded rags can ball-up and block downstream pipes and plant.

#### Grit Removal

For grit removal, constant-velocity grit channels are preferred to proprietary grit traps unless the wastewater is of such a volume that it makes the provision of channels impractical.

Constant-velocity grit channels have:

- no mechanical nor electrical plant, and therefore negligible maintenance requirements;
- minimal operational requirements.

The O&M requirements, as well as the running costs, of the whole works will be increased by the incorporation of automatic grit separators, mechanical screens or comminutors. Likewise, the satisfactory performance of the works would be jeopardised should any mechanical plant breakdown and not be promptly replaced or repaired.

Disposal of grit and screenings needs to be addressed in each local situation. They can be included in solid waste disposal systems to sanitary landfills or, in some circumstances, disposed of by burying on site.



### 3.4.3 Primary Treatment

#### Primary Sedimentation Tanks

Primary sedimentation tanks should be provided wherever the secondary process necessitates it. Primary sedimentation tanks have:

- minimal operational requirements;
- mechanical scrapers and skimmers and associated motors that require some regular maintenance unless they are deep vertical flow tanks;

Primary sedimentation tanks should have minimal retention times for both sludge and supernatant in order to reduce the potential for septicity and odour nuisance.

Extended aeration systems can be designed to receive unsettled wastewater, thus obviating the inclusion of primary sedimentation tanks. Likewise, trickling filters if packed with open structure, plastic packing medium, can receive unsettled wastewater, but the incoming flow must first pass through a fine screen.

#### Imhoff Tanks

The principal advantage of Imhoff tanks and anaerobic ponds over sedimentation tanks as the first stage in a sewage treatment works is that they offer a degree of controlled anaerobic sludge digestion. Furthermore:

- the sludge from Imhoff tanks can be disposed of to sludge drying beds or constructed wetland 'reed' beds;
- the sludge from anaerobic ponds can be disposed of to landfill or agricultural land;
- the sludges are less odorous than primary sludges.

Imhoff tanks require daily removal of scum and the reversal of the wastewater flow twice-monthly. The well-stabilised sludge wasted from an Imhoff tank could successfully undergo further treatment on sludge dewatering reed beds.

#### Primary Ponds

Operating and maintenance requirements of anaerobic ponds are extremely low.

#### Septic Tanks

Septic tanks, if properly constructed and maintained, can provide acceptable primary sedimentation prior to effluent disposal to a soakaway, to a series of waste stabilisation ponds or to a constructed wetland system. The advantages and disadvantages of septic tanks in Iran are:

- experience of their construction, operation and maintenance already exists;
- some towns have a desludging service;
- on-site disposal of effluent in soakaways may lead to groundwater contamination.

Septic tanks are normally sited immediately adjacent to the buildings which they serve. Maintenance of the tanks is often the responsibility of the individual households and therefore

may not always be adequately undertaken. In some situations, however, the local municipality can be made responsible for the maintenance service.

Treatment and disposal of sludges produced in settlement options is discussed later.

### 3.4.4 Secondary Treatment

#### Technical Backup

All of the technologies discussed in Appendix D3, with the exception of ponds and constructed wetlands, incorporate mechanical and electrical plant. They consequently also have varying degrees of operational and maintenance requirements and relatively high running costs. The success of technologies relying on mechanical and electrical plant is directly dependent on the reliability of the power supply feeding the works, and on effective skilled operation and maintenance. For these technologies poor process performance, and eventual environmental contamination and increased public health risk, are inevitable results of an intermittent power supply or inadequate operation and maintenance. Whilst some plant equipment will inevitably be required in any sewerage and sewage treatment system, it is recommended that this be kept to a minimum.

#### Mosquito Nuisance

Any body of stationary water that provides shade will be a suitable breeding site for midges and mosquitoes. Such potential breeding sites should be minimised at any sewage treatment works, be they conventional or more 'natural' systems, so that the works does not promote the infestation of these insects in the vicinity.

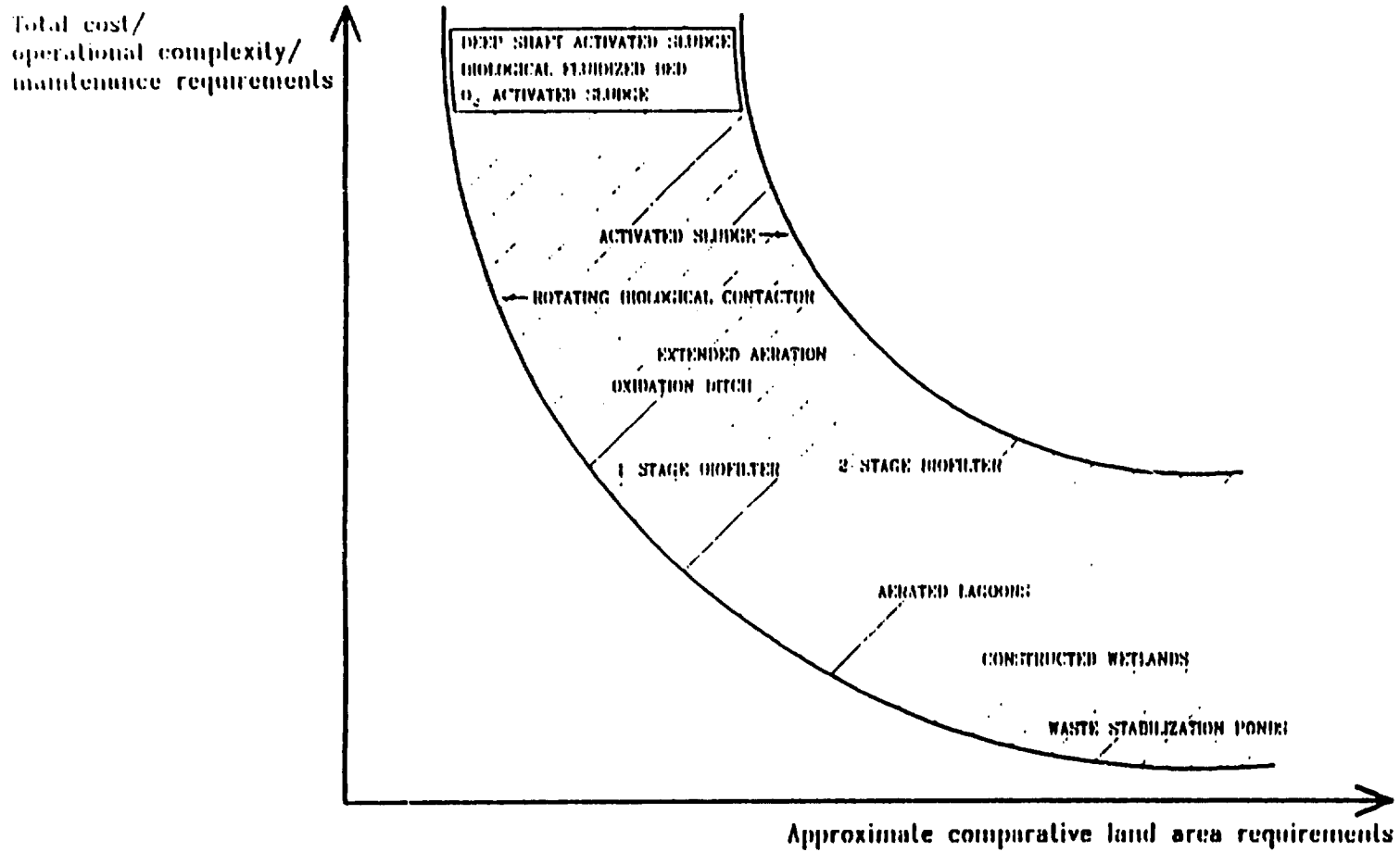
Concern has been raised that waste stabilisation ponds or constructed wetland systems would act as suitable breeding grounds for mosquitoes. If pond embankments are properly maintained so that grass and other flora is prevented from growing down into the ponds at the peripheries, then mosquito breeding is not a problem. This is a very simple maintenance task more akin to gardening than to engineering. There are many examples of pond systems throughout the world which have no problems with mosquito breeding. The few ponds currently in use in Iran similarly have no reported mosquito nuisance.

Similarly, properly designed, operated and maintained constructed wetland systems should have no free-standing water on the surface of the gravel beds and consequently no potential mosquito breeding sites. Vertical flow wetland systems, which undergo surface flooding, incorporate parallel beds which are used in rotation. The intermittent drying out period, when a bed is not receiving any flow, serves to prevent mosquito breeding.

#### Comparative Land Areas and Costs

Figure 3.1 shows a relative comparison of the various secondary treatment methods described in Appendix D in terms of their respective total costs/degree of operational complexity and their land area requirements. It also includes some high-tech, high-cost technologies not referred to in the Report (deep-shaft activated sludge, biological fluidised beds and O<sub>2</sub> activated sludge: they are too costly or difficult to operate and maintain to be considered for application in Iran but are shown in the figure for purposes of comparison).

Figure 3.1 is also a simple graphical comparison of treatment methods intended to demonstrate that, in general, the more expensive and complex the technology, the less land the sewage



RELATIVE COMPARISON OF LAND AREA REQUIREMENTS AND TOTAL COST / DEGREE OF COMPLEXITY OF VARIOUS WASTEWATER TREATMENT OPTIONS

treatment plant requires. It is evident from the figure that the real cost of adopting a land-saving option is not only monetary, in terms of both capital and running expenditure, but can also be measured in terms of operational complexity. The further up the curve the technology is located the greater are its operational and maintenance requirements. Evidently, waste stabilisation ponds and constructed wetland systems are the cheapest wastewater treatment options to construct and run and the simplest to operate and maintain.

### **Activated Sludge**

In Figure 3.1 'activated sludge' refers to both the conventional and nitrifying activated sludge processes. In summary, conventional and nitrifying AS together with extended aeration systems have the following disadvantages:

- inherent problems of high capital and running costs
- high operational and maintenance inputs
- difficult and complex process control requiring trained and skilled management
- systems are susceptible to shock loadings.

### **Extended Aeration**

Extended aeration plants, however, are more robust than the other AS systems, since they:

- do not necessitate primary sedimentation
- can buffer hydraulic and organic surges in flow
- produce a highly mineralised, low volume, easy to dewater sludge.

A disadvantage of the extended aeration process, especially in hot climates, is the potential for denitrification and rising sludge to occur in the secondary settling tank. Denitrification can be achieved by incorporating an anoxic zone with mechanical (or low rate air diffuser) mixers at to the aeration tank inlet. This has the added advantage of reducing the oxygen demand of the wastewater. Extended aeration activated sludge is the technology that can most reliably reduce the ammonia content of the wastewater to low levels.

### **Trickling Filters**

Although two-stage trickling filters can be designed to achieve high standards of treatment, they are not usually the chosen method if this is a prime objective; extended aeration being preferred in their place. Disadvantages of trickling filters are:

- larger land areas than activated sludge and RBC systems
- high construction costs
- necessity of good grit and rag removal
- odour release, especially in hot climates
- fly and midge nuisance, especially in hot climates
- costly intermediate pumping stations often needed for 2-stage nitrifying biofilters
- sludges are putrescible and require digestion before dewatering.

Their advantages over extended aeration alternatives are:

- relatively simple to maintain and operate
- low power requirement

- can withstand shock loading without serious effects on the treatment process.

Biofilters are, however generally more economic and straightforward to operate than their conventional treatment counterparts.

### **Rotating Biological Contactors**

Rotating biological contactors can be designed to produce a range of effluent and being of relatively small plan area can be readily covered for smaller communities of say less than 12,000, particularly in, say, the mountain areas.

Disadvantages of RBCs are:

- Frequent motor failure commonplace
- shaft fracture or start-up failure due to unbalanced film growth on discs
- grit and sand in shaft bearings can cause discs to slow or cease rotation
- inability to accommodate organic or hydraulic surges
- danger of reactor head turning anaerobic.

### **Aerated Lagoons**

Aerated lagoons are simpler and cheaper to construct and operate than other conventional treatment systems, but require more land area. Their disadvantages are:

- maintenance and operation of aerators often time consuming and costly
- poorly mineralised sludge produced requiring further treatment
- cannot achieve low effluent ammonia levels
- Effluents can be high in solids requiring further treatment.

### **Waste Stabilisation Ponds**

The suitability of waste stabilisation pond systems are discussed in Appendix D3. In summary, the advantages of WSPs are:

- recommended by the WHO where effluents are destined for reuse in irrigation
- confidently designed to meet WHO microbiological effluent guidelines
- lower costs (for construction, maintenance and operation) than other treatment processes
- expend no energy; other than solar energy
- high capacity to absorb organic and hydraulic shock loadings
- extremely simple to operate and maintain
- ability to treat a wide variety of industrial and agricultural wastes.

The main disadvantages of pond systems are:

- potential for odours if anaerobic lagoons are used as first stage
- large land area requirements when compared to conventional wastewater treatment systems.

### **Aer-o-Fac/Accel-o-Fac**

As discussed in the text these relatively new technologies are showing effective performance in the US and are worthy of trial through demonstration in Iran. Initial enquiries suggest the plant is relatively expensive to purchase, but when total land area costs, running costs and performance are considered the systems may be effective. Local manufacture under license might be a consideration to reduce costs.

### **Constructed Wetlands**

The technology of constructed wetlands is worthy of consideration as full treatment for some of the smaller communities or as tertiary/polishing systems to WSP or activated sludge systems in view of the advantages of:

- cheapness of construction;
- minimal mechanical plant to operate;
- smaller land area than WSP systems;
- potential for disinfection without chemical addition;
- potential for environmental enhancement and beautification if designed as a landscaped feature;
- potential for cash cropping within the process.

Operational requirements for vertical flow gravel beds will be greater than for ponds since the incoming flow has to be regularly switched between parallel beds.

## **3.4.5 Tertiary Treatment**

### **Disinfection**

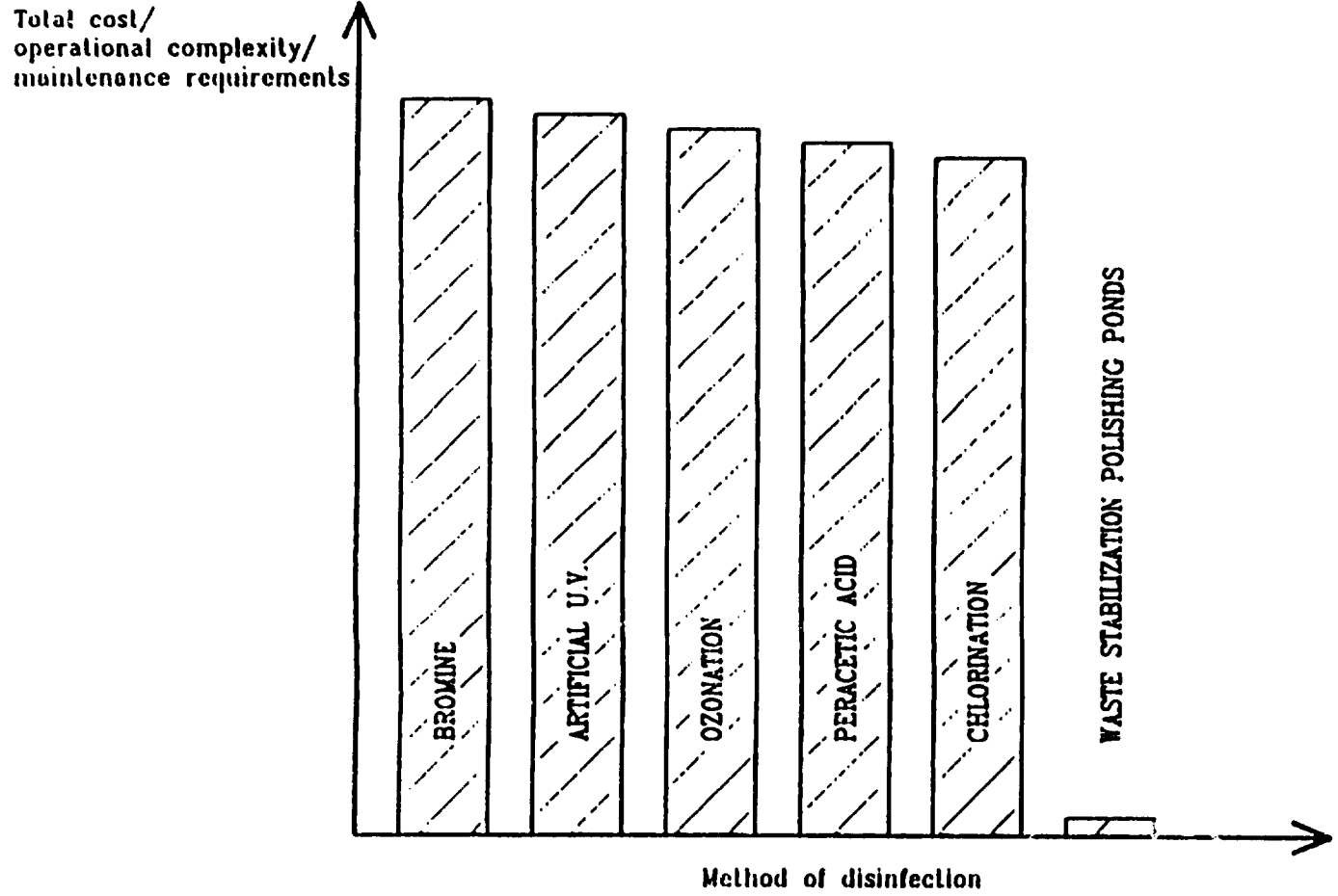
Although chlorination is an expensive process, it can be seen from Figure 3.2 that it is slightly cheaper than the other disinfecting processes. The figure is a relative comparison of the total cost and operational complexity of a number of effluent disinfection methods. As is demonstrated, there is little difference in the cost and complexity of disinfection to bring about a similar degree of bacterial removal by the application of bromine, artificial UV or peracetic acid, or by ozonation or chlorination. In contrast, however, it is very clear how much cheaper and simpler is bacterial removal through a series of waste stabilisation polishing ponds. The advantages of disinfection through polishing ponds are:

- costs are limited to initial construction costs, since ponds have no running costs
- operational and maintenance tasks are minimal
- pathogen removal process is extremely robust and reliable

Polishing ponds require much larger land areas than do the alternative disinfection processes.

The other five disinfection methods:

- have high capital and running costs
- are extremely complex to operate and maintain
- do not guarantee a disinfected effluent on a continual basis
- have no known anti-heimintic effects.



RELATIVE ADVANTAGES OF WASTE STABILIZATION POND SYSTEMS COMPARED TO OTHER EFFLUENT DISINFECTION METHODS IN ATTAINING SIMILAR DEGREES OF BACTERIAL REMOVAL.

Although not widely documented there is increasing evidence of effective bacterial removals in constructed wetland systems which might be considered in a similar category to WSPs.

### **Filtration**

Filtration of secondary effluent is:

- high on operational and maintenance requirements
- high in capital and running costs

In the smaller communities of Iran effluent filtration should therefore be avoided wherever possible. It should only be included in a scheme if:

- effluent is found to clog irrigation water distribution pipework
- additional helminth ova removal is required where land for polishing ponds is not available.

### **3.4.6 Sludge Treatment**

#### **Standard-Rate Anaerobic Digestion**

Standard-rate anaerobic digestion in unheated and unmixed reactors is a suitable sludge treatment option for much of Iran. Generally it:

- requires little or no operation and maintenance
- will perform efficiently in the ambient temperatures experienced in most of Iran
- has negligible running costs.

Standard-rate anaerobic digestion occurs in anaerobic waste stabilisation ponds, certain facultative ponds and in Imhoff tanks.

#### **High-Rate Anaerobic Digestion**

High-rate anaerobic digestion, in comparison, is not considered appropriate for the small communities of Iran because it has:

- higher capital and running costs
- greater operational and maintenance requirements

#### **Composting**

Composting of sewage sludge is a complicated process that requires either considerable operational control (windrow composting) or significant amounts of mechanical plant (aerated pile composting). It is not considered suitable for the smaller communities of Iran.

#### **Sludge-drying Beds**

Sludge-drying beds are a possible technology since they are:

- cheap to construct and operate
- suited to hot, dry climates
- simple to operate and maintain



To avoid odour and fly nuisance from sludge-drying beds only well-digested sludge, such as that from an extended aeration or an Imhoff tank, should be applied to them. They do, however, have the disadvantage of a significant operational requirement.

### **Sludge Reed Beds**

An interesting development of the sludge-drying bed, that promises to give even better dewatering rates, is the sludge reed bed. Advantages of sludge reed beds are:

- improved dewatering through water uptake by the reed root system
- improved drainage along the root/sludge interface
- longer periods between desludging operations (up to 5-10 years)
- more humus-like end product.

Discussions have already been held with the Manager of the Esfahan WWTP and literature sent to him about the possible conversion of existing sludge drying beds to sludge reed beds.

### **3.4.7 Effluent and Sludge Reuse**

The potential for effluent and sludge reuse should be seriously addressed in both legislation and the preparation of national guidelines. Appendix D4 discusses possible reuse applications and some of the implications on the selection of treatment process.

## **3.5 PROCESS SELECTION (GUIDELINES)**

Table 1.1 in Section 1 summarises the selection options discussed below.

### **3.5.1 Mountainous Regions**

These regions are likely to experience prolonged periods of deep freezing conditions. It is therefore necessary to ensure that any plant installed will not freeze up, or that the temperature of the sewage will not fall to a level below which the micro-organisms responsible for treatment will become seriously impaired in their activity. There are three preferred options:

- Extended aeration activated sludge treatment for the larger installations. If these are operated using blowers as a diffused air system the tank can be totally enclosed and heat generated during air compression will assist in warming the tank contents. This system would be applicable down to about 2000 population.
- For populations below 12,000 pe, biological percolating filters might also be adopted but would still need to be enclosed with forced draft.
- Rotating biological contactors (RBCs) might also be considered for communities in the medium and smaller-sized ranges. RBC's are normally totally enclosed. In this region the primary and final settling tanks for both filters and RBCs would also need to be enclosed to safeguard against freezing conditions.
- Constructed wetlands of the vertical flow type have been used in northern European countries subject to periods of freezing conditions, without any marked deterioration in performance. They might be considered for smaller communities in the less severe conditions.

- Sludge reed beds can operate satisfactorily in freezing conditions.

### 3.5.2 Central Plateau

For treatment plants located on the central plateau the options are broadly similar to those for use in the mountainous regions. However, depending on the precise altitude and latitude, plants may not always need to be enclosed and surface aeration could be used in the extended aeration plants.

Wastewater Stabilisation Ponds are also a feasible option (and are being installed near Esfahan) and variations of Constructed Wetlands can be adopted for the smaller communities, both with and without lagoons.

### 3.5.3 Caspian Sea Area

This is a temperate zone close to the sea where it is not expected that serious problems will be encountered due to very cold weather. The area is, however, more generally flat which will perhaps mean gravity sewers being laid at the shallowest practicable gradients and pumped rising mains also being adopted. Both of these circumstances will greatly increase the risk of septicity occurring in the sewers and pumping stations.

Septicity in sewage commonly has three effects, namely:

- (i) Corrosion and structural damage to the fabric of sewers, manholes and mechanical equipment such as pumps
- (ii) Odour release from manholes or pumping stations, as well as at the sewage works inlet
- (iii) Treatment difficulties, caused by the high sulphide concentration in the sewage.

Treatment difficulties caused by sulphides can be numerous, but include rising sludge in primary tanks, inhibition of biological activity due to low pH and the sulphide concentration and encouragement of filamentous organisms in activated sludge plants. This latter condition is known as sludge bulking, if the filamentous organisms achieve a high enough concentration to inhibit the speed of sludge settling. This may result in the sludge being carried over in the final clarifier effluent.

At large treatment works, site restrictions may require an intensive process such as activated sludge. Conventional activated sludge plants are particularly prone to sludge bulking. This is a result of retention in the primary sedimentation tanks giving rise to further septicity, as well as rising sludge being washed periodically into the aeration basin. Anoxic zones (at nitrifying plants) and chemical addition of ferric salts into the settled sewage are two methods of improving sludge settleability under such circumstances.

Extended aeration plants operate at low biological loading rates (i.e. F/M ratio), which give better settling sludges. This advantage is, however, offset by the fact that they are usually operated at higher mixed liquor concentrations. This in turn results in stable scums forming and sludge washout due to the higher mixed liquor more than compensating for the better settleability.

Provided these considerations are taken into account at the design stage, extended aeration plants have the benefit of ease of operation. They have a low labour input requirement, but higher electricity cost associated with them.

A suitable application of extended aeration would be to adopt the 'oxidation ditch' system in its form as originally intended by Dr Pasveer. This involves very simple engineering methods and materials for its construction and also carries the benefit of requiring very little attention or maintenance.

For the medium and smaller sized sewage treatment plants Wastewater Stabilisation Ponds including facultative lagoons or aerated lagoon systems might be adopted. These will, of course, require very much space, can give rise to odour problems and require some stand-by capacity to permit desludging when this becomes necessary.

The AeroFac process would also be a consideration with the advantage of lower maintenance and energy and lower land areas.

At the lower end of the size range, the use of 'Constructed Wetlands' may be adopted for their low maintenance and environmental enhancement attributes.

#### **3.5.4 Persian Gulf Area**

Similar processes to those suggested for the Caspian Sea area would be appropriate around the Gulf region. However, in this predominantly hot and humid region odour problems could present a more serious challenge, as will the problems which arise from sewage septicity.

#### **3.5.5 Tourist Resorts**

Where large fluctuations in the population served are to be expected, if space permits, Natural WSP and wetland systems are likely to have a greater flexibility for the loading variations and can be landscaped into attractive features.

### **3.6 RECOMMENDATIONS FOR STAGE II**

#### **3.6.1 Data Collection**

The identification of the small communities in Iran which are not yet connected to main drainage and sewage treatment facilities would be a useful exercise in order to quantify and assess the overall situation. This would best be achieved by preparation of a database subdivided in size bands of population to be served (or population equivalent) and with each of these bands subdivided into climatic regions.

The next step will then be to accord some priority for implementation of construction projects. This would most sensibly be on the basis of the local environmental impact.

#### **3.6.2 Setting Standards**

Interim and long term environmental quality objectives need to be decided upon, from which will derive discharge consent requirements for domestic and industrial wastewater discharges.

Once the appropriate interim and long-term discharge requirements are known, then priorities for implementation of works can be set and appropriate technology selected for each site. The possibility of a phased approach to dealing with the pollution from larger communities discharging to larger water courses should be considered. For example, in instances where higher-tech processes are accepted, the installation of preliminary treatment and chemically assisted primary sedimentation as a first stage may provide a more significant environmental improvement than installing full secondary treatment at a smaller number of sites.

### **3.6.3 Assessment of Indigenous Capabilities**

During the study a visit was made to one supplier of sewage treatment equipment. This particular company appeared to produce good quality mechanical items 'in house' but relied on imported electrical components and more complicated mechanical items such as gearboxes.

Since Iran wishes to expedite its environmental improvements it will be preferable to reduce the import of expensive imported components as far as possible. The indigenous capability to produce reliable items of electrical and mechanical equipment therefore needs to be assessed in relation to the types of process adopted.

Judging from some of the treatment plants visited, it would appear that more attention by qualified civil engineers needs to be given to site supervision. Most of the installations visited had concrete work which was poorly finished, and in fewer instances, possibly structurally unsound (e.g. exposed reinforcement).

Once preferred treatment processes are defined and demonstrated (see below) full scale local manufacture of plant (under licence) could be evaluated and export potential considered.

### **3.6.4 Full Scale Demonstration Plants**

It is strongly recommended that "model" WWTPs are established based on a range of recommended technologies, to demonstrate their effectiveness and typical layouts. An overview of existing WWTPs may determine that some existing plants, possibly with modifications or improvements, could be used as models.

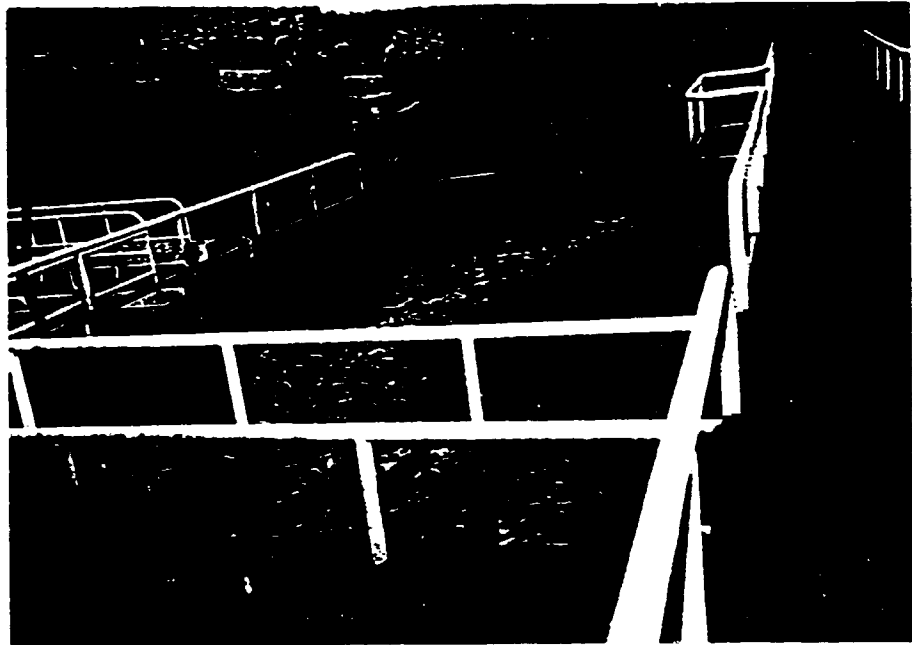
Experienced consultants should be appointed to conduct the review and to design and supervise construction and commissioning of schemes utilising the selected technologies for the different types of site, viz climate and population. It is recommended that full-scale pilot schemes of the following type are developed, possibly in more than one region:

- (i) constructed wetlands
- (ii) anaerobic facultative and aerobic lagoons and maturation ponds
- (iii) aerated lagoons (plus wind driven/power assisted aerators)
- (iv) Imhoff tanks plus RBCs
- (v) extended aeration AS plants plus FST
- (vi) oxidation (Pasveer) ditches

See Table 1.1, "Climate - Recommended WWTP Processes for Small Communities", in Section 1 for general process applicability.



*Plate 1*  
Tehran  
Gheytarieh Pilot WWTP



*Aeration tank*



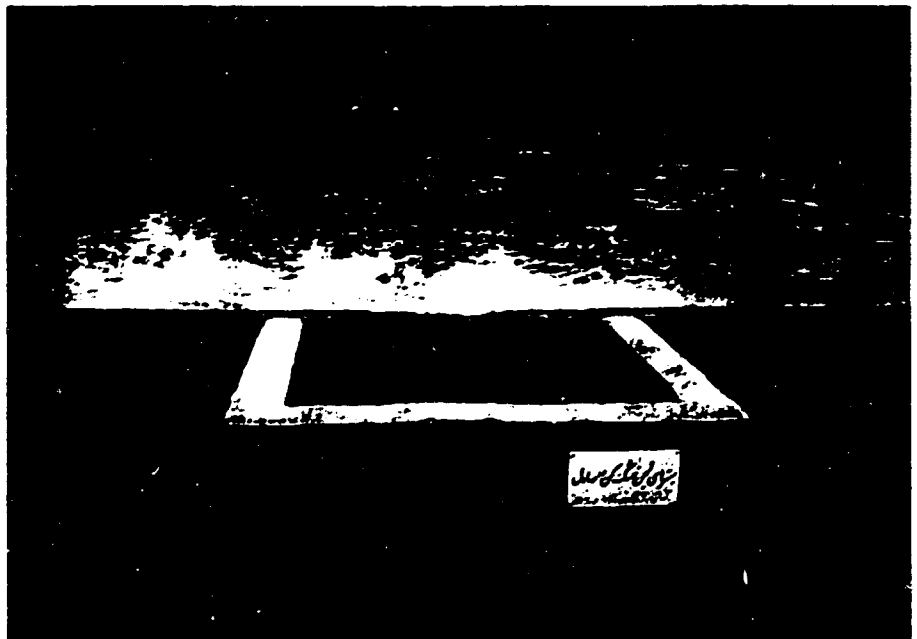
*Settlement tank*

Process: Extended aeration. Well-maintained, high-quality effluent.  
Concrete poorly-constructed and deteriorating.

*Plate 2*  
Tehran  
Shoosh Pilot WWTP



*Aeration tank*

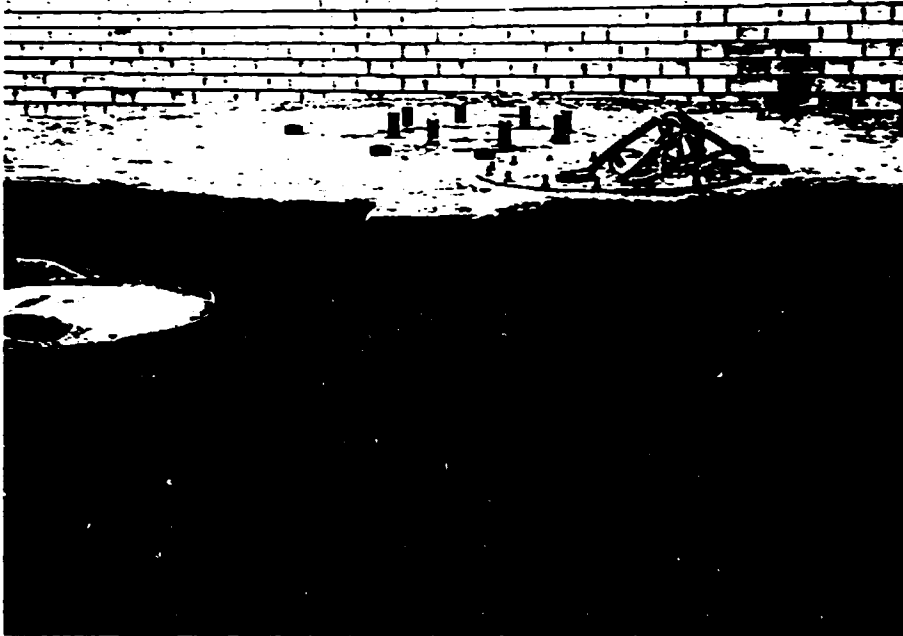


*Sludge drying bed*

Process: Extended-aeration activated sludge. Good-quality effluent.  
Medium-quality concrete construction.

*Plate 3*

**Mashad Holy Haram WWTP**



*Locally-manufactured  
aerator: failed at the  
shaft during trials*



*Lagoons awaiting  
installation of aerators*

**Process: Aerated lagoon (extended aeration). Awaiting installation of aerators**



## SECTION 4 INDUSTRIAL WASTE MINIMISATION

### 4.1 PATTERNS OF INDUSTRY IN IRAN

#### 4.1.1 Preamble

During the study some 21 factories have been visited, 11 associated with pipe manufacturing and 10 covering a range of other industries.

Iran has a very large industrial base with numerous industries. The study has resulted in a recommendation of 3 factories to be used for waste minimisation demonstration programmes in Stage II. These represent different industries from a cross-section of the industrial base of the country. The industries were chosen partly through the interest of the management since co-operation will be essential if the programme is to succeed.

A much larger database will be required in order to develop a pragmatic and comprehensive approach to the adoption of waste minimisation on a national level in order to obtain the greatest environmental benefits and cost savings in the shortest time.

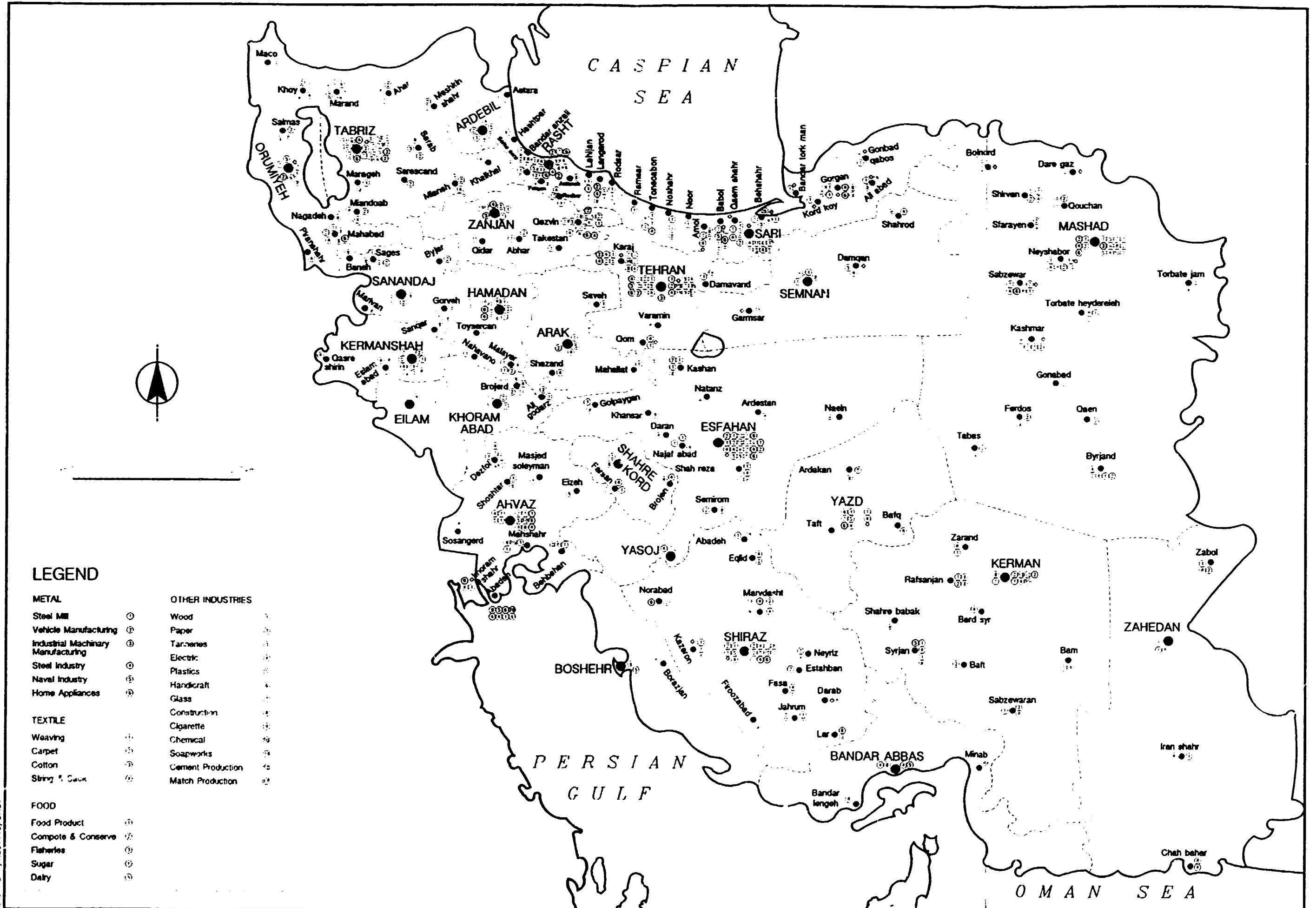
We have therefore recommended that an updated and more detailed database should be developed. This would not only classify factory types and output but would also link to information concerning water consumption, effluent flows and polluting loads.

#### 4.1.2 Industry Overview

Figure 1 is a map illustrating the distribution of the various national industries and the locations where particular types of factory are situated. It is indicative and in this short study it has not been possible to identify the numbers of these factories at each site.

For simplicity the many factories are categorised into groups and are indistinguishable individually.

Table 4.1 on the next page summarises the industries and Tables 4.2, 4.3 and 4.4 give information regarding the quantities of waste used and effluent discharged for the years 1983 and 1987 and future projections to year 2007.



**LEGEND**

- |                                    |   |                         |    |
|------------------------------------|---|-------------------------|----|
| <b>METAL</b>                       |   | <b>OTHER INDUSTRIES</b> |    |
| Steel Mill                         | ① | Wood                    | 1  |
| Vehicle Manufacturing              | ② | Paper                   | 2  |
| Industrial Machinery Manufacturing | ③ | Tanneries               | 3  |
| Steel Industry                     | ④ | Electric                | 4  |
| Naval Industry                     | ⑤ | Plastics                | 5  |
| Home Appliances                    | ⑥ | Handicraft              | 6  |
| <b>TEXTILE</b>                     |   | Glass                   | 7  |
| Weaving                            | ① | Construction            | 8  |
| Carpet                             | ② | Cigarette               | 9  |
| Cotton                             | ③ | Chemical                | 10 |
| String & Cask                      | ④ | Soapworks               | 11 |
| <b>FOOD</b>                        |   | Cement Production       | 12 |
| Food Product                       | ① | Match Production        | 13 |
| Compo & Conserve                   | ② |                         |    |
| Fisheries                          | ③ |                         |    |
| Sugar                              | ④ |                         |    |
| Dairy                              | ⑤ |                         |    |

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**Table 4.1**  
**List of Industrial Sectors in Iran**

Ind No.		No. of Plants
	<b>METAL INDUSTRIES :</b>	
1	IRON MELTING	2
2	CAR PRODUCING	6
3	INDUSTRIAL MACHINS PRODUCING	5
4	MOULDING , TURNERY , METAL MELTING AND ROLLING INDUSTRIES	19
5	SHIP , JETTY , RAILWAY AND ELECTRICITY METAL MASTS	7
6	DOMESTIC MATERIALS PRODUCING	17
	<b>WEAVING INDUSTRIES :</b>	
7	WEAVING	38
8	CARPET WEAVING INDUSTRIES	51
9	COTTON REFINING	27
10	COTTON SPRING AND SACKING	7
	<b>FOOD INDUSTRES :</b>	
11	FOOD PRODUCTS PRODUCING	76
12	COMPOTE AND CONSERVE PRODUCING	6
13	FISHERIES INDUSTRIES	8
14	SUGAR INDUSTRIES	56
15	DAIRY AND MILK AND MEAT COMPLEX	23
	<b>OTHER INDUSTRIES :</b>	
16	WOOD INDUSTRIES	16
17	PUBLISHING AND PAPERS INDUSTRIES	14
18	CURRIERY INDUSTRIES	9
19	ELECTRICITY INDUSTIES	9
20	PLASTIC AND ELASTIC MATERIAL INDUSTRIES	11
21	GLASSWORKS	8
22	BUILDING INDUSTRIES	118
23	FINE AND HANDICRAFT INDUSTRIES	9
24	TOBACCC PRODUCTS	17
25	CHEMICAL INDUSTRIES	12
26	SOAPWORKS	4
27	CEMENT FACTORY	20
28	MATCH FACTORY	9
	<b>MINES :</b>	
29	Pb	14
30	Zn & Pb	15
31	CHROMITE	3
32	Fe	5
33	Cu	12
34	Mn	4
35	OTHER METAL MINES	8

Table 4.1 Cont'd

		No of Plants
	<b>* NONMETALLIC MINES :</b>	
36	CHALK AND GYPSUM	42
37	SALT AND ROCK SALT	38
40	MARBLE	17
41	WHITING	4
42	Si & QUARTZITE	3
43	Kaolinite	6
44	TURQUOISE	2
45	OTHER NONMETALLIC MINES	45

Reference: Complete Atlas of Gita Shenasi, 5th Edition, 1373.

**Table 4.2**  
**Industrial Water Use and Wastewater Effluent - 1983**

No.	Industry Type	Water Use (Mm <sup>3</sup> /yr)			Consumption	Effluent		
		Surface Sources	Underground Sources	Sum		Surface Sources	Underground Sources	Sum
1	Food, Drinkable & Tobacco Products Ind	57	96	153	55	22	76	98
2	Weaving, Clothing & Leather Industries	7	47	54	22	10	22	32
3	Wood Products & Wood Industries	12	2	13	1	11	1	13
4	Paper, Cardboard, Print & Bookbinding Industries	18	3	22	3	1	18	18
5	Chemical Industries	37	44	81	33	11	37	48
6	Non-metallic Mineral Industries	7	50	57	32	4	22	25
7	Basic Metals Producing Industries	26	4	30	7	0.5	22	23
8	Machines & Mobilisation Industries	12	20	32	14	10	7	18
9	Other Industries	0.01	0.09	0.1	0.05	-	0.05	0.05
	<b>Sum</b>	<b>176</b>	<b>266</b>	<b>442</b>	<b>167</b>	<b>70</b>	<b>205</b>	<b>275</b>

Source: National Water & Wastewater Company

**Table 4.3**  
**Industrial Water Use and Wastewater Effluent - 1987**

No.	Industry Type	Water Use (Mm <sup>3</sup> /yr)			Consumption	Effluent		
		Surface Sources	Underground Sources	Sum		Surface Sources	Underground Sources	Sum
1	Food, Drinkable & Tobacco Products Ind	113	74	187	66	58	63	121
2	Weaving, Clothing & Leather Industries	23	58	81	27	13	41	54
3	Wood Products & Wood Industries	17	3	15	1	16	2	18
4	Paper, Cardboard, Print & Bookbinding Industries	23	4	27	4	20	3	23
5	Chemical Industries	64	33	97	40	14	44	57
6	Non-metallic Mineral Industries	22	66	87	47	12	28	40
7	Basic Metals Producing Industries	30	7	37	9	5	22	28
8	Machines & Mobilisation Industries	20	16	37	16	12	9	21
9	Other Industries	0	0.4	0.4	0.1	0	0.3	0.3
	<b>Sum</b>	<b>312</b>	<b>261</b>	<b>572</b>	<b>210</b>	<b>150</b>	<b>212</b>	<b>362</b>

Source: National Water & Wastewater Company

**Table 4.4**  
**Industrial Water Use Predictions (million cubic meter) - 2000**

No.	Industry Type	1983	1987	Base Variant			Acceptable Variant		
				2007 Prediction	Mean Yearly Growth %		2007 Prediction	Mean Yearly Growth %	
					1983 - 2007	1987 - 2007		1983 - 2007	1987 - 2007
1	Food, Drinkable & Tobacco Products Ind	153	187	429	4	4	678	6	6
2	Weaving, Clothing & Leather Industries	54	81	141	4	3	230	4	5
3	Wood Products & Wood Industries	13	19	31	4	2	99	7	9
4	Paper, Cardboard, Print & Bookbinding Industries	22	27	96	6	7	209	10	11
5	Chemical Industries	81	97	306	6	6	583	9	9
6	Non-metallic Mineral Industries	57	87	194	5	4	272	7	6
7	Basic Metals Producing Industries	30	37	159	7	8	170	8	8
8	Machines & Mobilisation Industries	32	37	60	3	2	130	6	7
9	Other Industries	0.1	0.4	3	15	10	4	17	12
	<b>Sum</b>	<b>442</b>	<b>572</b>	<b>1419</b>	<b>5</b>	<b>5</b>	<b>2375</b>	<b>7</b>	<b>7</b>

Source: National Water & Wastewater Company

### 4.1.3 Future Impact on Water Resources and Waste Disposal

From this limited data available and summarised in the tables it can be seen that the Food, Textiles and Leather, and the Chemical Industries are currently the largest consumers of water and also the biggest dischargers of effluent. The projections suggest that these will continue to be large water consumers and effluent dischargers up to the year 2007. However, even the more conservative estimates suggest dramatic increases of water consumption in:

- The chemical industries
- the non-metallic mineral industries
- the basic metals producing industries

It would, therefore, seem appropriate to address these industries in waste minimisation programmes for the future, to reduce the impact of industrial expansion upon the demand for the water resources and additional pressures on the environment.

## 4.2 WASTE MINIMISATION PRINCIPLES

### 4.2.1 Definition of Waste Minimisation

Waste minimisation is the reduction of waste at source. It is based on the philosophy that it is better to prevent waste being produced in the first place than to treat it afterwards. In other words, prevention is better than cure; and usually cheaper.

In the case of liquid industrial effluents, waste minimisation is the alternative to an 'end-of-pipe' solution. But that is only one aspect. A large quantity of solid waste is generated by many industrial activities which now requires increasingly costly disposal off-site, often by specialised contractors.

Quite apart from saving on disposal costs, waste minimisation exercises usually identify ways of minimising costs for raw materials, electricity, fuel and water.

The principles of Waste Minimisation are summarised on the figure on the facing page.

A sustained waste minimisation programme can pay substantial dividends by:

#### Reducing

- production costs
- on-site waste monitoring and treatment costs
- handling, transport and off-site disposal costs
- raw material costs
- energy and water costs
- long term environmental liability and insurance costs
- the risk of spills and accidents

#### and improve

- the income through the sale of reusable waste
- overall operating efficiency
- the safety of employees
- the company's image in the eyes of shareholders, employees and the community

These benefits are derived in a variety of different ways, such as:

- Use of alternative raw materials
- Alteration of processing and production methods
- Recycling of some by-products, including water and energy
- Recovery of by-products for sale
- Alternative use of by-products

#### 4.2.2 Execution of Waste Minimisation Exercises

It cannot be overemphasised that Waste Minimisation is a *philosophy* to be adopted by a Company on an ongoing basis. It is not a one-off exercise in which an outside agency, e.g. 'Consultants' are appointed to enter a factory for a fixed period to "undertake a waste minimisation exercise". The role of the Consultant is to:

- explain the concept and benefits
- observe independently and target key areas for attention
- train management and employees
- assist in setting up a framework whereby all relevant information can be collected and from which decisions can be made
- be available (but not necessarily on site) for advice whilst surveys are being undertaken
- provide guidance and assistance on interpretation of data to identify opportunities for waste minimisation.

#### 4.2.3 Preparing the Ground

To be effective, a waste minimisation audit needs the backing of a continuing commitment to waste minimisation by management, the support of employees at all levels and management systems which will help to keep progress under review. So steps to take in preparation for audit include:

##### **Demonstrating management commitment**

The commitment of top management is essential to the success of a waste minimisation audit. Reducing waste can require substantial capital investment and technical effort. The risks to output and quality must also be properly evaluated. These are legitimate concerns, but they could stifle potentially profitable ideas unless it is clear to all employees that senior management welcomes waste minimisation proposals and will support cost effective projects. Allocating specific responsibility for waste minimisation to a senior executive is one way for management to demonstrate its commitment.

##### **Establishing clear targets**

Setting a clear waste minimisation target for a company and keeping all company personnel informed of progress towards the target will help to focus the efforts of management and employees. In its simplest form the target can be "to reduce waste". In some cases, it will be possible to set quantified targets ("to reduce waste by x% a year"). Much will depend on the nature of the company's activities. There may be a need to conduct a waste minimisation audit before it is possible to set a sensible quantified target. In any event, the target should be:

- compatible with the company's other targets and objectives



- realistic
- reappraised regularly

#### • **Allocating waste disposal costs to the departments which generate them**

Companies sometimes group all waste disposal costs together. And some waste handling costs such as storage and transport may not be attributed to the generation of waste at all.

Allocating all costs associated with waste to the departments which generate the waste highlights the real impact of waste on production costs - and helps to show the true value of waste minimisation projects.

#### **4.2.4 Training and Motivating Employees**

Employees are a valuable source of information about operational problems and can often provide insight into possible solutions. They also play a vital role in implementing waste minimisation options, particularly those involving "good housekeeping" measures. This means that training and motivating employees should be key features of a company's waste minimisation strategy.

**TRAINING** can demonstrate to employees:

- how waste minimisation
  - keeps the company competitive by increasing efficiency and reducing waste disposal costs
  - improves working conditions and reduces the impact of industrial activity on the environment
  - improves the company's image and its relationship with the community
- the importance of each individual's role in reducing the waste generated by the company
- the basic principles of reducing waste at source, recycling and re-use

**MOTIVATING** employees to come forward with new ideas and to achieve waste minimisation targets can be helped by incentive schemes. Some companies present letters of commendation. Others provide lump sum awards, bonuses or shares of the saving made as a result of a new idea.

Information itself can motivate employees; news of successes in one department or company often sparks off ideas in another.

#### **4.2.5 Monitoring and Control**

##### **Effective Monitoring**

To be successful, waste minimisation programmes need to be underpinned by information systems which will help to:

- track waste streams
- ensure good communication between departments
- monitor individual waste minimisation projects
- gauge the overall success of the programme
- keep management and employees informed of progress

## Selecting the Audit Team

Careful selection of the audit team helps to ensure that all opportunities for waste minimisation are identified and properly evaluated. The team should report directly to senior management, should be led by a senior member of staff and should include personnel who can ensure that the audit takes full account of all aspects of the company's operations, notably:

- production/process engineering
- health and safety
- quality control
- purchasing/stock control
- finance
- research and development
- marketing
- legal advice
- personnel and training
- transport

If these responsibilities are not allocated to separate departments or individuals in a company, it would be advisable to ask each member of the team to focus on particular aspects of the company's operations for the purposes of the audit.

It can be useful to include an individual from outside the plant - either a senior employee who works elsewhere in the same company but is familiar with the plant being surveyed, or a consultant with expertise both in the production processes used and the appropriate waste minimisation technology. An outside opinion can act as a catalyst and counter any pre-conceived views held by those closely involved with the existing operation of the plant.

## Finding the Facts

The audit team first has to identify the waste generated, to examine where, how and why it is generated and to calculate current handling and disposal costs.

## The questions

Questions to be answered by the team include:

- what waste streams are generated on the site and how are they disposed of (for example emissions into the atmosphere and liquid discharges into the sewers or elsewhere as well as solid waste)?
- what are their characteristics (for example, composition, concentration and variations in rate of production or composition)?
- which processes or other activities on the site generate these waste streams - and don't forget that waste can be generated in an office as well as by a production process?
- what is the total quantity of waste generated?
- what quantity of raw material, product or waste is lost accidentally?
- which waste streams are classified as hazardous and what makes them hazardous?
- do the waste streams get contaminated and if so how?
- is extra waste being generated by the mixing of recyclable materials with non-recyclable wastes?

- how efficient are the production processes and other activities on the site in terms of materials usage?
- what are the current costs of handling, storing, treating, transporting and disposing of the waste (including hidden costs such as storage space and the use of vehicles)?
- what good housekeeping and other waste reduction practices are currently in use?

#### Sources of information

Sources of the information for the team include:

- analyses of waste, emission and effluent discharge records
- specifications of raw materials and products, stock inventories, production records, records of material purchases for processing or other activities on site
- process flow diagrams, equipment operating manuals, process descriptions and piping instrument diagrams
- costs for materials, water, energy, operating, maintenance, storage, handling, transport and waste treatment and disposal

An important source of information is the production line itself. So the team needs to visit the site to observe the key waste streams from the point of generation to the point of disposal. The visit should coincide with important operations such as equipment cleaning. It can be useful to observe operations in more than one shift, particularly if activities differ from one shift to another or if waste generation is highly dependent on employee activities. A visit also allows the team to discuss current housekeeping practices with operational staff and to clarify ambiguous diagrams and plans.

It can be helpful to summarise the information gathered into a "mass balance" of all inputs and outputs. Unexpected discrepancies between raw materials input and output in the form of product and known waste will indicate that there are further losses to be identified and quantified. But the precision of the data collected is important. Mass balances performed over a complete production run can be the easiest to compile and are often the most accurate.

#### 4.2.6 Implementation

##### Identifying the Options

When the facts have been assembled, it is useful to list all the waste minimisation options including even those which, at first sight, seem uneconomic or technically difficult.

The extensive range of options to be considered includes:

##### Inventory management and good housekeeping

- clear specification of good housekeeping and materials handling procedures
- better training and motivation schemes
- regular auditing of materials purchased against materials used
- reducing the loss of materials due to mishandling, exceeded shelf-life or incorrect storage conditions
- improving raw material purity
- replacing toxic chemicals with non-toxic alternatives
- repairing leaks and recovering spills immediately
- regular preventative maintenance

### **Modifying production processes**

- introducing new processes or equipment which produce less waste ("clean technology")
- modifying the product to avoid waste generating processes
- optimising operating conditions (for example reaction rates, pressures and residence times)
- installing flow meters and analysers to detect below par performance
- ensuring that equipment operates at optimum efficiency
- improving the layout of equipment and piping (for example to avoid unnecessary pipe or tank cleaning operations)

### **Recycling and reuse**

- separating hazardous and non-hazardous waste streams
- segregating waste in a way that allows it to be recovered or reused
- recycling waste within the production process
- recovering or reusing waste on site (for example in heat recovery systems)
- finding markets for the waste (for example through exchange schemes or links with industries dealing in secondary materials)

### **Evaluating the Options**

#### **Initial Screening**

Several options may be identified for each waste stream.

An initial screening of the options will identify inventory management and good housekeeping measures which are obviously beneficial and can be implemented quickly and cheaply without undue disruption of production.

Other options can be ranked according to the benefits which they are likely to bring. As a general guide, it is useful to consider the options in the following order:

- measures to prevent the generation of waste
- measures to reduce the volume of waste generated or to reduce its hazardous content
- measures to recycle or re-use waste within the same production process
- measure to re-use the waste or reclaim part of it for some other purpose (for example energy recovery or use by another plant or company)

Selecting the right priorities for a company will involve a broad assessment of such factors as economic benefits, technical feasibility, impact on employees' working conditions and on the environment and compliance with current and expected environmental legislation.

#### **Detailed technical and economic assessment**

The most promising options can then be given a more rigorous examination to assess technical and economic feasibility. The whole audit team should be involved in this process so that balanced proposals can be presented for decision by management.

## The technical assessment

Important technical questions for the team are:

- will the new equipment/material/procedure be compatible with existing operating procedures and work flow?
- will production rates be affected and if so by how much?
- will product quality be affected?
- is special expertise or additional labour required for operation and maintenance?
- will energy and water needs be affected?
- is space available?
- will new waste streams be generated and if so what will their volume and characteristics be?
- will other problems be created?

## The economic assessment

Waste disposal charges are rising and controls are becoming stricter. This has important implications for a company's waste disposal costs which need to be explored fully in the cost/benefit analysis of the options. Factors to be considered include:

- present and forecast waste disposal costs
- the cost of compliance with present and forecast waste disposal controls
- the capital cost of installing new equipment or processes
- the impact of each waste minimisation option on the cost of:
  - labour for operating and maintaining the plant (taking into account any hidden benefits in the form of, for example, reduced sick leave)
  - raw materials
  - energy and water consumption
  - insurance and liability
  - handling, storing, treating, transporting and disposing of the waste
  - dealing with spillages

and the impact on revenue from:

- increased or decreased production
- improvement or deterioration in product quality
- the sale of materials previously destined for disposal

This economic evaluation can be carried out using standard measures of profitability such as payback period and return on investment. But where the standard analysis suggests that the option is not economically viable, it would be worth considering less predictable factors such as the costs of corrective action after spills and the benefits of an improvement in the company's image in the eyes of shareholders, employees and the community.

### 4.2.7 Examples of Waste Minimisation

Montgomery Watson has a growing portfolio of experience of setting up waste minimisation projects in many parts of the world. UNIDO is undertaking extensive waste minimisation programmes in developing countries and useful reference documents are:

- (i) "Audit and Reduction Manual for Industrial Emission and Wastes" - published by UNEP/UNIDO
- (ii) "Guidelines for Minimising Waste in the Pulp and Paper Industry" - a report produced by the National Productivity Council, India.

Both of these documents contain good examples of the way in which waste can be minimised and are relevant to the situation in Iran.

Examples of successful waste minimisation programmes in the UK are given in the following table:

Manufactured Product	Action
Liquid Dispersion polymers	Separation before dilution Recovery of solvent Improvement of remaining sludge dewaterability Saving of £10,000/week
Abattoirs(s)	(a) Anaerobic digestion of non-recyclable waste to produce energy source and good quality fertiliser. Saving £2,000 pa on fuel and £300/week on disposal of waste (b) Recovery of blood for sale (c) Recovery of protein for animal feedstuffs
Dairies	(a) Recovery and recycling of whey as feedstuff (b) Recovery of lactic acid (c) Recovery of lactose
Citric Acid	Anaerobic digestion of mycelium waste to produce 10% of the factory's energy besides achieving large reductions in the cost of BOD removal
Lead recycling	Introduced process to wash, granulate, dry and extrude polypropylene battery cases. 1,000 tpa of black co-polymer sold to building industry
Confectionery	Improved flow and sugar concentration monitoring led to waste reduction and savings of £30,000 pa in trade effluent charges
Animal Feedstuffs	Improved monitoring led to recovery of recyclable by-product and savings in disposal costs
Film processing	Recycling of fixer and recovery of silver from the waste saves £3,000 pa
Metal processing and coating	Two different companies saved £25,000 pa and £10,000 pa by installing acid recovery units
Aire and Calder Project - West Yorkshire	Eleven companies in two adjacent river catchments in West Yorkshire participated in a Waste Minimisation scheme. They included chemicals manufacturing, soft drinks, printing, engineering and laundering. In all cases opportunities for environmental improvements and accompanying costs savings were identified

## 4.3 SELECTION OF DEMONSTRATION PLANTS

### 4.3.1 The Situation in Iran

Visits to some 11 pipe manufacturing plants and 10 other industrial premises were undertaken. Visit reports are included in Appendix B and other pipe manufacturing visits are reported in the parallel pipe manufacturing study report.

Whilst clearly representing only a very small cross-section of Iranian industries the visits did give a reasonable impression of the wide range of standards of factory in Iran and the differing attitudes to environmental issues and efficiency.

The factory visits included one of Iran's largest complexes, the Esfahan Iron Smelting Plant, and a number of major polluting industries.

The confectionery and pharmaceutical factories (Minoo Industries - Tehran) produced virtually no liquid effluent; only floor washing which is to be treated in an extended aeration plant along with the domestic effluent. The tyre factory on the Kavah Complex produced only contaminated cooling water as effluent.

The following production activities were worth considering for waste minimisation demonstration programmes:

These are:

- Iron smelting (Esfahan)
- Leather tanning (Tehran)
- Paper Mill (Chuka)
- Textile dyer (Mazandaran)
- Sugar refinery (Karaj)
- Abattoir (near Tehran)

Whilst the actual factories visited may not necessarily be the best of their type to represent the industries as a whole, sufficient examples of potential factories for demonstration programmes were included.

Other manufacturing industries are known to produce large volumes of polluting aqueous effluents, besides significant quantities of solid wastes for which recycling and waste minimisation opportunities exist.

Of the factories visited, two factories stand out as being suitable as demonstration plants, not only because good opportunities exist but especially because of the enthusiasm and commitment of the management to waste minimisation and environmental improvement. These factories are (i) the Esfahan Iron Smelting Plant and (ii) the Chuka Paper Mill.

The new Tannery complex in Tehran has also expressed interest in the programme and we have nominated it as a third candidate, particularly since it is an industry in which the principles of waste minimisation can be readily demonstrated.

The sugar refinery at Karaj already does much to minimise its waste and recycle by-products to other uses (e.g. cattle feed cake), but other sugar refineries might be worth investigating.

Other types of factory known to be likely to benefit from waste minimisation projects are dairies and abattoirs where good recycling and waste minimisation opportunities exist.

We have, therefore, identified three levels of priority for the types of factory which can benefit significantly from waste minimisation related to its liquid wastes. If it is the wish to proceed rapidly into the demonstration programme then the three selected factories in Category A could be selected. If, however, further investigation is thought to be beneficial, Stage II of this project could include visits to more of these types of premises before making final selections for demonstration projects.

#### **PRIORITY**

- A. Papermills \*, Tanneries\*, Iron Smelting \*
- B. Sugar refining, Dairying, Abattoirs
- C. Food processing, Textile processing\*, Chemicals

\* These factories visited are known to be appropriate and enthusiastic.

#### **4.4 RECOMMENDATIONS FOR STAGE II**

##### **4.4.1 Waste Minimisation Programme**

Consultants should be appointed to target individual factories to co-operate in the Waste Minimisation Demonstration Projects and assist in the development of the programme.

- The prime targets identified in the previous section should be approached for discussions with management and presentations on the concept, implementation and benefits of waste minimisation schemes. From the outcome of these talks, either:
  - (a) Arrangements for implementation will be initiated
  - (b) Alternative targets in the same industry or in a different industry will be selected for approach and discussion.
- A more detailed database of individual manufacturing companies throughout Iran should be developed. The Ministry of Commerce and Industry should assist in the development of this database.

This would then be compared with experience elsewhere to identify categories and factories which would benefit most from the introduction of Waste Minimisation Schemes.

- In view of the almost universal success derived where Waste Minimisation schemes have been implemented, it may be possible, after assessing the Iranian industry in depth (as in Section 4.4.1 above), to advise the Iranian Government that a wider range of industries should be encouraged to co-operate in this exercise. The involvement of a wider range of industries co-operating with each other under the leadership and guidance of UNIDO would lead to more immediate and widespread benefits being derived. Regular meetings between individuals appointed at each factory to 'champion' the Waste Minimisation project, would provide mutual encouragement and also a cross fertilisation of ideas and experiences as the projects develop.
- The appointed consultants would preside over meetings and discussions between the industrial appointees (champions) to:



- (a) Explain the concept of Waste Minimisation;
  - (b) Describe how implementation of Waste Minimisation schemes would be achieved (Stage III);
  - (c) Advise on suitable literature to be studied;
  - (d) Emphasise that Waste Minimisation is an on-going philosophy undertaken by the management and employees of the Company with guidance (only) being provided by outside agencies.
- Visits to the factories would be made at the start of the programme and at intervals to assist in the identification of target areas and in the development of auditing and monitoring procedures. Further visits would be made throughout the programme.

#### **4.4.2 Database Inventory of Discharges to the Environment**

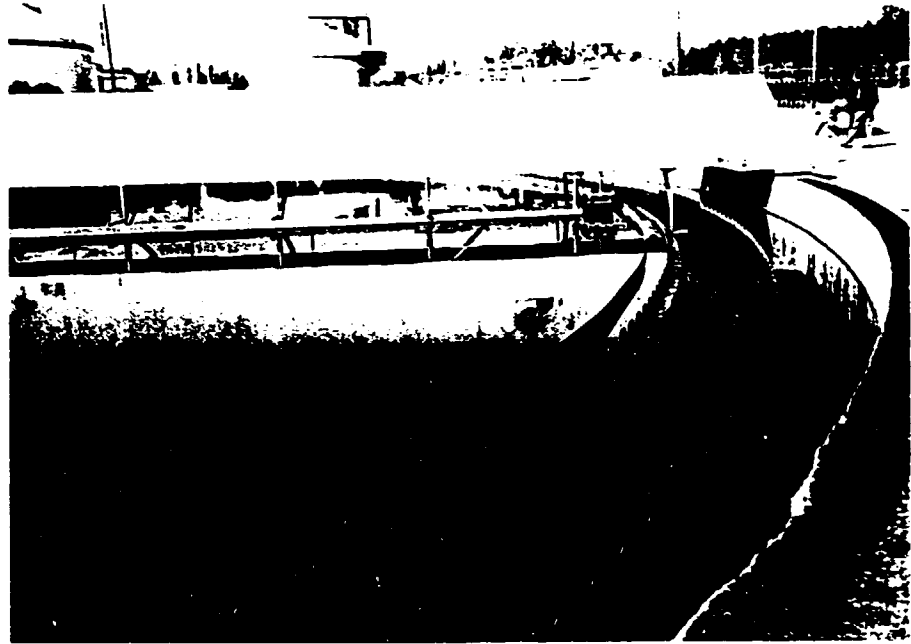
- In order to give a framework for understanding and monitoring the industrial discharges a consultant should be appointed to develop a comprehensive database recording system of aqueous, terrestrial and atmospheric discharges. The database should relate to and contribute to the development of legislation for the control of discharges.
- Training in the collection and inputting of data should be given to Ministry personnel.

#### **4.4.3 Training Visits**

A Programme of training visits should be undertaken with UNIDO's support and backing to witness successful waste minimisation programmes. This could include visits to the Ministry of Water Resources and Environment in the Oman, which has successfully implemented a computerised database inventory of waste discharges, and could also include selected factories which are known successfully to have implemented waste minimisation schemes. Training visit recommendations are included in Section 1.

*Plate 4*

**Esfahan South WWTP**



*Primary settlement tanks, with digesters in the background*



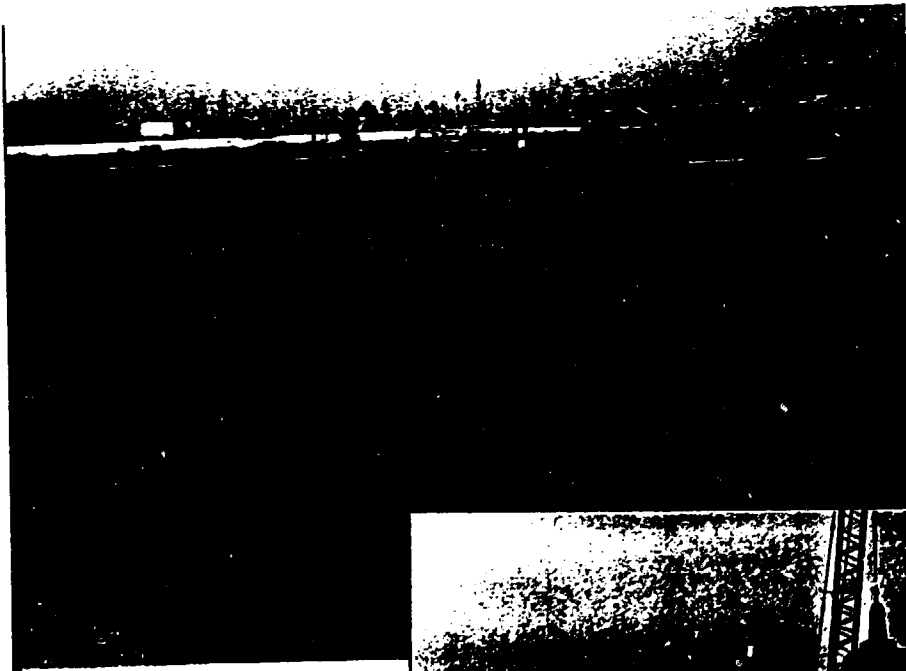
*Sludge drying beds*

**Process: Biological filtration and conventional activated sludge.  
Well operated and maintained, but overloaded.  
Major sludge management problem.**

*Plate 5*  
**Bandar Anzali**  
**Chuka Paper Mill**



*Settlement tank*



*Sludge drying*



*Sludge removal*

*Plate 6*  
**Ghaem Shahr  
Textile Company**



*Oxidation ditch*



*Scum*



*Illegal discharge of  
domestic and industrial  
waste - plant by-pass*

*Comment: Bad performance and no control*

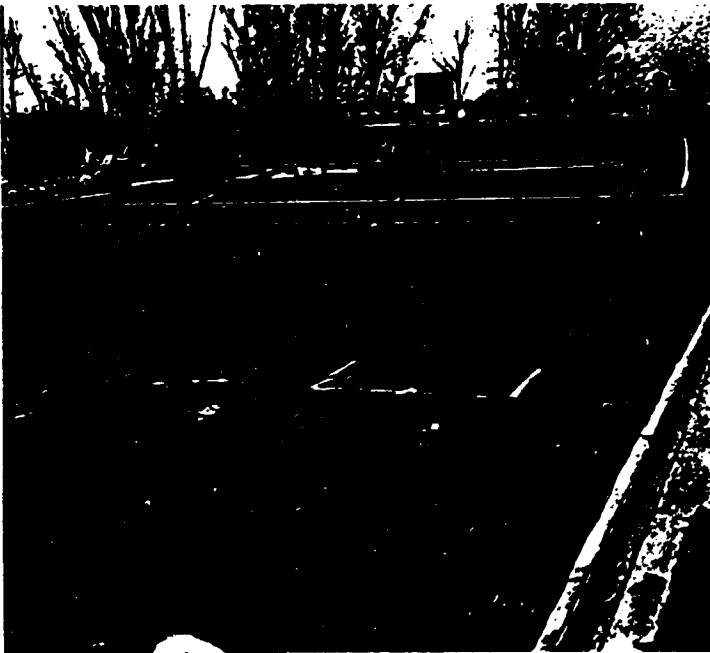
*Plate 7*  
**Karaj Sugar Refinery**



*1930's screening plant*



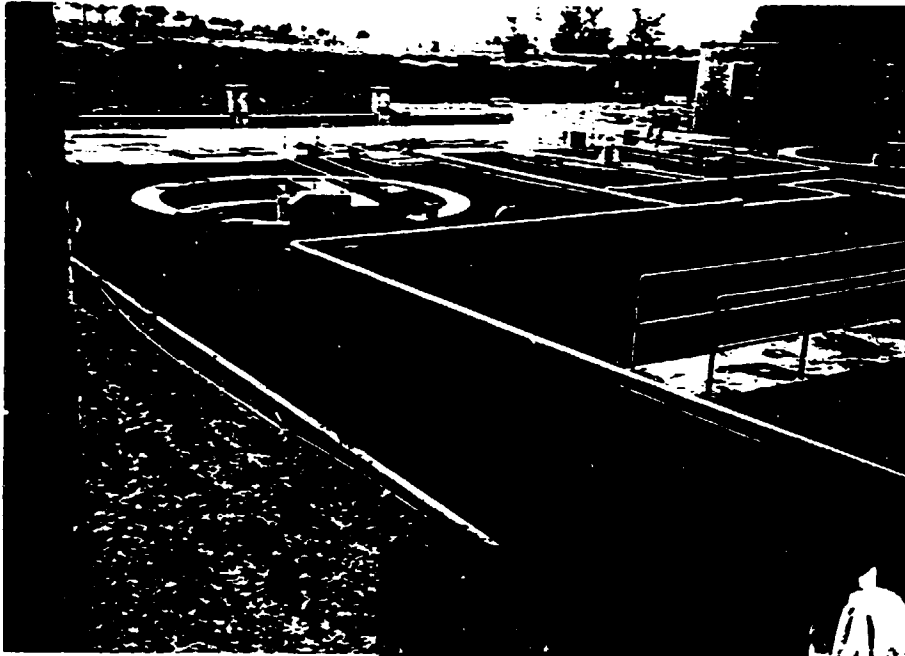
*Beet washing*



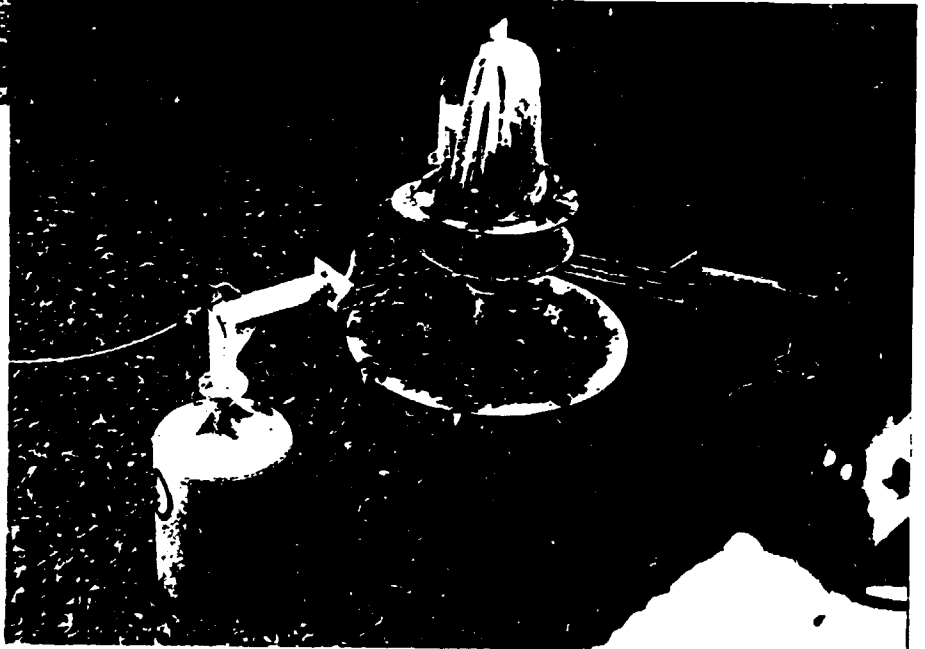
*Unused settlement tank*



*Untreated effluent discharge*

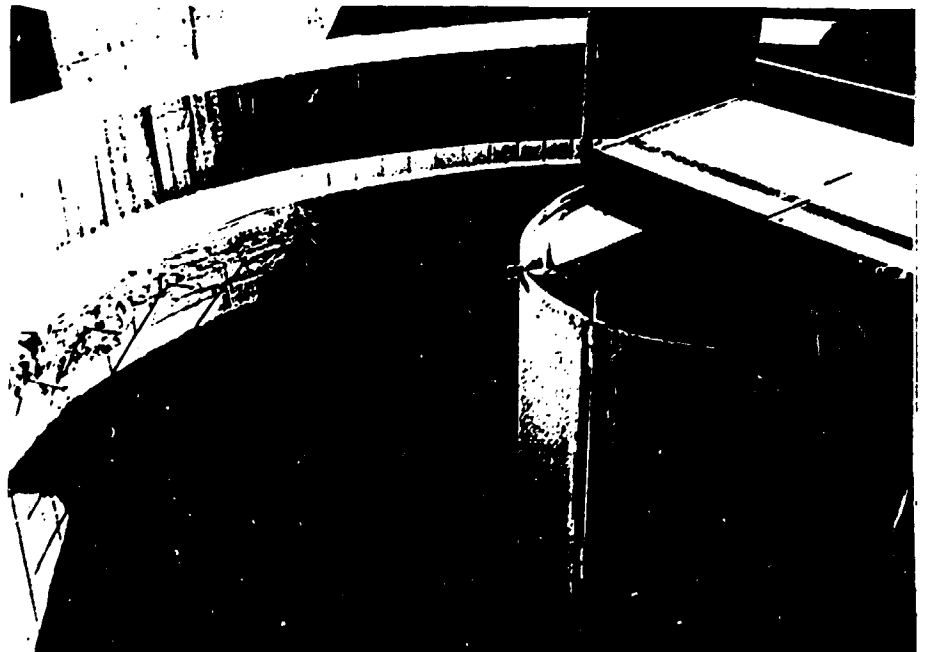


*General view  
of treatment plant*



*Aerators*

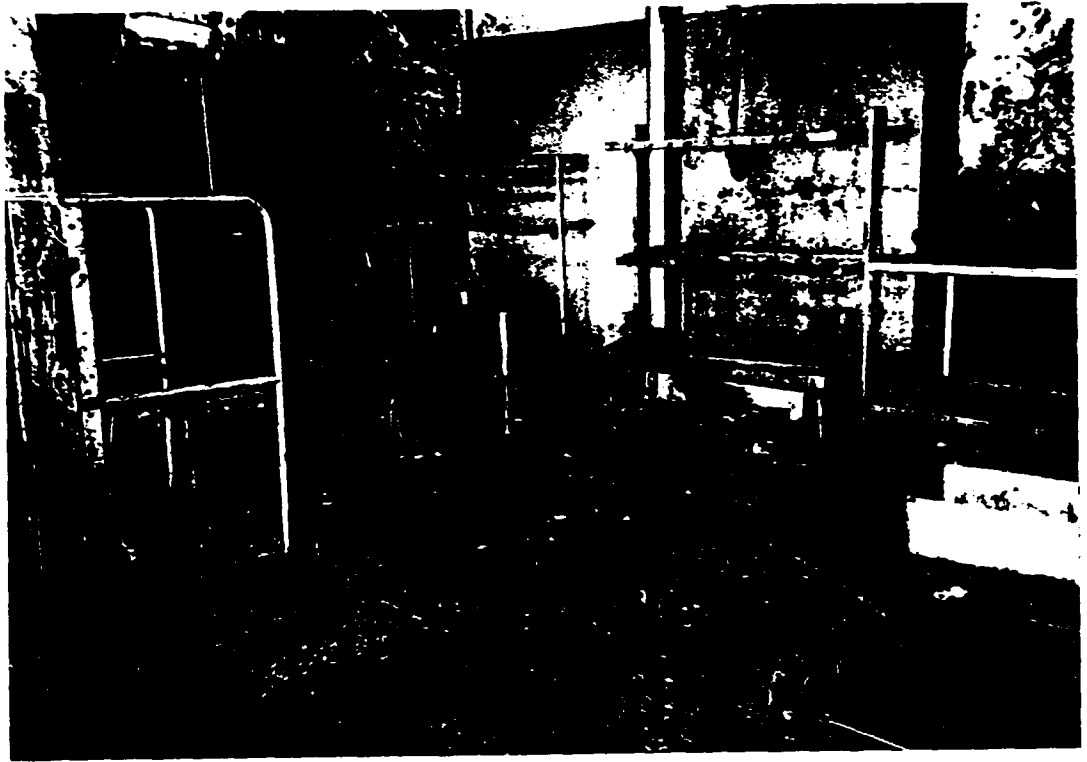
*Settlement tanks,  
showing projecting  
reinforcement bars*



Process: conventional  
activated sludge.  
Commissioning due in  
December 1994.  
Iranian-manufactured  
equipment.  
Poor concrete  
construction.

*Plate 9*

Tehran South Abattoir



*Blood residues that are currently wasted*

*Plate 10*  
Iranian Manufacturer of  
Wastewater Treatment Plants,  
Tehran

*Aerator*



*Electric motors*

Good-quality products used in various plants.



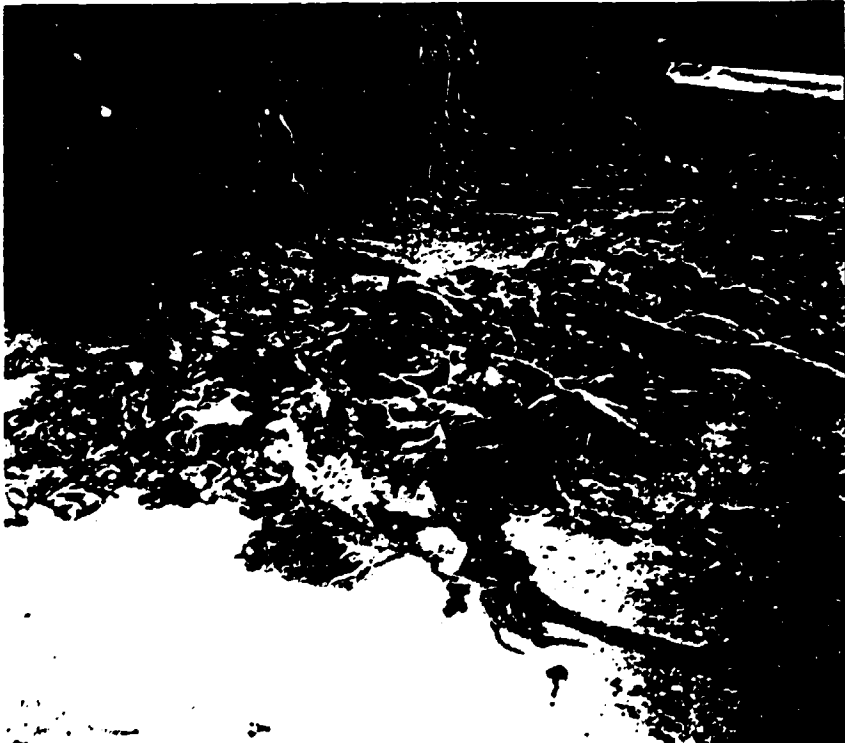


*Plate 11*  
**Charm Shahr**  
**Tannery Complex, Tehran**

*Skimming wastes for  
gelatine production*



*Untreated effluent discharge  
to desert*



*Discarded trimmings*

**Appendix A**

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**Works Visit Reports - Wastewater Treatment Plants**

**A1 TEHRAN Ghitarieh WWTP**

7 Nov 1994

<b>Present</b>	<p>.....</p> <p><i>Ali Taghavi</i></p> <p><i>Peter Lawrence</i></p> <p><i>David Bailey</i></p> <p><i>Tom Sangster</i></p> <p><i>Azadeh Peyman</i></p> <p><i>Ali Tavassoli</i></p>	<p>Plant Manager</p> <p>MW Project Manager</p> <p>MW Project Director</p> <p>MW Specialist</p> <p>MW Specialist</p> <p>RayAb UNIDO Office Manager</p> <p>RayAb Staff</p>
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Average daily flow 1500 m<sup>3</sup>  
 Maximum rate of flow 143.5 l/s  
 Population 12,000 persons  
 Inflow BOD 260 mg/l  
 Effluent BOD 7mg/l

**Process**                      Extended aeration plant comprising inlet lift pumps, screening, grit removal, extended aeration activated sludge treatment (MLSS 3500 mg/l) and final sedimentation. The aeration plant is 2 No rectangular concrete tanks fitted with 2 No vertical spindle surface aerators.

**Comments**                    The site is located in a restricted space between dwelling houses/ office buildings. The benefits resulting from the elimination of primary settlement and the use of extended aeration are that there are no noticeable malodours and no complaints.

**A2 TEHRAN Shoosh WWPT**

7 Nov 94

<b>Present</b>	<p>.....</p> <p><i>David Bailey</i></p> <p><i>Tom Sangster</i></p> <p><i>Azadeh Peyman</i></p> <p><i>Ali Tavassoli</i></p>	<p>Plant Manager</p> <p>MW Specialist</p> <p>MW Specialist</p> <p>RayAb UNIDO Office Manager</p> <p>RayAb Staff</p>
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**Two Units - each unit:**

Average daily flow 3000 m<sup>3</sup>  
 Population 20,000 persons  
 Per-capita flow 150 l/d  
 Inflow BOD 370 mg/l  
 Effluent BOD 5 to 20 mg/l

**Process:**                      Two extended aeration plants comprising screening and grit removal, extended aeration (MLSS 3500 mg/l) followed by final sedimentation and chlorination. Outfall pipe 5 km to river.

**Comments:**                    No serious malodours observed on this site. No primary sedimentation is provided.

Poor concrete work in places in aeration tanks, (eg steel reinforcement exposed and aggregate *exposed* in places).

### A3 SAVEH, Kaveh Industrial Complex WWTP

10 Nov 94

<b>Present</b>	-----	Complex Manager
	<i>David Bailey</i>	MW Specialist
	<i>Tom Sangster</i>	MW Specialist
	<i>Azadeh Peyman</i>	RayAb UNIDO Office Manager
	<i>Ali Tavassoli</i>	RayAb Staff
	<i>Shahin Mostafaie</i>	RayAb Staff

Currently under construction, Civils work 85% complete. M & E scheduled to start in two weeks.

**Process** Screening, grit separation (parabolic channels), Primary Sedimentation, Activated sludge (complete mix carousel type) using Passavant Mammoth rotors.  
Anoxic zones created to promote denitrification.

### A4 ESFAHAN WWTP SOUTH

12 Nov 94

<b>Present</b>	<i>Mr Hosseinkhani</i>	Plant Manager
	<i>Ali Taghavi</i>	MW Project Manager
	<i>Peter Lawrence</i>	MW Project Director
	<i>David Bailey</i>	MW Specialist
	<i>Tom Sangster</i>	MW Specialist
	<i>Azadeh Peyman</i>	RayAb UNIDO Office Manager
	<i>Ali Tavassoli</i>	RayAb Staff

This is the oldest of three WWTPs serving the city. Another is in the North of Isfahan, whilst the third is still under construction at SHAHIN, 25 km distant (lagoons).

Esfahan South has been developed in 3 No stages.

Stage 1 - 26 years old. 93000 pe  
Flow = 1000 m<sup>3</sup>/h (160/h.day)  
Stage 1 not in current use due to refurbishment.  
Stage II - 7 years old - 400 000 pe  
Stage III - 6 years old - 400 000 pe

**Process:** Stage 1 - Primary Settlement - 4m deep biological filters, final sedimentation. Stages II and III are conventional AS with final settlement. Sludge is dried in concrete based drying beds - no drainage layer. Drainage is to single drain channels at one side. Hence mechanical equipment used to remove dried sludge.

**Comments:** The plant was producing generally good quality effluents within the constraints of the shock loadings from abattoir and textile/dyeing industries in the catchment. Overflows from the works, however, pass directly to the Zayandeh Rud river untreated. The Shahin-Sitar wastewater stabilisation pond works is under construction 25 km from Esfahan to take this extra loading. The Manager commented that he favoured these lagoon systems for Iran for their simplistic and effective operation compared to his plant.

**A5 ESFAHAN Steel Co - Domestic Sewage WWTP****13 Nov 94**

<b>Present</b>	<i>Mr ?</i>	Plant Manager
	<i>Mr Namdari</i>	WWTP Manager
	<i>Mr Mokhtari</i>	Public Relations Officer
	<i>Mr Rezvani</i>	Water Supply Manager
	<i>Mr Kheradmand</i>	Laboratory Manager
	<i>Ali Taghavi</i>	MW Project Manager
	<i>Peter Lawrence</i>	MW Project Director
	<i>David Bailey</i>	MW Specialist

This plant comprised 4 No Imhoff Tanks (covered) which provide settlement and storage of the settled sludge in a separate compartment beneath the tank where some anaerobic digestion takes place.

**Process:** Primary sludge is removed from these tanks and passed to long term storage lagoons where the sludge slowly dehydrates and further stabilises.

Secondary treatment is provided by 4 by 4m deep Biofilters. Two of these were not working at all, and on the other two the distributors were not rotating. This was because of a fundamental fault in the design of the distributors which we were told had been manufactured "in house".

The jet holes in the distributors had been equally spaced along the entire length of the arms. This resulted in too much sewage being placed near the centre of the bed overloading it at that point, and insufficient at the extremities, where the major part of the reactive rotating force should have been provided.

Final Sedimentation was provide by 4 No Radial Flow tanks.

**Comments:** 2 out of 3 holes close to centre of the distributor should be blocked off. 1 in 2 holes near the middle should be blocked off and additional holes should be created towards the extremity of the distributor arms. Final effluent from the works was pumped to maturation ponds, which we believe also acted as soakaways.

**A6 GHAHDERIJAN STW****13 Nov 94**

<b>Present</b>	.....	Plant Manager
	<i>Ali Taghavi</i>	MW Project Manager
	<i>Peter Lawrence</i>	MW Project Director
	<i>David Bailey</i>	MW Specialist

This WWTP is fully completed and comprises two parallel concrete lagoons.

**Comments:** This STW is not currently in operation, owing to the inability of the new transfer sewer to carry the wastewater from the town to the STW inlet works. This transfer sewer has been constructed through ground with a very high water table and infiltration of groundwater into the transfer sewer exceeds the rate at which the inlet liftpumps can transfer the sewer contents to the lagoons.

## A6 GHAHDERIJAN STW Continued

13 Nov 94

It was noted that two egg shaped pipe sections were of very poor quality, especially at the area of the recessed socket joints. Since the sewer pipes were also laid without joint gaskets, it is likely that large volumes of groundwater can enter this sewer. It is likely that in-situ lining of sewer will remedy the problem.

## A7 MASHAD - Holy Harem WWTP

10 Nov 1994

Present:

*Dr Nairizi*

*Mr K Takavou*

*Ali Taghavi*

*Peter Lawrence*

TussAb

TussAb

MW Project Manager

MW Project Director

Plant Manager for the Ali Reza Foundation

- Sewer from Harem area - 9 km - 2m by 1.4 m - Ovoid concrete gravity line - sewage grey and septic looking
- Sewer capacity 2500 l/s - planned for future additional STW serving city.
- WWTP is three sets of ponds: first (pair) planned to be aerated but currently anaerobic second stage series of about 3 currently anaerobic chlorination between facultative and maturation - contact channel installed but no chlorine Single large maturation lagoon - currently pink in colour- anaerobic - likely to be short-circuiting from single inlet to outlet - might be improved with baffles/wind mixers. effluent to fields
- Capacity quoted as 300l/s receiving 500l/s plus septage
- Incoming strength unknown - effluent BOD about 100-150 and dark grey still!
- Experimenting with local construction of aerator to Simon Hartley pattern - problems with gearbox
- Works construction quite good except for unfilled expansion joints.

## **Appendix B**

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### **Industrial Site Visits**

**B1 TEHRAN Minoo Industrial Factory**  
**Confectionery Factory**

9 Nov 94

<b>Present</b>	.....	Plant Manager
	<i>David Bailey</i>	MW Specialist
	<i>Tom Sangster</i>	MW Specialist
	<i>Azadeh Peyman</i>	RayAb UNIDO Officer Manager
	<i>Ali Tavassoli</i>	RayAb Staff
	<i>Shahin Mostafaie</i>	RayAb Staff

This factory produces confectionery using as input materials, flour, sugar, oil and fat, cocoa beans and cereals. No liquid effluent is produced by the process and most of the imperfectly finished material was recycled.

**Process:** The only aqueous effluent discharged is that resulting from the washing of floors, (and sometimes equipment and machinery). The total effluent volume is comprised of 90% domestic waste and has a BOD of 760 mg/l.

The current method of disposing of the effluent is by injecting it into the ground (i.e. a "Soakaway") via a borehole which extends to 50m below the ground surface where it connects into two horizontal "Soakaway" adits which each extend for 20m from the borehole.

An extended aeration activated sludge plant has been designed to treat the wastes and the construction of this plant is planned to commence in about 8 weeks. The design F/M loading is 0.075 kg BOD/kg of MLSS, which is very likely to result in an effluent BOD well within the required limit of "20 to 40 mg/l", (sic).

**B2 TEHRAN Minoo Industrial Factory**  
**Pharmaceutical Products**

9 Nov 94

<b>Present</b>	.....	Plant Manager
	<i>David Bailey</i>	MW Specialist
	<i>Tom Sangster</i>	MW Specialist
	<i>Azadeh Peyman</i>	RayAb UNIDO Officer Manager
	<i>Ali Tavassoli</i>	RayAb Staff
	<i>Shahin Mostafaie</i>	RayAb Staff

The MINOO Co also produces and packages medicinal materials.

**Process:** Only a small volume of wastewater results from these processes and this will be treated in the extended aeration plant in admixture with the confectionery wastewater where it will contribute about 10% of the total flow.



Present	.....	? Manager
	<i>David Bailey</i>	MW Specialist
	<i>Tom Sangster</i>	MW Specialist
	<i>Azadeh Peyman</i>	RayAb UNIDO Officer Manager
	<i>Ali Tavassoli</i>	RayAb Staff
	<i>Shahin Mostafaie</i>	RayAb Staff

This factory produces a range of ductile iron pipework and fittings.

**Process:** No significant liquid effluent is produced by this process. There is, however, a very significant wastage of heat in the hot exhaust gases which result from the pipe annealing process. In this process the items are raised to bright red heat (600 to 800 deg. C) and allowed to cool under controlled conditions. The exhaust gases appear to be vented directly to atmosphere. These gases could be passed through a heat exchanger to preheat the incoming combustion air, or else be used in a waste heat boiler to produce steam and thence electricity, which is consumed in the pipemaking process in large amounts.

A further use of this surplus heat might be its use to reheat the pipes before they are coated with bitumen instead of using additional gas.

It was observed that the bitumen coating process itself is evidently inefficient in the use of bitumen and variable in the thickness of the coating produced by this technique. It was pointed out that the adoption of spray-application techniques would produce more consistent coatings besides resulting in a more economic use of bitumen.

<b>Present</b>	.....	Complex Manager
	<i>David Bailey</i>	MW Specialist
	<i>Tom Sangster</i>	MW Specialist
	<i>Azadeh Peyman</i>	RayAb UNIDO Officer Manager
	<i>Ali Tavassoli</i>	RayAb Staff
	<i>Shahin Mostafaie</i>	RayAb Staff

This site complex at Savah was visited in the company of the Site Manager. This site is planned to accommodate up to 420 different manufacturing units, but only 20 of these discharge any trade effluent. (All will contribute to the flow of domestic sewage).

**Process:** The products made at these effluent producing factories are as follows:

- Paper factory (4 No.)
- Fruit juice (2 No.)
- Tile factory
- Automobile engine assembly
- Aluminium sheet
- Cotton sheet production
- Detergent manufacture
- Margarine manufacture
- Ceramic plates
- Adhesives
- Potato chips
- Carbon black
- Automobile tyres
- Others (3 No.)

- \* The largest producers of pollution were stated to be
- (a) Paper manufacturers
  - (b) Fruit juice producers

(Since this site was visited on a Thursday the only factory available for inspection was the tyre factory. this was visited and it was found that the only effluent arises from cooling water. There is waste from imperfect tyres/rejects, but this cannot be recycled because the vulcanisation of the rubber is chemically irreversible.)

## B5 SAVEH Industrial Complex Communal Treatment Plant 10 Nov 94

Present	.....	Complex Manager
	<i>David Bailey</i>	MW Specialist
	<i>Tom Sangster</i>	MW Specialist
	<i>Azadeh Peyman</i>	RayAb UNIDO Officer Manager
	<i>Ali Tavassoli</i>	RayAb Staff
	<i>Shahin Mostafaie</i>	RayAb Staff

All aqueous wastes from the 420 factories gravitate to a communal (shared) effluent treatment plant which is designed to treat flows of up to 300 l/s, 45% to 50% of which is the industrial process waste. This plant is still in the course of construction (85% civils complete).

**Process:** This treatment plant provides:

- Coarse screening
- Grit removal
- Primary sedimentation
- Extended aeration activated sludge treatment
- Final sedimentation and
- Disinfection (Chlorination)

The aeration is a complete mix activated sludge plant and comprises of two parallel units. The four "Passavant Mammoth" horizontal aeration rotors fitted in each of the two units are spaced so as to promote the process of biological denitrification which occurs within the anoxic zones created immediately downstream of the rotors. Besides eliminating nitrate, this will also help to reduce electricity costs.

Present	.....	Plant Manager
	<i>Mr Mokhtari</i>	Public Relations Officer
	<i>Mr Rezvani</i>	Water Supply Manager
	<i>Mr Kheradmand</i>	Laboratory Manager
	<i>Ali Taghavi</i>	MW Project Manager
	<i>Peter Lawrence</i>	MW Project Director
	<i>David Bailey</i>	MW Specialist
	<i>Tom Sangster</i>	MW Specialist
	<i>Azadeh Peyman</i>	RayAb UNIDO Officer Manager
	<i>Ali Tavassoli</i>	RayAb Staff

This factory consists of an iron smelting plant which supplies an associated steel production and rolling mill. A useful meeting was held with the Senior Engineer and his staff to discuss the iron and steelworking processes, the production of waste material and the source and treatment of the aqueous effluents.

**Process:** Three types of effluent are produced at this site:

- (a) water from the wet scrubbers used to clean the blast furnace off gases;
- (b) water used to clean off-gases from the "Pure Oxygen" steel converter; and
- (c) liquid effluent resulting from the coking plant.

The scrubber wastes (a) and (b) were recirculated through cooling towers and settlement tanks. These latter did not appear to be performing optimally. The recirculating water was said to contain 20mg/l of cyanide.

The liquid effluent from the coking plant contains ammonia, phenols, cyanide and thiocyanate, besides many other components. These substances are partially broken down by treatment in a (somewhat overloaded) activated sludge plant. The effluent leaving this process is then piped to a series of evaporation lagoons about 800m from the factory site.

The evaporation lagoons are well engineered and lined with an impervious membrane to prevent percolation into the groundwater.

There are several areas within the factory complex where solid waste is produced. Some of this is already recycled, i.e. pig iron and refractory material from casting area.

<b>Present</b>	<i>Mr Shojaie</i>	Plant Manager
	<i>Mr Jahangiri</i>	Production Manager
	<i>Mr Farazmand</i>	Public Relations Manager
	<i>Mr Karimi</i>	Technical Manager
	<i>Ali Taghavi</i>	MW Project Manager
	<i>David Bailey</i>	MW Specialist
	<i>Tom Sangster</i>	MW Specialist
	<i>Azadeh Peyman</i>	RayAb UNIDO Officer Manager
	<i>Shahin Mostafaie</i>	RayAb Staff

This Company produces both asbestos cement and concrete sewage pipes.

### **CONCRETE PIPES**

They produce 54,000 tpa of concrete and reinforced concrete pipes. The articles inspected were of a better quality than seen previously in Iran. Slightly imperfect rejects were used for agricultural purposes.

### **ASBESTOS CEMENT PIPES**

These were made in a range of lengths and diameters plus fittings. A close inspection procedure was in force to ensure good quality products.

Some asbestos cement mixture was lost during manufacture and the watery slurry was transferred to settlement tanks. The supernatant water was recycled to the process but no asbestos or cement was recycled owing to the advanced state of cement hydration.

Some reject asbestos pipes were cut-up into sections and filled with concrete to be used for various items of 'street furniture', e.g. pillars.

<b>Present</b>	<i>Mr Alidad</i>	Plant Technical Officer
	<i>Ali Taghavi</i>	MW Project Manager
	<i>David Bailey</i>	MW Specialist
	<i>Tom Sangster</i>	MW Specialist
	<i>Azadeh Peyman</i>	RayAb UNIDO Officer Manager
	<i>Shahin Mostafaie</i>	RayAb Staff

**Raw Materials:** 10cm thick steel slabs are rolled into sheets and used to produce welded steel pipes from 0.5 inch to 6.0 inch diameter.

**Solid Waste:** A little scrap metal (off-cuts) is sold to another steelmill and is recycled. Some ferric oxide resulting from descaling, about 1.5% of total steel production is dumped off-site except for a small quantity which is sold to sandpaper manufacturers.

**Liquid Waste:** Oil and grease/water mixtures are separated by tank skimmers. 70% of this is removed by the skimmers and dumped whilst 30% goes to the river.

**Production:** The Company intends to expand it's operations to produce sheet steel from steel slabs.

Currently some pipes are galvanised for use in irrigation water supply, (not domestic or public). Zinc oxide is currently washed-off and dumped containing 20 mg/l of zinc (as Zn).

#### Potential Methods of Reducing Waste:

1. Improved quality control to give fewer rejects of unrecyclable material.
2. Recover oil for reuse (as fuel?).
3. Recovery of zinc from dumped oxide and Acid cleaning bath ( $ZnCl_2 + HCl$ ).
4. Size of main steel rolls should be produced to size (for pipes) to minimise off-cut waste.

Zinc plating process is: - NaOH bath (to clean), HCl bath → hot dip with Zn metal, finally clean-up with HCl.

All effluent is currently neutralised and discharged to sewer without further treatment.

**B9 KHUZISTAN Pipeline Manufacturing Company****15 Nov 94**

**Present:**

<i>Mr Shariatini Niagar</i>	Managing Director
<i>Ali Taghavi</i>	MW Project Manager
<i>David Bailey</i>	MW Specialist
<i>Tom Sangster</i>	MW Specialist
<i>Azadeh Peyman</i>	RayAb UNIDO Officer Manager
<i>Shahin Mostafaie</i>	RayAb Staff

After a brief introduction this meeting was abandoned. The MD explained that 24 hours notice was officially required before any visit could take place.

**B10 AHWAZ Concrete Pipe Company****15 Nov 94**

**Present:**

<i>Mr Hashemi</i>	Plant Manager & Owner
<i>Ali Taghavi</i>	MW Project Manager
<i>David Bailey</i>	MW Specialist
<i>Tom Sangster</i>	MW Specialist
<i>Azadeh Peyman</i>	RayAb UNIDO Officer Manager
<i>Shahin Mostafaie</i>	RayAb Staff

**Process:** The Company manufactures large diameter reinforced concrete pipes only, ranging from 700 mm to 2,400 mm.

**Quality:** These pipes were the best quality concrete pipes viewed to date (15 November 1994). Very good quality workmanship by fully automated concrete casting plant. (Reinforcement cages still hand welded on mandrel).

**Comment:** No significant waste was noted from this plant.

## B11 ABADAN Sewerage Scheme

16 Nov 94

### Present

*Ali Taghavi*

MW Project Manager

*David Bailey*

MW Specialist

*Azadeh Peyman*

RayAb UNIDO Officer Manager

*Shahin Mostafaie*

RayAb Staff

A visit was made to the site where current work is in progress on a new trunk sewer to the proposed STW to serve a section of Abadan. 1,600 mm reinforced concrete pipe sections were being utilized. Jointing was not good due to pipe quality. Joints required caulking with sisal rope and mastic to seal completely. Cement mix used to finish-off.

The pipes were given an external coating of bitumen to avoid SO<sub>2</sub> corrosion.



**Present:**

<i>Mr Fazli</i>	Mill Manager
<i>Mr J G Bakhshayesh</i>	R & D Manager
<i>Ali Taghavi</i>	MW Project Manager
<i>David Bailey</i>	MW Specialist
<i>Azadeh Peyman</i>	RayAb UNIDO Office Manager
<i>Ali Tavassoli</i>	RayAb Staff
<i>Shahin Mostafaie</i>	RayAb Staff

**Raw Materials:** Oak, Beech, Maple, Hornbeam, Sycamore

It was ascertained that these materials were not the main trunk, but offcuts and only represented 10-20% on the timber felled. Four grades of material are produced from timber:-

Grade 1 for plywood  
 Grade 2 for furniture  
 Grades 3 and 4 for pulping

**Outputs:** 3,500 m<sup>3</sup>/annum plywood  
 110,000 tpa paper for carton manufacture

**Production Process:** Wood chips produced from timber. Digested for 8 hours in Na<sub>2</sub>S/NaOH @ 7 to 8 atmospheres pressure and 170°C. This produces CRUDE PULP and BLACK LIQUOR. Black Liquor is evaporated to concentrate it and burnt. (Organic matter as fuel, inorganic to recycle Na<sub>2</sub>S and Na<sub>2</sub>CO<sub>3</sub> from Na<sub>2</sub>SO<sub>4</sub>, ie a *reducing* atmosphere in boiler).

Pulp goes to 'blow tank' (flash-off steam), then roll press, then to 'high density' refiners and is then stowed in 4-No. pulp storage tanks (silos).

For use the pulp travels to 'head box' where it is diluted with water (1% pulp + 99% H<sub>2</sub>O), and is then fed into the screen wire. After screening the pulp content is 10% plus 90% water. This is then fed via a colander and onto 63 drying rollers in the paper machine. After collection on a large roll (2m dia), it is removed, trimmed up and divided onto 1m rolls.

**Side Line:**

Power Boiler : 160 tph of steam at 60 atm - 450°C fed to H.P. turbine of 80 MW.

Steam at low pressure used to heat digesters and for drying.

## B12 GILAN Chuka Iran Wood & Paper Industries *Cont'd.*

### Recovery Boiler:

Produces 90 tph of steam using concentrated Black Liquor as fuel. Fly ash consists of  $\text{Na}_2\text{S} + \text{Na}_2\text{CO}_3$ . Sodium sulphate in the Black Liquor is reduced in the incinerator to sodium sulphide  $\text{Na}_2\text{S}$ , and sodium carbonate  $\text{Na}_2\text{CO}_3$ , (viz  $\text{Na}_2\text{SO}_4 \rightarrow \text{Na}_2\text{S} + \text{Na}_2\text{CO}_3$  ie reducing atmosphere in the incinerator).

The Black Liquor from pulping contains 13-14% d.s. This is increased to 60 - 65% d.s. by evaporation before feeding to the recovery boiler.

### "Causticising Unit":

The ash from the recovery boiler is then kilned to produce sodium sulphide and sodium hydroxide ( $\text{Na}_2\text{S} + \text{NaOH}$ ). This can then be recycled to the pulping process. It consists of 75%  $\text{NaOH} + 25\% \text{Na}_2\text{S}$ .

### Wastewater Process:

There are two types of wastewater drained separately:

- (a) fibre containing
- (b) alkaline

- (a) Clarifier (PST) 1.5d R.T. (27,000 m<sup>3</sup>)

Aeration lagoons	Design	Actual
R.T. (days)	9	(5)
2-No.	9	(5)
Final Sett. Tank		
R.T.	2	(1.2)
Post aeration		
135,000 m <sup>3</sup>	9	(10)

Then to River.

Sludge and sawdust used to go to power (/) boiler, but this has now been discontinued (why?). Fibre from PST is now recycled to process - 60% of fibre present in the effluent is recovered.

Nowadays, Alkaline waste does not go to the PST. By passes PST direct to settlement basin.

### Wastes

Waste cut-off from end of papermaking m/c is already recycled.

Sludge from lagoons goes to forest (only for dumping out-of-sight!). (Question - what about use as fuel?).

## B12 GILAN Chuka Iran Wood & Paper Industries *Cont'd*

### Inputs To Plant

	Design	Actual
Lumber	100,000 m <sup>3</sup> /a	Nil (uneconomic)
Plywood	10,000	7,000
Chips (pulp)	350,000	300,000
Water: from R Shafaroud	27,000 m <sup>3</sup> /d (x 360 pa)	45,000 m <sup>3</sup> /d of which 5,000 m <sup>3</sup> /d to town supply

*Energy:* 17,000 kW TOTAL  
11,000 factory generated  
4-5,000 kW FROM GRID

*Power boiler:* H.P. turbine 60 kg/Pressure → 11 MW.

*Fuel:* Power Boiler : Natural gas or Gas oil  
Recovery boiler : Black Liquor concentrate

### *Other Raw Materials Inputs*

NaOH	Long fibres
Na <sub>2</sub> S	Resin
Alum	Starch
H <sub>2</sub> SO <sub>4</sub>	Polyelectrolyte
Limestone	Antifoam
Na <sub>2</sub> SO <sub>4</sub>	Pitch dispersant
Hydrogen (boiler feed)	Sludge dispersant
Chlorine gas (disinf)	Gas Oil (fuel)

*Gas utilisation :* 287m<sup>3</sup> per tonne of paper.

### **Outputs**

3,500 m<sup>3</sup>/a plywood  
110,000 tpa paper  
24 → 27,000 m<sup>3</sup>/d wastewater  
(nominal design 13,000 m<sup>3</sup>/d wastewater)  
(ie 1.7 x design flow)  
Hence, nearly double design flows - *attributed to wastage of water.*

Not all of the alkaline waste is recovered, but all Black Liquor is recovered totally in recovery boiler.

(NOTE: At time of visit overflow of Black Liquor was seen to be going out in the alkaline effluent stream!!).

60% of the fibres lost within the factory is recovered from the clarifier  
- 40% goes to the lagoons, and ends up landfilled in the forest.

## B12 GILAN Chuka Iran Wood & Paper Industries *Cont'd.*

### Effluent

	Ex Wks	Treated	Limits
COD	1400	600-740	50
BOD	338	25-65	20

Colour only reduced a little 3200 down to 3000 units.

### *Other Wastes:*

Sawdust        )       goes to forest for landfill  
Bark            )

### Waste Minimisation Options

1. Sawdust and bark → fuel or parks
2. Sludge → fuel/soil conditioner/agriculture/forest
3. Further improve fibre separation  
Only 50% of factory loss is recycled  
40% left in sludge from clarifier
4. All Black Liquor to boiler.
5. Heat recovery from steam and hot water ?

<b>Present:</b>	<i>Mr Abbas Payravan</i>	Director Factory No 2
	<i>Mr Haddad</i>	Director Factory No 3
	<i>Mr Taghavi</i>	R&D Director
	<i>Mr Afradi</i>	R&D Deputy Director
	<i>Mr Yaxdani</i>	
	<i>Mr Jafari</i>	Industrial Office of Mazandaran Province
	<i>Ali Taghavi</i>	MW Project Manager
	<i>David Bailey</i>	MW Specialist
	<i>Azadeh Peyman</i>	RayAb UNIDO Office Manager
	<i>Ali Tavassoli</i>	RayAb Staff
<i>Shahin Mostafaie</i>	RayAb Staff	

**Total of three factories are under this organisation**

Site No 1 - Sack Making, 32 years old

Site No 2 - Textile & Fabrics, full dyeing process (Mr Peyravan, Director), 32 years old, No WWTP facilities

Site No 3 - Textile & Fabrics only; A biological WW treatment facility (Mr Haddad, Director), new factory

There are currently no treatment facilities for wastewater from factory Nos. 1 and 2. Phase I study for such WWTP is completed, and the plant management are thinking to combine the waste from a nearby cannery for this WWTP, as well. The phase II study and design is to be bid out soon.

**Capacity:** Plant capacity is 30 million meters/yr of fabric, of which only 7 million meters/yr is from plant No 3. The dyeing factory has capacity of 50 million meters a year. The WWTP will be designed based upon 50 million meter/yr.

**Process:** The domestic wastewater is from 350 workers in plant No 1, 2,500 in plant No 2 and 1,100 in plant No 3, total of 4,050. Plant Nos. 1 and 2 directly discharge both the industrial and domestic waste into Sianrood (Black River). Plant No 3 discharges the effluent from WWTP and the untreated domestic WW into ...?.... River.

The WWTP at Plant No 3 has fairly good design, but not working to standards.

The plant consists of a complete mix Activated Sludge Aeration Plant, incorporating a radial flow final settlement tank. A tertiary treatment stage consisting of coagulation using polymers and further settlement in another radial flow settlement tank was not operating in any effective way due to lack of control.

The biological stage was not operating correctly and the Operator was unaware of MLSS in aeration tank, which appeared to be very low. He said there was no equipment to carry out analysis.

## B13 MAZANDERAN Textile Co *Cont'd*

**Comments:** Visual observations using Imhoff Cones (dirty), seemed to indicate MLSS ca 200 mg/l.

Aeration was by 2 No. horizontal shaft Passavant rotors.

Domestic sewage from the factory (1,100 p.e.) was discharged direct to the river about 1 km distant. The outlet fed into a small stream (a man made trench) running to the main river.

Very gross pollution was visible due to black oil in the waste. (Despite this about 10 frogs took quick refuge in the stream when approached, despite its covering with a thick oil slick).

It was suggested to management that the ASP would be better able to develop an active and retainable biomass if the domestic waste was also discharged to it. In this case, it would be essential to ensure that the oil which currently contaminates the domestic waste, was completely removed before feeding into the aeration tank. Feeding the domestic waste into the activated sludge plant would:

- (a) improve the river, and
- (b) improve the trade effluent discharge.

At present the factory effluent also contains the rainwater. This should be separated in the future and discharged direct to the river.

Present:	<i>Mr Magide</i>	Managing Director
	<i>Mr Kashi</i>	Agricultural Manager
	<i>Ali Taghavi</i>	MW Project Manager
	<i>David Bailey</i>	MW Specialist
	<i>Azadeh Peyman</i>	RayAb UNIDO Office Manager
	<i>Ali Tavassoli</i>	RayAb Staff

Factory established 1932 - wholly Government owned.

**Raw Materials:** 3,000 hectares of land  
 Agreements with farmers : 85,000 tpa beet within 140 km radius. ca 1,300 farmers.

**Process:** Production 1,100 t/d for 100 days/year.  
 Sugar beets are washed in water to remove the soil.  
 (The soil and water are returned to Agriculture via a canal system to local farms.)

The beet is then shredded and fed into a counter current diffuser/extractor for extraction into water at 70°C. Formalin is added to prevent the growth of micro-organisms.

The beet contains 16.5 % of sugar (varies) 12 - 13% is recovered, and therefore 3% is wasted. (80% recovery).

The extracted liquor is treated with  $\text{Ca}(\text{OH})_2$  in 2 stages to precipitate the "residuals".

Next  $\text{CO}_2$  is added to precipitate the  $\text{Ca}(\text{OH})_2$  as carbonate;  $\text{CaCO}_3$ .

The precipitate is then flocculated and separated from the syrup. Further separation is then carried out in a vacuum filter (drum type), to remove residual  $\text{CaCO}_3$ .

The syrup is then passed to evaporators to produce a 60% syrup. This is then fed to crystallisers. Final separation is by automatic batch semi-continuous centrifuges - 2 No. The crystallised sugar is then washed in centrifuge (hydro-extractor) using live steam. It is then dried and bagged. (Colour removal is by  $\text{SO}_2$  at some stage.)

#### By Products

Beet waste is dried and compressed to pellets ('Millet of Beet') and used for animal feed. There are also secondary and tertiary stages of crystallisation to recover more sugar. The tertiary stage sugar (at *this* factory) goes into the cattle feed. Sometimes it is also used in alcohol production.

(Some factories use the tertiary stage to obtain more sugar).

## B14 KARAJ Sugar Refinery *Cont'd.*

### Effluent

From	(1)	Washwater
	(2)	Vacuum filter
	(3)	Mechanical filter
	(4)	Floor washing

Current Staff 105 permanent  
250 seasonal

### Effluent Treatment

Effluent treatment originally was by Primary Sedimentation in a large tank with water being recycled for re-use. The settled sludge was pumped to drying beds, where it did not dry very quickly during the rainy season and gave rise to odour problems. This system was therefore abandoned, no water being recycled, and the untreated effluent is currently channelled for irrigation of local farmland via a canal. This also gives rise to complaints of malodours.

All washwater goes straight to land via a 'canal' (channel). Complaints of smells.

A discussion was held on what might be done with the sludge if sedimentation tank is brought back into use. It was suggested that the sludge be spread on land using tankers fitted with a soil injection system. It was also established that additional sludge thickening would *not* be required as it came out of the PST @ 20% d.s.

The Agriculture Manager enquired about the effects of the alkalinity of the sludge being spread on land which is already alkaline soil. The Consultants pointed out that if the farmland was already on limestone terrain, then the additional calcium carbonate would have no additional effect on the pH value.

The Managing Director enquired whether other potential outlets might be found for 'Millet of Beet'. We were not able to provide an answer to this at present but it could be looked into under any waste minimisation scheme.



<b>Present:</b>	<i>Mr Moin Darbari</i>	Company MD
	<i>Ali Taghavi</i>	MW Project Manager
	<i>David Bailey</i>	MW Specialist
	<i>Azadeh Peyman</i>	RayAb UNIDO Office Manager
	<i>Ali Tavassoli</i>	RayAb Staff

A small abattoir outside Teheran was visited.

We were met by the Contractor responsible for construction of the wastewater treatment plant which was inspected prior to inspection of the abattoir itself.

**Process:** The treatment plant is designed to treat up to 400 m<sup>3</sup>/d of wastewater having a BOD of 1200 mg/l and is based on activated sludge principle but incorporates some novel features. The plant incorporates an aerated mixing and flow balancing tank from which the wastewater is pumped without primary settlement to the first activated sludge aeration pocket. A small baffled tank is provided to permit separation of oil and grease before the wastes enter the aeration system. Mixed liquor flowed to a first stage radial flow settlement tank. Return sludge was recycled at four times the forward flow rate.

The first stage effluent then flowed to a second aeration tank and final clarifier. The return sludge rate of this stage was 1 to 1.

The final effluent is chlorinated and stored in a covered tank before being used for agricultural irrigation.

The surplus sludge will be thickened and anaerobically digested before drying on open drying beds, before ultimate disposal to agriculture. The plant was still in the course of construction at the time of the visit.

The concrete work in many places was seen to be rather poorly finished. Nails or wire were also protruding from the workface and one of the settlement tanks had sheets of polythene apparently incorporated in the concrete and protruding in several places. A section of the overflow weir had also appeared to have collapsed.

**Plant:** The visit to the Abattoir itself was rather uninformative since production had ceased at 11.00 am, it being Thursday. The factory management were not available for discussion or conducting the visit.

The Consultants were informed that hides and skins were sent to a local tannery and offal was disposed of off-site. Blood was not at present recovered and would constitute an appreciable load on the effluent treatment plant. Its recovery should be seriously considered as it could be a valuable by-product.

<b>Present:</b>	Mr. Tahmasbi Mr. Ghasri Ali Taghavi Azadeh Peyman	Charmshahr Board Director President, Mofid Charm Co. MW Project Manager RayAb UNIDO Office Manager
<b>Plant Ownership</b>	100% Iranian - Private ownership	
<b>Sponsorship</b>	Iranian Industrial Complexes Co., a subsidiary of the Ministry of Industry	
<b>Current Status</b>	The complex is planned to house 72 major tanneries in and around Tehran. The goal is to move all the tanneries out of the capital city. At present only 8 major tanneries are operational, not at full capacity, yet.	
<b>Planning</b>	The complex demands more support from the Ministry to promote investment by other tannery companies to move to this complex. They offer financial incentives, such as long term loans, and low rates on land and water charges. The complex has a very good and planned wastewater collection system. In some areas the system is separate for chrome tanning section, for ease of treatment. Currently, the domestic sewerage is also collected in the same system as the industrial system. At present, the combined effluent is disposed of in the Salton Sea, a few kilometers outside the complex. A treatment plant is, however, envisioned in the long-term plans for the complex.	
<b>Quality Comment</b>	Iran has one of the best qualities of leather for different uses. The tannery complex is a superb idea for both business and industrial development, as well as, environmental effects.	

## **Appendix C**

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**Iranian Environmental Protection Agency (IEPA)**

**Domestic and Industrial Discharge Standards**

**Table C1**  
**The Maximum Permissible Level of Contaminants in the**  
**Wastewater Treatment Plant Effluent.**

NO.	CONTAMINANTS	MAX. PERMISSIBLE CONCENTRATION	UNIT	COMMENTS
1	Biochemical Oxygen demand 5 (day)	30	mg/l	
2	Chemical Oxygen demand	60	mg/l	
3	Free Residual Chlorine	1	mg/l	
4	Coliform	100/100 ml	number/ 100 ml	
5	Colour	16	colour unit	
6	Detergents	1.5	mg/l	According to A.B.S. Equivalent
7	Dissolved Oxygen	2	mg/l	
8	Fluoride	2.5	mg/l	
9	Heavy Metals			
10	Nitrogen :			
	Ammonia Nitrogen	2.5	mg/l	According to Nitrogen
	Nitrogen of Nitrate	50	mg/l	According to Nitrogen
	Nitrogen of Nitrite	10	mg/l	According to Nitrogen
11	Oil and Fat	10	mg/l	According to Nitrogen
12	PH	6.5 - 8.5	pH units	
13	Phosphate	1	mg/l	According to Phosphorus
14	Radio Active Material	0	mg/l	
15	Settleable	0.1	mg/l	
16	Suspended	40	mg/l	
17	Sulphate	400	mg/l	
18	Sulphite	1	mg/l	
19	Turbidity	50	G.T.U.	

Source: Iranian Environmental Protection Agency

**Table C2**  
**The Maximum Permissible Level of Industrial Sewage Contaminators for**  
**Discharge into Various Sources.**

NO.	CONTAMINANTS	Surface Water (mg/l)	Absorbent Wells (mg/l)	Ag. & Irrigation (mg/l)
1	Al	5	5	5
2	Ba	5	1	1
3	Be	0.1	1	0.5
4	B	2	1	1
5	Cd	0.2	0.2	0.2
6	Ca	75		
7	Cr	0.5	1	1
8	Cr	2	2	2
9	Co	1	1	0.05
10	Cu	1	1	0.2
11	Li	2.5	2.5	2.5
12	Mg	100	100	100
13	Mn	1	1	1
14	Hg			
15	Mo	0.01	0.01	0.01
16	Ni	2	2	2
17	Fe	3	3	3
18	Pb	1	1	1
19	Se	1	0.1	0.1
20	Ag	1	0.1	0.1
21	Zn	2	2	2
22	V	0.1	0.1	0.1
23	Radio Active Material	0	0	0
24	As	0.1	0.1	0.1
25	Cl	1	1	0.2
26	Cl-	60	6000	600
27	F	2.5	2	2
28	P as Phosphorous	1		
29	CN	0.5	0.1	0.1
30	C6 H5 OH	1		1
31	CH2OH	1	1	1
32	N as NH4	2.5	1	
33	N as Nitrite (NO2)	10	10	
34	N as Nitrate (NO3)	50	10	
35	SO4-	400	400	500
36	SO3--	1	1	1
37	T.S.S.	40		100
38	Sediments	0		
39	Sulphide	3	3	3

Table C2 *continued*

NO.	CONTAMINANTS	Surface Water (mg/l)	Absorbent Wells (mg/l)	Ag. & Irrigation (mg/l)
40	T.D.S.			
41	Oil and Fat	10	10	10
42	B.O.D.	50	50	100
43	C.O.D	100	100	200
44	D.O.	2		2
45	Detergents (A.B.S.)	105	0.5	
46	Turbidity	50		50
47	Colour	75 Colour Units	75 Colour Units	75 Colour Units
48	Temperature	The discharge must not increase the temperature of the river water by more than 3°C at point within the 200 radius.		
49	pH	6.5 - 8.5	5 - 9	6.5 - 8.5
50	Digestive Coliform	400 / 100 ml	400 / 100 ml	400 / 100 ml
51	M.P.N.	1000 / 100 ml	1000 / 100 ml	1000 / 100 ml

## **Appendix D**

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**Options for Sewage Collection, Treatment and Reuse**

**Broad Review of Sustainable Options**

# APPENDIX D

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## APPENDIX D

# OPTIONS FOR SEWAGE COLLECTION, TREATMENT, AND REUSE BROAD REVIEW OF SUSTAINABLE OPTIONS

### D1 INTRODUCTION

This Appendix describes the principles of the most favoured options for wastewater management in Iran. It is a "standalone" section which is referred to in the main text of the report (Section 3).

#### D1.1 Basic Principles

It is the experience of many organizations throughout the Middle East that mechanical sewerage and sewage treatment systems are prone to failure or poor performance through a variety of reasons including inadequate maintenance, underfunding and unavailability of spare parts.

The smaller communities under consideration are widely distributed across Iran and may well be in relatively remote locations. To minimise the problems of operation and maintenance it is recommended that wastewater management systems are based on the following basic principles:-

- Sewerage systems should make maximum use of available gradients to minimise the numbers of pumping stations.
- In long term economic considerations it is preferable to design deeper sewers (within reason) than to incur additional pumping stations.
- Gradients and velocities should be such as to minimise retention times and septicity
- Materials of construction should be resistant to corrosion from both internal and external environmental conditions
- Mechanical items of plant and equipment in collection and treatment systems should be kept to a minimum
- Controls should be as straightforward as possible.

Above all else, it is essential to utilize systems of wastewater management that are sustainable and maintainable under the climatic and organisational constraints of the communities under consideration. These may vary considerably across the country and relate, to some extent, to the proximity of larger city centres.

#### D1.2 Options and Methods Considered

In line with the principles set out in Section D1.1, the options/methods detailed have been limited to those which are considered practicable in Iran.

In particular, more sophisticated systems of treatment developed in recent years such as *Biological Aerated Filters (BAF)* and various physico-chemical systems which are generally designed to meet new legislation for discharge of treated effluents in Europe and the USA are not considered valid. They are either geared to "small footprint" designs due to space limitations or to complex processes to limit nutrients in effluents and these situations are unlikely to apply to the smaller communities throughout Iran.

For sewage collection conventional piped sewerage, tankering and non conventional small bore sewerage are discussed in this section.

Similarly wastewater treatment options have been restricted to the following:

- Preliminary treatment
  - screening
  - grit removal
  - comminution
  
- Primary treatment
  - primary sedimentation tanks
  - Imhoff tanks
  - primary ponds
  - septic tanks
  
- Secondary treatment
  - trickling filters
  - rotating biological contactors
  - activated sludge
  - extended aeration
  - oxidation ditches
  - aerated lagoons
  - waste stabilization ponds
  - constructed wetlands
  
- Tertiary treatment
  - disinfection
  - polishing ponds
  
- Sludge treatment
  - sludge drying beds
  - anaerobic digestion
  - sludge lagoons
  - sludge reed beds
  - composting

Treated effluent in the more arid regions of Iran is a valuable resource due to the high demand for water. Uses to be considered include landscape irrigation, aquaculture, aquifer recharge, countering saline intrusion, horticulture and forestry. Sludge reuse in agriculture and beautification is also to be considered.

Options for the disposal of treated effluent and sludge will depend on legislation which is in need of review to allow for the widely differing situations throughout Iran.

## D2 SEWAGE COLLECTION

### D2.1. Conventional Sewerage

By far the most popular and widely used method of sewage collection in the developed world is the conventional sewerage system.

The UK was one of the first countries to develop sanitary sewerage. The need for systems of water sanitation in large towns became evident during the Industrial Revolution of the early 19th century. Urban areas were developed without adequate provision for water supply or for the removal of waste. Accumulations of waste matter resulted in contamination of water supplies. High mortality from the water-borne diseases, typhoid, cholera and forms of dysentery, was widespread in the densely populated areas.

As Secretary to the Poor Law Commission, Edwin Chadwick realised that much poverty was the result of disease and early death. Though it was not then known that bacteria were responsible for the spread of diseases such as cholera, Chadwick became convinced that the failure to remove waste matter promptly and the lack of clean water supplies had some connection with the prevalence of disease. Chadwick and his supporters campaigned energetically for improvement.

The solution proposed by Chadwick is the one now familiar. Each dwelling is supplied internally with clean water, continuously under pressure, and the water used conveys waste matter through a system of pipes at velocities high enough to prevent silting. Previously sewers had been constructed of stone or brick. Silting and blockage were common and sewers were made large enough to accommodate deposits. John Roe had shown that deposition could be avoided by using 'tubular' or pipe sewers of small cross-section provided that the gradients were steep enough.

The proposals put forward by Chadwick were embodied in schemes produced as a result of the Public Health Act of 1848.

Today sewerage is generally defined as 'a system of sewers and ancillary works to convey sewage from its point of origin to a treatment works or other place of disposal'. A Sewerage System is one of a number of vital public utilities upon which modern communities are dependent. Unfortunately, so much of the work is not visible to the general public that there is a lack of appreciation of its importance.

Conventional Sewerage is designed to transfer domestic or industrial water-borne wastes (sewage) by means of a network of gravity pipes supplemented as required by pumping installations (ancillary works). Economies are realised in the long term by keeping the number of pumping installations and thus the associated operations and maintenance costs to a minimum. Bearing this in mind, sewerage design is influenced by a number of factors; principal among these are the following:

- (i) Topography
- (ii) Population Projections & Distribution
- (iii) Water Supply & Demand
- (iv) Land Use

The layout of a sewerage network is prepared with a view to taking advantage of the natural falls in the local topography wherever possible. By this means pipe depths are kept to a minimum reducing the possible need for pumping facilities.

Sewer pipes are sized to cater for peak flows generated by projected populations with due consideration being given to the available water supply situation and nature of the development to be served. Pipe gradients are employed to ensure the minimum self cleansing velocity (0.75 m/sec) is achieved at least once a day.

A typical sewerage system would comprise some or all of the following elements :

- Inspection Chamber (IC):** Located within the property to be served, the final IC acts as the focal point for the domestic foul sewerage. It also commonly marks the limit of the operating authority's maintenance responsibilities.
- House Connection (HC):** The HC is a 150 mm diameter gravity pipe which conveys flows from the property IC to a collector sewer. It is usually short (< 20 m) and laid with a steep gradient (between 2.0 and 16.7 %) to ensure good flow velocities at the head of the system.
- Sewers:** Sewers are gravity pipelines which are linked, like the branches of a tree, to form a sewerage network. Sewers are commonly identified by internal diameter :
- (i) Collector Sewers -  
150 - 200 mm diameter
  - (ii) District Sewers -  
201 - 400 mm diameter
  - (iii) Trunk Sewers -  
> 400 mm diameter
- Manholes:** Sewers are punctuated by manholes at frequent intervals to provide access for maintenance purposes. Manholes are located at each sewer junction or change in sewer direction, gradient or diameter. The maximum spacing between manholes on small diameter sewers should not exceed 60 metres.
- Pumping Stations:** Pumping stations are provided in a sewerage system generally to either avoid the construction of uneconomically deep sewers or to transfer sewage flows from isolated communities which cannot be connected to the treatment works or point of disposal by a gravity pipeline. Two general types of pumping stations are normally incorporated in sewerage systems, these are:
- (i) Submersible stations
  - (ii) Wet well/dry well stations

The type of station is a matter of preference although larger stations tend to be of the more expensive wet well/dry well variety due to the practicalities of maintaining the larger equipment in situ. If either type of station does not employ a pressure main, it is more appropriate to describe it as a lift station.

**Pressure Mains:**

Also known as rising or pumping mains, these pipelines serve to transfer flows under pressure from the pumping station to the head of another sewerage network or to a treatment works. A number of access points are provided on the pipeline for maintenance purposes; these are supplemented by air release valves and wash out facilities at the high and low points respectively.

Conventional sewerage is eminently suitable for communities with dense housing and ordered street systems. It becomes uneconomical, however, to construct in areas where the population distribution is very sparse, i.e. through the plantations/agricultural areas present in some of the smaller rural towns of Iran. It can also be uneconomical or impractical to lay conventional sewerage in very dense, old developments due to the difficulties involved with working in the limited space available. Excavations in particular are severely restricted to avoid damage to existing structures.

The main advantage of the Conventional Sewerage System is that it immediately removes sewage from its point of origin. From a public health stand-point this is extremely important as it greatly reduces the risk of infection or disease being picked up by the local populace especially the children.

A second advantage is that piped sewerage eliminates the need for septic or holding tanks, which, if not maintained or allowed to flood regularly, are a prime source of pollution and malodour.

The disadvantages of a Conventional Sewerage System are :

1. Large initial construction costs, particularly in areas with a high water table and/or rock close to ground level
2. Disruption to existing developments during the construction phase
3. Cost of setting up and running an operations and maintenance section for the system

Conventional Sewerage may be divided into two types of collection. These are either centralized or local. As the description suggests a centralized system collects flows from a town or community as a whole and transfers them to one treatment facility. Local collection, on the other hand, comprises a number of smaller individual sewerage systems which convey flows to either large communal tanks at one end of the scale, or to small treatment works at the other. The choice between centralized or local systems is often dictated by the factors listed at the beginning of this section.

Local sewerage to communal tanks is feature of some housing developments being constructed at present in the smaller towns of Iran and could be recommended for some future developments. The advantages of the system are as follows:

- Individual septic or holding tanks and their associated upkeep are eliminated.

- The contributing community as a whole are responsible for the emptying and maintenance of the system.
- The system forms the very important first stage of any sewerage network. It should therefore be a relatively simple task to connect the development once main sewerage is established in the area.

## D2.2 Tanker Collection

In most of the small towns of Iran domestic sewage is discharged to some form of tank for storage. The most common forms are the septic tank and the holding tank. Although these tanks differ in their functions, as described below, they both ultimately require to be emptied by tanker.

To appreciate the tankering system it is necessary to examine the function and performance of individual septic and holding tanks.

### D2.2.1 Septic Tanks and Holding Tanks

A Regulation Septic Tank should be a water-tight structure comprising two compartments built underground from reinforced concrete for the purpose of treating wastewater by settlement and anaerobic biological degradation. Tanks may be sized to cater for an equivalent population of up to 150. Access is provided to both compartments for desludging and maintenance through manholes located in the cover slab. The main compartment should be ventilated. Treated effluent passes over a weir and flows under gravity to an approved soakaway or other approved means of disposal.

Septic tanks are normally designed with a capacity which requires desludging once every three to six months. The resultant septage is strong in comparison to normal sewage.

Holding Tanks differ from septic tanks in that they have no overflow facility and so store the incoming wastewater for short periods until pumping out is required. A holding tank should be constructed as an underground, water-tight, reinforced structure consisting of a single, ventilated compartment with a covered access hole in the top slab. The tank is sized to hold a minimum of two days storage with a capacity of not less than 2 000 litres. The contents of the holding tanks are tankered away to an approved discharge point.

In practice, many of the tanks in use in the Middle East, and it is expected that Iran is no exception, do not conform with either accepted design or construction methods.

Notwithstanding the unpleasant odours and unsightly appearance of ponding effluent which characterise poorly constructed and/or maintained sewage tanks, there is always the real danger of the facility being a hazard to the health of the community it is designed to assist, i.e.

- Contamination of the potable water supply by infiltration into the piped system - particularly in the situation where flexible house connections are laid on or close to the ground surface, where they may suffer damage.
- Pollution of the water supply through seepage directly into the local well or borehole.
- Pollution of the groundwater from which the domestic supplies are drawn.

- Ponding which provides breeding grounds for flies and insects, in particular the mosquito.
- Broken covers to tanks which can be a danger to pedestrians particularly children.

In some countries Government housing schemes utilise communal tanks, wherever possible, one tank serving four or more housing units. This arrangement reduces initial construction costs and continues to be cost efficient as the number of journeys to the properties are less. As communal property the tanks are located outside boundary walls which normally makes access for desludging much easier.

### D.2.2 Tankering

The onus is generally placed on the tank owner or user to arrange for it to be emptied regularly and maintained. Tankers used for this purpose vary in size from 2 000 gallon lorries to much smaller units. The type used depends upon the ease of access to the premises and the size of tank concerned.

- Large institutional, government or private establishments often run their own tankers which can reach up to 5 000 gallons capacity.
- Local municipalities may own tankers which may be used routinely as a service for emergency works.
- Many residential and other tank owners are reliant upon private contract tankers for the collection of their septage or wastewater. Charges levied by private contractors vary considerably, the spread being a function of tanker capacity, load, distance to point of disposal and discharge fees.

Wastewater Treatment Plants make a charge per tanker to discharge at the works. Again this discharge fee is a function of the tanker capacity. If regional tankering is adopted with discharge a WWTP provision should be made for tanker reception and discharge at the inlet works.

In many towns the tanker contents are commonly dumped on an approved area of land at, or adjacent to, the municipal refuse dump. The disposal is generally not controlled: the wastewater is dumped to a, usually hollow, area of ground with no provision made for its treatment or containment. Gross contamination of the surrounding soil is common as effluent streams emerge from the lagooned waste. Contamination of local groundwater is also a potential danger.

### D3.2.3 Non Conventional Sewerage Systems

As a compromise between conventional sewerage systems and tankering as a means of sewage collection, a third system commonly known as small bore sewerage is sometimes used. This system is a member of the non conventional group of sewerage systems which also include the more popular vacuum system and the small bore pressure main system which employs chopper pumps. Both of these systems are too technically sophisticated to merit further consideration in this study.

The non conventional sewerage (NCS) system, considered feasible for use in some towns, comprises small bore, shallow depth pipe networks. They have recently been implemented in a number of high density urban situations throughout the world. Most of the proposed and installed NCS systems incorporate interceptor tanks which are intended to prevent the bulk of wastewater solids from entering the sewer lines. By reducing the solids load of the sewage smaller diameter and slacker



gradients of pipe can be utilized with a reduced risk of solids deposition and consequent blockage occurring. Interceptor tanks also have a balancing effect, with lower peaking factors in the downstream pipes.

A few systems have been installed that do not incorporate interceptor tanks in situations where wastewater solids levels were low or where there was confidence that blockages would not occur.

The main advantages of NCS systems, as compared to conventional sewerage systems, are :

- smaller diameter pipework (100 mm or less for pipes downstream of interceptor tanks);
- lower pipe gradients (house connections less than 1:100, collector sewers less than 1:200);
- lower peaking factors (less than 1.8);
- sewers laid along backyards, often on private property;
- shallower cover if laid in areas (for example, backyards and pavements) with little or no traffic loads;
- use of fewer, smaller and shallower inspection chambers, or simpler inspection tubes or underground boxes;
- lower minimum velocity requirements for self-cleansing;
- if interceptor tanks are included, a reduced load on the STW;
- lower risk of groundwater contamination as posed by septic tank sculkways.

Reports on the performance of NCS systems in various countries throughout the world have been mixed. They have mainly been implemented in high-density, low-income urban and semi-urban areas where conventional sewerage would either be too difficult or too costly to install. In the context of the nine towns under consideration NCS systems may be a cost effective alternative to conventional sewerage in some of the older, more congested areas of the towns. The excavation for and laying of conventional sewers in such areas would be extremely difficult and costly. Furthermore, the existing septic and holding tanks would have to be demolished and backfilled. Such construction work may risk damaging the poorly-founded buildings that are ubiquitous in such areas.

The NCS features listed above all have as their primary objective the reduction of costs. The cost effectiveness of interceptor tanks themselves depends upon:

- whether they have to be purpose built or can be adapted from existing septic or holding tanks;
- the design desludging period and the cost of desludging;
- any savings in treatment costs as a result of the weaker settled sewage arriving at the STW.

## Sewerage Options

For smaller communities of Iran the proposed sewerage alternatives must be consistent with the intended planning policies for the older, congested areas of the towns. The options for sanitation systems are :

- maintaining the status quo, but implementing a septic and holding tank refurbishment programme;
- expensive conventional sewerage with demolition of septic and holding tanks;
- conversion of septic and holding tanks to interceptor tanks and introduction of NCS system.

The advantages of non conventional sewerage systems may be summarized as :

- significant saving in construction costs;
- ease of construction in unplanned, densely populated areas;
- potential for reducing water flush volumes.

The disadvantages of NCS systems are :

- sludge has to be removed from the tanks on a regular basis;
- removed sludge has to be disposed of.

Before making widescale recommendations a demonstration NCS system serving a selected area in one of the towns would be worth considering in order to evaluate the suitability and acceptability of the system in Iran.

## D3 SEWAGE TREATMENT

### D3.1 Factors Influencing Treatment Process Choice

The choice of the wastewater treatment technology to be adopted in any particular situation is dependent, *inter alia*, upon the following parameters:

- the use or disposal route of the treated effluent;
- relevant national standards or guidelines pertaining to such use or disposal;
- the regional climatic conditions;
- the short-term financial resources for capital construction costs;
- the long-term financial resources for running costs;
- the infrastructure available for operation and maintenance of the works and for repair or replacement of faulty plant.

These parameters are discussed further in the following sub-paragraphs.

### D3.1.1 Treated Effluent Reuse

The reuse of treated wastewater for irrigation in both agricultural and beautification schemes, the replenishment of sub-surface resources or in industrial horticultural or forestry schemes will be an important component in safeguarding some of the community water resources by liberating potable water, that has been traditionally used for such irrigation, for alternative uses. The practice of effluent reuse will be more critical in the more arid areas of Iran than in the temperate or mountainous zones where rainfall is plentiful. Where effluent reuse is to be practiced, wastewater treatment options must therefore be evaluated for their ability to produce an effluent considered safe for reuse in either restricted or unrestricted irrigation - Categories A and B, respectively, of Table D3.1. 'Recommended Microbiological Guidelines to Wastewater Use in Agriculture', reproduced from WHO Technical Report 778, 1989.

The choice of wastewater treatment technology is thus directly dependent, amongst other factors, on the treatment objectives. Where the effluent is to be reused in irrigation, the sewage treatment options will be restricted by the standards and regulations adopted for such reuse.

### D3.1.2 Treated Effluent Standards and Regulations

The current Iranian EPA Regulations for treated wastewater reuse and discharge are reasonably compatible with the latest World Health Organisation guidelines (WHO Technical Report Series 778, 1989). The latter which are given in Table D3.1 are based on epidemiological evidence and they emphasise the importance of the helminthic and bacteriological quality of the treated effluent when it is to be used in unrestricted crop irrigation.

The WHO guidelines do not set limits for the ammoniacal nitrogen concentration of the effluent, as this element is considered as a valuable crop fertilizer which serves as a nutrient when present in irrigation waters or in fish ponds. The WHO state in their report that, with proper management, higher crop yields may be achieved when treated wastewater effluent and its associated fertilizing nutrients (especially the organic matter and the nitrogen, phosphorus and potassium compounds) are used for irrigation. These pollutants, if not used in controlled irrigation but instead discharged directly to the environment, can create serious pollution problems.

It is appropriate that the current standards are reviewed and updated to cater for the wide range of circumstances throughout Iran.

### D3.1.3 Sewage Treatment for Reuse

The WHO Technical Report recommends the advantages of Wastewater Stabilization Pond systems for the treatment of wastewater whose effluent is destined for reuse in agriculture or aquaculture, and states that they are the preferred method of wastewater treatment in warm climates wherever land is available at reasonable cost.

The report asserts that conventional wastewater treatment processes, unless supplemented by disinfection, are not able to produce an effluent which complies with the recommended bacterial guideline for unrestricted irrigation. Moreover, conventional systems are not generally effective in removing helminth eggs and have little effect on chemical contaminants in wastewater. Table D3.2 shows the expected efficiencies of removal of the major microbial pathogens in various wastewater treatment processes, reproduced from the WHO Technical Report Series 778.

Recommended Microbiological Guidelines for Wastewater Use in Agriculture<sup>(a)</sup>

Category	Re-use Conditions	Exposed Group	Intestinal Nematodes <sup>(b)</sup> (arithmetic mean No. of eggs per l <sup>(c)</sup> )	Faecal coliforms (geometric mean No. per 100 ml <sup>(c)</sup> )	Wastewater treatment expected to achieve the required microbiological quality
A	Irrigation of crops likely to be eaten uncooked, sports fields, public parks <sup>(d)</sup>	Workers, consumers, public	< or = 1	< or = 1000 <sup>(d)</sup>	A series of stabilisation ponds designed to achieve the microbiological quality indicated, or equivalent treatment
B	Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees <sup>(e)</sup>	Workers	< or = 1	No standard recommended	Retention in stabilisation ponds for 8-10 days or equivalent helminth and faecal coliform removal
C	Localised irrigation of crops in Category B if exposure of workers and the public does not occur	None	Not applicable	Not applicable	Pretreatment as required by irrigation technology but not less than primary sedimentation

(a) In specific cases, local epidemiological, socio-cultural and environmental factors should be taken into account and the guidelines modified accordingly

(b) *Ascaris* and *Trichuris* species and hookworms

(c) During the irrigation period

(d) A more stringent guideline (< or = 200 faecal coliforms per 100 ml) is appropriate for public lawns, such as hotel lawns with which the public may come into direct contact

(e) In the case of fruit trees, irrigation should cease two weeks before fruit is picked, and no fruit should be picked off the ground. Sprinkler irrigation should not be used

**Table D3.2**  
**Expected Removal Of Excreted Microorganisms**  
**In Various Wastewater Systems<sup>a</sup>**

Treatment Process	Removal (log <sub>10</sub> units) of			
	Bacteria	Helminths	Viruses	Cysts
Primary Sedimentation				
Plain	0-1	0-2	0-1	0-1
Chemically assisted <sup>b</sup>	1-2	1-3 <sup>h</sup>	0-1	0-1
Activated Sludge <sup>c</sup>	0-2	0-2	0-1	0-1
Biofiltration <sup>d</sup>	0-2	0-2	0-1	0-1
Aerated Lagoon <sup>e</sup>	1-2	1-3 <sup>h</sup>	1-2	0-1
Oxidation Ditch <sup>e</sup>	1-2	0-2	1-2	0-1
Disinfection <sup>f</sup>	2-6 <sup>h</sup>	0-1	0-4	0-3
Waste Stabilization Ponds <sup>f</sup>	1-6 <sup>h</sup>	1-3 <sup>h</sup>	1-4	1-4
Effluent Storage Reservoirs <sup>g</sup>	1-6 <sup>h</sup>	1-3 <sup>h</sup>	1-4	1-4

- a    Source: WHO Technical Report Series 778 (1989)
- b    Further research is needed to confirm performance
- c    Including secondary sedimentation
- d    Including settling pond
- e    Chlorination and ozonation
- f    Performance depends on number of ponds in series and other environmental factors
- g    Performance depends upon retention time, which varies with demand
- h    With good design and proper operation the recommended guidelines are achievable

The objective of treating wastewater for use in agriculture or aquaculture is to remove excreted pathogens and thus prevent disease transmission. However, this is not the purpose for which conventional wastewater treatment systems, normally used in Europe and North America, were originally developed. Their primary objective was the removal of organic matter and suspended solid material. In recent years, with increasing awareness of environmental pollution, sophisticated tertiary treatment processes have been added to conventional systems to improve pathogen removal. Efficient removal of wastewater pathogens requires processes specifically designed for this purpose; incidental removal in other processes developed for other purposes is unlikely to be cost-effective.

#### D3.1.4 Capital and Operational Budgets

Availability of financial resources will affect the choice of treatment process. Limited funding will tend to favour:

- Processes which minimise the importation of plant
- natural process which can be constructed locally and operated with minimal specialised operational controls
- systems which can be developed in phases with greatest flexibility.

#### D3.1.5 Operation and Maintenance

It is the experience of many organisations throughout the Middle East that highly mechanised sewage treatment technologies are prone both to system failure and to poor process performance. These problems arise as a result of the harsh regional climatic conditions, the lack of suitable infrastructure to provide adequate operation and maintenance on a continual basis, and the unavailability of spare plant.

Many of the smaller communities of Iran are in relatively remote locations and consequently, to minimise the problems associated with operation and maintenance, it is recommended that mechanical items of plant and equipment should be kept to a minimum, and that the process control be as straight forward as possible. Systems of wastewater management must be sustainable and easily maintained within the climatic and organisational constraints of the towns under consideration.

#### D3.1.6 Process Options

In consideration of the above alternative wastewater treatment options have been evaluated and their individual advantages and disadvantages discussed within the particular constraints and characteristics identified for Iran. The options considered relevant to Iran's small communities are:

- Preliminary treatment
  - screening
  - grit removal
  - comminution
  
- Primary treatment
  - primary sedimentation tanks
  - Imhoff tanks
  - primary ponds
  - septic tanks
  
- Secondary treatment
  - trickling filters
  - rotating biological contactors
  - activated sludge
  - extended aeration
  - oxidation ditches

- aerated lagoons
  - waste stabilization ponds
  - constructed wetlands
- Tertiary treatment
    - disinfection
    - polishing ponds
    - filtration
    - algal removal
  - Sludge treatment
    - sludge drying beds
    - anaerobic digestion
    - aerobic digestion
    - sludge lagoons
    - sludge reed beds
    - composting

### D3.2 Preliminary Treatment

The first stage of sewage treatment is usually the removal of large floating objects (for example rags and large pieces of wood) and heavy mineral particles (sand and grit). This is done in order to protect from damage any mechanical equipment such as pumps used in the subsequent stages of treatment and to reduce the risk of blockages in pipelines. This preliminary treatment comprises *screening* and *grit removal*. A common alternative to screening is *communition*. In the arid, sandy regions of Iran the raw wastewater may contain large quantities of sand and grit. Grit removal will be a key process prior to secondary treatment involving mechanical equipment or subterranean piping.

At small works utilising waste stabilization ponds or extended aeration reactors, there is often no preliminary treatment, or at most only coarse screening to remove the larger floating solids. However, in situations where grit and sand intrusion is identified as a major problem grit removal may also be incorporated. The operational advantages afforded by the preliminary treatment processes increase directly with the volume of waste being treated.

#### D3.2.1 Coarse Screening

Coarse solids are removed by a series of closely spaced mild steel bars placed across the flow. The velocity through the screen should be  $> 0.3$  m/s in order to prevent the deposition of grit but  $< 1$  m/s so that the solids already trapped on the screen (the *screenings*) are not dislodged. The spacing between the bars is usually 20-40 mm and the bars are commonly of rectangular cross-section, typically 10 mm x 50 mm. At small works screens are raked by hand and in order to facilitate this the screens are inclined, commonly at  $60^\circ$  to the horizontal. The submerged area of hand-raked screens is calculated on the empirical basis of 0.15-0.20 m<sup>2</sup> per 1 000 population; this assumes that the screens are raked at least twice each day.

For flows  $> 200$  m<sup>3</sup>/d mechanically raked screens are often preferred since they can be cleaned more frequently (every 10-30 minutes) and are therefore considerably smaller than the corresponding hand-raked screen. A standby hand-raked screen should be provided for use when the mechanical screen is out of action. This emergency screen is normally the same size as the mechanical screen and it will therefore require raking at frequent intervals when in use.

Screenings are particularly obnoxious in both appearance and content and should be disposed of as soon as possible. At small works this is readily achieved by burial, a small area being set aside for this purpose. At larger works screenings may be dewatered in a hydraulic press and then incinerated, or macerated in a disintegrator and then returned to the sewage flow below the screens. The quantity of screenings that are removed varies considerably but, for 10 mm bars at 20 mm spacings, an approximate figure is 0.01-0.03 m<sup>3</sup>/d per 1 000 population.

### D3.2.2 Fine Screening

Automated fine screens are currently gaining favour in Europe and the United States both as a form of pre-treatment prior to marine disposal and in some conventional and novel treatment systems. They are commonly accompanied by screen presses which both rinse and dewater the screenings to aid in the transportation and final disposal of the screenings.

By their nature they remove more organic material than do the coarser screens and this can lead to problems of putrefaction in hotter climates. As screenings digest they will cause odour problems and release methane gas which can, in some circumstances, lead to explosive conditions (if trapped in pockets within a landfill, for example).

### D3.2.3 Grit Removal

Grit is the heavy inorganic fraction of sewage solids. It includes road grit, sand, glass and pieces of metal. Grit has an average relative density of about 2.5 and thus has a much higher settling velocity than organic sewage solids. It is this difference in sedimentation rates that is exploited in grit removal plants where, for ease of handling and disposal, the organic fraction must be kept to a minimum. There are two basic types of grit removal plant: constant velocity grit channels and the various proprietary tanks or traps available commercially.

#### D3.2.4 Constant Velocity Grit Channels

Constant velocity grit channels maintain the velocity of flow through them at about 0.3 m/s for all rates of flow. At this velocity the grit particles settle out but the organic solids do not. At least two channels are provided so that one may be closed for manual grit removal. The channel length is determined by the settling velocity of the grit particles.

#### D3.2.5 Grit Separators

For flows > 5 000 m<sup>3</sup>/d proprietary grit separators are often more economical than several long, constant-velocity grit channels, but obviously have inherently greater operation and maintenance requirements. There are several models available, one of the simplest being the 'Pista' grit trap which has the advantage that no moving parts come in contact with the grit and that the grit is automatically cleaned before discharge.

The quantity of grit collected may be as high as 0.17 m<sup>3</sup>/1 000 m<sup>3</sup> of sewage, although the average figure is 0.05-0.10 m<sup>3</sup>/1 000 m<sup>3</sup>. Grit quantities for the Sultanate can be expected to be towards the high end of the range due to the ingress of large amounts of sand in the semi-arid regions. The grit is either used for landfill or disposed of by burial; it has been observed that the grit is sometimes added to the sludge drying beds for ultimate disposal with the desiccated sludge.



### D3.2.6 Comminution

A comminutor is a self-cleansing shredding machine which cuts up sewage solids as they pass or are pulled through the outer periphery of the machine. It consists of a hollow cast-iron drum which is continuously rotated about its vertical axis by an electric motor through a reduction gearbox. The drum is in fact a screen with 6-8 mm horizontal slots on which cutter bars and a large number of projecting cutting teeth are fixed; the bars and teeth engage with stationary steel combs. The solids which are held against the outside of the moving drum by the sewage flow are carried by the drum to the stationary combs where they are shredded by the combined action of the cutter bars and the cutting teeth. Comminutors are installed in special concrete chambers which are spiral in plan. A bypass channel should be provided for use during periods of maintenance or power failure.

Following comminution, shredded rags often reform into lengths of string which 'ball-up' and thus cause blockages in downstream pipes and pumps. Grit and sand can damage the comminutor's cutting teeth. This is a particular problem in semi-arid areas where sand may be blown directly into the comminutor or into the channels feeding it. Comminutors require a high level of maintenance and operation and are prohibitively expensive for many situations.

### D3.2.7 Sand Ingress

Generally, where sand intrusion is identified as a potential hazard, barriers may be erected around all the reactors at a sewage treatment plant to prevent the sand entering them and silting them up. Sheet walling may be used for this purpose: as the sand builds up around the external face of the walls it is removed either manually or by automatic means such as air-jetting.

Tree and shrub screens are also an effective way of reducing sand ingress and improving the environment of the works.

## D3.3 Primary Treatment

Primary treatment employs the simple phenomenon of sedimentation. Sedimentation is the gravitational separation of a suspension into its component solid and liquid phases. In the primary sedimentation of sewage there are two aims: to produce high degrees of both clarification and thickening. A high degree of clarification is required to reduce the load on the secondary (biological) treatment plant and a high degree of thickening is desirable so that sludge handling and treatment is minimized.

### D3.3.1 Primary Sedimentation Tanks

#### (i) Radial Flow Tanks

Radial flow tanks are circular in plan, with small floor slopes (2.5°-7.5°). The sewage enters centrally, passes through an inlet baffle (to minimize turbulence) and then flows outwards and upwards to the overflow weir. Sedimentation tank side wall depths are usually maintained at about 2 m. Mechanical scrapers are provided for sludge collection and surface scum is removed by skimmer arms. The scraper arms rotate slowly (1-3 rev/h) and move the sludge towards a central hopper from where it is periodically removed. Primary sedimentation is commonly used to precede the conventional biological treatment processes of activated sludge and biofiltration.

(ii) **Vertical Flow Tanks**

These can be square or circular in cross section (plan). They rely on a 60° shaped bottom such that the sludge falls unaided to the bottom outlet, thus avoiding the need for mechanical scrapers. In this system sewage enters at the centre of the tank about 2 or 3 m below the surface and flows upwards and outwards over a peripheral weir. The plan area is limited due to the need for a base sloping at 60° down which the sludge will fall unaided.

(iii) **Horizontal Flow Tanks**

These are rectangular tanks along which sewage flows from one end to the other whilst the solids settle to the base.

They may be fitted with mechanical scrapers to move the sludge towards a transverse hopper at one end of the tank from where it is removed.

For smaller works where twin units are provided they can be desludged manually on a fill and draw basis in which a floating arm decanter is first used to remove the supernatant water. This latter system might be fairly satisfactory for smaller communities in Iran where capital costs need to be minimised.

Sedimentation tanks are usually designed to have a minimum hydraulic retention time of 2 hours at peak flow. However in hot climates, such as that encountered in Iran, the retention time in sedimentation tanks ought to be minimized to reduce the danger of septicity and subsequent odour nuisance occurring. For the same reason the tanks ought to be desludged on a regular basis otherwise the sludge itself will turn septic and present problems of malodour.

### **D3.3.2 Imhoff Tanks**

The Imhoff Tank consists of a two storey tank in which sedimentation is accomplished in an upper compartment and digestion in a lower one. Settling solids pass through slots in the base of the clarification chamber into the unheated sludge storage chamber where they undergo anaerobic digestion. Scum accumulates in the upper compartment. Vents are provided to release gases produced during digestion.

Before the development of separate heated digestion tanks, Imhoff tanks were common in Europe and the USA but application is limited in these countries nowadays to very small plants. Some experimentation has taken place with heating the sludge compartment but such refinement would not be necessary in Iran.

Operation consists of removing scum daily and discharging it into the nearest gas vent and reversing the flow of wastewater twice a month to even up the solids in the two ends of the digestion compartment.

### D3.3.3 Primary Ponds

An anaerobic pond or a primary facultative pond provides the first treatment step in a series of waste stabilization ponds. Where mean ambient temperatures exceed 15°C, anaerobic ponds need only be desludged every 5-10 years, once half full of sludge. Operation and maintenance tasks are minimal, and capital and running costs very low.

Retention times in anaerobic ponds are commonly 0.5-1 day. The removal of BOD in these ponds is a function of temperature. At temperatures of 20°C and greater removals of 60 percent can be expected. After undergoing a period of *in situ* desiccation, the sludge removed from an anaerobic pond can be disposed of directly to landfill or to agricultural land as a soil conditioner/plant fertilizer.

### D3.3.4 Septic Tanks

Septic tanks are small, rectangular chambers, usually sited just below ground level, in which sewage is retained for 1-3 days. During this time the solids settle to the bottom of the tank where they are digested anaerobically. A thick crust of scum is formed at the surface and this helps to maintain anaerobic conditions. Digestion of the settled solids is reasonably good, especially if the ambient temperature is > 15°C, as is the case for the nine towns under consideration for the majority of the year. Even at elevated temperatures some sludge accumulates and the tank must be desludged at regular intervals, usually once every 1-5 years. Although septic tanks are most commonly used to treat the sewage from individual households, they can be used as a communal facility for populations up to about 300. All the household wastewater, including *sullage* (that wastewater resulting from personal washing, laundry, food preparation and the cleaning of kitchen utensils) should be led to the septic tank.

A two-compartment septic tank is now generally preferred to one with only a single compartment as the suspended solids concentration in its effluent is considerably lower. The first compartment is usually twice the size of the second. The liquid depth is 1-2 m and the overall length to breadth ratio 2-3 to 1. In order to provide sufficiently quiescent conditions for effective sedimentation of the sewage solids the liquid retention time should be at least 24 hours. Two-thirds of the tank volume is normally reserved for the storage of accumulated sludge and scum, so that the size of the septic tank should be based on 3 day retention at start-up; this ensures that there is at least 1 day retention just prior to each desludging operation.

The tank should be emptied when it is approximately one-third full of sludge. The rate of sludge accumulation is temperature dependent and as a result of the efficient anaerobic digestion mentioned above, will be relatively low in the high temperatures generally experienced in some parts of Iran. Sludge pumped from septic tanks, termed *septage*, is best discharged to a nearby wastewater treatment plant for treatment, if one exists. In Iran septage is commonly disposed of, together with the wastewater from holding tanks, to dumping sites usually located somewhere outside the town. However, some newly constructed sewage treatment plants in Iran, such as Mashad (Holy Harem) and Esfahan, have tanker facilities to allow the discharge of tankered septage and wastewater.

Subsurface irrigation in drainfield trenches (*soakaways*) is the most common method of disposal of septic tank effluent. The drainfield soil must, of course, be permeable. In situations where the water table is particularly high or the overlying soil and bedrock is too porous, there is the potential danger of groundwater contamination occurring. For large flows from communal tanks waste stabilization ponds or constructed wetland systems may be a more suitable treatment method to local soakaways.

Since septic tanks are invariably located close to the houses they serve, any overflowing sewage poses a serious health risk to the population. This is especially true in the case of children, who tend to play in the yards and roads where the overflows and leaks occur, and who are more susceptible to infection in the first place.

### D3.4 Secondary Treatment

#### D3.4.1 Trickling Filters

The trickling filter, or biofilter, is a circular or rectangular bed of coarse aggregate, usually 1.8 m deep. Settled sewage is distributed over the bed and trickles down over the surface of the media. On these surfaces a *microbial film* develops and the bacteria, which constitute most of this film, oxidize the sewage as it flows past. As the sewage is oxidized the microbial film grows. Some of the new cells so formed are washed away from the film by the hydraulic action of the sewage. These cells are separated from the liquid phase in secondary sedimentation tanks termed *humus tanks*. Humus tanks are basically similar to primary tanks but without the scum-skimming facilities. The clarified effluent is discharged and the humus sludge pumped to the sludge treatment unit.

Conventional biological trickling filters cannot reliably remove ammonia to low levels. Construction costs of these systems are high and sometimes involve the importation of the filter media. A nitrifying biofilter system incorporates a primary coarse media filter bed for carbonaceous BOD removal followed by a secondary filter bed with smaller media to promote nitrification. Plastic media for biofilters have considerable advantages over traditional stone media: the voidage is > 90% and their surface area per unit volume is 3-6 times higher; such media could be manufactured in Iran (*it has been made locally in Dubai before*). Each filter stage has its own humus tank and this can lead to problems with the hydraulic gradients across a proposed plant, thereby necessitating the inclusion of costly intermediate pumping stations. Consequently, nitrifying trickling filter systems require more land area than do nitrifying activated sludge systems to treat the same wastewater flows.

Good grit and rag removal prior to the first filter bed is an essential requirement of these systems to ensure that the bed's distribution pipework is not blocked and the filter surface not blinded, the latter leading to the phenomenon known as ponding. If a fine screen is incorporated in the preliminary treatment then primary sedimentation can be omitted prior to a biofilter.

Odour release from low-rate biological filters can be so intense that in many hot climates, for example California, activated sludge plants are used simply to overcome the biofilter odour problem. The microbial film in biological filters is used as a breeding ground by various flies and midges. This is beneficial in that the larvae feed on the film and thus help to prevent ponding. However, although none of the species found in filters actually bites humans, their sheer numbers can be a severe nuisance in hot climates: clouds of *Psychoda* flies can effectively stop all human activity in and near a sewage treatment works. High-rate biofilters, which contain a special plastic packing of open structure and regular geometry, can generate even greater odour problems.

#### D3.4.2 Rotating Biological Contactors

A rotating biological contactor (RBC) consists of closely spaced circular discs of polystyrene or polyvinyl chloride. The discs are partially submerged in wastewater and rotated slowly through it. In operation, biological growth becomes attached to the surfaces of the discs and eventually forms a slime layer over the entire wetted surface of the discs. The rotation of the discs alternately contacts the biomass with the organic material in the wastewater and then with the atmosphere for adsorption

of oxygen. The disc rotation affects oxygen transfer and maintains the biomass in an aerobic condition. The rotation also is the mechanism for removing excess solids from the discs by the shearing forces it creates and maintaining the sloughed solids in suspension so that they can be carried forward to a clarifier.

RBCs are usually used for population equivalents of up to 10 000. Rotating biological contactors are oxygen-limited systems, which means that if the organic loading to the head of the works is too high then the system will turn anaerobic and cease to perform satisfactorily. For this reason RBCs are not good at accommodating surges in flow, and are easily overloaded if the incoming hydraulic or organic load gradually increases with time. Other treatment systems such as waste stabilization ponds and the extended aeration variant of activated sludge can handle surges in flow much more readily. In general, RBCs are relatively complex and expensive to operate and maintain; they have a poor history of operation in some Gulf states.

The possibility of grit and sand entering the disc rotation bearings in arid sandy areas also poses a significant danger to the performance of RBCs. The sand can cause the rotation of the discs to slow, and in extreme cases to cease, thereby increasing their organic loading and reducing the oxygen transfer to the waste. In such situations the reactor inlet can rapidly turn anaerobic. RBCs are relatively small in plan area and hence can be readily covered.

Unequal amounts of biofilm growth on the discs can occur, especially if power failures are commonplace and the discs sit half-immersed, half-exposed for some time. This phenomenon causes an imbalance on the rotation shaft which in turn may lead to a start-up failure, or to fracture of the shaft itself. Furthermore, as a result of the large loads that the motors have to work against, motor failure is commonplace.

#### D3.4.3 Activated Sludge

Activated sludge is the conventional alternative to biofiltration. Raw or settled sewage is led to an aeration tank where oxygen is supplied either by mechanical agitation or by diffused aeration. The bacteria which grow on the settled sewage are removed in a secondary sedimentation tank. In order to maintain a high cell concentration in the aeration tank, most of the sludge is recycled from the sedimentation tank to the aeration tank inlet. The sludge contains some inert solids but the main components making up its loose, flocculent structure are living bacteria and protozoa.

There are two phases of BOD removal by activated sludge. First there is the rapid initial removal by the entanglement of suspended solids within the gross sludge matrix and absorption of colloidal matter on to the floc surfaces. This phase is followed by a slow progressive solubilization and oxidation of these waste compounds by the bacteria present within the sludge flocs.

The conventional activated sludge (AS) system consists of a plug flow aeration tank, a secondary clarifier and a sludge recycle line. Oxygen is supplied at a uniform rate throughout the aeration tank, even though the oxygen demand decreases along the length of the tank. Sludge wasting is accomplished from the recycle line. Both influent settled wastewater and recycled sludge enter the tank at the head end and are aerated for a period of about 6 hours. The reactor contents are mixed by the action of the diffused or mechanical aeration; the concentration of mixed liquor suspended solids (MLSS) in the reactor is commonly 2 000-3 000 mg/l. The mixed liquor is settled in the final clarifier, and sludge is returned at a rate of approximately 25-50% of the influent flowrate.

Variations on the conventional AS system are *tapered aeration*, in which the oxygen supply is progressively reduced along the tank, and *stepped aeration*, in which the influent is added in several stages. Both these modifications ensure that oxygen demand better matches oxygen supply along the reactor length.

If the hydraulic retention time in the aeration tank is increased to 10-12 hours, and the MLSS to 3 000-4 000 mg/l, then nitrification is also achieved: the longer retention time allows an effective population of the slow-growing nitrifying bacteria to be established. This process is termed *nitrifying activated sludge*.

#### D3.4.4 Extended Aeration

If the retention time in an activated sludge reactor is still further increased, to 24 hours or greater, the rate of sludge autolysis increases and substantially less sludge is produced. This variant is known as *extended aeration* (EA). The sludge which is produced is better mineralized and nearly fully stabilized; it is less offensive than other wastewater sludges, and readily dewateres in sludge lagoons or on sludge drying beds. The extended aeration process, like nitrifying AS, also achieves full nitrification. An EA reactor can receive either raw or settled sewage. The MLSS in an extended aeration reactor is maintained at 3500-5000 mg/l. The principle of extended aeration is the basis of the oxidation ditch (see below).

The extended aeration process is used extensively for prefabricated package plants that are often used for the treatment of wastes from housing subdivisions, isolated institutions, small communities, schools and so on. However, it can also be used successfully for larger Municipal sewage treatment facilities and there are many examples of such systems in the Middle East serving communities up to approximately 100 000.

An advantage of the EA process is that it requires no primary sedimentation and in some situations preliminary screening and grit removal can be obviated. A disadvantage of extended aeration activated sludge, especially in hot climates such as those found in parts of Iran, is the potential for denitrification to occur in the secondary clarifier should the sludge turn anoxic. Denitrifying bacteria, which convert nitrates to nitrogen gas, thrive in such conditions. Gas bubbles rise to the clarifier surface buoying sludge particles up and over the discharge weir. This phenomenon is termed *rising sludge* and it can cause a marked deterioration in the quality of the final plant effluent. Weir scum guards are a simple solution that help minimize the quantity of solids allowed to escape from the clarifier in this way. A pre-anoxic zone in the aeration tank can be utilized. The anoxic zone performs two roles: firstly, it encourages denitrification to occur in it, rather than in the secondary clarifier; and secondly, it reduces the oxygen demand of the waste since the bacteria involved utilize nitrate, rather than free oxygen, to oxidize organic matter as they grow. Denitrification can be controlled by skilled and experienced operation.

#### D3.4.5 Oxidation Ditches

Developed initially for small towns in the Netherlands, the oxidation (or Pasveer) ditch is a modification of the extended aeration process. It receives screened or comminuted raw sewage and provides long retention times: the hydraulic retention time is commonly 0.5-1.5 days and that for the solids 20-30 days. The latter, achieved by recycling > 95% of the sludge, ensures minimal excess sludge production and a high degree of mineralization in the sludge that is produced.

The two other major differences from the conventional process lie in the shape and type of the aerator. The oxidation ditch is a long continuous channel, usually oval in plan and 1.0-1.5 m deep. The ditch liquor is aerated by one or more cage rotors placed horizontally across the channel; for large flows it is usually more economic to provide the more powerful 'mammoth' rotors. The rotors also impart a velocity of 0.3-0.4 m/s to the ditch contents, sufficient to maintain the active solids in suspension. The concentration of total suspended solids in the ditch is maintained at 3 000-5 000 mg/l, as for the other EA systems. BOD removals from oxidation ditches are consistently > 95%.

The oxidation ditch was first developed to provide small communities of 200-1 5000 people in temperate climates with sewage treatment facilities at the same per capita cost as conventional works serving much larger populations. They are becoming an increasingly popular treatment choice in hot climates sometimes for larger communities where there is a reliable electricity supply but insufficient land for a waste stabilization pond (WSP) system; ponds are usually more favourable both in terms of cost and the removal of pathogens. In tropical climates oxidation ditches are unlikely to be used for populations <1 000 for which WSPs are usually more suitable.

#### D3.4.6 Extended Aeration Sludges

Extended Aeration (EA) if it is to be compared with other forms of sewage treatment, must be considered as a wastewater *and* a sludge treatment process since a considerable amount of sludge oxidation is also achieved in the reactor. The power input for EA will consequently be generally higher but sludge handling and disposal is considerably easier.

For all activated sludge processes, whenever gravity flow is not possible, screw pumps should be used to transport aeration tank effluent to the clarifiers and return activated sludge to the influent. This provision minimizes the shear on the sludge flocs and so prevents them from being broken up prior to clarification.

#### D3.4.7 Aerated Lagoons

Aerated lagoons are activated sludge units operated without sludge return. Historically they were developed from waste stabilization ponds in temperate climates where mechanical aeration was used to supplement the algal oxygen supply in winter. It was found, however, soon after the aerators were put into operation the algae disappeared and the microbial flora resembled that of activated sludge. Aerated lagoons are now usually designed as completely mixed non-return activated sludge units. Floating aerators are most commonly used to supply the necessary oxygen and mixing power.

Aerated lagoons achieve BOD removals of > 90% at comparatively long retention times (2-6 days); retention times < 2 days are not recommended as they are too short to permit the development of a healthy flocculent sludge (even so the activated sludge concentration is only 200-400 mg/l, in contrast to the 2 000-6 000 mg/l found in conventional and extended aeration activated sludge processes). They are often useful as pretreatment units before a series of ponds, particularly when used as a second stage of development to extend the pond capacity.

The construction of aerated lagoons is essentially the same as that for waste stabilization ponds. The major differences are: greater depths (usually 3-5 m), steeper embankment slopes (1 to 1.5-2) and frequently the provision of a complete butyl rubber or polythene lining to prevent scour by the turbulence induced by the aerators.

The effluent from an aerated lagoon secondary clarifier will not achieve the low ammonia standard stipulated by the MoE for effluent reuse, and also will not attain the WHO recommended microbiological guideline levels for unrestricted irrigation. However, aerated lagoons can be used as a pretreatment step before a series of ponds if the latter has been overloaded, or as a second stage of development to extend their capacity where further land area is not available.

The lagoon effluent is discharged to a series of waste stabilization maturation ponds to reduce its pathogenic content. The first pond acts as a settling basin and, to allow for the accumulation of sludge, it should have a retention time of 10 days and a depth of 1.5-2.0 m. The size and number of remaining ponds depends upon the degree of treatment required. Alternatively, the aerated lagoon effluent is discharged to a conventional secondary sedimentation tank. A drawback of this process is that the sludge is poorly mineralized and needs further treatment if problems of odour are to be avoided. It is normally pumped to an aerobic digester, which can be a small aerated lagoon, where it is aerated for 4-10 days. After this period of intense aerobic stabilization the sludge is sufficiently mineralized to be placed on drying beds without fear of odour release. However, such sludge treatment is expensive, and the consequences of the system breaking down are evident in a hot climate.

Maintenance and operation of the surface aerators can often be time consuming and costly; they also have considerable power requirements. A lagoon which does not have all of its aerators functioning is not much better a sewage treatment system than no treatment at all, since problems of poor quality effluent and odour nuisance will rapidly occur. This statement also holds true for the activated sludge and rotating biological contactor systems.

#### **D3.4.8 Waste Stabilization Ponds**

As the WHO report states, if effluent is to be reused in agriculture waste stabilization ponds are usually the wastewater treatment method of choice in warm climates, wherever land is available at reasonable cost. They are large shallow basins enclosed by earthen embankments in which raw sewage is treated by entirely natural processes involving both algae and bacteria. They should be arranged in a series of anaerobic, facultative and maturation ponds with an overall hydraulic retention time of 10-50 days, depending on the design temperature and the effluent quality required. Pond series can be readily designed to produce effluents that meet the WHO guidelines for both bacterial and helminthic quality; these effluents are also low in BOD and suspended solids. A number of ponds connected together in series will give better pathogen removal than a single pond with the same total retention time.

**Anaerobic Ponds** receive raw wastewater and are most advantageously used with strong wastes or those with a high suspended solids content. The organic loading is so high that the ponds are completely devoid of dissolved oxygen, and the suspended solids settle to the pond bottom where they undergo vigorous anaerobic digestion at temperatures  $> 15^{\circ}\text{C}$ . Such temperatures are usual for many parts of the year in many regions of Iran. Odour release (mainly hydrogen sulphide) is commonly thought of as a major disadvantage of anaerobic ponds. Yet if designed to receive a volumetric loading of less than 400 g BOD per  $\text{m}^3$  per day, odour nuisance does not occur with domestic wastewaters containing less than 500 mg sulphate per litre.

**Facultative Ponds** receive either raw wastewater (primary facultative ponds) or settled wastewater (secondary facultative ponds). They have a lower anaerobic zone and an upper aerobic zone where oxygen for bacterial metabolism is largely provided by the photosynthetic activity of microalgae which grow profusely to give the pond liquid a deep green colouration. Maturation ponds, which are



also photosynthetic, receive facultative pond effluent and are used principally to reduce the number of excreted pathogens and nutrients, although there is some additional removal of BOD. The size and number of the maturation ponds control the number of faecal coliforms in the final effluent of the pond series, and the design process specifically selects the optimum combination of maturation pond size and number required to achieve the desired final effluent quality.

The high degree of confidence with which pond series can be designed to produce effluents meeting the WHO guidelines is only one of the many advantages of pond systems. Others are:

- lower costs (for construction, operation and maintenance) than other treatment processes;
- no expenditure of energy, other than solar energy (ponds are therefore especially efficient in hot climates);
- high ability to absorb organic and hydraulic shock loads;
- extreme simplicity of operation and maintenance;
- ability to treat a wide variety of industrial and agricultural wastes.

The main disadvantage of pond systems is their relatively large land area requirements, and this may limit their use, especially in metropolitan areas. Furthermore, they do not achieve as much nitrification as do extended aeration systems, although ammonia removals of 80-90% are possible.

#### "Accel-o-Fac" and "Aero-Fac"

Recent developments from America which are attracting attention and are worthy of consideration for Iran have been developed by a US company concerned with upgrading the performance of lagoon systems.

Accel-o-Fac is a system of wind-powered mixer-aerators which are floating units incorporating low-energy back-up powered motors to boost the effects when wind speeds drop. These can be designed into Facultative Lagoon Systems to enhance the overall performance. Many examples exist in the US of these units improving the performance of existing lagoons.

Aero-Fac combines with the floating wind-powered units a low-pressure, diffused-air process designed as a "race-track" configuration. The units have claimed advantages of much lower maintenance than the higher powered surface and brush aerators used on conventional lagoon and oxidation pond systems.

Little experience exists outside the US, but the systems are worthy of serious consideration for Iran and a trial unit could be installed to demonstrate the effectiveness of the process.

### D3.4.9 Constructed Wetland Systems

#### The History

*Constructed Wetlands* is a generic term for a relatively new technology in sewage treatment which has been developing over the last two decades.

Original research conducted in Germany was by the scientist Dr Kathie Seidel. She demonstrated the ability of certain types of aquatic and marginal plant to host aerobic bacteria on the root and rhizome systems, and developed a number of systems for the treatment of sewage from small communities using vertical flow beds. She also demonstrated the ability of certain plants to remove pathogenic

bacteria through the mechanism of complex chemicals exuded through the root systems. Her work has formed the basis of extensive research and implementation over the last twenty years using a variety of physical configurations and plant species. Many researchers have used horizontal flow beds and some have combined both vertical and horizontal flow systems.

The results have varied widely - from almost complete failures to very economic and environmentally sound successes.

In principle the systems require the formation of beds ranging from 600 mm to a metre in depth with an impermeable lining. The lining can be an impermeable cohesive natural clay, a plastic or rubberoid membrane or concrete depending on local availability and cost. The bed is formed from a layer of media about 600 mm in depth. Trials have been conducted using various media types: cohesive soils as well as a range of granular media and gravels.

### Horizontal and Vertical Flow Systems

The flow configuration through the media can be either horizontal or vertical. In the latter it is necessary to have a layer of fine sand over the top of the media in order to distribute the flow. The systems have been used for complete treatment of sewage, for the secondary treatment of settled sewage and for tertiary treatment or polishing of effluents.

In general terms the trials with horizontal flow systems require a much larger surface area than with vertical flow systems. For purposes of secondary and tertiary treatment, horizontal flow systems require 3-8 m<sup>2</sup> per person; the area generally increasing with fineness of soil particles. There are many examples of horizontal flow, soil-based systems which suffer from clogging and oversurface flow. Such occurrences will decrease process performance, and provide potential breeding sites for mosquitoes.

Vertical flow systems, when compared to horizontal flow schemes, can increase the biological treatment performance, whilst decreasing the area requirements to 1-2 m<sup>2</sup> per person. The most effective performance with vertical flow beds occurs when beds in parallel are used in rotation allowing a period of a few days for the solids collected on the surface during operation to mineralize.

### Gravel Bed Hydroponics

Some of the most interesting research conducted in relation to the Iranian climate is the United Kingdom government-funded work of Portsmouth University of the UK and Suez Canal University at Ismailia, Egypt. This work has concentrated on long gravel horizontal flow beds which receive settled sewage. The technology has been termed *Gravel Bed Hydroponics* (GBH). Considerable success has been achieved and the research programme is extended to include the incorporation of vertical flow beds and to investigate the treatment of industrial wastewaters.

Whilst GBH systems can achieve effective removal of organic material and suspended solids, the reduction of ammoniacal nitrogen to very low levels may prove difficult to achieve. However, preliminary results suggest that a combination of vertical and horizontal flow beds in series may be able to produce an effluent which approaches this standard.

The work in Egypt has experimented with a wide range of indigenous plants and research is continuing into both the treatment efficacy and into the economics of cropping. It is generally

accepted that the common reed *phragmites* has a great potential for biological treatment related to its extensive root and rhizome system which transfers valuable amounts of oxygen to the root zone.

Other plants included in the programme include Napier grass (a local fodder crop), other fodder crops and cotton. Portsmouth Polytechnic has an ongoing programme and has appointed a specialist plant biologist to investigate the particular characteristics of the various species.

#### Environmental Enhancement

An interesting potential advantage of the technology is the ability to landscape the treatment into an attractive feature to enhance and "green" the environment. This has been achieved at some sites in the UK to the extent that the works have attracted considerable media attention. Some research has shown that combinations of GBH systems and waste stabilization pond series can improve the overall process performance and can increase the environmental interest of the project.

A demonstration project, partly funded by the EU is being commissioned in northern Greece for two neighbouring villages with a combined design population of 3 500.

### D3.5 Tertiary Treatment

Tertiary treatment processes were originally developed to improve the quality of secondary (activated sludge or biofilter) effluents, mainly to reduce further the BOD and concentrations of suspended solids or to remove nutrients, although some processes (for example disinfection) were developed to reduce the number of excreted pathogens. With the growing use of pond systems which feed in particular drip irrigation networks, the removal of algae has also become necessary.

Processes designed to improve physicochemical quality - such as rapid sand filtration, nitrification-denitrification, and carbon adsorption - have little or no effect on excreted bacterial removal, but some of them (for example filtration) may be effective in removing helminth ova. However, these processes are usually complicated and expensive technologies, and their use in many countries to produce suitable effluents for crop irrigation is unwarranted.

#### D3.5.1 Disinfection

The disinfection of sewage effluents is the subject of much debate in the technical press. It can be achieved by a number of means:

- peracetic acid
- bromine
- chlorination
- ultraviolet radiation
- ozonation
- pond systems
- plant exudates

Historically the disinfection of effluents has been achieved by the use of chlorination. Chlorination can be used to reduce the numbers of excreted bacteria in the effluent from a conventional treatment plant if the plant is operating well. A chlorine dose of 10-30 mg/l is usually required, with a contact time of 30-60 minutes. The dose required must be verified by laboratory tests, as it varies widely with the concentration of organic matter in the waste.

As has been stressed by recent researchers of the subject, however, chlorination of wastewater effluents is a vastly more complex and unpredictable operation than chlorination of water supplies. It is extremely difficult to maintain a high, uniform and predictable level of disinfecting efficiency without a high level of experienced operational control. Irregular or inadequate disinfection is of little use for health protection. In any case, chlorination will leave most helminth eggs totally unharmed, and is probably ineffective in removing protozoal cysts.

The environment produced by chlorination of treated effluent, rich in nutrients but low in microbial activity, is ideal for the growth of some excreted bacteria. Coliforms and other species have been observed to multiply after chlorination to thousands of times the number surviving the initial treatment. Effluent chlorination also contributes to the formation and environmental proliferation of chlorinated organic compounds that can be toxic to fish and other aquatic life. However, neither coliform regrowth nor chlorinated organic compounds have been reported as significant problems in agricultural use.

Chlorination is generally the cheapest of the chemical methods of disinfection. However, ozonation and ultraviolet radiation are popular alternatives to chlorination in Europe and North America. There is also a revival of interest in the concept of tertiary treatment using maturation polishing ponds where land area is available.

### **D3.5.2 Polishing Ponds**

Waste stabilization polishing ponds are a more appropriate tertiary treatment option for Iran. Polishing ponds may be used in their own right as part of a complete pond series or as a complementary stage to other secondary treatment processes. They are designed in the same way as conventional pond systems to give the desired degree of removal of excreted bacteria and helminths. They are particularly suitable in situations where little maintenance input is available since they are a reliable technology if competently designed and built.

Polishing ponds are the only system capable of consistently removing intestinal nematode eggs to levels deemed acceptable by the WHO for reuse in irrigation. The other disinfection processes have little or no reported ovicidal effects.

### **Constructed Wetlands**

The root exudates from some plants used in constructed wetland schemes may have bactericidal properties. Little reliable data exists from full scale operations but more may become available in the next few years as a result of on-going research projects. A demonstration constructed wetland plant in Iran would help to ascertain the ability of such systems to disinfect wastewaters.

### **D3.5.3 Filtration**

Conventional extended aeration followed by clarification can achieve a 20 mg/l BOD, 30 mg/l suspended solids (20/30) effluent quality. However, tertiary filtration would be required to achieve a higher 10/10 standard currently stipulated by some countries. A series of waste stabilization ponds, designed for the appropriate level of pathogen removal for restricted or unrestricted irrigation, might also need tertiary filtration to attain a 10/10 effluent.

The filtration of effluents from wastewater treatment processes is a relatively recent practice, but much literature has nevertheless been published on the subject. The complete filtration process essentially involves two processes: filtration and backwashing. Filtration is accomplished by passing the wastewater to be filtered through a filter bed composed of granular material with or without the addition of chemicals. Within the granular filter bed, the removal of suspended solids contained in the wastewater is accomplished by a complex process involving one or more removal mechanisms (including straining, interception, impaction, sedimentation and adsorption). The end of the filter run is reached when the suspended solids in the effluent start to increase beyond an acceptable level, or when a limiting head loss occurs across the filter bed.

Once either of these conditions is reached the filter must be backwashed to remove the material that has accumulated within the filter bed. This is usually done by reversing the flow through the filter. A sufficient flow of wash-water is applied until the granular filter media is fluidized. The material that has accumulated within the bed is then washed away. In most treatment plants, the wash-water containing the removed suspended solids is returned to either the primary sedimentation tank or the biological reactor.

Filters may be classified according to the direction of flow as downflow, upflow or biflow filters. The downflow filter is by far the most common type used. Effluent filter systems are also classified according to the number of filtering media used as single-medium, dual-medium and tri-medium (or multi-medium). A further classification is made according to stratification of the media. Granular media commonly used in filter beds include sand, anthracite, activated carbon, weighted spherical resin beads (charged and uncharged), garnet, and ilmenite. Because filter performance is related directly to the characteristics of the liquid to be filtered, pilot-plant studies are often carried out to determine the optimum combination of filter materials. Either the force of gravity or an applied pressure force can be used to overcome the frictional resistance to flow offered by the filter bed. Pressure filters are generally used at smaller treatment plants.

#### D3.5.4 Algal Removal

There are various chemical and physical processes, such as coagulation, flocculation, filtration and dissolved-air flotation for removing algae from water, but all these are relatively expensive and require a degree of operation and maintenance which may be unacceptable in Iran. For a small rural pond system it would be more appropriate to employ some form of biological process, which although utilising more land than the above processes, would not significantly increase the overall land areas required.

Biological algal removal processes include the following:

##### Grass Plots

Grass plots are simple to construct, require very little maintenance and can produce a high quality effluent. In this treatment system the effluent is allowed to flow across gently sloping plots of land. The algae become trapped in the grass where they decompose, releasing nutrients for uptake by the plants.

##### Rock Filters

These too are cheap to construct and operate and are also ideal for small communities. The effluent flows through a submerged porous rock bed where the algae settle out and decompose. An added

advantage of rock filters is that they provide some degree of nitrification. Summary results obtained by the US Environmental Protection Agency for the rock filter in California, Missouri are as follows:

	Influent	Effluent
BOD (mg/l)	21	12
SS (mg/l)	69	22
Dissolved oxygen (mg/l)	16	7.4

### Floating Macrophytes

Floating plants such as water hyacinth and water lettuce have been extensively used in hot climates, not only for algal removal, but as a treatment system in their own right. By shading out light from the water they cause algae to settle to the pond bottom where they decompose, releasing nutrients which are taken up by the roots of the floating plants. Some nitrification may also be promoted by microbial films growing on the roots of the plants. A plant suitable for use in temperate climates for small rural communities would be duckweed. This can survive freezing conditions and makes excellent poultry feed, being composed of 25% dry weight protein.

### Fish

Herbivorous fish (such as carp) have been successfully reared in sewage-fed ponds in Germany and Hungary with yields of over 1 000 kg/ha/year. Until health risks have been more fully assessed, the fish produced would probably only be useful for fishmeal.

### Micro-invertebrates

Potential exists for removing algae from ponds by promoting grazing by, for example, *Daphnia*. This has been successfully demonstrated in natural water-bodies such as the eutrophied Norfolk Broads in the UK and should also be feasible for WSP which often harbour large numbers of these animals.

## D3.6 Sludge Treatment

The sludge that results from wastewater treatment operations and processes is usually in the form of a liquid, or a semi-solid liquid, which typically contains from 0.25 to 12 percent solids, depending on the operations and processes used. Of the constituents removed by treatment (screenings, grit, scum and sludge), sludge is by far the largest in volume, and its processing and disposal is one of the most complex problems confronted in the field of wastewater treatment.

The problems of dealing with sludge are complex because:

- it is composed largely of the substances responsible for the offensive characteristics of untreated wastewater;
- the portion of sludge produced from biological treatment requiring disposal is composed of the organic matter contained in the wastewater but in another form, and it, too, may decompose and become offensive;
- only a small part of the sludge is solid matter.

On removal from the wastewater treatment stream, it is therefore important to reduce the water and the organic content of sludges. This can be achieved by a number of treatment processes, which are discussed below.

### D3.6.1 Anaerobic Digestion

Anaerobic digestion is one of the oldest processes used for the stabilization of wastewater sludges. It involves the decomposition of organic and inorganic matter in the absence of molecular oxygen. In the anaerobic digestion process the organic material in mixtures of primary settled and biological sludges under anaerobic conditions is biologically converted to methane and carbon dioxide. The process is carried out in an airtight reactor. Sludges are introduced continuously or intermittently and retained in the reactor for varying periods of time. The stabilized sludge, which is withdrawn continuously or intermittently from the process, is nonputrescible and its pathogen content is greatly reduced.

Two types of digesters are generally in use: standard-rate and high-rate. In the standard-rate digestion process the contents of the digester are usually unheated and are unmixed. Detention times for this process vary from 30 to 60 days. In a high-rate digestion process the contents of the digester are heated and completely mixed. The required detention time is 15 days or less. A combination of these two basic processes is known as the two-stage process.

#### Standard-Rate Digestion

Standard-rate (conventional) sludge digestion is usually carried out as a single stage process: digestion, sludge thickening and supernatant formation are carried out simultaneously. Untreated sludge is added to the zone where the sludge is actively digesting and the gas is being released. The sludge is sometimes heated by means of an external heat exchanger. As gas rises to the surface it lifts sludge particles and other materials, such as grease, oils and fats, thus forming a scum layer.

As a result of digestion the sludge becomes more mineralized (for example, the percentage of fixed solids increases), and it thickens under the affect of gravity. This leads to the formation of a supernatant layer above the digesting sludge. As a result of the stratification and the lack of intimate mixing not more than 50% of the volume of a standard-rate single-stage digester is used. Because of these limitations the standard-rate process is used for small installations.

#### High-Rate Digestion

The high-rate digestion process differs from the conventional single-stage process in that the solids loading rate is much greater. The sludge is intimately mixed by gas recirculation, pumping or draft-tube mixers (separation of scum and supernatant does not take place), and it is heated to achieve optimum digestion rates. With the exception of higher loading rates and improved mixing there are only a few differences between the primary digester in a conventional two-stage process and a high-rate digester. The mixing equipment should have greater capacity and should reach to the bottom of the tank, the gas piping will be somewhat larger, fewer multiple sludge drawoffs replace the supernatant drawoffs, and the tank should be deeper, if practicable, to aid the mixing process in the high-rate digester.

Sludge should be pumped to the digester continuously or by time clock. The incoming sludge displaces digested sludge either to a holding tank or to a second digester for supernatant separation and residual gas extraction. Because there is no supernatant separation in the high-rate digester and

the total solids are reduced by 45-50% and released as gas. the digested sludge is about half as concentrated as the untreated sludge feed.

### Two-Stage Digestion

In the two-stage digestion process the first tank is used for digestion. It is heated and equipped with mixing facilities consisting of one or more of the following:

- sludge recirculation pumps;
- gas recirculation using short mixing tubes, one or more deep-draft tubes or bottom-mounted diffusers;
- mechanical draft-tube mixers;
- turbine and propeller mixers.

The second tank is used for storage and concentration of digested sludge and for formation of a relatively clear supernatant. Frequently the tanks are made identical so that either one may be the primary tank. In other cases the second tank may be an open tank, an unheated tank or a sludge lagoon. Tanks may have fixed roofs or floating covers. Any or all of the floating roofs may be of the gas holder type. Alternatively, gas may be stored in a separate gas holder or compressed and stored under pressure. Tanks are usually circular and between 6 and 35 metres in diameter. They should have a water depth of not less than 7.5 m at the centre and may be as deep as 14 m or more. The bottom should slope to the sludge drawoff in the centre and have a minimum inclination of 1:4 (vertical:horizontal).

In large plants digester gases may be used as fuel for boiler and internal combustion engines which are, in turn, used for pumping wastewater, operating blowers and generating electricity.

Proper mixing is one of the most important considerations in achieving optimum process performance. Various systems for mixing the contents of the digester have been used. The most common ones involve the use of:

- single- or multiple-draft tubes through which the sludge is circulated by a turbine mixer located within the tube;
- gas recirculated through diffusers in the base of the digester or by means of drop pipes.

The heat requirements of digesters consist of the amount needed:

- to raise the incoming sludge to the digestion-tank temperature;
- to compensate for the heat lost through walls, floor and roof of the digester;
- to make up the losses that might occur in the piping between the source of heat and the tank.

The sludge in digestion tanks is normally heated by pumping the sludge and supernatant through external heat exchangers and back to the tank. Less energy will obviously be required to raise the sludge temperature into the optimum range for a digester located in a hot climate. Efficient anaerobic sludge digestion can proceed where the ambient temperature is in excess of 15°C, as is the case in many of the towns in Iran being evaluated for the majority of the year.



### D3.6.2 Aerobic Sludge Digestion

Aerobic digestion is an alternative process for stabilizing organic sludges produced from wastewater treatment operations. In Europe and North America aerobic digestion has been used primarily in small plants, particularly those using the extended aeration and contact stabilization variants of activated sludge.

Advantages claimed for aerobic digestion as compared to anaerobic digestion are:

- volatile-solids reduction is approximately equal to that obtained anaerobically;
- lower BOD concentrations in supernatant liquor;
- production of an odourless, humus-like, biologically stable end product that can be disposed of easily;
- production of a sludge with excellent dewatering characteristics;
- recovery of more of the basic fertilizer values in the sludge;
- fewer operational problems;
- lower capital costs.

The major disadvantage of the aerobic digestion process is the higher power cost associated with supplying the required oxygen. Furthermore, methane, the useful by-product of anaerobic digestion, is not recovered from aerobic digestion.

Two variations of the aerobic digestion process are currently in use:

- conventional aerobic digestion;
- pure-oxygen aerobic digestion.

Aerobic digestion accomplished with air is the most commonly used process. The maximum reduction of volatile solids attainable is 45-70%, depending on the temperature of digestion. The required time and degree of volatile solids removal also varies with the characteristics of the sludge. Typically, volatile solids reductions vary from about 35-45% in 10-12 days at temperatures equal to or above 20°C. The oxygen requirements that must be satisfied during aerobic digestion are those of the cell tissue and, with mixed sludges, the BOD in the primary sludge. On the basis of operating experience, it has been found that if the dissolved-oxygen concentration in the digester is maintained at 1-2 mg/l and the detention time is greater than 10 days, the sludge dewateres well.

To ensure proper operation the contents of the aerobic digester should be well mixed. In general mixing is achieved by the air that is supplied to meet the oxygen requirement, but on occasions additional mechanised mixing is needed.

Traditionally, aerobic digestion has been conducted in unheated tanks similar to those used in the activated sludge process. However, more use is anticipated for well-insulated or even partially heated tanks. Aerobic digesters should be equipped with decanting facilities so that they may also be used to thicken the digested solids before discharging them to subsequent thickening facilities or sludge-drying beds.

Pure-oxygen aerobic digestion is a modification of the aerobic digestion process in which pure oxygen is used in the place of air. It is particularly applicable in cold climates because of its relative insensitivity to ambient air temperatures. This technology can be used only at large installations

when the incremental cost of oxygen-generation equipment is offset by the savings obtained by reduced reactor volumes and lower energy requirements for dissolution equipment.

Thermophilic aerobic digestion represents a refinement of both the conventional-air and pure-oxygen aerobic digestion. Thermophilic digestion can be achieved by using the heat released during microbial oxidation of organic matter to heat the sludge without any external heat input. Both the thermophilic and the pure-oxygen aerobic digestion processes are emerging technologies in Europe and North America.

### D3.6.3 Sludge-Drying Beds

Sludge-drying beds are used to dewater digested sludge. Sludge is placed on the beds in a 200 - 300mm layer and allowed to dry. After drying the sludge is removed and either disposed of to landfill or to soil as a fertilizer/conditioner. The economical use of sludge-drying beds is generally limited to small and medium sized communities. For sewage treatment works serving populations of 20 000 and greater consideration should be given to alternative means of sludge dewatering.

The drying area is partitioned into individual beds approximately 6 m wide by 6 to 30 m long or of a convenient size so that one or two beds will be filled by a normal withdrawal of sludge from the digesters (or directly from an extended aeration reactor or an Imhoff tank). The interior partitions commonly consist of two or three creosoted planks, one on top of the other, to a height of 380-460 mm stretching between slots in precast concrete posts. The outer boundaries may be of similar construction or of earthen embankments for open beds, but foundation walls are required if the beds are to be covered.

Open beds are used where adequate area is available and where they are sufficiently isolated to avoid complaints caused by occasional odours. Covered beds with greenhouse-type enclosures are used where it is necessary to dewater sludge continuously throughout the year regardless of the weather. Covered beds are not necessary in Iran since the climate is generally very hot and dry, and rates of evaporation far exceed those for precipitation. Well-digested sludge discharged to drying beds should present no problems of malodour but, to avoid nuisance from poorly digested sludge, drying beds should be located at least 100 m from dwellings.

Sludge dewatered by drainage through the sludge mass and supporting sand and by evaporation from the exposed surface. In temperate climates, most of the water leaves the sludge by drainage. However, in a climate such as that encountered in Iran evaporation will play a major role in the rapid dewatering of the sludge. Drying beds are equipped with lateral drainage tiles (for example, vitrified clay pipe laid with open joints) spaced 2.5-6 m apart. The tiles should be adequately supported and covered with coarse gravel or crushed stone. The sand layer is usually 230-300 mm deep with an allowance for some loss during cleaning operations. Deep sand layers retard the cleaning process. Sand should have a uniformity coefficient of not over 4.0 and an effective size of (0.3-0.75 mm.

Piping to the sludge beds is usually of cast-iron. It should drain to the beds and be designed for a velocity of at least 0.75 m/s. Arrangements should be made to allow flushing of the lines should blockages occur. Distribution boxes are required to divert the sludge flow into the selected bed. Splash plates are placed in front of the sludge outlets to spread the sludge over the bed and to prevent erosion of the sand.

Sludge can be removed from the drying bed once it has dried sufficiently to be spadeable. Dried sludge has a coarse, cracked surface and is black or dark brown. The moisture content is typically

60% after 10-15 days in temperate climates, but more rapid and more complete dewatering can be expected in the arid Iran climate. Sludge removal is accomplished by manual shovelling into wheelbarrows or trucks or by a scraper or a front-end loader. Provisions should be made for driving a truck onto or along the bed to facilitate loading.

#### D3.6.4 Sludge Lagoons

Drying lagoons may be used as a substitute for drying beds for the dewatering of digested sludge. Lagoons are not suitable for dewatering untreated sludges since they can cause odour problems (as also can sludge-drying beds treating such sludges). However, they are appropriate for treating the highly-mineralized surplus sludge wasted from extended aeration units, for example. The performance of lagoons, like that of drying beds, is affected by climate: dry climates with high temperatures accelerate dewatering. Lagoons are most applicable in areas with high evaporation rates.

Sludge is discharged into the lagoon in a manner suitable to accomplish an even distribution of sludge. Sludge depths usually range from 0.75-1.25 m. Evaporation is the main mechanism for dewatering. Facilities for decanting the supernatant are usually provided; the liquor is recycled to the wastewater treatment facility. Sludge is removed mechanically, usually at a moisture content of about 70%. The cycle time in lagoons varies from several months to several years. Typically, sludge is pumped to the lagoon for 18 months and then the lagoon is rested for 6 months.

#### D3.6.5 Composting

Composting is a process in which organic material undergoes biological degradation to a stable end product. Sludge that has been properly composted is a sanitary, nuisance-free and humus-like material. Approximately 20-30% of the volatile solids are converted to carbon dioxide and water. In addition, because the sludge is normally processed in the thermophilic temperature range, the composted sludge is essentially pasteurized. Composted sludge may be used as a soil conditioner and fertilizer.

Composting consists of two basic steps:

- preparation of the wastes to be composted;
- decomposition of the prepared wastes.

The waste preparation step comprises receiving, sorting, separation, size reduction and addition of moisture and nutrients. Several techniques have been developed to accomplish the decomposition stage. In windrow composting the prepared wastes are placed in windrows in an open field. The windrows are turned once or twice a week for a composting period of about 5 weeks. The material is usually cured for an additional 2-4 weeks to ensure stabilization. As an alternative to windrow composting several mechanical systems have been developed, including the aerated pile process. By carefully controlling the process in a mechanical system it is possible to produce a humus within 5-7 days. Often the composted material is removed, screened and cured for an additional period of about 3-4 weeks. Once the compost has been cured it is ready for application to the receiving soil. An enclosed mechanical compost system is usually preferred to open composting in excessively humid or cold areas to allow better control of the composting conditions.

Sludge may be composted either separately, as discussed above, or in combination with woodchips, farm waste, palm trimmings or other solid wastes, termed co-composting. Co-composting of sludge

usually requires that the sludge be dewatered initially. In addition it must be blended with the bulking material. Conversely, co-composting of sludges and municipal solid wastes does not normally require initial sludge dewatering.

All composting processes need much operational attention if they are to perform satisfactorily. Although the operational requirements of mechanised composting systems are less, more maintenance has to be carried out on the mechanical plant.

#### D3.6.6 Sludge Reed Beds

Research has been carried out into the treatment of sludges on beds planted with *phragmites*. The root systems take up the water in the sludge as well as providing a drainage path for free water to escape more readily to underdrains. The operation is similar to a sludge drying bed except that the sludge can be applied intermittently to the bed without the need to remove the sludge cake. It has been reported that dewatering occurs rather more rapidly than with conventional sludge beds, evapotranspiration being partly responsible for this improvement. The reeds continue to grow through the sludge layer as it builds up and have the effect of producing a humus-like material which can be dug out after several years and used as a soil conditioner. Examples of sludge reed beds are found in Europe and North America.

#### D3.6.7 Wastewater Treatment Processes for Minimal Sludge Production

Much advantage is gained from employing those wastewater treatment processes that produce small volumes of well-mineralized sludge, since sludge treatment facilities are consequently considerably simpler and cheaper.

Extended aeration achieves a considerable degree of sludge oxidation in the reactor. The small quantities of sludge that are wasted from an EA plant are highly stabilized and readily dewatered on sludge-drying beds with no intermediate treatment, and no danger of odour release. This sludge treatment is, however, attained at a cost: the long retention times and associated high aeration costs are the reasons that such good sludge treatment is achieved in the aeration tank.

In contrast to the aerobic aeration that occurs in EA plants, the sludge that collects in the bottom of an Imhoff tank undergoes anaerobic digestion. If sufficient anaerobic digestion is achieved in the Imhoff tank, then the sludge wasted from the tank can also be applied directly to sludge-drying beds without further treatment.

Anaerobic waste stabilization ponds also provide a high degree of sludge treatment. In climates such as that in Iran, where mean ambient temperatures exceed 15°C, vigorous anaerobic digestion will take place in the sludge layer. As a result anaerobic ponds need only be desludged every 1-5 years, once half full of sludge. Two anaerobic ponds are normally provided in parallel at the head of a pond series, one receiving the wastewater and the other off-line awaiting desludging. When an anaerobic pond is first taken off-line, the supernatant can be syphoned off and the sludge left to undergo a period of *in situ* desiccation in what becomes, effectively, a sludge lagoon. Since the sludge has already undergone considerable digestion, there is no danger of odour release. Once spadable, the sludge can be manually or mechanically dug out of the pond and applied directly to soil as a fertilizer/conditioner, or disposed of to landfill, without further treatment. For waste stabilization pond series there are consequently no sludge treatment requirements or costs.

The use of anaerobic ponds, extended aeration systems and Imhoff tanks are recommended whenever appropriate for the treatment of wastewater, because they also provide varying degrees of sludge treatment. Anaerobic ponds could be beneficially used, for example, as the primary settlement stage prior to a constructed wetland system in lieu of sedimentation or Imhoff tanks.

## D4 EFFLUENT AND SLUDGE REUSE

### D4.1 Effluent Reuse

The arid parts of Iran have scarce water resources and the reuse of treated wastewater effluent in irrigation will be a significant component of any measures taken to redress the water balance deficit.

#### D4.1.1 Treated Effluent as a Resource

Wherever possible, treated wastewater effluent should be reused for the irrigation of agricultural and industrial crops. By reusing an effluent that is considered safe for either restricted or unrestricted irrigation, potable water can be released for drinking, cooking, washing and other domestic chores. Such reuse strategies are extremely important for arid countries faced with declining water resources.

Recent advances in epidemiology are suggesting that past standards for hygiene in wastes reuse are stricter than are necessary to avoid health risks. A realistic approach to the use of treated wastewater has been advocated by the World Health Organisation in their publication *Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture*.

Some pollutants, which, if discharged directly to the environment, could create serious pollution problems, serve as nutrients when present in irrigation water or in fish-ponds. The World Health Organisation reports that studies in many countries have shown that with proper management, crop yields may be increased by irrigating with wastewater effluents. For an irrigation rate of 20 000 m<sup>3</sup>/ha per year, which is commonly required in semi-arid areas, typical concentrations of 15 mg/l of total nitrogen and 3 mg/l of total phosphorus in treated sewage corresponds to annual nitrogen and phosphorus application rates of 300 and 60 kg/ha, respectively. Such nutrient inputs can reduce or eliminate completely the need for commercial fertilizers. In addition, the organic matter added through wastewater irrigation acts as a soil conditioner, increasing the capacity of the soil to store water.

#### Environmental Control

The discharge of untreated or partially treated wastewater into the environment can give rise to pollution problems in both surface and ground waters and on land. The planned use of treated wastewater in irrigation or aquaculture prevents such problems and minimises the resulting damage, thus partly offsetting the cost of the scheme. The World Health Organisation states that the use of wastewater for irrigation instead of groundwater in those areas where over-utilisation of the latter is causing problems, such as salt-water intrusion in coastal areas (as at Sur and Saham, for example), might result in further environmental benefits. As the WHO remarks in its Technical Report 778, wastewater reuse is often the preferred disposal method from the point of view of environmental protection.

One possible environmental problem which might result from the use of treated effluent in irrigation, and from applying sewage sludge to land, is groundwater contamination; nitrate accumulation in ground water is a serious problem in many countries. The risk of contaminating ground water through treated wastewater irrigation will depend on local conditions as well as on the rate of application. Where a deep homogeneous unsaturated zone overlies the saturated layer of the aquifer, most pollutants are removed in the unsaturated layer and there is very low risk of ground-water contamination. Only if there is a shallow or highly porous unsaturated zone above the aquifer, and especially if this zone is fissured, will a high risk of nitrate accumulation arise. On the other hand, crops will take up nitrogen from the irrigation wastewater and thereby reduce groundwater contamination.

Similarly, there also exists the potential for groundwater to be contaminated by the pathogenic microorganisms present in wastewater effluent and sludge when they are applied to land. Again, the risk of such contamination occurring is very much site-specific: those conditions which promote the leakage of nitrate to the groundwater will also present more opportunity for the migration of pathogens to aquifers.

### Chemical Pollutants

Municipal wastewater is likely to contain chemical pollutants wherever industrial discharges are allowed to enter the sewerage system. Of particular concern are those that are toxic to man, plants, and aquatic biota; heavy metals and non-degradable organics fall into this category. Boron, a constituent of synthetic detergents, is toxic to plants, especially citrus crops, and should be monitored when wastewater effluent is used for irrigation. Preventing chemical pollutants from entering sewers is the best way of dealing with the problem, but this is difficult to achieve where there are many small-scale industries, unless industrial zones are isolated and provided with their own wastewater treatment plants.

A possible long-term problem with wastewater irrigation is that toxic materials or salinity may build up in the soil. As the unsaturated zone removes chemical pollutants, particularly heavy metals, their concentration in the soil will increase with time and, after many years of irrigation, it is possible that levels will be reached at which crops will take up such pollutants at concentrations toxic to man. Soil salinisation is common in arid regions where irrigation water is saline, and irrigation with saline wastewater could have the same result in the long term. Provision of adequate drainage is imperative in any irrigation scheme as a means of minimising salinisation.

#### D4.1.2 Reuse in Aquaculture

Aquaculture means *water-farming* just as agriculture means *field-farming*, and it refers to the ancient practices of fish culture, notably of carp and tilapia, and the growing of certain aquatic crops, such as water spinach (*Ipomoea aquatica*), water chestnut (*Eleocharis dulcis* and *E. tuberosa*), water hyacinth (*Echhornia crassipes*), water caltrop (*Trapa* spp) and lotus (*Nelumbo nucifera*). The fertilization of aquatic ponds with human wastes has been practiced for thousands of years in Asia.

More recent aquacultural developments have been the culture and harvesting of microalgae in high-rate algal ponds, and the raising of valuable crustaceans such as shrimps and crayfish. Fish can be successfully raised in the maturation ponds of a series of waste stabilization ponds, and annual yields of up to 3 000 kilogrammes per hectare per year have been obtained. Care is needed to obtain aerobic conditions and to keep un-ionized ammonia levels low in order to avoid fish kills. The fish in

the last maturation pond in a WSP series can help to reduce the level of algae in the final effluent. Furthermore, the sale of harvested fish can be used to pay for improved operation and maintenance of municipal sewerage systems.

#### **D4.1.3 Recharge of Aquifers**

Subject to requirements of the IEPA regulations, effluent may be used to recharge aquifers.

#### **D4.1.4 Counteracting Saline Intrusion**

In coastal areas where groundwater supplies are being gradually depleted, saltwater intrusion into the aquifer is a commonplace occurrence and where this phenomenon has the potential to seriously deplete the potable groundwater available for extraction.

Treated effluent might be injected at the coast to maintain positive groundwater gradients and inhibit saline intrusion, but in situations of overdraft it would be drawn into nearby wells serving the coastal communities. It is therefore safer to inject inland, a considerable distance upstream of any habitation.

#### **D4.1.5 Recycling in Industry**

The largest of the industrial water demands is for process cooling water. Waters with a high mineral content and those that do not meet other reuse standards are recycled back into the industries which make them in many countries throughout the world. Public health dangers and aesthetic concerns are generally eliminated because of the use of closed-cycle processes.

#### **D4.1.6 Reuse in Forestry**

The use of wastewater in forestry can also bring considerable environmental benefits to the surroundings of towns and cities. In arid zones, tree belts help to stabilise the desert around conurbations and control dust storms, while at the same time improving the environment and providing a potentially valuable crop.

#### **D4.1.7 Reuse in Beautification Irrigation**

There are many examples of beautification schemes in towns and cities throughout the Persian Gulf region, a significant proportion of which utilise precious potable water supplies for the irrigation. Whilst this practice adds to the overall aesthetic appeal of the townscapes, it should only be encouraged where water supplies are plentiful. It is important to use treated effluent in beautification schemes in preference to potable water but it is also important to address the relative importance of beautification to other water demands in each of the towns.

#### **D4.2 Sludge Reuse**

Most wastewater treatment processes produce sludge as a by-product which is often disposed of by land application, burial, incineration or dumping at sea. Sludge from wastewater treatment is valuable both as a source of plant nutrients and as a soil conditioner, and can be used in agriculture or to fertilise aquaculture ponds.

Limits for the concentration of heavy metals in sludges destined for disposal are given in the Regulations for Wastewater Reuse and Discharge.

#### D4.2.1 Sludge Reuse in Agriculture and in Beautification

Reuse of wastewater sludge as a soil conditioner or fertilizer, to agricultural or other plants, is much practiced worldwide. Many wastewater treatment plants apply the desiccated sludge removed from drying beds to land set aside for beautification projects, to act as both a conditioner to the soil and a fertilizer for the plants. If care is taken to ensure that the pathogens in the sludge have been killed, or that the sludge applied to the soil does not come into direct contact with the crops, then sludge can also be beneficially applied to agricultural lands to improve the fertility of the soil and the yield of the crops.