

Organisation for Waste Recycling and Composting

OWRC

Tehran Solid Waste Management Project

Landfill Preparation Study

# Final Report



**October 2004**

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Waste  
Management  
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Landfill  
Preparation  
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# Final Report

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**BC<sup>®</sup> GOPA**  
Berlin WORLDWIDE CONSULTANTS  
in co-operation with **Gueno**  
CONSULTING ENGINEERS

## Executive Summary

### The Tehran Landfill Preparation Study

The objective of this study is to identify an optimised landfill design for the new landfill in Houshang through a consultative process between all stakeholders. Included in this design objective is the need to outline a simple and cost-efficient operations plan that would be sustainable both technically and economically to meet the resources and capacities of the Municipality of Tehran. Furthermore, optimized ways of waste transport from the Tehran transfer stations should be analyzed and compared. The study is divided into three parts.

Part 1 describes the background of waste management in Tehran and introduces alternative waste disposal and pre-treatment techniques.

Part 2 presents the landfill design including all related site preparation, operation and required equipment. All described investments and operations are financially quantified and described in detail in a complete set of technical drawings.

Part 3 is a comparative analysis of waste transport alternatives and outlines the steps necessary for the introduction of an optimized waste transportation system to the new landfill in Houshang.

### Solid Waste Management in Tehran

Currently the waste disposal takes place at the present landfill in Kahrizak, which will soon reach its maximum capacity. It is therefore envisaged by the Municipality of Tehran to close this site at the end of 2006. The transportation of the waste is carried out by waste collection vehicles operated by the different districts and then brought to 12 transfer stations which are operated by the Municipality of Tehran. About 210 large semi-trailers with an open top transport the waste to the Kahrizak landfill. Due to the age of the fleet, approximately fifty per cent of these semi-trailers are usually in maintenance. Apart from the landfill, there is the Tehran compost plant which works far below its optimum capacity.

### Estimation of Waste Volumes and Composition

The landfill design should at least provide sufficient capacity for the next 15 years. The study considers the entire area of the designated land and assumes a lifetime of up to 50 years for the disposal of waste. The study assumes for the next 15 years a total waste generation of 3.25 million Mg/a. The chosen design is flexible enough to adjust to faster or more slowly growing waste volumes.

### Overview of Landfill Systems

The World Bank classifies landfills, according to the engineering level, from open dumps to engineered and sanitary landfills and concludes with controlled containment release landfills as the most sophisticated way of land filling. German

and European classifications are backed up by the relevant standards, but apply higher minimum requirements in terms of environmental protection. Several and partly in Tehran recently tested land filling methods (e.g. semi-aerobic landfill reactor, full controlled anaerobic landfill reactor) could not pass the testing phase and are consequently not considered as suitable for a new landfill which has to accommodate up to 8000 Mg/d of waste. Consequently, and as a result of the environmental considerations, a conventional and in large operations tested landfill concept was chosen: the site will be fully engineered in terms of the bottom liner system, the leachate collection and the control of the waste disposal.

### **Overview of Waste Pre-Treatment**

On-site pre-treatment of waste can include mechanical separation, composting and rotting as well as compaction of waste. The most cost-efficient and best feasible method with unsorted waste is the mechanical-biological waste treatment, which is applied in several countries. For this method, the waste is shredded and stored on aerated rotting heaps where the organic material is degraded over a period of six to nine months. Provided a sufficient quality, the rotted material can be used as compost.

This system is currently operating in Kahrizak and is suitable for the high share of organics in the current waste and for the arid climate. It also requires no high financial investments. The system depends nevertheless on the current waste composition, with specific moisture content and sufficiently structured material which ensures the essential aeration.

The costs for the on-site treatment with this method will reach or even pass the break-even point provided there are significant amounts of compost to be sold. That, on the other hand, requires as input a good quality of lowly contaminated waste. The system depends furthermore on a specific waste composition, which in Tehran cannot be granted for the future. The study therefore recommends testing the introduction of a pre-treatment scheme after the first three years of successful operation of the new landfill and the implementation of the currently pending waste reduction strategy. Alternatives, closer to the source of waste generation, are recommended to be explored in the future.

### **General Data and Selection of the Site in Houshang**

Thirteen locations in a distance between 60 to 90 km were proposed. According to the selection criteria developed the site in Houshang was chosen as the most suitable. Key factors were the suitable terrain, the low local precipitation and the absence of settlements in the direct vicinity.

### **Geographical Description of the Houshang Landfill Site**

The land designated for the future landfill is about 50 km in the south of Tehran, spreading on both sides of the old road from Tehran to Qom, and encompasses 4,000 hectares. The area has a north-west to south-east declining slope of

approximately 2 per cent, and the major part of this area is of gentle inclination, only interrupted by some hilly areas raising about 30 to 40 m above the level of the plane.

There is no homogenous soil cover. The area is rather characterised by the sediments of low permeability, interrupted by deposits of gravel from active and former erosion channels.

The existence of deep groundwater could not be proven, but there are several indicators in the surroundings of the landfill that such deep ground water aquifer (>100 m) is not existing. There is temporary groundwater, which was also proven by various boreholes. The general groundwater flow direction is equivalent to the inclination of the site and surfaces partially in the south of the designated landfill area.

The soil provides, according to the geo-technical study, in large parts a suitable underground for the construction of a landfill, but the initial tests are not sufficient to provide sufficient certainty for the suitability to construct the landfill. Therefore further tests are recommended, such as plate bearing, grain- size distribution and chemical composition as well as permeability tests.

### **Basic Landfill Design**

The **entire site of 4,000 hectares** was evaluated in order to determine the most suitable locations for the placement of the landfill cells. The decision was based on the following criteria: inclination < 10 per cent, a minimum coherent area of 50 hectares and a groundwater table more than 2 m under surface. Consequently, three sections were identified as potentially suitable:

- Section 1: Disposal area, first stage of operation (370 ha)  
in the north of the road Tehran - Qom
- Section 2: Disposal area, second stage of operation (209 ha)  
in southern direction of Section 1
- Section 3: Disposal area, third stage of operation (227 ha)  
in eastern direction, approximately 1 km closer to Tehran.

The conditions are similar in all the sections. In each section a 15-year lifetime for waste-disposal activities should be possible, and the common utilization of the key infrastructure installation is envisaged. The traffic concept is shown in Drawing F1 and avoids risky turning and crossing of the highly frequented road Tehran – Qom.

For the **development of section one** the area was divided into four cells and various alternatives were elaborated in order to make maximum use of the area by minimizing the required ground-leveling works (see Annex 5). The section is clearly defined in the north-east by a high-voltage line, in the south-east by the road Tehran – Qom, and limited by hilly areas in the south and in the western parts.

The landfill bodies were directed from west to east to ensure the best utilization of the existing natural inclination. This includes the placement of the leachate collection pipes in an angle of 60 degrees. The maximum length of the cells is 500 m to ensure that the flushing of the drain pipes will still be possible. Four cells will encompass an area of 2.27 million square meters and provide a total volume of 50.4 million m<sup>3</sup>.

**The design of landfill cell one** will allow to accommodate the waste for the first 3 years of operation and has a total capacity of 13.1 million m<sup>3</sup>.

The traffic concept distinguishes three different types of roads (see Drawing F5); access roads as link between the main road Tehran – Qom and the section; internal transport roads for the transport of waste inside the section; internal maintenance road, for maintenance purposes only.

The surface water collection will provide sufficient capacity to collect the maximum amount of surface water for the further usage in the operation of the landfill (e.g. the flushing of pipes, greenery, clay compaction etc.) The complete system of surface water collection, discharge and installation to protect against storm water consists of the following elements (Drawing F 4, F 9): outer peripheral ditches, peripheral dam and ring road, inner peripheral ditches and the main drainage channel.

The entrance area (see Drawing F15) will accommodate all administrative and social buildings, including the workshop. The area will be embedded in a green belt. The entrance control is one central unit which will control all incoming and outgoing traffic. On the southern side of the access road the gas treatment facilities and the contingency area for further extension (e.g. sorting plants) are located. The leachate-treatment area with the treatment ponds and evaporation lagoons is separated from the entrance area and the main road with a three meters high dam.

The main principles of the layout of cell 1 result from the requirements on leachate and surface-runoff drainage and the possibilities for minimizing earth works.

Consequently, the site will be divided into sub-cells which all last for approximately one year. Those cells will be separated by temporary dams and build the basis for the successive preparation of the bottom liner and leachate collection system.

The base of the landfill has to be prepared before the bottom liner system can be installed. This includes clearing of the site, earth excavation and stockpiling, grading and compaction. Special attention has to be paid to areas with changing composition and the consequences for the bearing capacity. Especially the erosion channels on Houshang site have to be considered.

The site is placed in an area with high risks of earthquakes and the high moisture of the waste can cause a saturated landfill body. Therefore, the entire landfill will be surrounded by a bottom dam and several bordering dams at higher levels. For the same reason, the slope of the landfill is defined at 1:3, which also ensures a problem-free covering of the landfill and reduces the potential for erosion of the top



cover. Earthworks (cuts and fills) will be needed to prepare the base of the landfill and the top cover. Those cuts and fills will add to a total of 854,895 m<sup>3</sup> for cell one only and has already been optimized as much as possible.

### **Leachate Generation and Quality**

The generation of leachate and appropriate management is usually one of the major concerns when designing a landfill. In order to give a well established background to the proposed design, the quantities and qualities of the leachate were calculated based on international experience and locally available material. The daily leachate discharge is therefore 1200-1400 m<sup>3</sup> a day during the operation, and will drop to approximately 100 m<sup>3</sup> after the end of waste disposal and the re-cultivation.

The expected leachate quality can be characterized by a long and intensive acetic phase which is due to the rapid growth of height and the high ratio of organic material (ph ~6.0; BOD<sub>5</sub> ~ 40,000 mg/l; COD ~ 60,000 mg/l , NH<sub>4</sub> ~ 1,000 mg/l).

### **Bottom Liner System**

The bottom liner system is the essence for the containment system and the control of the leachate as it serves as the barrier which separates the internal polluted area from the surrounding environment. The decision on the bottom liner should be taken under consideration of the geotechnical stability, hydraulic conductivity, locally available know-how in operation and installation of the liner system, and of course the investment and operation costs. The different possible bottom liner options are as follows:

- Improved profiling of subsoil
- Adapted mineral liner
- Mineral liner system
- Geomembrane liner system
- Asphalt sealing
- Geo-Synthetic clay liner in combination with a silt layer.

The first two options were not considered as suitable, since neither the inhomogeneous physical nor the chemical composition of the material can provide the assurance of a consistent quality for the entire landfill. Even a very dense testing scheme could not exclude the possibility of potential leakages of contaminated leachate into the underground and unpredictable subsurface migration along the former and current erosion channels.

The geo-synthetic clay liner is frequently used as surface liner system, but there is only little experience in the utilization of the bottom liner system. Given the size of

the landfill, the higher cost in comparison to other well established methods, and finally the lacking long-term experience in large-scale operations make this option less favorable.

The three remaining options, namely the mineral liner system, the geomembrane liner system, and the asphalt sealing are considered as equally suitable from an environmental point of view.

The mineral liner system, consisting of several layers of 50 cm compacted and quality-assured off-site clay from the nearest identified clay pit would have, with USD 12, a similar price per square meter as the geomembrane. The material needs close supervision during the compaction and installation to avoid fast loss of moisture which will cause cracks in the liner structure. Therefore, this option can be seen as possible, but less favorable alternative.

The HDPE geomembrane is one of the most widely used bottom sealing material for landfills. The price ranges, depending on the thickness of the material (1.5 to 2.5 mm) from USD 12 to 14. The installation of the geomembrane needs technologically advanced skills. The risk of malfunctioning due to incorrect installation is very high and would undermine the usefulness completely. This option would therefore require extensive quality control measures. Consequently, the option of HDPE could be considered only under observance of international procurement procedures, international construction supervision and rigorous quality assurance procedures.

The technically best option is the asphalt liner system. This system provides the highest stability; the installation is technologically very simple and common in Iran. Hence no supervision and extensive quality control is needed. The cost is the major limiting factor, but it is believed that those could still be reduced during negotiations following a tender. Furthermore, all of the money would be spent in the country, and tax benefits may apply.

### **Landfill Shape and Surface Cover**

The landfill will have an average height of 30 m in order to maximize the volume, and will have a slope inclination of 1:3 to minimize erosion and to optimize the operation. The landfill body will be surrounded by berms to maintain the surface cover system, to drill the gas wells and to collect the surface runoff at the slopes (see Drawing F13, F8 and F12). The berms can also be used for waste transfer, but in this case need special pavement of gravel and split.

The surface cover will be made of a compensation/bearing layer with gas drainage function (30cm), a percolation layer for the storage of moisture (100 cm) and a top soil layer (50cm) of loamy-sandy material, which should be mixed with compost to provide the basis for the vegetation cover of stress-resistant species.



## Leachate Collection and Treatment

The landfill bottom requires a **leachate collection system** to collect leachate, to discharge it at defined points at the bottom of the dumping area and thus to avoid the accumulation of leachate at the bottom of the landfill. The detailed design defines the following design parameters for a drainage collection system. The drainage system proposed is shown in Drawing F 7 (ground plan of cell 1) and in Drawing F 9 (details of bottom liner system).

The **leachate treatment** is required to reduce its quantity and the significant odor. Since there will be no discharge of the leachate into the surface water or potential other usages, the reduction of contaminants plays a secondary role only. In principle, there are the following management and treatment possibilities: recirculation, evaporation, and physical, chemical or biological treatment.

The leachate from the landfill will be lead into an anaerobic storage/buffer lagoon of 10,000 m<sup>3</sup> volume and an assumed BOD<sub>5</sub> reduction of 50%. A partial anaerobic treatment of leachate is useful due to the very high concentrations of organics and the warm climate in summer. Anaerobic pre-treatment will reduce the number of aerators to be installed and energy consumption for aeration. A total anaerobic pre-treatment of leachate seems not to be possible because of the cold temperatures in winter.

According to the measurements of the stations Mehrabad and Qom temperatures below 10 °C are normal in December, January and February. Anaerobic lagoons will not work sufficiently below temperatures of 15 °C, and considering the high concentration of volatile fatty acids, the process of methane generation will stop in winter times. Therefore a combination of anaerobic and aerobic lagoons is assessed to be the best solution. The aerated lagoon will have a capacity of 10,000 m<sup>3</sup> and can reach an assumed BOD<sub>5</sub> reduction of 50%.

The evaporation lagoon is a flat pond without artificial aeration. The low surface/volume ratio guarantees a maximum of evaporation. The sealing of the evaporation ponds will be done using the natural soil in combination with a geomembrane. In peak times when the amount of leachate will reach the maximum capacity, a partial recirculation of the leachate will be considered. The leachate treatment system is shown in Drawing F18.

Other methods, such as re-pumping the leachate, need permanent installations, high maintenance and can cause operational difficulties. The creation of wetlands might become an interesting alternative but would require pre-treated leachate in order to provide a suitable habitat for plants. If successful, it would also provide an ideal habitat for migrating birds.

## Gas Collection and Treatment

The prognosis of the gas volumes can be calculated according to formulas developed in recent years and reflecting the practical experience in landfill gas

collection. In This case, after one year of disposal at the Houshang landfill, cell one will generate 9,825 m<sup>3</sup>/h gas. In principle, a passive gas collection system could be installed, but this could collect only up to 10% - a top cover sealing provided. Furthermore it requires strict monitoring to avoid potential risks.

In order to collect as much of the gas as possible and to ensure proper functioning of the degasification system, an active degasification system is designed, which can collect up to 50 percent of the produced landfill gas. Gas wells will be installed in the landfill body and will be complemented with gas suction lines and collection stations. The condensate will be separated and the gas will be lead to a booster station and flare. In this way, the methane emissions for section one will be reduced from 3,112 million m<sup>3</sup> to 1,244 million m<sup>3</sup>.

### **Landfill Operation**

Each landfill cell will surrounded by a bordering dam, when the height of the bottom dam is reached. The bordering dams have several distinct tasks in the concept of a sanitary landfill.

The bordering dams are constructed simultaneously with the growing of height of the landfill. Drawing F 9 shows the details of these bordering dams. The landfill development will be done in phases, consisting of the successive construction and filling of sub-cells, which last for one year on average.

The working area consists of the tipping edge, the compaction area and the access/maneuvering zone for the waste trucks. In order to permit smooth operation, a size of 6 hectares is suggested for the working area. Every day, the area is covered with a thin layer of soil, unless the waste composition does not require daily cover. The tipping and maneuvering zones will need pavements from building rubble in order to stabilize the underground.

The waste disposal will be done in horizontal layers, which are as thin as possible (20-50cm) in order to reach a maximum compaction rate. For the compaction, a total of six 36 ton compactors will be operating on the site, reaching six overpasses on each waste layer. For every week, a new waste disposal operation plan will be prepared.

The incoming waste must be controlled to ensure that only waste of permitted specifics will enter the landfill; detailed records on the delivery are to be kept registering weight, time, vehicle etc. For the operation of the landfill and the administration, on-site safety and operation of the mobile equipment approximately 160 workers will be required.

### **Entrance Area**

The entrance area will accommodate all administrative and social buildings, the weighbridge, parking and other required facilities such as workshop, laboratory and water and electrical installations. The area will be surrounded by a green belt.

## Monitoring

The monitoring of the landfill and the surrounding area will take place from the very beginning and will continue up to 30 years after the end of the operation. The following parameters should be monitored: meteorological data, leachate emissions, landfill gas emissions, groundwater and surface water, and data on the landfill body (waste types, height, volume, slope stability and top cover functioning).

## Volumes and Cost Estimates

The specifications for the required equipment and works are based on local and international experience and were compared to internationally accepted benchmarks. All volumes and numbers of staff are based on the design specifications and the operational requirements as described in the study.

The costs are divided into site facilities (USD 5 million), mobile equipment (USD 10.4 million), landfill sealing system (with the options: USD 40 million for HDPE and/or USD 62 million for asphalt), earthworks (USD 4.5 million), leachate drainage system (USD 15.5 million), treatment system (USD 6.1 million), gas management (USD 13.3 million), storm water drainage system (USD 1.6 million), surface sealing system (USD 1.6 million), monitoring (USD 65,000), and the green area (USD 1.4 million). The investment, including aftercare, contingencies, implementation design and supervision sums up to a total investment of USD 141 million (USD 117 million for the HDPE liner option respectively). In the first year, 15 % of the total investment sum will be required. The operation costs increase with the growth of the landfill from USD 2.3 million to USD 4.3 million.

The gate fee resulting from these investment and the operation costs is USD 5.72 per Mg (or alternatively, when using HDPE: USD 4.94 per Mg).

In case of a successful implementation of a waste reduction strategy, leading to 25 % reduction after the third year of operation, the gate fee will be slightly reduced to USD 5.69 per Mg and the lifespan of the landfill will increase from 15 to 19 years.

## Alternatives for Transfer Systems

All transfer stations in Tehran were analysed with regard to their potential for optimizing. Based on this analysis as well as on the waste qualities and quantities, different storage, loading, transportation and off-loading alternatives were developed.

## Comparative Analysis of Transportation Systems

Based on the analysis of the available technologies and the situation at the Tehran transfer stations the following options were identified: open semi-trailer, container with compaction on road, container with compaction on rail, open semi-trailer on rail.

The feasibility study concluded that the most cost-efficient option is the preload compaction into containers. The railway system cannot compete in this context

since there is no existing railway network in the city of Tehran and a separate rail-road transfer station would have to be built. This would then still require the transport to the transfer station by road and the rail transport to the landfill over a short distance of 30km.

The most preferred option is the closed container system attached to semi-trailers with push-out blade and preload compaction. This refers to the current system but the containers are fully closed and permit pre-compacting and pose no environmental impacts during the transportation. This system will permit to use the possible payload to almost 100 %.

Due to the greater distance from the transfer stations to the new landfill the compaction system is more effective in both terms of capital and operation costs. The lower numbers of vehicles for the compaction alternative results in less capital costs. This would also reduce the number of trips by 20%. The compaction will have another positive side effect: during the pressing of the waste, a significant amount of moisture will be pressed out.

As a general rule the following can be stated: The costs for preload compaction are estimated at 10 to 15 % of the total investment sum, while the resulting reduction in transportation equipment will be more than 20 to 40%.

The implementation of the new system should take place gradually and must be accompanied by an extensive recording and monitoring system and staff training in order to find the best solutions for the conditions in Tehran.

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# Part 1

Scope and

Alternative Disposal Techniques

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# 1. Tehran Landfill Preparation Study

## 1.1. Project Objectives

The objectives of this assignment are to identify a landfill design through a process of review, analysis and optimization. Included in the design objective is the need to outline a simple and cost-efficient operations plan that would be sustainable both technically and economically to meet the resources and capacities of the Municipality of Tehran. Furthermore, optimized ways of waste transfer from the Tehran transfer stations should be analysed and compared.

## 1.2. Scope of Work

### 1.2.1. Analysis of Alternative Disposal Techniques

The analysis should look at various landfill techniques and a limited number of low cost pre-treatment methods for mixed solid waste that would be implemented at the new landfill site near Houshang. The alternatives to be can combine together one or more of the technologies from the long list below. The following is a long list of generic alternatives that should be compared based on technical, environmental and economic data.

1. **Basic landfill options** (e.g. open dumping, semi-controlled, and full sanitary landfills) for mixed household wastes that include alternatives for groundwater protection (e.g. impermeable lining systems such as geomembranes, clay, composites, etc.) and their associated costs and risks.
2. **Technologies for more advanced landfill management** with more sophisticated leachate collection and treatment systems for treatment of household wastes such as leachate recirculation to create active bio-stabilization (note: a Canadian system is now under detailed assessment by OWRC).
3. Other **on-site landfill related (pre-) treatment** of mixed waste in order to reduce the amount of waste to landfill including: simple mechanical separation; hand-picking on belts; bio-compost German technology as recently pilot-tested at the Kahrizak landfill; Fukoka Japanese technology previously pilot-tested at the Kahrizak landfill. Anaerobic digestion, incineration, high-cost investment composting schemes and other high-cost investment technologies are excluded from this study component.

This task should result in a selection of a short list of practical disposal technologies.

### **1.2.2. Preliminary Landfill Design with Preliminary Cost Estimates**

The preliminary design step should result in the basic site layout and its main facilities, as well as a general breakdown in unit costs for the cost estimate. At the preliminary design stage a general operations plan should be prepared along with the estimated operations cost for the first 10-15 years of operations.

The preliminary design should focus on:

- (i) the preferred landfill layout and design;
- (ii) preferred approaches and techniques for leachate treatment; and
- (iii) preferred landfill gas management designs. In addition, the preliminary design should include a preliminary design for the disposal of hospital wastes to be located at the Kahrizak landfill.

The design work will start with a review of all the relevant data and preferred design options to confirm the initial recommendation of the preferred option. Upon confirmation of the preferred option and preliminary design, the preliminary design concept would be produced (e.g. most suitable disposal system, site services, logistics within the site, site layout, landfill operations techniques etc.). A preliminary cost estimate would also be produced.

The purpose for the preliminary design is to confirm the feasibility of the landfill site at Houshang and to have a design package that will have a level of detail that makes it appropriate to serve as technical annex to design-built-operate (DBO) tender documents.

### **1.2.3. Detailed Landfill Design with Detailed Cost Estimates**

The detailed design step should then be produced to provide detailed specifications and detailed design drawings suitable for bidding documents under using a classic civil works construction procurement approach. The detailed design drawings and specifications would be used as inputs towards the bidding documents for the first 3 years of the investment project.

Construction of basic infrastructure and facilities and sufficient cell capacity for approximately 2-3 years of capacity, including a reservation in the layout for the location of future recycling demonstration projects

#### **1.2.4. Transfer Transportation Analysis (Technical and Economic)**

Included in the scope of the investment project is the transport from the city transfer stations to the new landfill at the Houshang site. A feasibility analysis is needed to compare the alternatives for the future transfer transportation system, as well as to compare results to the existing situation. Currently, the Municipality has started to replace its 175 semi-trailers that are open topped and without compaction of wastes. The feasibility analysis should identify various technologies for loading solid wastes at transfer stations and appropriate designs for semi-trailers to match the techniques to create better efficiency. Similarly off-loading techniques at the landfill should be studied.

The study should look into truck loading options at the transfer stations, with and without compacting, best means and structure for transport and related reception and unloading facilities at the landfill site.

The alternative of rail transport is part of the study and requires comparative analysis with road transport including capital and operational costs for specialized rail transfer stations, specialized rail cars and possible new rail spur to the proposed landfill site.

#### **1.2.5. Liaison and Coordination with EA Study**

The Municipality of Tehran is preparing an Environmental Assessment (EA) for the proposed project supported by its own funding, and the EA work will be carried out in parallel with the Social Assessment and the Landfill Feasibility Study. The first objective of the EA is to assure acceptability of the Houshang site for the new proposed landfill, and the second objective is to recommend environmental protection measures and community participation plans. Close cooperation and liaison is required between these three parallel activities (particularly liaison between EA and Feasibility Study). An example of a task that requires close coordination is public participation and consultation with NGOs and affected stakeholders. For the EA, the public would be consulted very early in the process at the EA screening phase, and then later in commenting on the draft final EA. Such public participation is required to meet the World Bank environmental and social safeguard policies. As this would be the one of the first times that such public consultations would be incorporated into the EA procedures in Iran, this sub-component would serve as a model for preparing future EAs in Iran. The objective of this coordination activity is to assure that the draft and final results of the environmental and social assessments are incorporated into the above-described technical, financial and economic analysis. The Consultant will be responsible to attend on behalf of OWRC regular formal coordination meetings (every 4-6 weeks) to exchange

information and assure an integrated and consensus decision-making in developing the project concept and components. Informal communication is also encouraged between the preparation teams.

#### **1.2.6. Institutional Strengthening and Technology Transfer**

The study should prepare an overview of regulatory, operational, monitoring and enforcement requirements based on international experience that usually are carried out by the operator of a landfill site (either for private sector or public sector operations). Based on this review and the Consultant's experience, two formal workshops for training and technology should be carried out in Tehran for the counterpart staff at OWRC and other appropriate staff at the Municipality of Tehran and the Department of Environment. The technical proposal should describe the main topics that will be included in the two formal workshops.

Secondly, the Consultant should comment on the appropriate arrangements that should be made to build and operate the proposed landfill in Tehran, based on the capacity of technical skills of the private sector in both the consulting engineering and construction contracting sectors.

The Consultant should also design an outline for a recommended program of institutional strengthening and technology transfer that would be carried out in the future.

The recommended program should consist of formal workshops and presentations on:

- (i) various aspects of solid waste management;
- (ii) informal "on-the-job" training and transfer of skills;
- (iii) level of private sector participation to facilitate more private participation arrangements for landfills;
- (iv) strengthening construction contracting for landfills in Iran; and
- (v) an action plan to bring institutional arrangements and capabilities to an improved level

The recommended program of institutional strengthening should include an outline and scope of work for each topic, and a cost estimate over a 5 year duration that includes details (e.g. the number of formal and informal sessions and numbers of participants that would be included in the training program, main objectives, case studies etc).

## **2. Solid Waste Management in Tehran**

### **2.1. Country Background**

Iran is an important country in the Middle East region. With a population of 63 million, it is the most populous country in the region, and the 16<sup>th</sup> most populous in the world. With a GDP of USD 111 billion, Iran is the second largest economy in the region. It is also the second largest OPEC oil producer and has the world's second largest reserves of gas. Iran is progressively emerging from a long period of uncertainty and instability, marked of by the destructive war with Iraq, internal post-revolutionary strife, international isolation, and deep economic instability. As an ancient civilization, and an internationally important cultural pole, she exerts a great deal of influence not only in the region but also in the world. Iran's economic prosperity, social progress, and greater integration into the world economy will not only bring benefits for the Iranian population but will also have important spill-over effects for the region.

### **2.2. Sector Background on the SWM System for Tehran**

Currently, the Municipality of Tehran has a fully functional waste management system that handles all types of solid wastes (household, commercial, demolition, hospital, industrial, etc.) generated within the municipal boundaries. With a daytime population estimated at 10.5 million (2002), and a resident nighttime population estimated at 8.5 million (2002), approximately 2.5 million Mg/year of solid waste are generated. Several administrative units within the municipality, including the districts, the Motor Pool Department and OWRC, operate the overall municipal solid waste collection system. The Municipality of Tehran is in the process of transferring all of the coordination and management responsibilities for solid waste management to OWRC, who in the future will move to a new name - Tehran Solid Waste Management Organization (TSWMO). This institutional change follows closely the strategic actions in SWM that were recommended in a comprehensive study prepared by BC-Berlin (Final Report, April 1997), supported by a Japan PHRD Grant (1994-1997). The Municipality of Tehran supports all the basic costs for the overall SWM system from the general revenue base.

#### **2.2.1. Collection, Transfer and Disposal Services**

The administration of collection and services remains decentralized to the 21 municipal Districts that extensively contract private sector operators to provide services to households, retail stores and many commercial establishments. Collection contracts are usually divided by sub-districts and include both street



sweeping and general city cleaning tasks (primarily street sweeping services). There are approximately 90 collection service contracts covering the metropolitan region with each having an average value of USD 240,000 USD/year. The proportional service costs for each contract are approximately 25% for collection services and 75% for cleaning services. In addition, there is a large informal sector that is collecting and recycling all types of wastes in Tehran. The Motor Pool is owned by Tehran Municipality and has been partially corporatized, and thus acts as a private sector contractor by leasing trucks to other contractors, and also competing for SWM collection contracts. OWRC acts as a contractor for the Municipality of Tehran by fully operating the transfer transportation, the central Kahrizak landfill and the Kahrizak compost plant. However, most of the operational work is sub-contracted to the private sector.

There are now 12 transfer stations in operation in the Municipality of Tehran that are owned and operated by the Municipality and by the district administrations. Previously, OWRC operated the transfer stations for an interim period to facilitate the re-alignment of collection service areas that is now partially completed. Previous to that, the transfer stations were owned and operated by individual municipal districts. One main problem was the difficulty for a district to accept waste from other neighboring districts. During the interim period when OWRC operated the transfer stations it was easier to balance the capacities of each transfer station to newly defined geographic service areas, which are not as closely tied to the district administrative boundaries. However, this is an on-going process of redefining transfer station service areas, and is not yet fully finished. The transfer stations use a system of raised platforms or surface level platforms for arrival of collection vehicles which tip their loads into open topped transfer vehicles without compaction. The transfer stations are open air operations (i.e. not covered), and often there are odors due to lack of leachate or water treatment, which at time causes complaints as many of the transfer stations are located in residential areas. There are two basic designs for the transfer stations: (i) an above ground level raised platform design without any roof for 13 transfer stations, and (ii) a surface level design with transfer trailers placed in depressed (below ground level) receiving stations, also without any roof for 3 transfer stations.

The formally collected waste is transported by large 56.1 cbm transfer semi-trailers from a set of 16 transfer stations. There are approximately 210 semi-trailers owned by the Motor Pool Department, which the Municipality of Tehran has corporatized, and is now quickly moving to full privatization. Approximately 50% of the semi-trailers are usually in maintenance or repair status, and 50%

are in active service (note: for example in mid-2002, the status was 107 semi-trailers in active service, 30 undergoing repairs and 30-40 awaiting repairs). There are approximately 74 trucks or cabs (also called “horses”), of which 28 are owned by the Motor Pool Department and 46 are owned by private sector contractors. Each truck hauls 2-3 semi-trailer loads each night. The waste is transported in the semi-trailers over distances varying from 20 to 50 km to: (i) Kahrizak landfill (receiving 6600 Mg/day divided into three basic categories: 6100 Mg/day household and commercial wastes; 421 Mg/day industrial wastes; 60 Mg/day hospital wastes); and (ii) Kahrizak compost plant (currently operated at 300-400 Mg/day).

### **2.2.2. Other Special Waste Services**

In addition to the transfer operations carried out by OWRC, there are many private sector operators who collect waste directly from large facilities (e.g. central fruit and vegetable market etc.) for transport to transfer stations or directly to the Kahrizak landfill, where a gate fee per tonne is charged to private collection operators by OWRC. The Kahrizak landfill also receives many industrial wastes that are mixed with the incoming household waste or are transported separately and co-disposed with household wastes. Also many industries request in advance permission for waste disposal at the Kahrizak Landfill, and when the waste is considered extremely hazardous or toxic, the requests are usually refused. Infectious and special healthcare waste is also transported to the landfill and used to be buried until recently in separate cells. Through capacity problems these waste types are now co-disposed as well. Liquid wastes such as domestic sewage from disposal wells and septic tanks, and liquid hazardous wastes are currently not sent to the Kahrizak landfill. Approximately 11.5 million Mg of demolition waste are transported directly to a dedicated landfill called Abali, located 25-30 km from central Tehran. Hospital wastes are collected separately by a dedicated fleet of compactor trucks operated by the Motor Pool Department who transport the waste directly to a separate burial area at the Kahrizak landfill.

### **2.2.3. Kahrizak Landfill and Kahrizak Compost Plant**

The Kahrizak landfill has arrived at its full capacity. Currently, the incoming waste is tipped on top of previously created landfill compartments. In order to deal with the urgent capacity problem, the Municipality is in the process of acquiring 818 ha of land adjacent to the Kahrizak landfill to continue current operations. The site can be described as a “semi-controlled” landfill operation, and the costs of waste disposal are in the range of 2 USD per tonne (gate-fee). The leachate and gases generated at the facility are not well managed, and the

short and long-term environmental risks need to be evaluated so investments in appropriate mitigation actions can be carried out in the future.

A new large sanitary landfill site is essential to ensure a sustainable SWM system for Tehran. Several new landfill sites have been studied (approximately 13 candidate sites), and the most preferred site is located 50-80 km from the Tehran transfer stations in an arid area without residential or industrial development. This site is referred to as the Houshang and Aziz-Abad site.

The Kahrizak Compost Plant is a very large-scale operation receiving approximately 300-400 Mg/day of mixed municipal waste. Although the solid waste in Tehran is characterized by a very high organic content (approximately 70%), the compost plant produces only 15-20% of the input (equivalent to 45-80 Mg/day) of high quality “finished” compost. Much of the input (40-65%) is “rejected” during the sorting process and is disposed of at the Kahrizak landfill; and another large portion of the input mass (about 40%) is moisture that evaporates. Chemical testing of the finished products for contaminants (e.g. heavy metals) still has to be carried out, and the plant has very high operating costs (equivalent to 30USD per tonne for treatment of input waste, excluding depreciation costs). The Kahrizak Compost Plant is operated by OWRC. The expensive compost plant is still justified partly by its ability to reduce demand for precious landfill space at the existing Kahrizak site. Still, an alternative disposal technique with lower cost and environmentally safe is required to reduce reliance of the SWM system on the high-cost compost plant.

### **2.3. Institutional Development**

The Municipality of Tehran is in transition to form a clearer structure for the management of solid wastes. It is now consolidating and centralizing all of the solid waste operations, quality control and research and development functions within OWRC. In parallel, the Municipality is moving to full privatization of its Motor Pool Department, and the municipal districts are still fully responsible for collection and street sweeping services as well as franchises for recycling. The municipal districts also contract out to the private sector the operations for the transfer stations, although some transfer stations are self-operated by the districts. The formal arrangement between OWRC and the Municipality is as a contractor with a formal annual contract, and with monthly disbursements of payments. The actual scope of services is for management of transfer transport services, the landfill and the compost plant. OWRC in turn sub-contracts the private sector to deliver services for the transfer transport operations and the landfill operations. The property assets at the landfill and compost plant have been transferred to OWRC from the Municipality, but OWRC still has the legal status only of a municipal entity with a Board of

Directors. As of April 2002, it has not been formally privatized or corporatized. However, OWRC does receive other revenues, in addition to its contracting fees from the Municipality, from grants for its research and development activities and from selling recycled products from its demonstration plants. The cost-recovery structure at the Municipality for solid waste relies on an indirect means to generate revenues from the traditional general fiscal municipal base (e.g. from building permit fees). There are two major institutional barriers to improvements in the SWM sector for Tehran: (i) a clear delineation between the regulatory/standard-setting function and the operations/delivery functions; (ii) the identification of an improved cost recovery framework (including setting and adjusting tariffs, collection of revenues, distribution of revenues to operating entities).

## **2.4. Technical Studies**

### **2.4.1. Existing Technical Key Studies**

A Strategic SWM Master Plan was developed under a previous Japan PHRD Grant and extensive follow-up work has been carried out by OWRC during the past four to five years. The on-going work includes: (i) a detailed tariff study and proposal for a SWM tariff system; (ii) a new solid waste law that has passed the National Parliament providing the basis for regulatory controls on both municipal and industrial solid wastes; (iii) pilot testing of alternative municipal waste disposal options for leachate and landfill gas control; (iv) modified trenching technology and leachate generation testing at the existing landfill site; (v) a site location study for the proposed new landfill; (vi) an optimization study for transfer station location and design in the city; (vii) a detailed identification and characterization study of hazardous hospital wastes from all possible sources in Tehran with a pre-feasibility study of different hospital waste disposal options; and (viii) a desk and field study on industrial waste generation in Tehran and the surrounding region. These studies provide the basic input information to the sector policy and solid waste management strategy that is now being developed. A more detailed listing of existing studies and on-going studies for the landfill design is presented below.

**ABBASI GHARRE HASSANLOU, SIAVASH**

*Study of PET Situation in Tehran*  
O.W.R.C. (Organization of waste recycling and composting)  
Tehran

**O.W.R.C., 2000-2001**

*Optimization of the Current Tehran Solid Waste Transfer Stations and Locating New Transfer Stations*  
Tehran, 2000-2001 (1379 Persian Calendar)

**ALMIZAN INSTITUTE FOR SOCIAL RESEARCH AND PLANNING, 2004**

*Social Assessment of Tehran Solid Waste Recycling Project Preliminary Report*  
O.W.R.C. (Organization of waste recycling and composting)  
Tehran, June 2004

**O.W.R.C., SPRING 2003(VOLUME 1)**

*Tehran solid waste-Seasonal statistical report*  
Tehran, Spring 2003

**O.W.R.C., SUMMER 2003(VOLUME 2)**

*Tehran solid waste-Seasonal statistical report*  
Tehran, Summer 2003

**O.W.R.C. (AUTUMN 2003–VOLUME 3)**

*Tehran solid waste-Seasonal statistical report*  
Tehran, Autumn 2003

**ABDULI, M. A.**

*Hospital waste management in Tehran*  
Institute for Environmental Studies, University of Tehran

**O.W.R.C., 2001**

*Environmentally responsible approach to final waste disposal – the Fukuoka Method Report for Dubai International Award for Best Practices to Improve the Living Environment (DIABP),*  
Dubai Municipality - Ref. 21728. 2001.  
Tehran, July 2001

**AMIR KABIR UNIVERSITY - FACULTY OF CIVIL ENGINEERING AND ENVIRONMENTAL SCIENCES- GEOTECHNICAL LABORATORY, 2004**

*Geotechnical Report for New Landfill site for Tehran, Draft Report*  
O.W.R.C. (Organization of waste recycling and composting)  
Tehran, March 2004

**TEHRAN UNIVERSITY, DEPARTMENT OF ENVIRONMENTAL ENGINEERING, 2004**

*Environmental Assessment for New Landfill Site for Tehran City*  
First Draft Report  
O.W.R.C. (Organization of waste recycling and composting)  
Tehran, June 2004

**AMIR KABIR UNIVERSITY - FACULTY OF CIVIL ENGINEERING AND ENVIRONMENTAL SCIENCES- GEOTECHNICAL LABORATORY, 2004**

*Geotechnical Report for New Landfill site for Tehran*  
Final Report  
O.W.R.C. (Organization of waste recycling and composting)  
Tehran, June 2004

**TEHRAN ZIST CONSULTANT, 2001**

*Kahrizak Leachate Treatment System*  
Tehran Zist Consultant and Company – O.W.R.C.  
Tehran, Dec 2001

**JAPAN BANK FOR INTERNATIONAL COOPERATION, 2003**

*Feasibility Study Report on the Construction of Industrial and Medical Waste Treatment Project in Municipality of Tehran*  
Japan Bank for International Cooperation  
Assigned Party: Tsukishima Kikai Co., LTD.  
Tehran, March 2003

**ZISTAVARAN CONSULTING ENGINEERS**

*Study of the quality and quantity of Tehran hospital wastes,* Zistavarar Consulting Engineers-O.W.R.C

#### 2.4.2. Planned Related Studies

The Municipality, under the supervision of OWRC, is carrying out several other related studies. These are:

- Environmental Assessment (EA) Study
- Social Assessment Study

- Preparation of Sector Strategy based on 3Rs (reduction, reuse, recycling) and Recycling Pilot Projects
- Sustainable Financial Framework Analysis

The Environmental Assessment Study (EA) on the new waste disposal landfill site will be carried out in parallel to the Landfill Preparation Study. The other related studies will also be executed more or less simultaneously.

## **2.5. Tehran SWM Programme Description**

The scope of the project involves an integrated approach for solid waste management in the Greater Tehran area. The total costs for the project are estimated at USD 100 – 150 million (USD 70-105 million IBRD Loan and USD 30-45 million Government contribution). A summary of the initially identified project components is as follows:

### **2.5.1. Institutional Strengthening Including Pilot Recycling Projects**

The institutional arrangements for solid waste management in the Municipality of Tehran will be reinforced to encourage the ongoing transition towards the reduction-reuse-recycling (3Rs) strategy and greater private sector participation in delivery of SWM services. The institutional strengthening will focus on:

- Integrated waste management, with priority on a 3Rs Strategy
- Sustainable financing for solid waste
- Pilot projects for testing strategic objectives
- Participatory mechanisms to support strategic objectives
- Training in environmental monitoring and enforcement
- Long-term action planning (2010-2015)

### **2.5.2. New Solid Waste Landfill**

An investment planning for a new landfill is required immediately. The new sanitary landfill will be constructed to meet modern controlled landfill environmental protection objectives for general municipal solid wastes. Additional separate landfill cells for hospital wastes are also required at this time. A preferred site has been located approximately 60 km from central Tehran (near Houshang) on vacant land with few or no residents in the immediate vicinity. The hospital waste cells may be constructed at the Kahrizak site, at land adjacent to the Kahrizak site.



### 3. Estimation of Waste Volumes and Composition

#### 3.1. Baseline Data

The landfill design should at least provide sufficient capacity for the next 15 years. Therefore, basic assumptions on the waste volumes within the coming years must be calculated. Those volumes can be concluded from the four decisive factors:

- population development
- gross domestic product
- pre-treatment measures
- historical waste volumes

Due to the absence of reliable data a scenario approach has been chosen, and the landfill will have to accommodate all potential waste volumes according to the maximum scenario.

##### 3.1.1. Population

According to different sources, the population numbers for 2002 are shown in the graph below. Research suggests an annual increase in the population figures in the range from 1.88 to 1.59 % (OHADI, 2000). The data from the State Management and Planning Organisation are the most recently released numbers and will therefore be used.

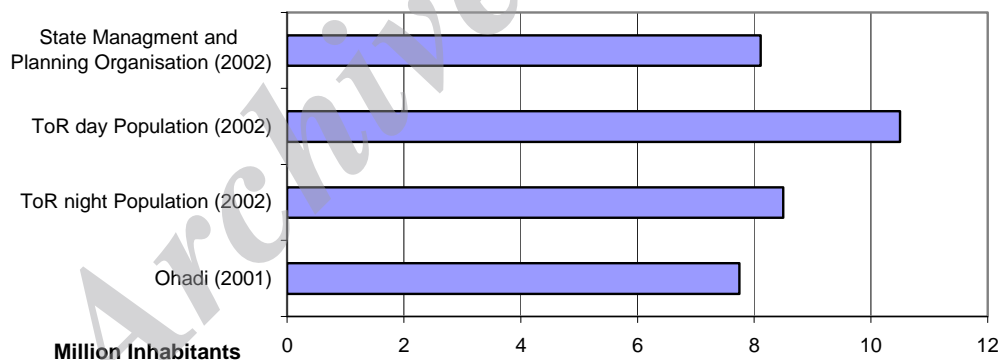


Figure 1-3.1: Population Figures for Tehran from Different Sources

##### 3.1.2. Gross Domestic Product

The influence of the GDP as an indicator of economic wealth on the waste production and the composition of waste are generally recognized. However, in the oil sector and other economies in Iran, the national revenue depends on the oil production as well as the oil prices. Changes in the oil markets do in turn not

have a direct influence on the waste generation in the households. (app.10% of GDP is oil-related GDP (World Bank 2003)).

According to the Head of the State Management and Planning Organization (SMPO) the province of Tehran reserves more than 25 % of Iran's GDP, with a 50% higher GDP per capita. The GDP per capita for Iran in 2002 stands at USD 1,324, and consequently the GDP per capita should be at around USD 1,986 for Tehran.

The Economist Intelligence Unit predicts a growth in real GDP between 2.0 % and 4.2 % for the coming years.

### 3.1.3. Pre-Treatment

As described in part 3, it is estimated that up to 30 % of the total waste volume can be pre-treated either on site or at the transfer stations.

### 3.1.4. Historical Waste Generation

The historical waste volumes per year give an inconsistent picture, since there is a reduction of waste from 1996 to 2000 which cannot be explained by experience. It can somehow be related to the drop in the Gross National Product of 50 % from 1993 to 1994 and a slow recovery afterwards. On the other hand, a simple technical defect can have caused this irregularity, which could also not be explained by the OWRC.

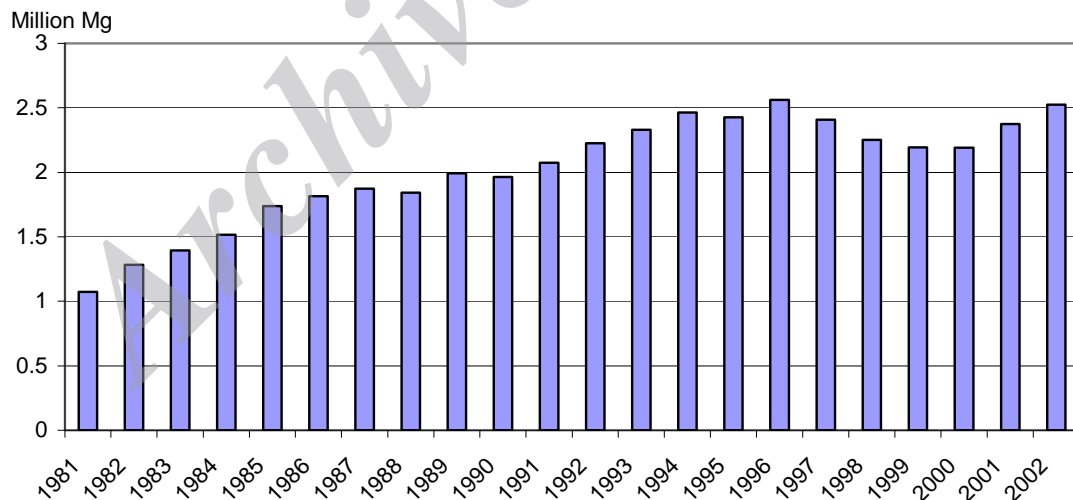


Figure 1-3.2: Waste Volumes in Tehran 1981-2002 in Mg per year (OWRC, 2004)

### 3.2. Prognosis of Waste Volumes

The prognosis of the waste generation for the next 15 years is based on estimated baseline figures and, as described above, depends on very variable factors. Hence, a prognosis cannot be made with exact certainty. Consequently, in order to plan enough capacity at the landfill for the next 15 years, a scenario approach has been chosen. In this case, average numbers will be used as future baseline figures, while the landfill should provide sufficient capacity for the maximum waste volumes predicted.

The scenario is based on the historical waste volumes, and is calculated with the numbers on the development of the population and the GDP (weighted at 50 %) as described in the chapters below.

Scenario	Waste		GDP		Population		Pre-Treatment
	Mg/year	kg/d/capita	USD/capita	Increase%/year	Inhabitants in millions	Increase %/year	
year							% of total
2002	2.50	0.845	1,986		8,11		
max 2019	3,87	1.061	3,996	4.2	11,13	1.88	10
mid 2019	3,25	1.024	3,388	3.1	10,84	1.73	20
min 2019	2,62	0.969	2,780	2.0	10,60	1.59	30

Table 1-3.1: Population Development and the GDP (Weighted at 50 %)

World Bank estimates suggest an average waste generation of 0.5 to 0.9 kg per day and capita for countries with an GDP per capita ranging from USD 360 to USD 3,500 (RUSHBOOK, 1999). All the above-mentioned figures are in line with those globally applicable data.

### 3.3. Prognosis of Waste Composition

The waste sorting analysis done by OWRC in years 2000 and 2003 is used as basis for the following table. These figures have been recorded during summer months over 22 districts of the city and are distinguished in three fractions. The secondary resource material comprise plastic, paper/carton, glass and metal. All other components are summarised under inert material fraction.

The waste composition was estimated from empirically established figures. A large increase of the secondary resource material is strongly dependent on the socio-economic development and is mainly caused by a large increase of the package wastes amount.

The reduction of inert material share is expected due to increased recycling activity and also specific selection and treatment of hazardous and industry waste fractions.

The still high share of organic fraction is a result of regional traditional eating custom and the distinctive social classifications with a high percentage of people with low income. The derivation of the data basis (population, waste volume increase etc.) and the GDP for 2019 is described in the previous chapter.

Base	Year	GDP (USD/capita)	Organic Material	Secondary Resource Material	Inert Material
OWRC	2000	1.986 (2002)	69.25 %	20.68 %	10.07 %
OWRC/	2003	1.986 (2002)	68.80 %	21.69 %	9.51 %
BC/Gueno	2019	3.388	approx. 60 %	approx. 35 %	approx. 5 %

Table 1-3.2: Waste Composition Prognosis

(Source: Waste physical analyses for area of Tehran 2000 and 2003 (average))

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## 4. Overview of Landfill Systems

### 4.1. Solid Waste Landfills in Middle-Income Countries

Landfills are advantageous as the sole waste disposal method because the technology is rather simple in comparison to other methods. Furthermore, the associated short-term considerations and the relatively low operational and investment costs are another important factor.

The current state-of-the-art technology permits the operation of landfills in a manner that largely avoids nuisances to adjoining residents, odours, fires or explosions and prevents environmental damage from the leachate.

The open dump approach is the primitive stage of landfill development and remains the predominant waste disposal option in most of the developing countries. As a default strategy for municipal solid waste management, open dumps provide indiscriminate disposal of waste and limited measures to control operations, including those related to the environmental effects of landfills.

An operated or semi-controlled dump is often the first stage in a country's effort to upgrade landfills. Operated dumps still practice unmanaged contaminant release and do not take environmental cautionary measures such as leachate and landfill gas management into account. This is especially relevant where leachate is produced and is unconstrained by permeable underlying rock or fissured geology.

As cities grow and produce more waste and their solid waste collection systems become more efficient, the environmental impact of open dumps becomes increasingly intolerable. The first step and challenge in upgrading open dumps to engineered and sanitary landfills involves reducing nuisances such as odours, vermin and birds.

Leachate will continue to be generated even after a landfill is closed, and landfill gas can have significant risks and environmental impacts even if the gas is spreaded within the boundaries of the site. Landfill gas contains approximately 50% methane, which, when released into the atmosphere, can contribute 2 - 4 % of the total global release of greenhouse gases. Simple and often inexpensive measures, including flaring or gas recovery for energy purposes, may be a possible source of income and significantly reduce the environmental effects of methane gas.

### 4.2. World Bank Landfill Classification

A number of general characteristics according to region, nation, site etc. distinguish a sanitary landfill from an open dump. An *operated dump* may

inspect and record incoming waste and include limited compaction by bulldozer and compactor. *Engineered landfills* embody further attempts to minimise environmental impacts. *Sanitary landfills* incorporate a full set of measures to control gas and collect and treat leachate, apply a daily soil cover on waste, and implement plans for closure and aftercare long after waste has ceased to the site (see Table below).

	Engineering Measures	Leachate Management	Landfill Gas Management	Operation Measures
<b>Semi-Controlled Dumps</b>	None	Unrestricted contaminant release	None	Few, Some Placement of Waste-still scavenging
<b>Controlled Dump</b>	None	Unrestricted contaminant release	None	Registration and Placement/Compaction of Waste
<b>Engineered Landfill</b>	Infrastructure and liner in place	Containment and some level of leachate treatment	Passive ventilation or flaring	Registration and Placement/Compaction of Waste; uses daily soil cover
<b>Sanitary Landfill</b>	Proper silting, infrastructure; liner and leachate treatment in place.	Containment and leachate treatment (often biological and physico-chemical treatment)	Flaring	Registration and Placement/Compaction of Waste; uses daily soil cover. Measures for final top cover
<b>Sanitary Landfill with top seal</b>	Proper silting, infrastructure; liner and leachate treatment in place. Liner as top seal	Entombment	Flaring	Registration and Placement/Compaction of Waste; uses daily soil cover
<b>Controlled Contaminant Release Landfill</b>	Proper silting, infrastructure, with low-permeability liner in place. Potentially low-permeability final top cover	Controlled release of leachate into the, environment, based on assessment and proper silting	Flaring or passive ventilation through top cover	Registration and Placement/Compaction of Waste; uses daily soil cover. Measures for final top cover

**Table 1-4.1: Landfill Classifications (Source: Observations of Solid Waste Landfills in Developing Countries, World Bank)**

There are some styles of landfill management that are particular to each country, for example bio-remediation in Brazil is used to describe a sanitary landfill design aimed at remediation of existing open dumps.

Three different strategies can be identified with respect to leachate management.

Entombment or the *dry tomb* approach aims to prevent water from coming into contact with waste. While this approach minimises the volume of leachate produced, it slows the bio-degradation of the waste so that the potential hazard of the waste is not reduced after time. The entrance of water into waste at any time in the future will cause the encapsulation to fail and, consequently, generate significant pollution of water resources. This strategy approach is not a viable long-term leachate management or landfill option.

The containment strategy protects the environment by containing leachate and treating it before discharge. This strategy is based on the eternal system philosophy, which acknowledges that the production of leachate may continue

for 30-50 years after closure. Problems such as inadequate maintenance and power cuts may cause the approach to fail eventually. Unless coordinated with other options, the containment strategy is an unsustainable alternative. Even high-income countries that had initially implemented the containment strategy are now changing their approach.

The controlled contaminant release approach allows leachate to enter the environment in such a way that it is not expected to have a serious impact. This technique takes into account proper siting, environmental considerations, and careful monitoring, but it could be problematic in wet climate zones where leachate containment release goes from controlled to unrestricted. This may result in pollution of ground and surface waters.

Controlled contaminant release is seen as the most economically realistic and environmentally sustainable approach for low- and middle-income countries, especially in arid areas.

#### **4.3. Overview of Standards of Landfills in the European Union**

Directives and guidelines existing in the European Union can only be transferred to other countries with adaptation to the climatic, geological, technical and financial conditions in the respective region. The existing guidelines might be helpful to set standards of landfills under different conditions.

The European Union has passed a Directive on the Landfill of Waste, which will come into force in every member state of the European Union. According to this Directive three categories of landfills are distinguished:

**Category 1:** Landfill for inert waste (such as soil and debris)

**Category 2:** Landfill for non-hazardous waste (such as municipal waste)

**Category 3:** Landfill for hazardous waste

This principle of definition of different landfill categories is used by many states.

The following wastes are not to be accepted in any kind of landfill:

- liquid waste
- wastes which, under the conditions of the landfill, are explosive, oxidising or highly flammable
- hospital or other clinical wastes which are infectious

The Directive defines general standards for landfill operations (permit system, management, monitoring) and specific technical standards for each landfill category.



#### 4.4. Disposal Techniques According to German Classification

Since the mentioned World Bank classification falls short of providing standards and is often used inconsistently in various publications, we refer to three standard options commonly used for classifying landfills in Germany.

In order to back up the list of alternatives by a system of applicable norms, the German classification system serves as basis for those options. The following chapters give a short summary of the main characteristics of those alternatives. An elaborated version was submitted with the first progress report.

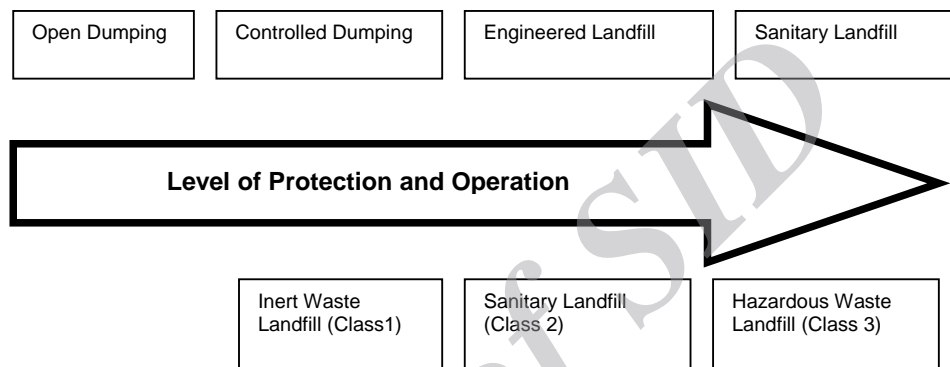


Fig. 1-4.1: Disposal Techniques

##### 4.4.1. Inert Waste Landfill (Class 1)

These are designated areas and rather simply engineered facilities for the disposal of mineral matter or materials that are inert in their character or of homogenous composition and pose no potential danger for the environment. These are usually excavated sites or abandoned quarries or open pit mines which meet the basic geo-hydrological requirements and make those sites often an inexpensive alternative to more sophisticated landfills. Inert waste landfills were common practice in many European countries for the disposal of waste from smaller settlements. However, with the application of higher environmental standards, the uncertainty about the potential risks of many dispersed and small sites was not tolerated anymore. Those sites are currently used for the disposal of building and demolition wastes for which the possibility of leachate production can be excluded. Neither the general composition of the waste of the city of Tehran nor the quantity make this model a suitable alternative.

##### 4.4.2. Sanitary Landfill (Class 2)

The development of sanitary landfills, as recognised in high-income countries, involves the continuing refinement and increasing complexity in engineering design and construction techniques. This can also involve a radical change in

the operational practices at the site in cases the sanitary landfill is being operated according to a bioreactor or a semi-aerobic concept. Sanitary landfills typically have many additional features to found of inert waste landfills, such as:

- Pre-planned installation of landfill gas control and utilisations systems
- Extensive environmental monitoring and environmental protection obligations
- An organised and well-qualified work force
- Detailed record keeping
- Where required, on-site leachate treatment as an additional feature to the leachate collection system
- Closed circuit monitoring
- Use of wide range of specialised mechanical equipment
- Complex, multi-layered lining system to isolate waste from the surrounding geology.

It is recognised that the development and operation of a sanitary landfill in this ultimate stage requires considerable capital investment and high operational costs: Many municipalities and regions will not be able to achieve and sustain this stage of landfill development in the foreseeable future.

Those landfills have been evolved in industrialised countries with a gradual upgrade of waste depositing techniques. many measurements were results of incremental improvements and testing of new methods at those sites. Another important aspect was the growing concerns of the citizens about landfills in their neighborhood. This resulted in the installation of sanitary landfills in competition with the construction of incineration plants, both of which require considerable capital investment and high operational costs. In Germany, the cost per ton of waste at sanitary landfills is estimated at Euro 30. For the site in Tehran, this would result in additional daily costs of a maximum of Euro 210.000.

However, the natural situation, social aspects, the remote location, lacking technical experience and high investment and operational costs do not justify a full cost model. Therefore, a low-cost option of a sanitary landfill, not exactly fulfilling all European standards, could be the most suitable solution for Tehran.

#### **4.4.3. Hazardous Waste Landfill/Deposit Site (Class 3)**

A hazardous waste landfill is a specially engineered and protected site for the safe deposition of hazardous and potentially hazardous materials, which cannot be deposited or treated elsewhere without lose of its potential risk to the environment.

Hazardous waste landfills are characterised by the dangerousness of the deposited materials. They are selected and designed to minimise the risk of hazardous substances polluting the environment. They can be set up as temporary storage places or permanent deposits. The costs for the operation and construction of those sites are generally very high. Since each site needs concrete specifications according to the particular kind of hazardous material which will be disposed, the costs can vary significantly.

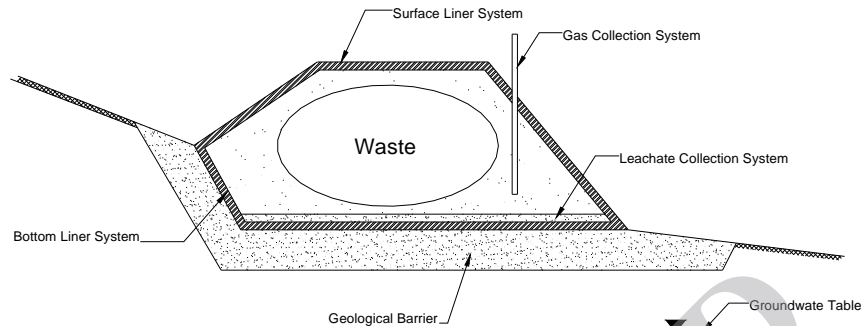
This option was included in order to provide the environmental assessment with the technical specifications for a highest possible protection scheme model. Due to the classification of the landfill incoming waste as household waste, this option will not be included in the further discussions.

#### **4.5. Multi-Protection Concept**

The multi-protection concept was developed in the 1970s and 1980s in industrialised countries based on experiences with sanitary landfills and the need for more environmental sound technologies. This concept illustrates the main principles of modern landfill technology and management. The following elements are considered to perform the role of protection against pollution of the environment (see Fig. 1-4.2).

1. Waste pre-treatment
2. Geological barrier
3. Bottom liner system with leachate recovery and treatment
4. Landfill body (waste) with predictable behaviour
5. Cover material and separate collection of runoff
6. Landfill operation according to operation plans
7. Controlled post-closure use of the landfill area and long-term monitoring

Each of the barriers should fulfill its purpose independently from the others. The geological barrier of the site is an important barrier against pollution of the environment – especially of groundwater and surface water – in the long-term.



**Fig. 1-4.2: Multi-Protection Concept**

The technical barriers – bottom liner system and surface liner system – might have a limited life span, but they can be constructed in a way that emissions during the critical phases of landfill development can be prevented.

The behaviour of the landfill body can be influenced by pre-treatment of waste before disposing and by landfill operation. The objective should be to realise a landfill body with minimised degradation processes and a low potential of emissions. Further, the calculation of the leachate and gas generation and the respective design of facilities should ensure long-term internal and external stability of the site.

Landfill operation, controlled post-closure use and long-term monitoring are “non-hardware” barriers, but the importance of “landfill management” cannot be underestimated. Only embedding the technical measures into proper management systems can guarantee the system’s long-term efficiency.

## 4.6. Management and Design Options

### 4.6.1. Trench and Area Method

There are three types of landfill development, area method, trench method and depression method. The types are used above all dependent on the topographical realities and groundwater level. In the area method the waste is deposited on the surface of an area. After filling up, the cells are covered with earth. In the trench method a canal is excavated and filled with waste. After full completion the final cover is introduced. The depression method uses terrains depressions of terrains. These depressions are filled accordingly.

	Advantages	Disadvantages
Area Method	Avoidance of high level ground water Lower operational and excavation cost	Need for borrowing pits for daily cover Less efficient usage of land Need perimeter berms in operation
Trench Method	More efficient usage of land Material for daily cover is available in site Don't need perimeter berms as support for waste	High cost of operation and excavation Long term and short-term slop stability problems Leachate pumping to treatment facility
Depression Method	Low costs for operation Excavation not necessary	Method not controllable Collection of leachate is complex Requires suitable depression in terrain

Table 1-4.2: Comparison of types of landfill development

The evaluation of the costs of trench and area methods leads to a significantly higher spending for the trench method. In cases of scarce land resources and the related reduction of transport distances the trench method may be used for small landfills. However, as the graph below shows, with increasing usage of trench method (which means more volume gaining in comparison with area method), the operation (excavation) becomes extremely inefficient.

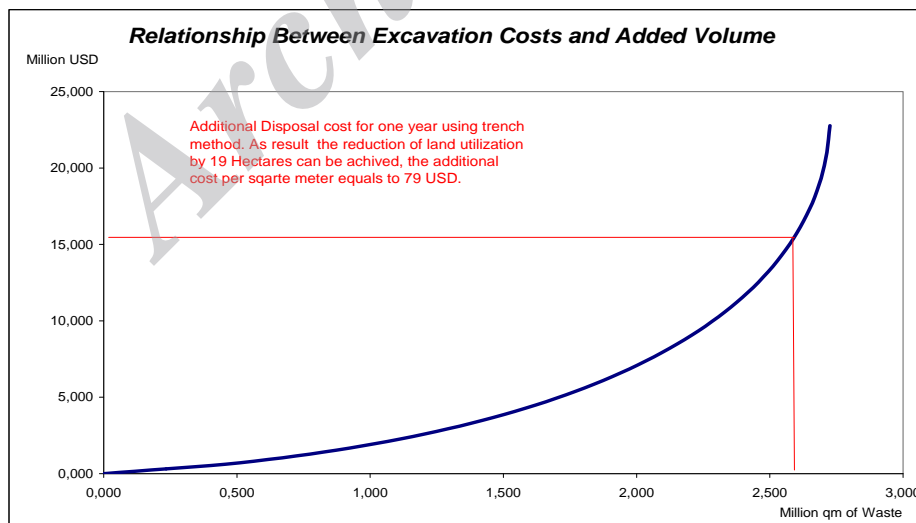


Fig. 1-4.3: Additional Costs of the Trench Method versus additional gained volume

#### 4.6.2. Landfill Operation Systems

The bioreactor landfill is a newly introduced landfill technology and proves to be effective in some cases. Major advantages of these systems are low costs of leachate treatment, reduction of waste volumes and increased degradation of organic materials. The major disadvantages of, applying their systems to the site in Houshang, are the lack of experience and the large amounts of daily waste, making the complex bioreactor system difficult to manage. No experience in the scale needed for the Houshang landfill site exists in the scientific literature. The different aspects of bioreactor landfills will be discussed in following passages.

#### Comparison of Bioreactor Landfills

Bioreactor- and conventional landfills are compared in the Table 1-4.3

	Conventional Landfill	Anaerobic Bioreactor	Aerobic Bioreactor
Typical settlement after 2 years	2 - 5 %	10 - 15 %	20 - 25 %
10 years	15 %	20 - 25 %	20 - 25 %
Anticipated waste stabilization time frame	30 - 100 years	10 - 15 years	2 - 4 years
Methane generation rate	Base case	Two times base case	10 - 50 % of base case
Liquid storage capacity utilized in the waste mass	None	30 – 60 gal./yd <sup>3</sup>	30 - 60 gal./yd <sup>3</sup>
Liquid evaporation	Negligible	Negligible	50 - 80 %
Average capital cost	Low	Medium	High
Average O & M cost	Low	Medium	High
Average closure / post-closure cost	High	Medium	Low

Table 1-4.3: Comparison of Landfills Systems (Source: MSW Management Magazine 2002)

#### Advantages and disadvantages

In the Table 1-4.4, advantages and disadvantages of reactor landfills are shown. An appraisal of semi aerobic reactors can be derived from the information.

	Anaerobic bioreactor landfills	Aerobic bioreactor landfills
Advantages	<ul style="list-style-type: none"> <li>Landfill volume savings (increase of rate of landfill settlement)</li> <li>More rapid waste stabilisation than conventional landfills</li> <li>Increase methane generation rates (200-250 % increase typical)</li> <li>Lower post-closure costs</li> </ul>	<ul style="list-style-type: none"> <li>More rapid waste and leachate stabilisation</li> <li>Landfill airspace savings (increased rate of landfill settlement)</li> <li>Reduction of methane generation by 50 - 90 %</li> <li>Capability of reducing leachate volumes by up to 100 % due to evaporation</li> <li>Reduction of environmental liabilities</li> </ul>
Disadvantages	<ul style="list-style-type: none"> <li>Leachate lagoons necessary (high leachate yield)</li> <li>Technical equipment necessary (expensive)</li> <li>"Channeling" problem for the leachate circulation</li> <li>Long duration and low volume reduction rate by the biodegradation process</li> </ul>	<ul style="list-style-type: none"> <li>Technical aeration necessity (expensive)</li> <li>possibility of formation of anaerobic parts</li> </ul>

Table 1-4.4: Comparison of Landfill Reactors (Source: MSW Management Magazine 2002)

### Experience in Tehran: Semi-Aerobic Landfill Reactor

The *United Nations for Human Settlements (HABITAT)* and OWRC started in 1988 a pilot project of the Japanese Fukuoka University at Kahrizak. A semi-aerobic landfill reactor was intended to ensure a cost-efficient, environmentally sound and low-emission treatment and disposal of waste.

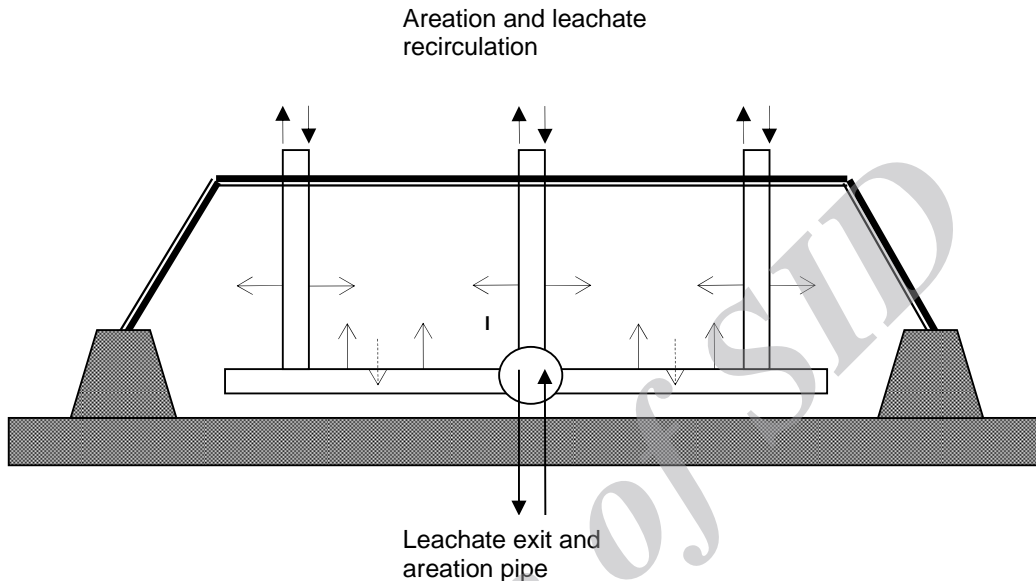


Fig. 1-4.4: Fukuoka Scheme

First experience with this system was made in Japan with a share of organic waste ranging about 20 %, resulting in significantly less leachate generation. There is no other project in the scale of the planned landfill which could serve as technical reference. The pilot project was also not successful due to technical and organisational problems in the implementation. The measured amount of methane was about 35 to 40 %, a clear indicator of anaerobic conditions.

### Experience in Tehran: Full Controlled Anaerobic Landfill Reactor

The EAMIC International Engineering Inc. and Canada AA Tech Inc. in cooperation with OWRC wanted to test the *Greenhouse Landfill Bioreactor Gas Emissions Abatement Program – Cells Demonstration Project*.

The generation of methane was intended to be regulated in a closed computer-monitored pilot project reactor to reach an optimal yield of landfill gas for electricity generation.



The leachate drainage was planned by a complex system of vertical drainage pipes. The settlement of the landfill was intended to be used. This would include re-opening the cover and filling the areas up to its original height.

This particular model would, if implemented in a large-scale operation, turn out to be very cost intensive. Increased costs would be related to the extra irrigation pipes, the sensors, the more complex gas system and the reactor for power generation. The costs of the increased pipe system alone would be at least 50 % higher than for the conventional methods. Cost recovery by selling the methane is in an oil-rich nation like Iran not possible. Finally, the complexity and sensitivity of the entire operation is not appropriate for the Iranian situation.

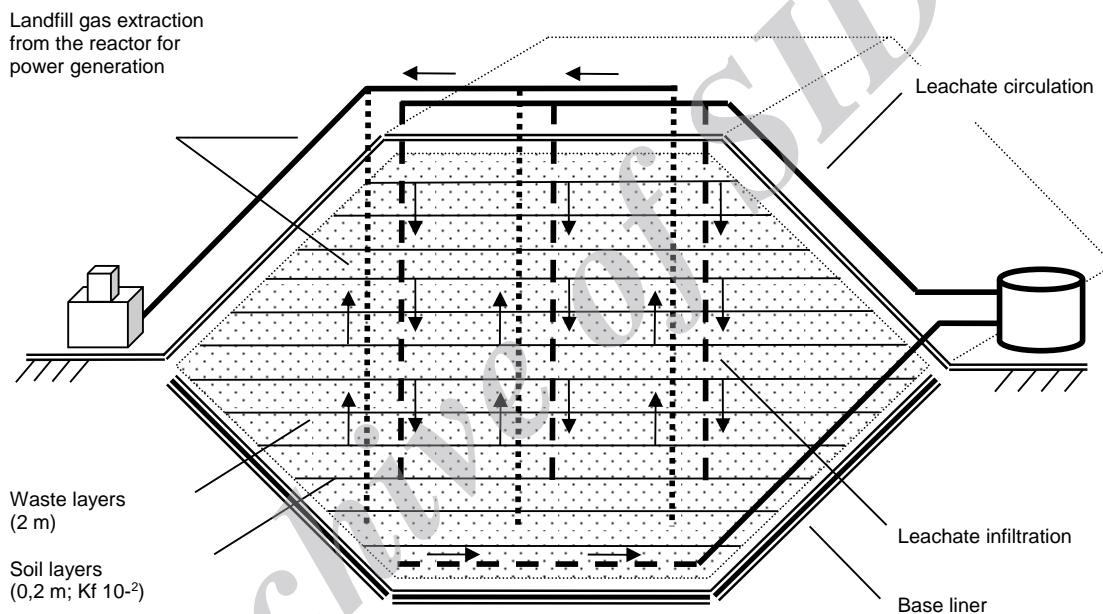


Fig.1-4.5 Anaerobic Bioreactor

#### 4.7. Conclusion on Landfill Method

Based on the preliminary environmental assessment data and the discussions at several levels the technical consultant has come to the conclusion that even though there seems to be no significant impact on the environment, certain risks related to groundwater pollution can not be excluded with sufficient certainty.

This relates to the general descriptive character of geological data, the soil and geological layers, and the uncertainty about the direction of the groundwater flow, its speed and its usability.

Emphasis is put on the results of further ongoing hydrological and geological testing in the surrounding areas.

After surveying the site, it can be concluded that in this wide-range grain size of material at the basement of the future landfill site, no exact statement about the hydraulic permeability will be possible.

The recommended landfill option is characterised as a sanitary disposal site where, through planning before construction, there is a gradual and obvious adoption of engineering techniques to manage the following:

Isolation of wastes from the surrounding geology by using bottom liner systems

Control and avoidance of surface water entering the deposited wastes by installing a well designed and constructed surface drainage system and surrounding dams

Collection and removal of leachate away from wastes into lagoons and similar structures and subsequent treatment

Spreading and compaction of wastes into smaller layers

Landfill gas collection

New parts of the landfill are prepared before receiving wastes

The creation of detailed waste disposal plans show how the site will be filled with waste and, subsequently, closed. This option involves the training and the accumulation of engineering expertise and operational experience within the municipality.

In Part 2 of this report, this design and operational recommendations, which have been discussed with all stakeholders and are agreed upon in principle will be described further.

## 5. Overview of Waste Pre-Treatment

### 5.1. Introduction

The biological decomposition and conversion of organic substances by microorganisms (bacteria, protozoa, fungi etc.) is part of the natural material cycle to which dumped waste is also subject. Biological decomposition processes in landfills produce a combustible, explosive gas (landfill gas) that easily escapes, contributes toward global warming and, hence, has detrimental climatic effects.

Leachate that seeps into the waste, or which was already contained in the waste, becomes polluted by picking up decomposition products and elutriants. Consequently, the landfill should be effectively sealed to prevent the leachate and the landfill gas from escaping to the environment. In such a landfill, the occurring gas and leachate can be carefully collected and treated.

Within the scope of mechanical-biological waste treatment, the controlled decomposition, or biodegradation, of organic substances at the biological treatment stage considerably reduces both the volume of gas and water emissions which otherwise would subsequently be generated at the landfill, and the volume of residual waste to be disposed of. Mechanical conditioning serves to prepare the waste for biological treatment. Additionally, the mechanical conditioning stage can also encompass the separation of certain materials, i.e., recyclables, pollutants and disturbants. As outlined in Figure 1-5.1, mechanical-biological waste treatment generally includes the following steps: waste input and control, mechanical conditioning, biological treatment and subsequent disposal of the pretreated waste at the landfill.

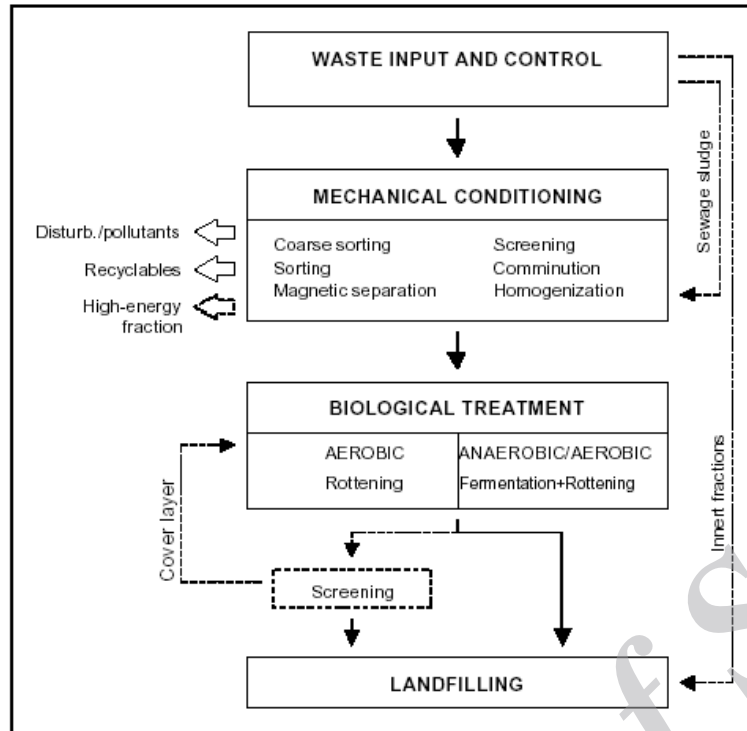


Figure 1-5.1: Typical Mechanical-Biological Treatment Sequence (GTZ, 2000)

## 5.2. Pre-Treatment Options

The presented procedures and methods are technologically simple. Consequently low-cost operation of pre-treatment is possible. Partially, existent installations (e.g. compost plant) and existent machines (CarCo-plant, Biomechanical technology) were also included in the concept. Advantages are firstly reduction of the investment costs and secondly possibilities of a fast implementation.

### 5.2.1. Mechanical Separation

#### Simple Hand Sorting

With this method, the delivered waste is stored in a depot. During this storage, the workers can collect the secondary resource materials directly from the wastes.

#### Technical Hand Sorting

The waste stream is escorted over a long conveyer belt. From there, workers sort out the recyclable materials by hand. The secondary resource material is fed back into the economic cycle.

## Separation of the Organic Waste

With this method, the organic waste is separated from the other fractions of the waste. The emerging fractions, screen underflow and screen overflow, can be treated separately afterwards. Advantages are an increase of the transportation efficiency and the treatment of the screen overflow for recycling activities. A premature separation of the waste is needed in order to prevent contamination of the organic material.

### 5.2.2. Composting and Rotting Methods

#### Composting

The triangular compost heap requires large surfaces, because of its shape and the space needed for the converter. The arid climate has a negative effect on it. The heaps are dried out fast because of the unfavourable relationship between surface and the volume. In order to gain a good compost quality or stable material, an irrigation system or a roof must be realised due to climatic conditions. A material selection (i.e. wire, cloths, etc.) is recommended before the heap construction; in this way the converter will be protected persistently.

#### Bio-Compost Method

In this type of composting pre-selected and separated organic material is used, and the contamination of waste material by pollutants is avoided. The quality of this compost is higher than the compost produced by waste materials.

Example: compost plant Kermanshah / Iran

#### Tehran Compost Plant



The plant has a capacity of 1.000 Mg per day. Two lines can process 500 Mg waste. At present, approximately 300 to 400 Mg waste are treated in the plant. It was built in 1998 by an Indian company. With the applied composting process, the material is set in fixed canals. They have been separated from each other by inner walls. The

content of each canal is aerated separately and is transferred into the next canal after a certain time. The process lasts between 2 to 12 weeks according to the temperature of rotting process. In the composting canal, the automatic converter will be worn out very fast.

Example: Kahrizak Landfill Tehran

### CarCo Plant



The existent plant has a capacity of 100 Mg per day. The plant is not in operation at present. The screen underflow is carried to triangle composting heaps and is transformed there by means of top turners. The screen overflow will be disposed.

Example: Kahrizak Landfill Tehran

### Mechanical - Biological Waste Treatment

By this procedure a mechanical waste preparation and a biological stabilisation will take place. In the pre-treatment, the waste is shredded and homogenised. Afterwards the secondary resource materials are collected by hand-sorting. During the aerobic biodegradation process, the organic substance is transformed to an earth-similar substratum. With good organic waste quality and a careful pre-treatment, the output can be used as compost.

### Adapted Bio-Mechanical Rotting

This method has been developed from the above mentioned mechanical-biological waste treatment procedure and was tested successfully under the specific conditions of Tehran. The stationary heap has several advantages.



Since no relocation or circulation is needed, it has no converting cost and the biodegradation process is not disturbed. An effective utilisation of the surface is possible even with a great amount of waste. A fine material cover operates as a roof and replaces an irrigation system even under arid climates. A

tube system is installed for aeration. The leachate storage layer, consisting of coarse material prevents the outflow of leachate into the ground.

Example: Kahrizak Landfill Tehran

### **5.2.3. Mechanical Compaction**

The Tehran low density of the material, typical for Tehran, requires large capacities for collection, handling, transportation and final disposal. Waste compaction can thus lead to significant cost savings. The waste structure can be pictured as an assemblage of particles interspaced with open air spaces called voids. When waste is compacted, the density is increased as a result of screening, crushing, deforming and relocating of individual items in the waste. With the compaction, the following points should be heeded:

Hollow containers, such as bottles and cans, begin to collapse at different pressures

The compaction of some materials is irreversible

Further explanations can be found in Part 3 - Comparative Transportation Analysis as well as in the description of the landfill operation in Part 2.



#### 5.2.4. Comparative Overview Pre-Treatment

The characteristics, advantages and disadvantages of the named methods and represented comparatives are shown in the following Table. The high waste amount and the low financial power of Tehran city influence the selection of the methods. The volume reduction and the operational costs need particular attention. Broadly, hand selection and simple procedure methods are preferred to highly mechanised methods. An optimisation of pretreatment operations must be done in transfer stations, in Kahrizak and further on in Houshang landfills.

Method	Reference	Situation	Volume reduction	Local oper. costs	Advantages	Disadvantages	Feasibility
Simple Hand picking on belts	-	-	app. 5 %	1,20 USD/Mg	<ul style="list-style-type: none"> <li>resource recovery</li> </ul>	<ul style="list-style-type: none"> <li>no reduction of the organic waste fraction</li> </ul>	Suitable, should be combined with composting.
Sorting Plant	BC Berlin	-	app. 10 %	2,40 USD/Mg	<ul style="list-style-type: none"> <li>resource recovery</li> </ul>	<ul style="list-style-type: none"> <li>no reduction of the organic waste fraction</li> </ul>	Suitable, should be combined with composting.
Rotting chamber composting process	Tehran Compost plant	in operation	app. 50 %	12,00 USD/Mg	<ul style="list-style-type: none"> <li>biodegradation of the organic fraction</li> <li>production of compost</li> </ul>	<ul style="list-style-type: none"> <li>leachate yield</li> <li>drying up</li> <li>insufficient capacity</li> <li>frequent technical breakdowns</li> </ul>	Suitable for up to 2000 Mg per day
Triangular compost heaps (waste compost)	Tehran CarCo plant	in operation (in the compost plant)	app. 50 %	2,40 USD/Mg	<ul style="list-style-type: none"> <li>biodegradation of the organic fraction</li> <li>production of compost</li> </ul>	<ul style="list-style-type: none"> <li>leachate yield</li> <li>drying up</li> <li>insufficient capacity</li> <li>frequent technical breakdowns</li> </ul>	Suitable, for up to of 150 Mg per day
Triangular compost heaps (organic waste fraction)	Compost plant Kerman-shah (humid climate)	in operation	app. 50 %	6,00 USD/Mg	<ul style="list-style-type: none"> <li>high compost quality</li> <li>production of compost</li> </ul>	<ul style="list-style-type: none"> <li>leachate yield</li> <li>drying up</li> <li>insufficient capacity</li> </ul>	Not suitable, separate waste collection necessary
Bio-mechanical	Germany, Brasilia, Mexico, Thailand	Pilot phase successful, implementation pending	app. 50 %	3,60 USD/Mg	<ul style="list-style-type: none"> <li>no leachate yield</li> <li>production of compost</li> </ul>		
German rotting process (MBA)	Germany, Austria, Swiss	in operation	app. 50 %	72,00 USD/Mg	<ul style="list-style-type: none"> <li>no emissions</li> <li>short operating time</li> </ul>	<ul style="list-style-type: none"> <li>surface consumption</li> </ul>	Suitable, if surface are available.

Table 1-5.1: Comparative Analysis for Pre-treatment Alternatives

#### 5.2.5. Conditions in Tehran

For any pre-treatment measures, the particular local conditions in Tehran must be considered:

- High share of organic waste - approximately 70 %
- Arid climate
- Low budget of Tehran administration for waste management

The quantity of organic waste is variable in different Districts. The waste composition changes in Tehran from north to south, the quantity of organic waste increases and the share of packages drops.

Separation of recyclable materials is recommended. At present, only a small share of recyclable materials is collected by private collectors. The materials are taken from the waste bags in front of residential buildings. Until now, only inefficient recycling activities take place. These activities should be increased as soon as possible.

A separated collection of waste fractions from residential areas does not take place in Tehran. Therefore the pre-treatment activities can take place at following locations:

- 12 transfers stations
- Old Kahrizak landfill
- New Houshang landfill

In Table 1-5.2, Tehran waste composition in the year 2003 is shown. The data were collected in transfer stations during three summer months. The share amount of organic waste is 68 %; the share amount of easily recyclable material is approximately 15 % (plastics, PET, paper, hardboard, ferrous materials and glass). The following quantities are calculated according to a daily waste volume of 6,050 Mg.

Organic waste	Dry bread	Soft/Hard plastic	PET	Paper / Hardboard	Ferrous	Glass	Others	Sum
67.82 %	0.98 %	2.75 %	0.71 %	8.13 %	1.55 %	2.40 %	15.66 %	100.00 %
4103.1 Mg	59.3 Mg	166.4 Mg	43.0 Mg	491.9 Mg	93.8 Mg	145.2 Mg	947.4 Mg	6050.0 Mg
Composting and secondary resource recovery								

Table 1-5.2: Pre-Treatment Quantities (Source: Waste physical analyses for area of Tehran at 2003 (Average) and Statistical Report from OWRC, Vol. 2, Summer 2003)

### 5.2.6. Conclusion on Pre-Treatment Options

In assessing the performance of mechanical-biological waste treatment, it must be reminded that the properties of the treated waste will depend on the chosen process, its duration, the output flows of material, and the local

conditions. In any case, however, the biodegradable content of the waste material is always significantly reduced. As a result, the biological decomposition processes taking place in the landfill subsequent to mechanical-biological waste treatment (MBWT) are also decisively diminished.

Both the moisture content and the mean particle size decrease, and the thus treated material becomes considerably more homogeneous. Consequently, the situation at the landfill where such waste is being deposited improves in the following ways:

#### **Smaller quantities for disposal**

The biodegradation of organic substance, perhaps accompanied by the extraction of material varieties at the mechanical conditioning stage, significantly reduces the quantity of waste to be dumped.

#### **Compaction**

Thanks to pretreatment, the layers of landfilled material can be compacted to a much higher density than that of conventional landfills. Likewise, the landfill body settles much less, and the higher packed density generally improves its stability, thus enabling greater landfill heights.

#### **Less incorporation of topsoil as daily cover material**

The working areas are covered with topsoil in order to keep the landfill trafficable while avoiding open expanses of waste. However, the topsoil takes up a substantial share of the landfill volume. Landfills containing waste that has undergone mechanical-biological treatment can get along with little or no topsoil.

#### **Extended landfill life-span**

The above factors can significantly lengthen the useful life of existing landfills. Depending on the initial situation and on which MBWT process is chosen, landfill life-spans can be increased twofold or more.

#### **Leachate**

In the medium term, the quality of seepage water increases markedly. This is attributable to, for one, the fact that the biological degradation phases that make the most relevant "contributions" to the seepage water's organic emburdenment take place prior to dumping. The TOC and COD levels decline by as much as 90 % . At the same time, the upstream extraction of pollutants additionally disburdens the leachate.

## **Gas**

Mechanical-biological waste treatment very significantly reduces the rate of landfill gas production. The precise extent of that reduction depends on how long the rotting process lasts. The residual gas evolution potential can decline by more than 95 % for rotting periods of 20 weeks or more.

## **Landfill fires**

Pre-treatment of waste also considerably reduces the danger of landfill fires. In fact, advance extraction of the high-energy fraction can completely preclude such fires.

Based on those above made considerations, the following chapters will describe ways for mechanical-biological pre-treatment.

### **5.3. On-site Pre-treatment in Houshang Abad**

#### **5.3.1. Pre-Treatment Method**

As described above, as applicable pre-treatment option a biomechanical system is proposed, which was operating successfully at Kahrizak landfill for several years. In Germany, where the system had been developed in the 70ies, it is in operation in several places (e.g. Schwaebisch Hall, Bad Kreuznach). The costs per ton are approximately USD 12.50. In further places it has been introduced as well (Brazil, Thailand, Mozambique), always after a testing period or a pilot project to adjust the system to the local water balance and waste composition.

The specific waste composition and the arid climatic conditions can easily be treated by this technology. Contrary to Germany, no extra water is needed since the moisture of the waste is higher and is maintained in the stationary rotting heap.

In the current working system, all Iranian requirements were met, especially to overcome the following obstacles: permanent water scarcity, high populations of insects and vertebrates, strong odour emissions, leachate production.

The stationary heap of the biomechanical system has the following peculiarities:

1. an integrated tube system for aeration,
2. a compost cover
3. a substructure layer of coarse material sieved from previous rotting heaps collecting the leachate. Thus leachate of initial existent water in to the ground is prevented completely. Neither separate bottom liner systems nor any additional irrigation and roofing is necessary. (Koertel, 2004).
4. initial shredding and homogenisation of the material is recommended.

During this procedure the total volume of the waste is reduced up to approximately 50 %. The microbiological biodegradation and the aeration system initiate a circulation of water and gas within the heap. Hence, under current circumstances no additional water is needed, and surplus water or leachate production occurs occasionally after longer periods or high precipitation.

The aeration is supported by the balance of moisture in the waste and the inclusion of non-organic stabilising material, which permits the penetration of air into the entire heap. A changing waste composition (e.g. higher or exclusively organic content) could cause difficulties to this system.

As a result approx. 65 % become fine compost which can be used for different purposes according to its quality. The major use from the currently operating pre-treatment plant is agricultural fertilizer which is sold at market prices. The remaining 35 % will be reused as water storage layer in new heaps of the pre-treatment plant and a small remaining percentage will be disposed at the landfill. Due to composition of the high caloric material a future use as alternative fuel can be considered.

The recycling option should be taken into consideration in any case. Based on Kahrizak surveys, approximately 10 % of waste contents are recyclable material such as glass, plastic, metal etc. The prices for recycled material create a private business opportunity and would not create additional costs to the landfill operator. In addition, the quality of the final bio compost would be increased and the total waste volumes arriving at the landfill would be reduced.

This system has several distinct advantages, of which the most important are listed below:

- low investment and operational costs
- little after care necessity
- reduction of total waste volume from 15 to 50%
- low emission of greenhouse gases
- significant reduction of leachate
- reduction of insect populations

### **5.3.2. Pre-Treatment Area and Technical Specifications**

In the practical application of this system, the household waste is piled up to a heap size of approximately 100x25x2m, which totals to an entire surface of about 50 ha. With an active vending system, rotting takes six months, while passive aeration results in nine months rotting time.

At the base of the windrow (along width), perforated drain pipes are embedded horizontally (from both sides) and are connected to a vertical pipe reaching to the top in the centre of the windrow. This ventilation – working like a chimney – is recommended every 3 m. The system aerates the windrow because of the

difference between the warm air temperature inside the windrow and the cooler air temperature outside. The circulation of air produces aerobic conditions and accelerates the aerobic decomposition of the organic fraction of household waste (including parts of paper etc.) After 6 to 9 month of “composting” the windrow is spread into 20 cm high layers and has to be compacted well.

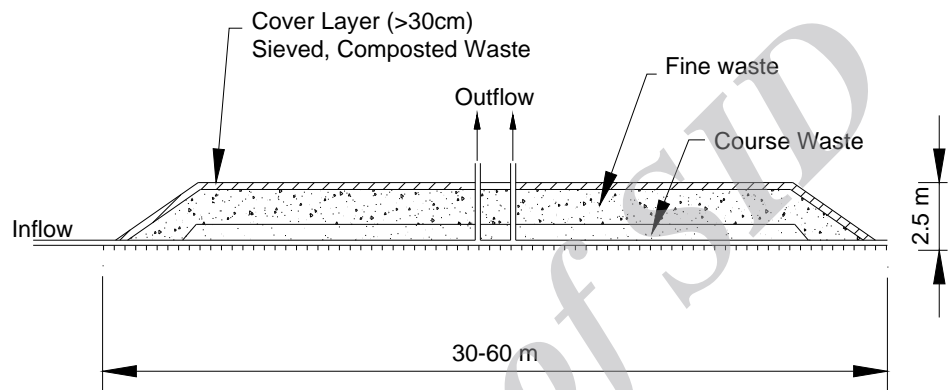


Fig 1-5.2.: Pre-Treatment Technical Description of Pre-Treatment Heap (Ramke, 2001)

The most suitable location is at the south-western extension of the area where the separation and recycling can take place prior to disposal. The area is too small for efficient waste disposal and the costs for excavation and backfill will be too high. For the pre-treatment area, levelling to platforms will be sufficient, and a total of up to 2500 Mg/d can be treated.

### 5.3.3. Costs

A high cost factor is the preparation of the surface in Houshang site. However, it must be named as economic advantage of the proposed alternative that no surface lining is necessary. Consequently, only leveling works are needed.

In the following table, the costs for investment and overheads are represented. The investment costs add up from the machines, technology and the mobile appliances.



	Item	Unit	Pcs	Price/Unit in USD	Total In USD
<b>Investment Costs</b>					
Heavy Equipment					
	Shredder		Pcs	1	480,000
	Gravitation Separator		Pcs	1	300,000
	Magnetic separator		Pcs	1	60,000
<b>Sum</b>					840,000
Construction technical					
	Land	ha	200	0	0
	Construction of working surface	lump-sum	1	240,000	240,000
	Roads	m <sup>2</sup>	8000	30	240,000
	Infrastructure	lump-sum	1	24,000	24,000
	Electricity	lump-sum	1	60,000	60,000
<b>Total</b>					564,000
Mobile Equipement					
	Loader (large)		Pcs	2	180,000
	Loader (medium)		Pcs	4	120,000
	Lorry		Pcs	4	90,000
<b>Sum</b>					1,200,000
<b>Total Investment</b>					<b>2,604,000</b>

Table 1-5.3: Investment Costs for Pretreatment

Operation Costs	Factor	Costs in USD
<b>Investment</b>		
Total		2,844,000
Heavy Machinery		840,000
Construction Equipment		564,000
Mobile Equipment		1,200,000
Other costs		240,000
<b>Capital Costs</b>		
Sum Cap Costs	8%	485,578
Heavy Machinery	10	125,185
Construction Equipment	20	57,444
Mobile Equipment	7	230,487
Other costs	4	72,461
<b>Operational Costs</b>		
Maintenance Heavy Machinery	3%	25,200
Maintenance Construction Equipment	2%	11,280
Mobile Equipment	10%	120,000
Other costs.	10%	24,000
Staff	1	115,200
Ventilation Material	1	268,800
Material Bottom/ Cover	1	250,000
Diesel	0,03 \$ / l	89,000
Sum Oper Costs		628,305
<b>Total Costs per year</b>	<b>USD / a</b>	<b>1,113,883</b>

Table 1-5.4: Operational Costs for Pretreatment

The Tables 1-5.3 and 1-5.4 describe the precise cost estimates for the investment and operation costs. Integrating this pre-treatment option into the cost estimated of the landfill, the waste streams have to be analysed:

<b>Baseline Data</b>	
Daily treated Waste	1000 Mg
Pre-selection	3 %
Reduction by pre-treatment to	60 %
Coarse Material	40 %
Rotted Material/Compost	60 %
Cost for Pre-treatment	3.05 USD/Mg
Costs for Landfilling	5.72 USD/Mg
Price for Compost	20 USD/Mg
Transport Houshang-Tehran	5.74 USD/Mg

<b>Daily Output</b>	<b>to Landfill sold as compost</b>
Composting Option	233 349
Rotting Option	582 0

<b>Composting Option</b>	
Waste transport after Pretreatment	233 Mg
Capacity of tipper	20 Mg
Cycle time	1.5 h
Working hours	16 h
Cycles per day	11
Needed tipplers	1
Transport costs	0.70 USD/Mg
<b>Rotting Option</b>	
Waste transport after Pretreatment	582 Mg
Capacity of tipper	20 Mg
Cycle time	1.5 h
Working hours	16 h
Cycles per day	11
Needed tipplers	3
Transport costs	0.70 USD/Mg

<b>Model Calculation for 1000 Mg</b>			
	Composting Price	Rotting Price	Land filling
Transport to Houshang	0	0	0
Pretreatment	3,050	3,050	0
Transport Pretreatment to Landfill	163	407	0
Sale of Compost	-6,984	0	0
Landfilling	1,332	3,329	5,720
Transport to Tehran	2,004	0	0
<b>Price per Ton</b>	<b>-0.75</b>	<b>11.66</b>	<b>5.72</b>

Table 1- 5.5: Integration of pre-treatment concept into the Operation of Houshang site

#### **5.4. Conclusions on On-Site Pre-Treatment**

Pre-treatment has a number of benefits as it has been described in the previous chapters.

In order to determine the inclusion of pre-treatment activities into the operation of the new landfill at Houshang, several aspects need to be considered:

The feasibility of the biological pre-treatment depends on the composition of the waste. Organic content and the particle size both have an influence on the rotting period. A changing waste composition as a result of the currently ongoing waste at-source-reduction strategy and other activities at the transfer station will need to be monitored and the impact on the pre-treatment has to be determined. The other objective of the reduction strategy is to minimize transportation distances of waste, which would suggest the selection of an alternative site, closer to the source of waste generation.

As reported, there are occasional cases when leachate will be produced. This speaks against a separate pre-treatment area, since the establishment of a bottom liner system create additional cost which make this option economically not feasible.

The costs for pre-treatment are almost twice the price per ton in comparison to bringing the waste directly to the landfill. The price can be significantly lowered when income is generated by the sale of compost. However, this source can not be considered as a reliable and sustainable option, since the changing waste composition can not guarantee the quality of the compost at marketable prices. The risk of low quality and contaminated compost entering the food production cycle is evident.

Finally, the environmental benefits of the pre-treatment for the operation of the landfill will still remain marginal, since the scale of the pre-treatment in relation to the amounts of waste handled in the landfill.

Summarizing the above mentioned facts, on-site pre-treatment is not recommendable to invest into pre-treatment while decisive key factors are not yet determined and the benefits are marginal. This option is however still considered as a valuable option after the new landfill is operating and the waste streams, qualities and quantities have consolidated. This would also permit the economic evaluation by private investors to assess if there is any profit margin to gain.

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## Part 2

# Landfill Design Study

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# 1 General Data and Site Selection

## 1.1 Pre-Selection of the Site in Haushang Abad

Prior to the commencement of this study, a Technical Committee was set up to select the most appropriate site for the development of an engineered landfill for the City of Tehran. The committee was comprised of:

- Organisation for Waste Recycling and Composting
- Department of Environment (Tehran Division)
- Soil and Water Management Department (Ministry of Energy)
- Agriculture Ministry (Province of Tehran)
- Natural Resources Department of Province of Tehran
- Provincial Government of Tehran
- Housing and Urban Planning Department
- Ministry of Health (Tehran Division)

Thirteen locations, which varied in distance from 40 – 90 km from Tehran, were proposed by the Natural Resources Department of the Province of Tehran. The selection criteria developed by the Technical Committee in order to evaluate the suitability of each site for the proposed landfill are shown in figure 2-1.1.

1. Available land area (relative weight factor: 2.0)
2. Proximity to settlement area (relative weight factor: 2.0)
3. Proximity to sensitive water resources (relative weight factor: 2.0)
4. Hydrology and hydrogeology (relative weight factor: 2.0)
5. Soil/ land conditions (relative weight factor: 2.0)
6. Topography (relative weight factor: 2.0)
7. Haul distance (relative weight factor: 2.0)
8. Cover material availability (relative weight factor: 2.0)
9. Unique natural and cultural treasures (relative weight factor: 2.0)
10. Current land-use (relative weight factor: 1.8)
11. Local ecological conditions (relative weight factor: 1.8)
12. Flooding occurrence (relative weight factor: 1.6)
13. Transportation links (relative weight factor: 1.6)
14. Site access road (relative weight factor: 1.4)
15. Land stability conditions (relative weight factor: 1.0)
16. Availability of infrastructure (relative weight factor: 1.0)

Figure 2-1.1: Pre-Selection Criteria for Site Selection of Houshang Abad

The map provided in the Environmental Impact Assessment Study shows the exact locations of the thirteen candidate sites. (Environmental Assessment Study, TSWMP, 2004)

Each site was given a score from 1 to 5 (1 denoting worst and 5 denoting best) for each of the selection criteria. This score was multiplied by the weight given to each of the selection criteria. The total scores were added and the site having the highest scores was found to be the best option.

Advantages	Disadvantages
Long distance from residential areas (10 km) Large surface area (app. 4000 ha) Proximity to Tehran-Qom railway Low groundwater table (110 m) Favourable soil (silty/ clay)	Long distance from Tehran

Table 1-1.1: Advantages and Disadvantages of Houshang Abad site.

Table 1-1.1 summarizes the key points for the site in Houshang Abad which was consequently chosen as the most preferential site. A detailed description of the site selection is given in the Environmental Study.

## 1.2 Key Parameters of the Houshang Site

The present Study is written for the construction of the new Houshang Abad landfill. This landfill will accept waste from the greater Tehran area. The design stipulates a daily delivery of approx. 7,000 tons at present and takes into consideration an increase of waste generation up to 3.5 million tons in the year 2019. An average waste delivery to the site of 2.5 million is anticipated in dimensioning this landfill for an operation time of at least 15 years for the first section (Section 1). After finishing Section 1 other opportunities of landfills still exist at the proposed Sections 2 and 3. The whole site development with the long-term perspective for about 50 years is described in chapter 4 on landfill development.

A summary of the findings from previous reports will be given in the following sub chapters; a short abstract of the key figures is presented here:

- Permeability of soil and subsurface is low ( $1.5 - 3.1 \times 10^{-8}$  cm/sec)
- Depending on the grain size of the soil material, the permeability in the vicinity of watercourses is higher
- High content of sulphate minerals of up to >10 %

- No useable groundwater in a depth up to 30 m, only temporary water has been observed
- Boreholes and wells analysed in or around the site show high concentration of TDS, high values of EC
- Presence of impermeable marlstones prevent deeper groundwater connection, if deeper groundwater exist (not investigated)
- Subsurface groundwater flow direction is like surface run off (NW to SE)
- Annual average precipitation rate below 200 mm
- Annual average evaporation approx. 2600 mm.

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## 2 Geographical Description of Houshang Landfill Site

### 2.1 Site Location and Topography

The Houshang landfill site is located at about 50 km south of Tehran extending along the old Tehran – Qom road and spreading on both sides of the road. The area is part of Fashapooyeh district of Ray city. Hassan Abad located about 10 km northeast of the site is one of the major counties of Fashapooyeh district with a few villages. Among the villages, Houshang Abad and Aziz Abad are the closest rural areas to the site. Houshang Abad area totally lacks any population and is not considered as a residential area. Aziz Abad, the only rural residential area in the vicinity of the site has a population of 20 people.



Figure 2-2.1: Overview of Future Landfill Area

The approximate site boundaries as provided by OWRC are shown in Drawing 1 and illustrated in Figure 2-2.1, topographically the site comprises a main northwest to southeast trending slope starting at a 1030 to 1050 m elevation (above sea level) to about 905 m. The general slope taking into account the overall elevation changes is approximately 2% northwest to southeast. Regardless of the local hills of about 1030 m elevation located at the western parts of the site, the topography has generally low variation with a gentle slope. The lowest variation of elevation is found to be extending to both sides of the old Tehran – Qom road where the elevations decline from 1030 m at the northwestern margin of the site to about 973 m at the southeastern part.

Insert Drawing M 1 showing the Location of Houshang Abad

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## 2.2 Hydrogeological Situation

### 2.2.1 Hydrogeology of the Site

The specific area has not been studied in terms of groundwater resources mainly because geological conditions of the area indicate lack of any groundwater system to be present. The specific project studies have shown some information on the permeability of the local soil profile up to a maximal depth of 30 m (see Figure and Table 2-2.1). The hydrogeological situation was assessed in the environmental impact assessment study and is summarised for the proposed site.

Hydro-dynamically, the region of the proposed landfill can be divided into two sections:

- seasonal rivers and watercourses beds with an average to fine-sized fluvial deposits and
- areas adjacent to the rivers and watercourses in form of hills made of sandstone, marlstone, silt and clay formations.

The land in this area is considered as hydro-geological impermeable or at least low permeable due to the specific formations comprising the area. There is nearly no secondary permeability of the subsurface layers because the fractures of the stones are filled with strips of gypsum, salt and lime. Additionally the surface is covered with very fine grained soil due to the type of stone erosion. These characteristics imply that there is a limited possibility of precipitation and/or surface runoff infiltration to subsurface layers.

Also the fractures at deeper locations within the above mentioned stones, which are highly elastic, the surface alteration effects are absent and the stones become impermeable due to the fact that the high pressure posed by the overlying layers results in absence of the fractures. Therefore, as already stated, most likely there is no deeper aquifer layer at site area.

Based on the geotechnical study of the proposed site, the permeability of the surface soil (up to 10 m) can be considered very low. However, the permeability tests are performed for only four of the boreholes and are limited to a depth of 10m (see following chapter on geotechnical situation). Only samples in the clayish ore less permeable layers were taken.



BH no.	BH Coordinate (UTM)		Elevation (m)	Depth (m)	Permeability (cm/sec)
	N	E			
BH1	-	-	-	9.5	$1.56 \times 10^{-8}$
BH3	3905173	39511552	1010	7	$1.53 \times 10^{-8}$
BH3	3905173	39511552	1010	10	$1.51 \times 10^{-8}$
BH5	3906105	39508956	1020	1.5	$3.10 \times 10^{-8}$
BH5	3906105	39508956	1020	10	$1.48 \times 10^{-8}$
BH6	3904490	39510711	1001	1.5	$1.89 \times 10^{-8}$
BH6	3904490	39510711	1001	10	$1.71 \times 10^{-8}$

Table 2-2.1: Result of Permeability Tests as Part of Geotechnical Study

1	□		ML	Gray to Light Brown Clayey Silt Stiff
۲	□			
۳	□			
۶	□			
۸	□		CL	Brown Silty Clay, very Stiff
۱۰	□		ML	Light Brown to Brown Clayey Silt very Stiff
۱۲	□			
۱۴	□		MH	Light Brown Clayey Silt with some Gypsum, very Stiff
۱۵	□			
۱۶	□		CL	Light Brown to Brown Silty Clay, very Stiff
۱۸	□			
۲۰	□		CL	Light Brown to Brown Silty Clay, very Stiff
۲۲	□			
۲۴	□			
۲۶	□		ML	Light Brown Clayey Silt with some Gypsum very Stiff
۲۸	□		CL	Light Brown Silty Clay very Stiff
۳۰	□		ML	Light Brown Clayey Silt very Stiff

Figure 2-2.2: Borehole log BH 4

As shown in table 2-2.1, the permeability rates especially of the stiff clayish material up to a depth of 10 m ranges from  $1.51 \times 10^{-8}$  to  $3.10 \times 10^{-8}$  cm/sec (see geotechnical study). Accordingly, the partly very low permeability of the soil confirms the resulting limited infiltration possibility of precipitation and surface runoff water to subsurface layers. On the other hand a high amount of precipitation has to be discharged by surface runoff through watercourses.

It is worth noting that the area of river and watercourses beds development is different from the other areas as described above. Geologically, river beds are formed through scaling of grain size by the intensity of surface runoffs and the related velocity of flow. These areas have been subject to periodical deposition of fluvial materials and washout.

At the foreseen site the bed of existing rivers and watercourses are covered with fine and to a lesser extent medium-size fluvial materials. These materials overlay the types of hard rocks which were described above. Development and extension of fluvial deposits in terms of thickness and area are lower at the upstream of the watercourses and increase along the flow direction with widening of the flow channel. The thickness of fluvial material at upstream may increase from a few decimeters to tens of meters at downstream and particularly at the connection point of the watercourses.



**Fig. 2-2.3: Relief Change**

As described, there is no homogenous top soil cover. The area is rather characterised by the fluvial terrace which is interrupted by active and former erosion channels. Figure 2-5.2 shows the bottom of a former water channel with the deposition of small stones and gravel which were not eroded as the adjacent fine material. This is most likely the case for the entire area.



**Fig. 2-2.4: Inhomogeneous Soil Cover**

Even if the soil cover would be surveyed every ten meters, there is still the possibility of high permeable material lying underneath in between the measuring points.

Consequently, a limitation to the clay is its chemical consistence and the possible reaction with the leachate (see chapter below on Natural Compacted Clay Layer). The physical swelling behavior of inhomogeneous soil can destabilize the underground of the landfill and may have an irreversible impact on the leachate collection system and the inclination.



**Fig. 2-2.5: Surfacing Groundwater**

Figure 2-2.5 shows the surfacing of groundwater 800 m south of the section 1 landfill area, permitting the growth of vegetation as shown.

A full risk analysis for this area is not possible and it is therefore not recommended to rely on the natural geological barrier as the only leachate containment system.

At a site visit of the landfill area in April 2004 borehole BH2, 4 and 5 were found filled with groundwater up to a depth of about 5 to 10 m. This groundwater was still there in the end of June.

In summary, the hydro-geological conditions of the proposed site indicate that at some parts of the area a possibility of infiltration exists. The infiltrated water flows through subsurface weathered stone regions and through alluvial deposits towards the rivers and watercourses beds and discharges into them. The velocity of migration of the groundwater towards the superficial runoff is difficult to calculate, but due to the inhomogeneous grain size and the related wide range of hydraulic conductivity in disturbed areas in the near of watercourses, transport velocities of groundwater (and infiltrated leachate in case of no sealing of landfill bottom) may be very fast (see figures above). That

means there is a possibility of quick subsurface migration of contaminants (diluted leachate) into the direction of watercourses.

### **2.2.2 Quantity of Groundwater in Alluvial Material**

The fluvial deposits and the at least temporally existing aquifer are underlying the whole territory of the foreseen landfill. However, there is no accurate information available on the thickness of fluvial deposits, since the only field investigation comprises boreholes of 30 m depth and less. The presence of groundwater in the fluvial deposits over the whole year also is not investigated.

The precipitation and surface runoff can infiltrate to a limited extent to the fluvial layer and flow on the bottom marlstone and sandstone, forming the existing groundwater. The EIA-report deduces the following sentences: At upstream, groundwater appears as a thin layer and/or soil moisture. The thickness of the so formed groundwater increases with increasing the thickness of fluvial deposits towards downstream. At the connection points where the fluvial material has a high area and thickness, the thickness of water-bearing layer (groundwater) flowing on the bottom stone layers can increase to a few meters.

### **2.2.3 Quality of Subsurface Water (Groundwater)**

The infiltrated precipitation dissolves the existing high gypsum and salt concentrations in the alluvial material. The existence of salted surface soil and river beds indicates the highly concentrated gypsum, salt and other mineral compounds which appear at ground surface as a result of capillary process and evaporation.

The so formed subsurface water has according to the EA report a lower concentration of dissolved solids at upstream of river beds. The concentration of dissolved solids increases gradually toward downstream. The subsurface water (groundwater) is completely saline at the outlet of the overall drainage system ending at Shour River at eastern part of the proposed site.

### **2.2.4 Groundwater Flow Direction**

The groundwater flow is directed from the area of highest elevation towards the watercourses and rivers considering the marlstone and sandstone stacks between the watercourses. Flow direction of watercourses and rivers are along with the topographic slope of the area and consequently the subsurface flow formed on the beds of watercourses is finally connected to that of Shour River. The general groundwater flow direction is therefore the same as the surface water flow generated as surface runoff.

### **2.2.5 Groundwater Use Downstream**

The very limited groundwater with a very poor quality (as described later in this section) practically cannot be used. The only wells in the vicinity of the site which were described in the EA report are not capable of providing sufficient and appropriate water. The depth of the wells at Aziz Abad, Ghale Mohamd Alikhan and army establishment (closer to the proposed landfill site), together with the inappropriate water yield and quality confirms the description presented above.

According to Qom General Office of Water Affairs (2003-2004), the majority of the area lacks any groundwater use in form of wells, springs and qanats. The only wells capable of providing water for domestic (mainly agricultural purposes) use are located around the western parts of Hoze Soltan Lake, namely Kooshk e Nosrat.

The amount of groundwater use through this set of wells and other sources including springs and qanats within Kooshk e Nosrat area is described in the EA report. According to this report these wells are considered the only set of wells in the Salt Lake field. Although this area is located quite far from the proposed site, contamination of the subsurface water (groundwater) within the site can potentially migrate to the Shour River discharge points near Hoze Soltan if not properly controlled. This can also potentially affect the groundwater in and around Hoze Soltan and consequently Kooshk e Nosrat set of wells.

The groundwater level, as described in chapter 2-2, reaches a level of only few meters below surface (April up to June 2004). Therefore usage of a liner system is recommended due to the migration aspect of contaminants back to surface in vicinity to Shour River and the potential effect on downstream water quality of Shour river.

## **2.3 Geotechnical Situation**

### **2.3.1 Description**

This area has arid and dry climate types of soil with high content of minerals, specially gypsum and anhydrid. The nearest river to the site is Shour River which starts from Alborz Mountains in Ghazvin and flows to Salt pond in Iran central desert. A sufficient distance of the foreseen landfill is kept from the Shour River floodplains and branches. But attention must be paid to rainfall range and flood capacity of the catchment area at landfill site.

Geotechnical Report describes the geology of the study area as follows: Geology classification belongs to the northern part of Iran Central Region and is formed of third geological period stones. In this area a periodicity of conglomerate, sand stone, marn and mud stone with some amount of gyps stone and salt is seen. In upper layers, stone types are mud stone and gyps which give brown color to the area. These layers have west-north west and east-south east direction with light wrinkles; in a way that layers slope will rarely be more than 30 degrees.

The area structure obeys the same way, and sufficient distance must be kept from the faults. The core stone (bedder) characteristics has been studied by geotechnical surveys and, as written before, some permeable conglomerate and sand stone and impermeable mudstone and marn are seen in the area.

The Geotechnical Report also describes the following: Due to 7 dug boreholes, bedder is formed of mudstone with gyps. Earth crust in these regions is moving 1.6 cm/a toward north east and is active. In this area at least 16 earth quakes with magnitude of 8 or more Richter and 138 with magnitude of 7-7.9 Richter had happened through ages. Therefore the Geotechnical Report recommends resistance against 7 Richter earth quakes for the landfill cells. All known faults in the area have influence on the landfill. Those are Alborz fault, Rei fault, Kahrizak fault, Varamin fault, Garmsar fault, Eipak fault and other existed faults which have a longitude between 12 to 40 km. No omitting indicators such as curst situation exist currently in the recommended area. Risk evaluation in the area is one of the parameters which can lend to election or omission of a land for hazardous waste disposal.

### **2.3.2 Field Survey and Laboratory Analysis**

In the field survey of the Geotechnical Report have been dug 7 boreholes (BH) in different depths from 16 to 30 m. In Figure 2-2.2 exact location of the BH is shown. Boreholes number 1, 3, 5 and 6 have been excavated by manual method and boreholes number 2, 4 and 7 by mechanical (percussion) method. Only BH 4 and 5 are lying on site of section 1 of the foreseen landfill site.

Touched samples from the boreholes were used to indicate physical, mechanical and chemical characteristics of the soil. Untouched samples were used to indicate density of the soil.



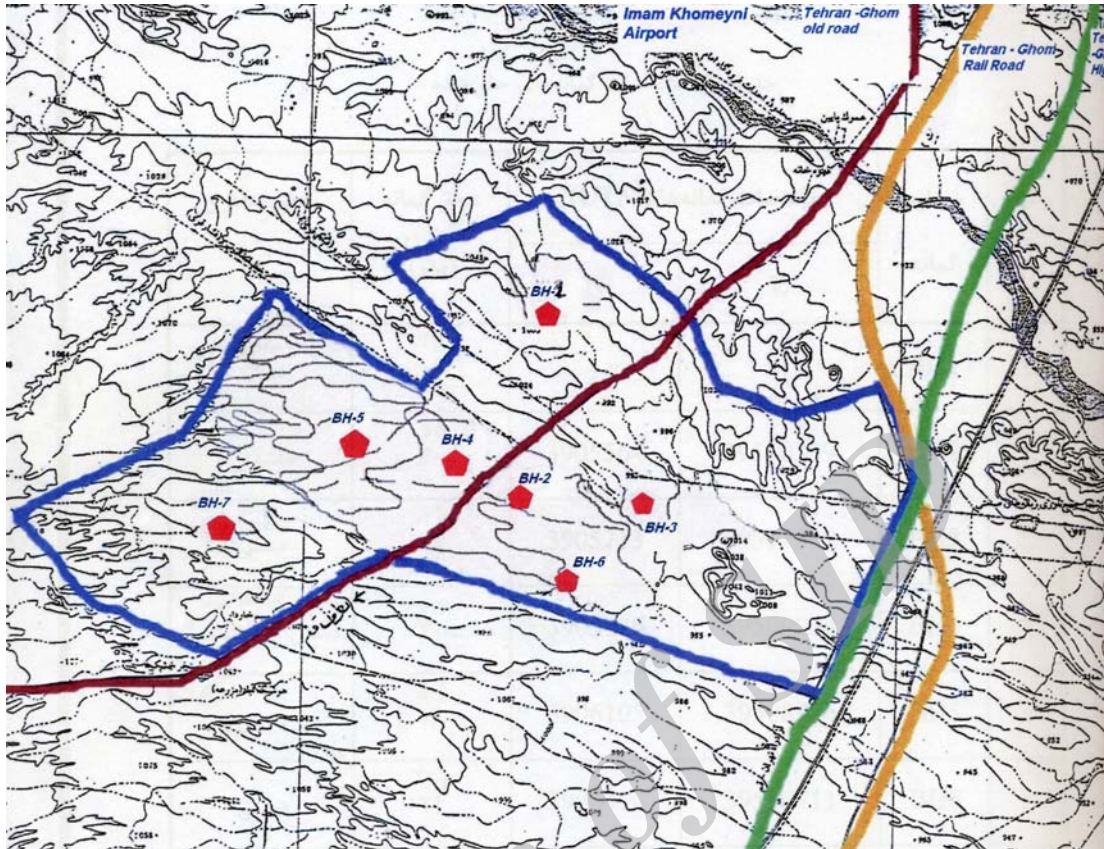


Fig. 2-2.6: Old Tehran-Qom Access Road Crossing the Site and dividing it in to 2 Parts.

R o w	BH no.	BH Coordinate (UTM)		BH Depth (m)	Excavation method
		N	E		
1	BH1	-	-	16	Manual
2	BH2	3905564	39510339	30	Mechanical
3	BH3	3905713	39511552	18	Manual
4	BH4	3905926	39509944	30	Manual-Mechanical*
5	BH5	3906105	39508956	26	Manual
6	BH6	3904490	39510711	24	Manual
7	BH7	3904392	39507976	30	Mechanical

Table 2-2.2: Coordinates of Boreholes

\* The first 4 meters have been excavated manually and the rest mechanically.

### 2.3.3 Assessment and Analysis of the Results

Generally Tehran soil texture in northern parts (after Azadi Ave.) is shaped from coarse grains (mostly sand and gravel) and has various cementations in different parts. In southern parts of Tehran contains fine grains (clay and silt), and get even smaller in direction to south. Due to site location south of Tehran,

geologically it is formed from alluvial layers and almost 100 percent of soil texture is formed of clay and silt with average to high cohesion. In the middle of soil body some streak of clay stone by approximate thickness of 1 to 2 meters is seen. Aerated soil with a thickness of 0.5 m has covered all over the site.

About earth quake issue, according to different surveys and analysis made in Tehran and its surrounding, high risk for future earth quake occurrence exist. Northern fault of Kahrizak fault might cause in order 6.5 and 7 Richter earthquakes. Due to the Geotechnical Report Houshang Abad site is situated in a high-risked area for earth quakes therefore any planned construction for this site high percentage of risk must be considered (in accordance to Guidelines for Seismic Design of structures 2800).

#### 2.3.4 Physical and Mechanical Characteristics of the Soil

Due to log of the boreholes 1 to 7 in the Geotechnical Report the formations of the subsurface are formed from gross and almost homogenate alluvial layers which contain mostly clay and silt materials with high solidity, soil cohesion is also high in most parts. Test results for humidity percentage and density are shown in boreholes log. Due to unified classifications, site soil is classified in CL, ML, CL-ML and SM groups. More than 95% of the site soil belongs to CL and ML groups. In accomplished excavations, they have not reached subterranean upstream drainage water or surface osmosis water. The average of soil geo-technical parameters used in designs is shown in table 2-2.3

Geo-Technical parameters	Average
Soil natural humidity percentage	15
Density	2.1 kN/m <sup>3</sup>
Poisson Factor	0.35
Elasticity model	70 Mpa
Permeability	1.6X10 <sup>a</sup> cm/s (a= -8)
Internal friction angle*	21°
Cohesion*	15 kPa
Optimised moisture	16-18 %
Maximum dry density	17-18 kM/m <sup>3</sup>

Table 2-2.3: Average of soil geo-technique parameters (\* These data belong to touched samples, cohesion of untouched samples is much higher)

BH no.	Depth (m)	CBR saturated	CBR non saturated	Turgidity percentage
1	9.5	12	7	2
3	7	11	6	2.3
3	3	10	5.5	2
3	10	11	6	2.1
5	1.5	7	5	1
5	10	10.5	5	2.4
6	1.5	11	6.5	2.2

Table 2-2.4: CBR Test Results in Saturated and Non-Saturated Form



Results of chemical tests done for measuring Sulfate and CL amount in 13 samples are shown in table 2-2.5

Row	BH No.	Depth (m)	Sulfate amount (%)	CL amount (%)
1	3	1	13.5	0.1
2	3	3	2.17	0.47
3	3	5	1.74	0.40
4	3	7	3.07	0.55
5	3	10	3.65	0.58
6	5	1.5	6.30	0.54
7	5	6	2.23	0.47
8	6	0.5	< 0.5	0.20
9	6	1.5	1.21	0.96
10	6	4	< 0.5	0.40
11	6	10	1.27	0.67
12	6	14	0.5	0.86
13	6	18	0.95	0.90

Table 2-2.5: Sulfate and CL amount of the Soil

### 2.3.5 Explanation of the Results and Technical Recommendations

The main results, conclusions and recommendations from the Geotechnical Report are the following:

The structure of subsurface is suitable in resistance matter. Soil cohesion is high in dry conditions. Even though cohesion in table 2-2.2 is around 15 kPa, this result belongs to direct cut test for touched samples. Texture and structure of fine grain soil in the area shows high hardness and rigidity in untouched conditions and cohesion more than 100, even 200 kPa (1 to 2 kg/sqm). SPT tests in the area can give more information about untouched soil cohesion conditions.

Mono-axial and tri-axial tests are not possible in the site due to high roughness of the samples. As written before tests like SPT, plate loading and if possible field direct cut tests give quite useful information about soil rigidity parameters in untouched condition.

A consolidation test is not possible either, due to hardness of samples. But soil status shows consolidate condition (because of aging and cementation) therefore subsidence will not occur.

Usage of untouched sample in permeability test is not possible. Natural density in the field (2.1 kN/m<sup>3</sup>) is more than maximum dry density (17-18 kg/cbm); therefore a lower permeability is expected in the field than the test results, this is quite suitable for landfill construction. This means a minimum thickness can be used for liners, due to low permeability of the bedder.

CL and ML soils of the area have the capability to be used as Clay Liner.

For the next stage of design it is recommended by the Geotechnical Report to excavate more boreholes in different parts of the site. Suitable excavation method is the rotational method with rock bit accompanied by water washing. Touched samples are provided by the core Barrel method. If these samples in such layers get done by experienced excavator with special preparation and scheming, then they will be suitable for mono-axial and tri-axial tests.

The Geotechnical Report also recommends SPT field tests, plate loading, if possible direct cut and permeability tests must also be done in the site. Due to project utilization and needs, this test must be done in different depths.

According to these recommendations and consultations with OWRC the following tests are will be conducted:

No.	Test Description	No of Tests
1	Plate bearing test on surface	32
2	Permeability test in laboratory for soil profile with depth of 30 m	1
3	In situ permeability test in existing borehole with depth of approximately 30 m	2
4	No.2 with leachate and soil which was in contact with leachate (leachate and soil will be delivered to geotechnical LAB.)	2
5	Grain size distribution, Hydrometry, Compaction, EC, Soil analysis, for a mixed specimen from bore hole 5 meter deep	3
6	No. 5 for specimen of 2 m deep bore hole	3
7	No 5 for mixed specimen from 10 meter deep borehole	5
10	Borehole up to the deep ground water (may be in 150 m depth) and taking specimen from deep ground water and shallow ground water. The borehole should serve as water supply well for the entire site	1

**Table 2-2.6: Necessary Tests**

With a better understanding of geotechnical aspects as a result of the new tests, some modifications to the design and the operation should be considered.

## 3 Leachate Generation and Quality

### 3.1 Introduction

Leachate generation and appropriate management is one of the major concerns when designing a landfill. Since there are little reliable data available, estimates were established. In order to give a qualified background to the proposed design, this chapter elaborates the derivation of the estimates based on international experience and locally available material.

### 3.2 Leachate Generation and Quality

#### 3.2.1 Estimation of Leachate Generation

##### 3.2.1.1 Theoretical Background

The water balance of landfills for municipal solid waste (MSW) can be described as follows (see RAMKE, 2001):

$$N - ET_a - S \pm R - A_B - A_O \pm W_B + W_K = 0 \quad (1)$$

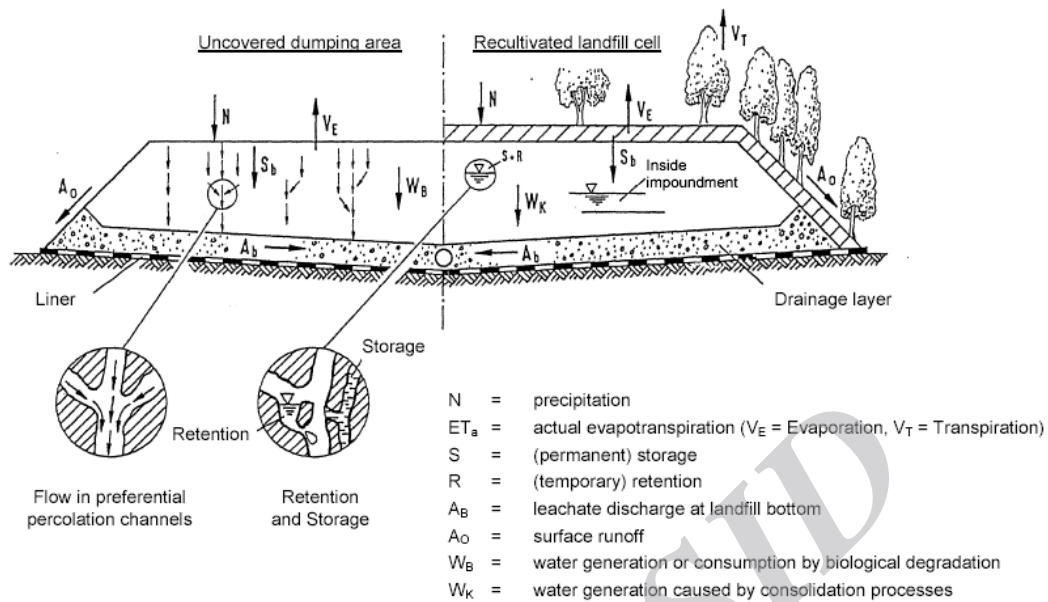
where

- N = precipitation
- ET<sub>a</sub> = actual evapotranspiration
- S = (permanent) storage
- R = (temporary) retention
- A<sub>B</sub> = leachate discharge at landfill bottom
- A<sub>O</sub> = surface runoff
- W<sub>B</sub> = water generation or consumption by biological degradation
- W<sub>K</sub> = water generation caused by consolidation processes

Figure 2-3.1 shows the two important stages during the whole lifetime of a landfill:

- uncovered dumping area
- recultivated landfill cell.

Especially the height of actual evapotranspiration is significantly influenced by the type of surface cover (waste or soil).



**Fig. 2-3.1: Schematic Diagram of Water Balance in a Landfill for MSW**  
(Source: RAMKE, 1991)

Compared to natural soils the water regime of landfills for municipal solid waste shows some important differences:

- The landfill body is a heterogeneous composition of different materials and particle sizes, therefore a uniform description of hydraulic properties of waste is not possible
- the relatively coarse structure of the waste prevents a uniform wetting of the landfill body, which leads to leachate percolation in preferential channels
- during landfill operation the landfill height increases, thus causes an increasing water storage capacity, biological degradation reduces the storage capacity.

These specifics do not really allow to develop a consistent model for the description of the water balance of a landfill and to determine the discharge of leachate in advance.

On the other hand a lot of experience with water balances of landfills have been collected in the Northern Hemisphere during the last two to three decades.

Data based ranges for leachate discharge can be given for landfills in humid areas, and some helpful models have been developed to estimate the most important parameters of the water balance equation which cannot be measured directly and to describe leachate production.

In general two main influences on the water balance of landfills can be distinguished:

- climatic water balance (precipitation – evapotranspiration)

The positive climatic water balance – higher precipitation than evapotranspiration – is the dominant factor for leachate generation in humid climates, other factors are of less importance.

- moisture of waste

Moisture of waste becomes of importance in arid climates. Here very often moisture of waste is very high, and the climatic water balance is negative. Most of the leachate generated or collected at the bottom can be attributed to consolidation processes, pressing the moisture out of the waste.

Other factors of Equation 1 like surface runoff, or water generation or consumption caused by biological processes can be neglected very often. A well operated landfill should not have any surface runoff from dumping areas, and the influence of degradation processes on the water balance is quite low in case of humid climates.

### 3.2.1.2 Connections Between Climatic Water Balance and Leachate Discharge

A detailed model of the correlation of climatic water balance and leachate discharge is – due to the above mentioned reason – not possible, but some general rules – developed for German landfills – might be helpful in arid climates, too:

- annual leachate discharge corresponds to the annual climatic water balance (if it is positive) when storage capacity of the landfill body is exceeded
- in periods of high evapotranspiration especial intensive precipitation will cause leachate generation
- storage and discharge occur simultaneously, before exceeding storage capacity minimum discharge is 10 % of precipitation
- after exceeding storage capacity leachate discharge increases rapidly.

The evaporation from an uncovered dumping area cannot be measured directly, but tests with lysimeters have shown, that the evaporation can be calculated:

- the potential evapotranspiration of an uncovered dumping area for MSW is the same like the potential evapotranspiration for an area with a good stand of grass, but limited to a maximum of 5 mm/d
- the actual evapotranspiration from the waste is limited due to the absence of capillary rise in dumps of waste, empirical measurements have proven a “surface storage capacity” of 20 mm.

For arid climates a method for estimation of the likelihood of leachate discharge has been developed by the Department of Water Affairs and Forestry, Government of South Africa (see RUSHBROOK/PUGH, 1999):

- the climatic water balance (precipitation – evapotranspiration) is calculated for the wet season (6 months) of the wettest year
- this calculation is repeated at least 4 times for the years ranking next
- if the climatic water balance is positive for less than one year in five (for the years for which data are available) there should be no significant leachate generation on account for the climate
- if the climatic water balance is positive for more than one year in five there should be significant leachate generation.

The estimation of leachate production for the Houshang landfill will consider this approach.

### 3.2.1.3 Moisture of Waste and Water Consumption Under Iranian Conditions

The influence of moisture content and water consumption caused by biological degradation under Iranian conditions is described by SAFARI/BARONIAN, 2002. Practical and scientific analyses of observations made at the current landfill of Tehran – the Kahrizak landfill – give valuable advice how the characteristics of the municipal solid waste of Tehran can be considered in the water balance.

The OWRC estimated the leachate quantity to be between 890 m<sup>3</sup>/d (summer) to 930 m<sup>3</sup>/d(winter), by summing up the volume of the leachate collected in certain ponds throughout a year and assuming a uniform distribution (see TEHRAN ZIST CONSULTANT AND COMPANY (2001).

SAFARI/BARONIAN, 2002 used a more elaborated approach and considered the following factors to calculate leachate generation:

- moisture content of waste and moisture holding capacity
- water consumption by gas production
- precipitation and evaporation.

SAFARI/BARONIAN, 2002 calculated the leachate quantity for a single cell with an area of app. 4,000 m<sup>2</sup> and a height of 20 m. Such a cell has a volume sufficient for 10 days of disposal of 6,500 Mg waste per day. The waste density has been estimated on 0.8 Mg/m<sup>3</sup>, the initial moisture content to be at 42 % wet weight.

Considering the decreasing moisture holding capacity (consolidation processes), water consumption by gas production, and neglecting precipitation and evaporation they calculated the leachate quantity in the first 10 days for a single cell between 630 and app. 30 m<sup>3</sup>/day. The resulting average value is 330 m<sup>3</sup>/day or 5 % of the daily quantity of waste delivered to the landfill, which seems to be a quite reasonable value. From day 10 until the end of the first year the cell shows a calculated leachate discharge of app. 7.5 mm/day (30 m<sup>3</sup> per day divided through 4,000 m<sup>2</sup>/cell).

Due to the fact, that every 10 days a new single cell has to be established and filled up, an absolute value of leachate discharge of 330 m<sup>3</sup>/day will be considered, in addition a relative value of 7.5 mm/day for each cell in the whole dumping area over a period of one year should be taken into account for calculations for Houshang landfill.

#### 3.2.1.4 Estimation of Leachate Generation at Houshang Site

The climate in the area of the Houshang Site is very arid. Table 2-3.1 shows the average monthly values of precipitation, evapotranspiration and the resulting monthly budget (climatic water balance).

The data were calculated with the mean values for precipitation and evaporation (pan) of the weather stations Tehran Mehrabad and Qom, using the data for the years 1996 – 2000. The annual sum of precipitation is about 185 mm, the annual sum of evaporation exceeds 2,600 mm.

The climatic water balance for the wet season was calculated for the period November to April, the evaporation values measured with a pan were diminished at 30 % to consider the lower evaporation of soil or waste. The average climatic water balance is negative even in the wet season, using mean values for calculation.

Month	Rainfall R [mm]	Evaporation V <sub>E</sub> [mm]	Monthly Budget R – 0.7 · V <sub>E</sub> [mm]
January	29.2	6.7	24.5
February	25.0	1.0	24.3
March	42.7	1.7	41.5
April	17.6	205.1	- 126.0
May	6.3	361.5	- 246.7
June	2.2	446.7	- 310.5
July	2.0	478.0	- 332.6
August	1.5	439.3	- 306.1
September	1.0	348.4	- 243.0
October	10.0	223.0	- 146.1
November	18.7	100.9	- 51.9
December	30.6	39.4	3.0
<b>Total</b>	<b>186.7</b>	<b>2,651.8</b>	<b>- 1,669.6</b>

Table 2-3.1: Climatic Water Balance for Houshang Landfill

Year	Rainfall R [mm]	Evaporation V <sub>E</sub> [mm]	Waste Evaporation [mm]	Monthly Budget R – 0.7 · V <sub>E</sub> [mm]
1996	249.8	344.5	241.2	8.6
1997	96.4	311.1	217.7	-121.3
1998	166.6	431.3	301.9	-135.3
1999	151.5	355.8	235.1	-83.6
2000	154.2	351.3	245.9	-91.7
<b>Average</b>	<b>163.7</b>	<b>354.8</b>	<b>248.3</b>	<b>- 84.7</b>

Table 2-3.2: Climatic Water Balance of the Wet Season for Houshang Landfill



Using the original monthly sums for calculation, only one year with a positive climatic water balance can be identified [see Table 2-3.2]. In 1996 precipitation in the wet season is app. 10 mm higher than evaporation in this period.

This indicates – according to the explanations in Chapter 1.2.1.2 - that leachate discharge could not be excluded.

This assessment is supported by the data of the daily maximums of precipitation, compiled in Table 2-3.3. Daily maximums of 10 to 15 mm are quite normal in the wet season.

Month	Precipitation Station Mehrabad [mm/d]	Precipitation Station Qom [mm/d]	Average Precipitation [mm/d]
November	7.0	10.7	8.9
December	18.4	11.4	14.9
January	13.4	13.9	13.7
February	11.2	8.0	9.6
March	18.0	11.4	14.7
April	8.2	10.0	9.1
<b>Average</b>	<b>12.7</b>	<b>10.9</b>	<b>11.8</b>

Table 2-3.3: Maximum Daily Precipitation

Considering the limited water storage capacity of waste near the surface (which limits the actual evaporation), and the high moisture of the waste, it seems to be reasonable to assume that these peak events will create leachate, and that this leachate will not be stored in the landfill body, but will become discharge (high moisture of waste).

For dimensioning purposes leachate generation and discharge caused by precipitation is estimated in a range of 30 mm/year, assumed for the non-recultivated dumping area. This is about 50 % of the average sum of peak events in the wet season (35 mm) and app. 20 % of total precipitation in this period (160 mm). After finishing tipping the dumping areas will be covered with a soil layer. This layer will allow more evaporation than the bare waste. Therefore leachate generation after recultivation is estimated to be just 50 % of the above values.

Leachate discharge will be distributed uniformly over the whole year, because retention effects in the landfill body and its low permeability will extend the discharge periods.

In addition to leachate generation and discharge caused by precipitation the influence of moisture of waste has to be considered. The local experience in

Iran with leachate generation caused by wet waste has been explained in Chapter 3.2.1.3. A disposal of app. 6,500 Mg waste per day causes an average leachate generation of 330 m<sup>3</sup>/d during the first ten days, due to consolidation processes. The degradation of organic substances and ongoing consolidation processes can be estimated using the model of SAFARI/BARONIAN, 2002 in a range of 7.5 mm/day for each cell over a period of one year.

In spite the fact, that it was not possible for SAFARI/BARONIAN, 2002 to prove these calculations by on site measurements, these data will be taken for calculations by two reasons:

- the absolute height of leachate quantity calculated is in the range of measurements of OWRC performed at the Kahrizak landfill
- the model considers all relevant processes, takes into account the properties of local municipal solid waste, and leads to reasonable results.

For a rough calculation of leachate generation the following data of one part of a cell shall be assumed, app. sufficient for disposal of municipal solid waste for one year:

- length 265 m
- width 450 m
- area 120,000 m<sup>2</sup>
- max. height 30 m
- aver. height 22 m
- volume 2,640,000 m<sup>3</sup>

This volume is to be compared with the mass of waste delivered annually to the landfill:

- mass of waste 2,500,000 Mg/a
- density after dumping 0.95 Mg/m<sup>3</sup>
- annual necessary volume 2,630,000 m<sup>3</sup>

The mass of waste disposed of on this part of a cell and the height of the landfill body in cell 1 are more or less the same like in Kahrizak, therefore the above explained data for leachate generation and discharge caused by consolidation processes can be taken without any conversion, if the period of operation of one sub-cell is assumed to be in the range of one year (like assumed above).

The data defined in the detailed design (see Chapter 4) differ from these data only as far as the length of one sub-cell and the period of operation is concerned, but this will not influence the results of calculation significantly.

The data used for estimation of the total volume of leachate discharge are compiled in Table 2-3.4; Figure 2-3.2 estimates the resulting annual and daily leachate discharge.

Process	Unit	Height	Duration	Remarks
Precipitation	mm/year	30	first year	open waste
	mm/year	15	after 1 year	recultivated
Consolidation	mm/year	2737.5	first year	
	m <sup>3</sup> /day	330	daily	during tipping

Table 2-3.4: Assumptions for Calculation of Leachate Discharge

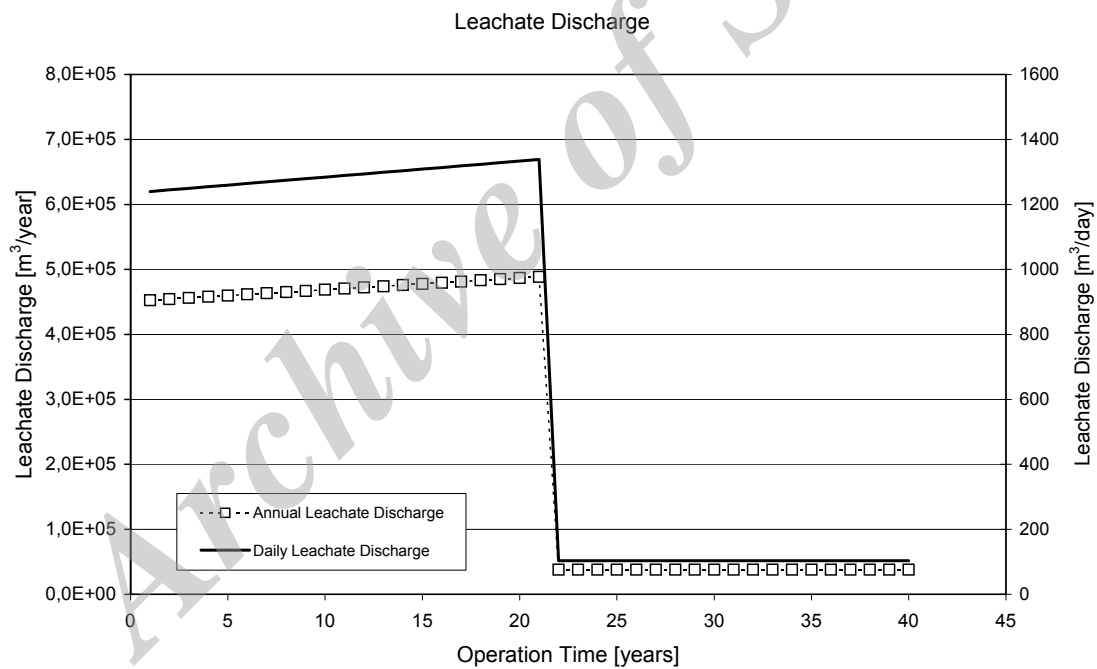


Fig. 2-3.2: Estimated Leachate Generation and Discharge

During operation leachate discharge is in a range of 1200 – 1400 m<sup>3</sup>/day, after finishing dumping in section 1 leachate generation is only caused by precipitation during the wet season and drops down to app. 104 m<sup>3</sup>/day (21 sub-cells in section 1, according to its whole disposal volume, see Table 2-4.4)

Calculating the absolute height of leachate discharge for the second year, we will get:

$$12.0 \text{ ha} \cdot (15 \text{ mm/a Cell 1} + 30 \text{ mm/a Cell 2} + 2737.5 \text{ mm/a Cell 2}) \cdot 10 \text{ m}^3/(\text{mm}\cdot\text{ha}) + 330 \text{ m}^3/\text{d} \cdot 365 = \mathbf{454,350 \text{ m}^3/\text{year} \text{ or } 1,245 \text{ m}^3/\text{day}}$$

A further recalculation shows, that the landfill with a total area of 252 ha (21 cells · 12.0 ha, see Table 2-4.4) and an annual leachate generation of 15 mm after recultivation will have a leachate generation of

$$252 \text{ ha} \cdot 15 \text{ mm/a} \cdot 10 \text{ m}^3/(\text{mm}\cdot\text{ha}) / 365 = \mathbf{104 \text{ m}^3/\text{day}}$$

The calculated loss of moisture caused by consolidation processes in an annual height of 2737 mm seems to be too high – compared with the total quantity of water in a 22 m high waste pile (app. 22 m (height) · 950 kg/m<sup>3</sup> (density) · 0.42 (moisture content) = 8,780 kg water/m<sup>2</sup> [mm]). Furthermore the total leachate volume calculated is 50 % higher than the leachate volume measured at the landfill Kahrizak.

But considering that leachate collection is not possible for the whole leachate quantity at Kahrizak, and assuming a ratio of 30 % of leachate percolating into the subsoil, the leachate volume calculated seems to fit to the data collected at Kahrizak and will be taken as a conservative approach for dimensioning the facilities necessary.

Finally it should be mentioned, that the estimation of leachate generation was only possible by using a couple of assumptions. These assumptions have been necessary both due to the lack of general experience of leachate generation in arid climates and due to the lack of measurements under the climatic conditions and with the type of waste in Iran.

The methodologies used have been developed during the last three decades of sanitary landfilling in the Northern Hemisphere, especial in Germany, have been amended by an approach developed in South Africa and could be focussed to the local situation by the very helpful data collected and the model developed in Tehran.

Therefore the best available methods and data have been used for this estimation, nevertheless additional investigations are recommended for the phase of final design, a stepwise construction of leachate treatment facilities seems to be reasonable, and measurements of leachate generation during landfill operation will be very helpful in future.

### 3.2.2 Estimation of Leachate Composition

#### 3.2.2.1 Development of Leachate Composition Within a Landfill

Leachate and gas composition of landfills for municipal solid waste are a consequence of anaerobic microbiological degradation of organic substances. Figure 2-3.3 describes the idealized development of leachate and gas composition for a homogenous volume of waste.

Five phases of degradation process can be distinguished [see CHRISTENSEN/KJELDEN, 1989]:

- Phase I

This is a short aerobic phase immediately after landfilling the waste, where easily degradable organic matter is aerobically decomposed during carbon dioxide generation.

- Phase II

A first intermediate anaerobic phase develops immediately after the aerobic phase. The activity of the fermentative and also the acetogenic bacteria results in a rapid generation of volatile fatty acids, carbon dioxide and some hydrogen.

The acidic leachate may contain high concentrations of fatty acids, calcium, iron, heavy metals and ammonia. The latter due to hydrolysis and fermentation of proteinoous compounds in particular. The content of nitrogen in the gas is reduced due to the generation of carbon dioxide and hydrogen. The initial high content of sulphate may slowly be reduced as the redox potential drops. The generated sulphide may precipitate iron, manganese and heavy metals that were dissolved in the initial part of this phase.

- Phase III

A second intermediate anaerobic phase will start with slow growth of methanogenic bacteria. The methane concentration in the gas increases, while hydrogen, carbon dioxide and volatile fatty acid concentrations decrease. Also, the sulphate concentration decreases due to continued sulphate reduction. The conversion of the fatty acids results in a pH and alkalinity increase which results in a decreasing solubility of calcium, iron, manganese and heavy metals. The latter are supposedly precipitated as sulphides. Ammonia is still being released and is not converted in the anaerobic environment.

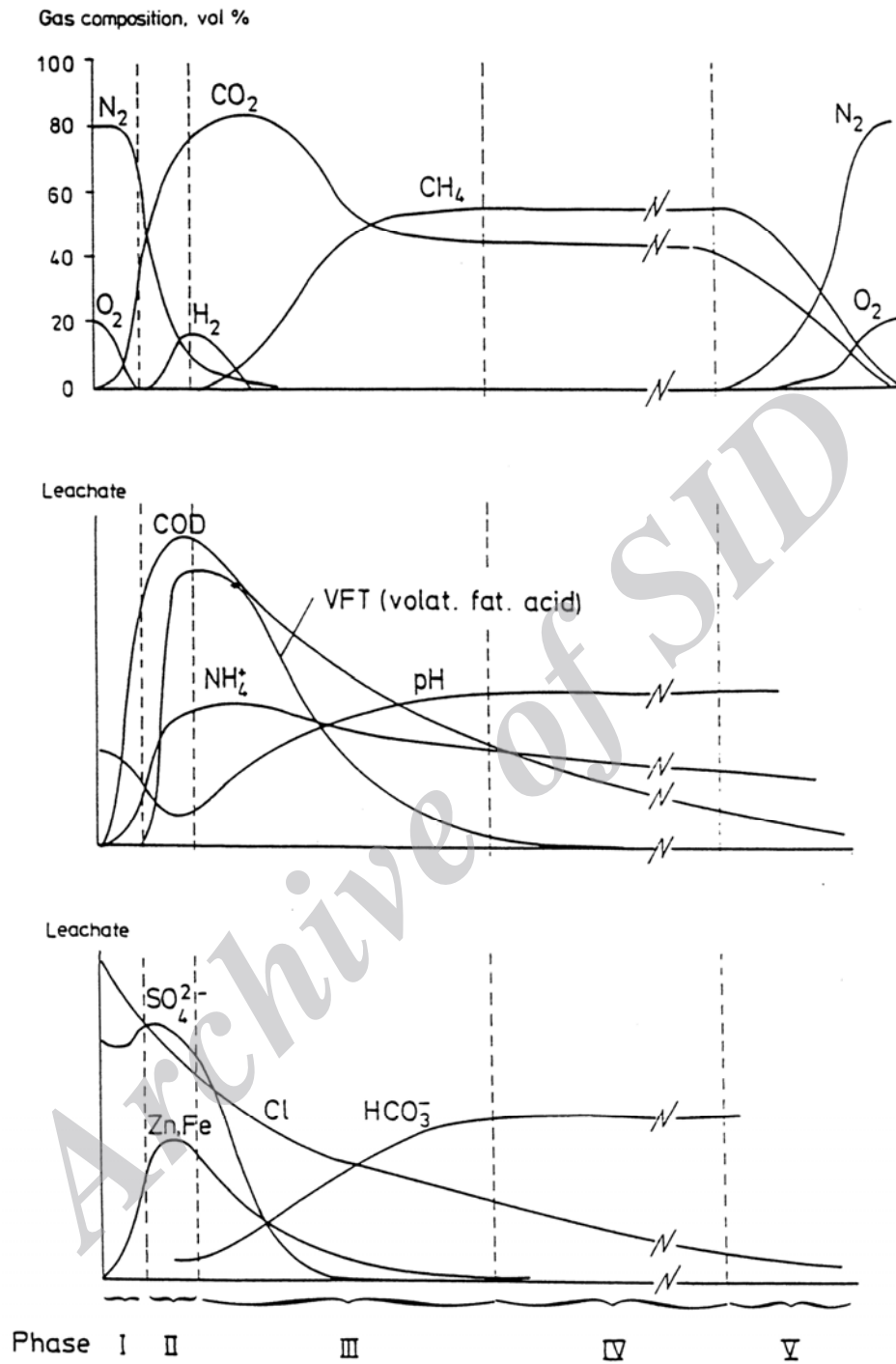


Fig. 2-3.3: Typical Leachate Composition from Landfills with MSW  
 (Source: CHRISTENSEN/KJELDSSEN, 1989)

- Phase IV

The methane phase is characterised by a fairly stable methane production rate resulting in a methane concentration in the gas of 50-65 % by volume. The high rate of methane formation maintains the low concentrations of volatile fatty acids and hydrogen.

- Phase V

Where only the more refractory organic carbon remains in the waste, the methane production rate will be so low that nitrogen will start appearing in the landfill gas again due to diffusion from the atmosphere. Aerobic zones and zones with redox potentials too high for methane formation will appear in the upper layers of the landfill.

In general the acetic phase is characterised by high organics with BOD<sub>5</sub>/COD-ratios > 0.4 and low pH, methane content and gas production. After the transition to the methanogenic phase the methane content and pH are high, but BOD<sub>5</sub>, COD and BOD<sub>5</sub>/COD-ratios are low.

The absolute concentration of leachate constituents and the quantity of landfill gas production depend on the composition of waste, waste pre-treatment and the type of landfill operation.

Both BOD – and COD – concentration are very sensitive to landfill operation (see EHRIG, 1989). Figure 2-3.4 shows the average trend of BOD<sub>5</sub>, which is marked “1”, for landfills built up in 2 m layers with 2 – 4 m per year. A build up of more than 4 m per year (marked “2”) increases the BOD<sub>5</sub> and COD concentrations and delays the change in the microbiological conditions in landfills.

On the other hand a slower build up and the implementation of other enhancement techniques (like mechanical-biological pre-treatment) may decrease the organic contents (marked “3”), with an earlier change to the methanogenic phase.

Besides the absolute values of BOD<sub>5</sub> and COD, the ratio BOD<sub>5</sub>/COD is an important factor. Values greater than 0.4 during the acetic phase indicate a good biodegradability.

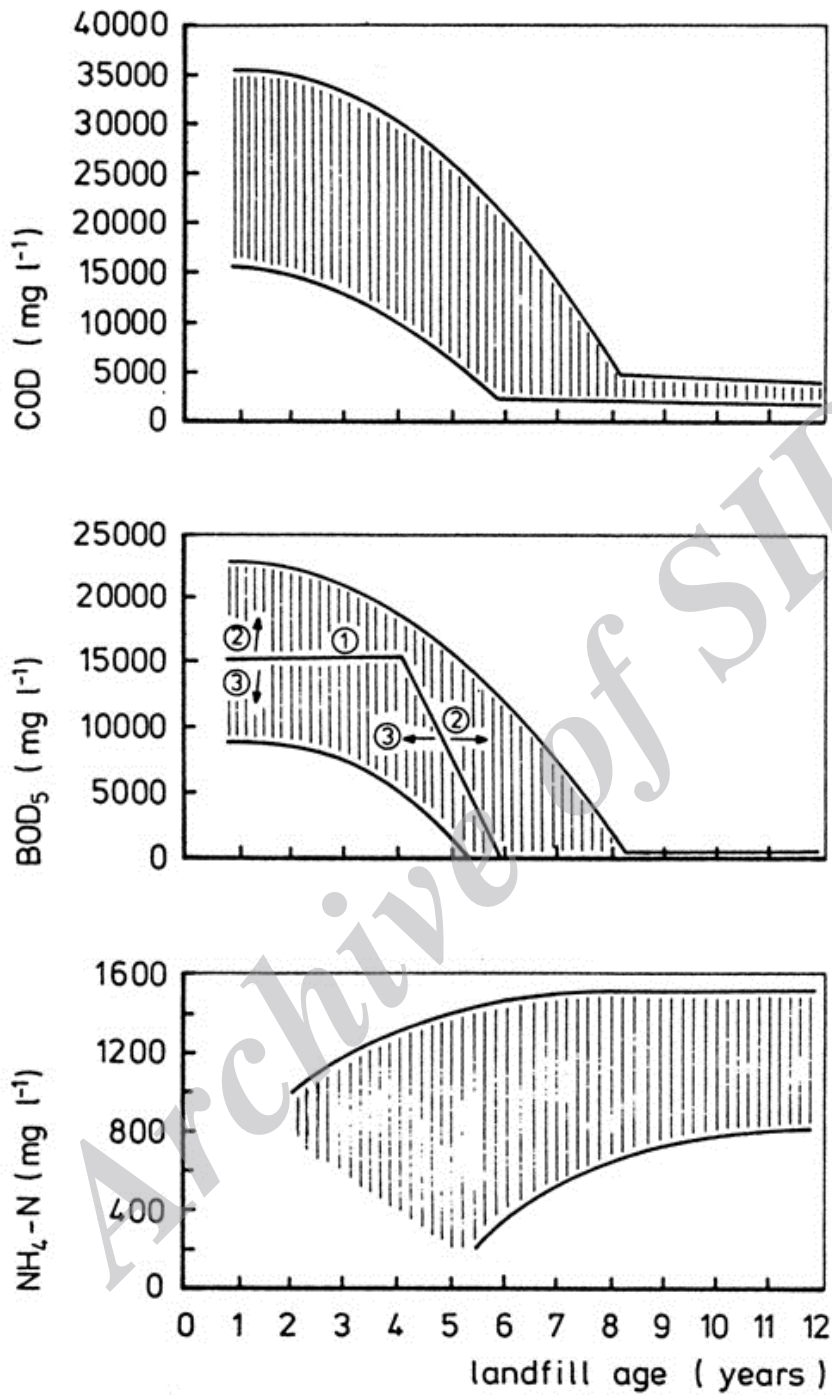


Fig. 2-3.4: General tendencies of COD, BOD<sub>5</sub> and NH<sub>4</sub> versus time (Source: EHRIG, 1989)



### 3.2.2.2 General Experience with Absolute Leachate Concentration

The typical composition of leachate from a MSW landfill is given in Table 2-3.5 for the acetic phase and in Table 2-3.6 for the methanogenic phase for parameters showing differences between these two phases.

Parameter	Unit	Average	Range
pH	[-]	6.1	4.5 – 7.5
BOD <sub>5</sub>	mg/l	13,000	4,000 – 40,000
COD	mg/l	22,000	6,000 – 60,000
BOD <sub>5</sub> /COD	[-]	0.58	-
SO <sub>4</sub>	mg/l	500	70 – 1,750
Calcium	mg/l	1,200	10 – 2,500
Magnesium	mg/l	470	50 – 1,150
Iron	mg/l	780	20 – 2,100
Zinc	mg/l	5	0.1 - 120

Table 2-3.5: Typical Leachate Composition from MSW Landfills in the Acetic Phase (Source: EHRIG, 1989)

Parameter	Unit	Average	Range
pH	[-]	8.0	7.5 – 9.0
BOD <sub>5</sub>	mg/l	180	20 – 550
COD	mg/l	3,000	500 – 4,500
BOD <sub>5</sub> /COD	[-]	0.06	-
SO <sub>4</sub>	mg/l	80	10 – 420
Calcium	mg/l	60	20 – 600
Magnesium	mg/l	180	40 – 350
Iron	mg/l	15	3 – 280
Zinc	mg/l	0.6	0.03 - 4

Table 2-3.6: Typical Leachate Composition from MSW Landfills in the Methanogenic Phase (Source: EHRIG, 1989)

In Table 2-3.7 values for parameters with no differences between the phases of degradation are compiled.

Parameter	Unit	Average	Range
Cl	mg/l	2,100	100 – 5,000
Na	mg/l	1,350	50 – 4,000
K	mg/l	1,100	10 – 2,500
NH <sub>4</sub>	mg N/l	750	30 – 3,000
NO <sub>3</sub>	mg N/l	3	0.1 – 50
AOX	µg Cl/l	2,000	320 – 3,500
Cd	µg/l	6	0.5 – 140
Pb	µg/l	90	8 – 1,020
Hg	µg/l	10	0.2 - 50

**Table 2-3.7: Typical Range of Leachate Constituents Independent from Phase of Degradation**  
(Source: EHRIG, 1989)

Using these data for landfills sited in arid and semi-arid climates it has to be considered, that the range of leachate composition is based on data from wet climate conditions in the Northern Hemisphere. Adequate data are not available (until now) from low and middle income countries.

### 3.2.2.3 Leachate Composition at Kahrizak Landfill

The results of some analyses of leachate of Kahrizak landfill were delivered to the consultant by OWRC (see Table 2-3.8).

Parameter	Unit	Kahrizak-Data Tehran Water-Organisation	Kahrizak-Data Trench Dumping
pH	[-]	6.0	6.0
BOD <sub>5</sub>	mg/l	47,300	43,718
COD	mg/l	66,300	66,741
BOD <sub>5</sub> /COD	[-]	0.71	0.65
NH <sub>4</sub>	mg/l	685	-
PO <sub>4</sub>	mg/l	-	645

**Table 2-3.8: Leachate Composition at Kahrizak Landfill**

Compared to the tables and figures above this compilation of data shows that the leachate of Kahrizak is heavily loaded with organics.

The data are in the very upper range of concentrations measured at other landfills. But the high concentrations of organic constituents can be explained easily considering the following circumstances:

- high content of organic material: 75 %
- low pre-treatment of waste < 5 %
- rapid growth of height: about 20 m/year

Therefore the acetic phase will be very intensive and its duration will be long. The typical result of such a kind of operation is a leachate with a low pH-value and high BOD<sub>5</sub> and COD concentrations, due to the high content of volatile fatty acids.

Apart from this the data measured at the Kahrizak landfill cannot be interpreted in total, because the circumstances of leachate sampling are unknown. It could not be excluded e.g., that leachate has been taken out of the "leachate pond", where the leachate is collected and evaporated, and that an increase of concentrations is caused by the evaporation of water.

Nevertheless this range of concentrations will be taken for the estimation of the leachate of the future Houshang site, because the conditions of operation are comparable.

#### 3.2.2.4 Leachate Composition at Houshang Site

Due to the rapid growth of height and the high ratio of organic material a long and intensive acetic phase is to be expected.

The most important values of leachate composition in this phase might be in these ranges:

- pH ~ 6.0
- BOD<sub>5</sub> 40,000 mg/l
- COD 60,000 mg/l
- BOD<sub>5</sub>/COD 0.67
- NH<sub>4</sub> 1,000 mg/l

The acetic phase is assessed to have a duration of 6 years, before the methanogenic phase with lower leachate concentrations will be achieved.

The values mentioned above for the acetic phase will be used for predimensioning the leachate management and treatment system, because most of the leachate will be generated during the first year of operation of a cell.

Pre-treatment of waste could improve this situation but should be established step-by-step to ensure the suitability of the method chosen.

Finally it is recommended to analyse some leachate samples taken at Kahrizak landfill to get verified data of leachate composition under local conditions.

### **3.2.3 Recommendations on Further Investigations and Tests**

The tests and analyses defined in the following are necessary (or recommended) for the further design process and might especially lead to improved design data in the stage of final design.

For an improved estimation of leachate generation two investigations are useful:

- Consolidation tests with samples of household waste of Tehran, using test cells with a diameter > 50 cm or a transfer-station compactor, to define the relationship between stress, consolidation and water generation;
- Measurements of precipitation and evaporation at the landfill site Houshang Abad to validate the average data used from Tehran and Qom Station.

For purposes of implementation design (leachate treatment) and the EIA more information are required concerning leachate composition.

- Analyses of leachate on sewage parameters like BOD<sub>5</sub>, COD, NH<sub>4</sub>, PO<sub>4</sub>
- Analyses of leachate on heavy metals

The samples of leachate can be taken from the “leachate pond” at the Kahrizak landfill. Sampling at different points and at different times is recommended to ensure a valid overview of leachate composition (these tests are part of the additional landfill test programme).

Beginning landfill operation at the Houshang landfill site further measurements are useful to develop the landfill site according the real requirements:

- Measurements of leachate quantity during operation will show whether further treatment capacities will be necessary
- Analyses of leachate discharge of the first cells will help to optimize the treatment capacities.

## **4 Basic Landfill Design**

### **4.1 Development of the Whole Site – Long-Term Perspectives**

#### **4.1.1 Division of the Site into Different Sections**

The whole site which was foreseen for the development of the landfill has a surface area of approximately 4,000 ha. This size would allow a landfill operation up to 50 years, considering reduced amounts of waste to be disposed of in future.

The whole site was evaluated for its suitability for future extension, while for the medium-term period (up to 15 years) the area in the south-west of the power line and in the north-east of the road Tehran-Qom is given priority.

The whole area was clustered according to the information contained in the topographical map in the scale of 1:50,000 and the information was verified by the utilisation of the available aerial photographs.

The main criteria for the pre-selection of areas for disposal and waste pre-treatment were

- a gentle inclination (< 10%)
- a minimum coherent area of 50 ha
- no major topographic features such as hills or deep erosion channels
- no groundwater table higher than 2 m under surface.

Based on this pre-evaluation, a walk-over survey together with OWRC and the topographical survey team took place on 8<sup>th</sup> of June 2004, and the following areas, which are directly accessible from the road Tehran-Qom, were identified as potentially suitable (see Map M2):

- Section 1: Disposal area, first stage of operation,  
in the north of the road Tehran - Qom
- Section 2: Disposal area, second stage of operation,  
in southern direction of Section 1, separated by the road
- Section 3: Disposal area, third stage of operation,  
in eastern direction, app. 1 km closer to Tehran.

The conditions are similar in all the sections. In each section a 15 year lifetime for waste disposal activities should be possible.

Include Map F 2

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In addition to the disposal areas a pre-treatment area has been defined. The pre-treatment area is sited in the south-west of section 1. Its shape is not very suitable for waste disposal, but is ideal for mechanical-biological pre-treatment of waste. Its neighborhood to the sections 1 and 2 will ensure short transport distances of the waste material pre-treated.

Table 2-4.1 gives an overview of the size and the disposal volume estimated for the different sections.

Section	Size	Disposal Volume
Section 1	370 ha	56,100,000 m <sup>3</sup>
Section 2	209 ha	31,700,000 m <sup>3</sup>
Section 3	227 ha	34,400,000 m <sup>3</sup>
Pre-Treatment Area	135 ha	-

**Table 2-4.1: Size and Gross Disposal Volume of the Different Sections**

The disposal volumes of sections 2 and 3 have been calculated by using the exactly determined size/volume-ratio of section 1 (see below).

#### **4.1.2 Concept of Site Development**

The following principles can be defined for the development of the Houshang site and its sections I, II, and III:

- use of the main installations in the entrance area of section 1 in all phases of development of Houshang site
- use of the installations for leachate and landfill gas treatment in section 1 in all phases of development of Houshang site as far as possible
- minimisation of traffic conflicts between the waste transporters and the normal traffic on the road Tehran - Qom
- direct connection of the pre-treatment area to the disposal areas of section 1 and 2 in order to use special transport vehicles like dumpers.

The main installations of the entrance area of section 1, which can be used at all stages of operation, are listed in Table 2-4.2 and will be described more in detail in Chapter 10.

The estimated net usable area is based on experience with similar sites and assumptions on the requirements in future.



Type of Building/Facility	Specification	Estimated Net Usable Area
Official Buildings	Administration Building	300 m <sup>2</sup>
	Laboratory	120 m <sup>2</sup>
Social Buildings	Staff Building (changing of clothes, dormitory)	300 m <sup>2</sup>
	Canteen Building	120 m <sup>2</sup>
Workshops and Garages	Open Shelter (for vehicles, open)	600 m <sup>2</sup>
	Workshop	420 m <sup>2</sup>
	Storage Building	240 m <sup>2</sup>
Operation Facilities	Fire Station (two trucks for fire fighting)	60 m <sup>2</sup>
	Fuel Station (on additional truck for on-site supply)	60 m <sup>2</sup>
Supply Facilities	Power Station (Transformer)	(60 m <sup>2</sup> )
	Water Storage Tank	(120 m <sup>2</sup> )
	Sewage Water Tank	(120 m <sup>2</sup> )

**Table 2-4.2: Overview of Buildings and Facilities in the Entrance Area**

Some other installations have to be replaced in each phase of operation:

- weigh bridge and control building
- garage/workshop for dozers and compactors
- tire washing facilities.

In addition to the use of the buildings and facilities belonging to the entrance area, the advantages (no large investments) and disadvantages (pipes, pumping costs) of the further usage of emission treatment facilities should be considered.

The main installations worth to be used for operation other the sections are

- ponds for anaerobic and aerobic pre-treatment of leachate
- evaporation ponds
- compressor station for landfill gas extraction
- flare/torch for landfill gas incineration.

Especially the place chosen for leachate management in section 1 could be easily used for disposal of leachate generated in the other sections (see Chapter 4.2).

#### 4.1.3 Analyses of Traffic Flow

The analyses of traffic flow has to consider the different stages of development of the site:

- Stage 1: operation of section 1
- Stage 2: operation of section 2
- Stage 3: operation of section 3

In all three stages the operation of the pre-treatment area has to be considered.

The analyses of traffic flow is shown in Table 2-4.3. The most important traffic is the delivery of waste from Tehran and the return journey. Of medium importance is the delivery of waste to the pre-treatment area and the return flow connected as well as the transport of waste pre-treated from the pre-treatment area to the disposal area. Of minor importance in any case is the flow from and to the South (direction Qom).

Importance	Purpose of Traffic	Source	Destination
High	Waste Disposal Return Journey	Tehran Landfill, Section 1-3	Landfill, Section 1 - 3 Tehran
Medium	Waste Treatment Return Journey	Tehran Pre-Treatment Area	Pre-Treatment Area Tehran
	Waste Disposal Return Journey	Pre-Treatment Area Landfill, Section 1 - 3	Landfill, Section 1 - 3 Pre-Treatment Area
Low	Waste Disposal Return Journey	Qom Landfill, Section 1-3	Landfill, Section 1 - 3 Qom
	Waste Treatment Return Journey	Qom Pre-Treatment Area	Pre-Treatment Area Qom

Table 2-4.3: Analyses of Traffic Flow

Calculating with an average daily waste generation of 7,000 tons/day and an average payload of 20 tons/truck there will be 350 trips per day from Tehran to the disposal sites including pre-treatment. This number has to be reduced by the number of trips directed to pre-treatment, but direct delivery of commercial waste with trucks, which is assumed to increase in future, should be considered.

Assuming a ratio of 2,000 tons/day of waste which is pre-treated, the medium traffic can be assessed in a range of 60 - 100 trips per purpose/direction/day. Only a few number of trucks will enter the landfill from the south.

#### 4.1.4 General Traffic Concept for the Houshang Site

The design of the access of the landfill site to the road Tehran – Qom and of the internal road net has to consider the different importance of directions as well as the different stages of operation.

In order to avoid accidents on the road Tehran – Qom between the waste trucks and the normal traffic, the most risky turning and crossing left of the waste trucks should be avoided. Therefore an underpass of the main road is recommended for the traffic flow of high importance (from and to Tehran).

Drawing F 1 presents the whole traffic concept for all the stages:

Stage 1:

- the traffic coming from Tehran is entering section 1 using a right-hand turn lane to leave the main road and a ramp to enter section 1
- the traffic to the pre-treatment area has to take the left-hand turn lane inside the section and follows an independent internal road
- the return trip traffic underpasses the main road and follows a loop to enter the road to Tehran
- the traffic from Qom uses the loop to enter the site and to underpass the main road, the return trip traffic uses a ramp.

Stage 2:

- a second loop is installed mirror-image to the first one for the traffic coming from Tehran with destination section 2
- the traffic coming from Tehran is entering the northern loop on a right-hand turn lane on the main road
- the return trip to Tehran uses an enlarged ramp in section 2
- the traffic from Qom to section 2 uses a short ramp from the main road into the section, the return trip traffic uses a lane connected to the internal road in section 1 to the pre-treatment area.

Stage 3:

- for the access to section three the concept for the stage 1 has to be repeated, if no internal lane will be constructed (this is not recommended because of the high investment costs).

Details of dimensions of the access and internal roads are given in Chapter 4.2.3.

## 4.2 Development of Section 1

### 4.2.1 Division of Section 1 into Different Cells

Map M3 gives an overview of section 1. The section is clearly defined in the north-east by a high-voltage line, in the south-east by the road Tehran – Qom, and limited by hilly areas in the south and in the western parts.

The pretreatment area is located about 1 kilometer into western direction nearby the Tehran - Qom road.

The area has a total size of about 370 ha. Inside this area all landfill cells, facilities, and infrastructure has to be positioned.

The division of section 1 into different cells follows some basic principles of landfill design:

- the disposal area should be adequate plain to avoid large extensive earthworks
- the disposal area should have a gentle slope which can be used for discharging the leachate
- maximum width of one landfill cell is about 400 – 500 m to ensure flushing of the drain pipes
- leachate treatment facilities and surface runoff catchment ponds have to be located at the lowest altitude to avoid pumping.

Analysing the direction of inclination of the site in detail, some further conditions become clear:

- the landfill bodies should be directed from west to east (southeast), to ensure enough inclination for ditches and leachate collection pipes outside the landfill cells
- inside a landfill cell sometimes it will be necessary to place the drain pipes for leachate collection in an angle of 60° instead of 90° to the baseline in order to ensure sufficient longitudinal slope.

The maximum width of a landfill cell has been defined to be 450 m (between the inner feet of bottom dams), which results in a maximum length of the drainpipes of 500 m.

This allows flushing of the drain pipes without special equipment, if the access to the drain pipes by two sides is ensured (then flushing tubes and nozzles can be pulled into the pipes).

Include Map F 3

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Eleven ideas of section division are compiled in Annex 5 to show the potentials of site development in general. In all the alternatives the entrance area and areas for treatment of waste are sited in the neighborhood of the road in front of the disposal areas. The leachate treatment area is located at the lowest point of elevation in the south-eastern edge of the site.

Considering the above mentioned general and site related principles of landfill design the first and the both last alternatives fulfill all the requirements, allow a straight development of the site, and guarantee a sufficient relation between disposal volume and investment costs.

Two different alternatives (the first and the last one of Annex 5) have been developed more in detail:

- Alternative 1 (Drawing F 2)

The whole section is divided into two disposal areas, following the northern and the southern borderlines of the section. Each of the two large disposal areas is divided into 2 cells.

The general orientation of the landfill bodies are from west to east, following the general inclination of the site. The area between the two landfill bodies can be used for the evaporation ponds.

This alternative has a good volume/size-ratio and allows the placement of additional facilities between the two landfill bodies.

- Alternative 2 (Drawing F 3)

The section is divided into three disposal areas. The southern disposal area is identical to the southern disposal area of alternative 1, but the northern part of the section is covered with two landfill bodies, whose northern borders follow the borderline of the section.

The approach of alternative 2 is – in distinction to alternative 1 - to make maximum use of the area available for disposal purposes. As a consequence the area for evaporation ponds cannot be found inside section 1.

The volume/size-ratio of alternative 2 is the same like alternative 1, but less space is available in the middle of section 1.

Table 2-4.4 shows the size and the volumes of all cells in section 1 for the two alternatives.

The gross disposal volume of alternative 2 is app. 11 % or 5,700,000 m<sup>3</sup> higher than the volume of alternative 1. The volume/size-ratio – which means the average height of the landfill – is about 22 (m) in both cases (22.0 – 22.2 (m)).

The volumes have been calculated using the following assumptions:

- the borderlines of the cells are showing the inner foot of the bottom dam of the landfill body
- average height of the landfill bodies: 30 m
- inclination of slopes: 1 : 3
- horizontal width of slopes: 90 m

Cell	Alternative 1		Alternative 2	
	Size	Volume	Size	Volume
Cell 1	591,000 m <sup>2</sup>	13,100,000 m <sup>3</sup>	591,000 m <sup>2</sup>	13,100,000 m <sup>3</sup>
Cell 2	469,000 m <sup>2</sup>	10,100,000 m <sup>3</sup>	507,000 m <sup>2</sup>	11,600,000 m <sup>3</sup>
Cell 3	664,000 m <sup>2</sup>	14,600,000 m <sup>3</sup>	669,000 m <sup>2</sup>	17,300,000 m <sup>3</sup>
Cell 4	547,000 m <sup>2</sup>	12,600,000 m <sup>3</sup>	788,000 m <sup>2</sup>	14,100,000 m <sup>3</sup>
Total	2,271,000 m <sup>2</sup>	<b>50,400,000 m<sup>3</sup></b>	2,555,000 m <sup>2</sup>	<b>56,100,000 m<sup>3</sup></b>

Table 2-4.4: Size and Gross Disposal Volume of the Cells in Section 1

The volume of the first landfill cell of approx. 13.1 million m<sup>3</sup> will be sufficient for at least the first 4 years of operation by using the following assumptions:

- average waste generation of 2.5 million tons/year
- average waste density to achieve after compaction 0.95 ton/m<sup>3</sup>
- net volume app. 80 % of the whole disposal volume

The density after compaction of 0.95 tons/m<sup>3</sup> can easily be obtained by proper operational methods and in particularly by the use of adapted compaction equipment. The difference between net and gross disposal volume is caused by the necessary volume for bottom dams and cover of waste with earth.

In the following alternative 2 will be developed more in detail, because OWRC decides to make maximum use of section 1 as far as possible.

Apart from this the design of alternative 2 can be used with slight modifications to establish alternative 1, if operation experience and development of waste generation shows alternative 1 to be the preferable one.

The basic assumptions concerning the development of landfill cells are compiled in the following Chapter 4.3, the assumptions concerning the final of the landfill are compiled in Chapter 7.



#### 4.2.2 Development and Infrastructure of Section 1

Drawing F 4 shows the cell layout and the traffic concept for section 1 in detail. The following information are given in this drawing:

- boundaries of the cells
- drainage areas and direction of slope of drain pipes
- access roads and internal roads
- surface water collection and discharge
- entrance area and treatment areas
- green belts and green areas.

The boundaries of the cells are defined by the inner foot of the border dams, which wall every landfill body. The streets at the foot of landfill bottom are shown in the resulting distances (details will described below). The southern boundaries of cell 1 and 2 follow the southern boundaries of the section, which are related to the begin of a very hilly area. The same situation can be faced for the north-western borderline of cell 3, while the north-eastern borderlines of the cells 3 and 4 are defined by the power line.

The maximum width of cells results from the drainage length, which is limited to 450 m between the inner feet of the bottom dams, and a maximum distance between the manholes of about 480 m. The width measured rectangular to the baseline of a cell is between 450 m in case of a drain slope rectangular to the baseline, too, and 390 m in case of an angle of 60° (30°) between the baseline and the drain pipes. A diagonal direction of the drain pipes is necessary if the natural slope in rectangular direction is not enough to meet the minimum inclination of 1 %. Between two landfill bodies a distance of 90 m – measured between the borderlines - is recommended, to have sufficient space for the perimeter dams, roads, and by landscape planing reasons.

#### 4.2.3 Traffic Concept of Section 1

Three different types of roads can be distinguished:

- Class 1: Access road  
link between the main road Tehran – Qom and the section
- Class 2: Internal transport road  
transport of waste inside the section, much traffic
- Class 3: Internal maintenance road  
for maintenance purposes only, little traffic

According to the traffic volume the three classes of roads have different widths and structures. Drawing F 5 shows standard sections of landfill roads. The dimensions of the roads have been chosen in accordance with the Iranian *Guideline for Geometrical Design of Roads* (Iranian MPO, 1996).

The internal traffic concepts has the following structure:

- the section is connected to the main road Tehran – Qom in the south-east
- here in stage 1 the underpass and two ramps are sited, in stage 2 a second loop is erected
- the internal “main road” (in prolongation of the underpass) accesses the whole section
- to the right of the internal “main road” the entrance area (with buildings for administration, social purposes and vehicle maintenance) is sited, to the left, just behind the end of the ramps, the link node to the pre-treatment area is placed
- the waste is transported in the north of cell 1 and 2, in the middle between cell three and four, and in the south of cell 4
- at the begin of operation of cell 3 a temporary internal transport road will be constructed on the area of cell 4, to connect the internal transport road in the south of cell 3 with the transport road in the north of cell 1
- when construction of cell 4 begins, the western part of cell three will be directly connected to the transport road in the north of cell 1 with a temporary road, too
- the eastern and central part of cell four will be accessed by an own transport road, the western part, which is quite small, will be served by the transport road in the north of cell 1
- after operation the internal transport roads will be used as maintenance roads like the perimeter roads in the south of cell 1 and 2 and the north of cell 3 and 4
- weigh bridge and control station are placed behind the access to the administration and workshop area and the link node to the pre-treatment area.

The access roads (for stage 1) and the southern part of the internal roads will be erected from the beginning, the transport roads and the maintenance roads will be extended with the ongoing process of site utilisation.

#### 4.2.4 Surface Water Collection and Discharge

Surface water collection and discharge can be subdivided into two different tasks:

- collection and discharge of surface runoff coming from outside the landfill (to prevent a flow into the disposal area)
- collection and discharge of surface runoff from the landfill bodies.

The intrusion of non-contaminated surface water (esp. surface runoff of rain water) can be prevented by means of peripheral dams and collecting ditches or intercepting drains. The non-contaminated surface water has to be discharged into the next receiving ditch, stream or river. Contaminated surface runoff has to be discharged into the leachate treatment plant.

Map M4 shows the catchment areas in up-stream of the site:

- Northern catchment area:

This catchment area is stretched from distant west side of section 1 to the northern part of it and then extended to the eastern part. This area is the most extensive area among all.

- Middle catchment area:

This area is placed in the south of the northern catchment area. The area consists of two main parts: the outer part and the section 1 itself (inner part). Some erosion channels meet in this catchment area.

- Southern catchment area:

This basin is placed at the southern boundary of section 1 between the section 1 and the southern hills.

Especially the erosion channels, shown in Map M4, give valuable advice on the direction of surface water flow.

Nevertheless it should be emphasized here, that an intensive hydrological survey is recommended before landfill construction.

Table 2-4.5 shows the related properties of each catchment area in addition to its concentration time, related precipitation and the resulting discharge.

Include Map F 4

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Catchment Area	Size of Catchment Area	Length of Catchment Area	Difference of Elevation	Concentration Time	Intensity of Precipitation	Run-off coefficient	Discharge
		L	H	T <sub>c</sub>	i	C	Q
	ha	m	m	hours	mm/hour	[-]	m <sup>3</sup> /s
1	827	7740	120	1.597	7.5	0.3	5.2
2	459	5819	110	1.188	8.0	0.3	3.1
3	82	3253	75	0.703	9.0	0.3	0.6

**Table 2-4.5: Properties of Catchment Areas in Section 1**

The time of concentration has been calculated using KIRPITCH formula (see RAGUNATH, 1991):

$$T_c = .949 \left( \frac{L^3}{H} \right)^{0.385}$$

with

T<sub>c</sub> = Concentration Time

L = Length of the water movement in basin

H = Attitude difference between lowest and highest point of the basin

For calculation of the precipitation (intensity) IDF curves (Intensity Duration Frequency) were used, which are introduced by VAZIRI ET AL., 1990 for different parts of IRAN using the concentration times calculated before.

After computation of precipitation intensity a rational method was used to predict the maximum discharge with following formula (see RAGUNATH, 1991):

$$Q = \frac{1}{36} C \cdot i \cdot A$$

with

Q = Discharge

C = Run-off Coefficient

i = Intensity of Precipitation

A = Size of Catchment Area

The complete system of surface water collection, discharge, and installation to protect against storm water consists of the following elements (overview see Drawing F 4, details see Drawing F 9):

- Outer peripheral ditches

Outer peripheral ditches around all the boundaries of section 1 and at the foot of each landfill cell will collect surface run-off from the areas outside section 1 and from outside of the disposal areas (non-used areas inside the section)

- Peripheral dam and ring road

Every landfill body (cell 1+2, cell 3, cell 4) is surrounded by a ring road for waste transport, control and maintenance purposes, which is placed on a peripheral dam. This peripheral dam prevents the site from being flooded by surface runoff (storm water) and separates the outer ditch from the inner ditch.

- Inner peripheral ditches

The inner peripheral ditches collect surface runoff from the landfill bodies and from the ring roads as well. This surface runoff can be polluted, therefore a separation of outer and inner ditches is necessary.

- Main drainage channel

The main drainage channel of the whole site, which is collecting the surface runoff from the middle catchment area, is conducted in the middle of the site at the northern foot of cell 1 and 2. This channel is combined with the outer peripheral ditch of these cells.

Five types of ditches can be distinguished in section 1.(see Map F 4).

The MANNING formula is used to calculate the capacity of each ditch (VEN TE CHOW, 1964):

$$Q = \frac{1}{n} \cdot A \cdot R^{\frac{2}{3}} \cdot S^{\frac{1}{2}}$$

Q = Discharge

n = Manning Coefficient

R = Hydraulic Radius

S = Slope of Channel

In Table 2-4.6 discharges and resulting properties of the ditches are shown, using the natural slope without considering any grading.

Ditch	Discharge	Slope	Bottom Width	Depth	Side Slopes
	m <sup>3</sup> /s	[-]	m	m	[-]
1	0.615	0.008	0.5	0.5	1:1.5
2.1	2.020	0.005	1.0	0.7	1:1.5
2.2	3.060	0.015	1.0	0.7	1:1.5
3	1.100	0.010	1.0	0.5	1:1.5
4	1.100	0.005	1.0	0.6	1:1.5
5	5.170	0.010	1.0	1.0	1:1.5

**Table 2-4.6: Properties of Outer and Inner Ditches in Section 1**

The channels proposed have a trapezoid shape with a side slope of 1:1.5. The outer ditches should be constructed by excavation and cement-lime stabilization, the inner ditches could be sealed with loam or clay. In areas with low natural inclination a minimum slope of 0.5 % is proposed.

The outer peripheral ditches will have in general a depth of 1 m, which ensures together with the peripheral dams a barrier with a height of 2 m to prevent flooding of the section. The calculation shows, that this depth – in combination with a slope of 1 % - meets all requirements on discharge capacity.

The inner peripheral ditches must have a sufficient cross section, too. A depth of at least 0.50 m and a bottom width of 0.50 m is chosen. The total width of the ditch results at top in 2.00 m. The inclination should not be less than 0.5 %.

The system has to be maintained at least once a year. It is also recommended, to control the water quality once a year (chemical analyses).

The surface runoff will be discharged into section 2 in the first stage of landfill operation. The outer and inner peripheral ditches will be merged at the foot of cell three. The outlet channel for the non-polluted surface runoff is connected to a surface water pond, the inner perimeter ditches will be lead through an intermediate storage basin, which can be connected to the leachate treatment ponds.

The surface water pond serves as fire extinction and industrial water reservoir and should have a capacity of 500 m<sup>3</sup> at minimum (depth 4 m), the intermediate storage basin, which is also to be used as sludge sedimentation basin, should have a capacity of 1,000 m<sup>3</sup> (depth 1 m). Both ponds should be sealed. The surface water pond should be sealed with a geomembrane liner, the intermediate storage basin with a clay or loam liner.

#### 4.2.5 Entrance Area and Treatment Areas

The entrance area and the treatment areas are sited in front of cell 1 and 4 in the south-eastern part of section 1. This part is directly sited at the main road – access to the entrance area and the waste treatment areas – and shows also the lowest altitude in section 1 – important for the placement of the leachate treatment facilities.

Details of the entrance area and the treatment areas are described in the Chapters 7 (leachate treatment), 8 (gas treatment) and 10 (entrance area). Drawing F 15 shows details of the entrance area and the leachate treatment area.

The border between section 1 and the main road is formed by a green belt of tamarisks, other bushes and little trees, which are adapted to the climate.

The different functional areas in the east of section one show the following characteristics:

- Entrance area

In front of the entrance area parking places are sited. The entrance area is separated into an administrative part, a part for social purposes, and a workshop area. The entrance area is embedded into a green space, which is important for the social acceptance and the welfare of the employees.

- Leachate treatment area

The leachate treatment area – the treatment ponds and evaporation lagoons - is separated of the main road and of the entrance area by a dam with a height of 3 m, an inclination of the slopes of 1 : 2, and a resulting width of the bottom of 14 m. This dam ensures, that the employees and the road users will not be interfered with the sight and the emissions of the leachate treatment area.

- Gas treatment area

The gas treatment is sited at the front of cell 1, which will be under operation in section 1 first. Choosing this place a short distance for gas collection pipes is ensured as well as their continuous slope, which supports the discharge of condensation.

- Contingency area

The contingency area is reserved for future waste treatment facilities like sorting plants. The contingency area guarantees, that the Houshang site has the spatial capacity to develop to a center of waste management.



#### 4.2.6 Green Belt and Green Area

Drawing 6.1 shows the green belt, which separates the landfill from the main road Tehran – Qom, and the green area, which surrounds the entrance area.

The green belt provides the direct view from the main road to the landfill area, improves the general impression and prevents erosion next to the main and the access road.

The area of the green belt has a size of about 3,500 m<sup>2</sup>, its width is 3.0 m. Three types of shrubs and three types of trees have been chosen:

- trees: *Eucalyptus camaldulensis*, *Fraxinus pendula*, *Tamarix aphylla*
- shrubs: *Atriplex leuoclada*, *Artemisia Escobar*, *Pennisetum orientale*

These types are all resistant to the landfill climate, have all low need for irrigation, and will cover the site properly. For plantation a hole has to be dug and filled with suitable soil for vegetation. This soil can be e.g. be a mixture of 1/3 compost and 2/3 clay and loam. The dimensions of the hole depend of the type of plant. For trees in general a hole with the dimensions 1.0 · 1.0 · 1.0 m is necessary, for shrubs 0.80 · 0.80 · 0.80 m are recommended.

In the green area which surrounds the entrance area (about 45,000 m<sup>2</sup>) the same plants are used like in the green belt. In addition *Fraxinus pendula* is recommended. Figure 2-4.1 shows the *Atriplex leuoclada*.



Figure 2-4.1: *Atriplex leuoclada*.

## 4.3 Development of Cell 1

### 4.3.1 General Principles of Design

The main principles of cells layout to be concerned at the design of cell 1 are resulting from the requirements on leachate and surface runoff drainage and on minimisation of earth works:

- maximum drainage length 450 m (between the inner feet of the dams)
- minimum slope of leachate drain pipes  $\geq 1\%$
- manholes at the front and the back of every manhole
- no angles in the drain pipes between two manholes
- slope of the peripheral ditches and leachate collection pipes  $\geq 0.5\%$
- compensation of cuts and fills.

The requirements derived by the leachate collection system will be justified in Chapter 7.

The base of the landfill has to be graded in such a manner, that a relative optimum can be achieved.

The possible shape of the landfill bodies follows some main principles, too:

- maximum height of the landfill at the top of the slope 30 m
- slope stability of landfills body
- suitable arrangements of temporary and permanent roads.

The height of the landfill (at the top of the slopes) was defined under consideration of reasonable stresses at the landfill bottom and in coordination with OWRC.

Choosing the adequate inclination of the slopes of the landfill body, the specific circumstances of the Houshang site and the properties of waste to be disposed of have to be taken into account:

- the site is placed in an area which has a high risk of earthquakes
- the high moisture of the waste can cause a saturated landfill body.

By these reasons, which both have a negative influence on the slope failure safety, the inclination of the slopes was chosen at 1 : 3. This slope also guarantees a problem-free covering of the landfill.

Drawing F 7 presents the groundplan of cell 1 in detail with its sub-cells, the drain pipes and the roads, Drawing F 8 shows schematic sections of cell 1 from bottom to top.

#### 4.3.2 Division of Cell 1 into Sub-Cells

Cell 1 in section 1 has the following dimensions:

- width: from 390 to 450 m
- length: 1440 m

All data are measured between the inner feet of the bottom dams.

Cell 1 can be divided into four sub-cells. In average each of these sub-cells has a volume which is sufficient for the disposal of waste of the City of Tehran over a period of one year.

The division of a cell into sub-cells allows a stepwise construction of the whole cell, which is minimising the problems of construction and maintenance of very large landfill areas. The distribution of cell 1 into sub-cells is shown in Drawing F 7. The cells are separated from each other by temporary dams.

All the cells will be developed consecutively according to the need starting in the south-eastern corner of the designated area. The construction should begin one year before operation is necessary. Drawing F 8 shows in the longitudinal section the stepwise development of the sub-cells

Due to the fact, that each sub-cell cannot be filled in total (the slopes at the back of the sub-cells have an intermediate slope of 1 : 3) in its first stage of operation, the differences in the volumes at the different stages of operation have to be considered.

The disposal volume shown in Table 2-4.7 for the first stage of operation is the whole volume, which can be used in the actual stage including fillings of slopes of neighbored sub-cells. The volume for the final stage of disposal considers “vertical” boundaries between two landfill cells, e.g. between cell 1 and 2.

Cell		First Stage of Operation	Final Stage of Disposal
	Size	Volume	Volume
Sub-Cell 1.1	152,000 m <sup>2</sup>	2,730,000 m <sup>3</sup>	3,170,000 m <sup>3</sup>
Sub-Cell 1.2	147,000 m <sup>2</sup>	3,360,000 m <sup>3</sup>	3,300,000 m <sup>3</sup>
Sub-Cell 1.3	147,000 m <sup>2</sup>	3,340,000 m <sup>3</sup>	3,330,000 m <sup>3</sup>
Sub-Cell 1.4	145,000 m <sup>2</sup>	3,300,000 m <sup>3</sup>	3,300,000 m <sup>3</sup>
Total	591,000 m <sup>2</sup>	12,730,000 m <sup>3</sup>	13,100,000 m <sup>3</sup>

Table 2-4.7: Size and Gross Disposal Volume of the Sub-Cells in Cell 1

#### 4.3.3 Requirements on the Base of the Landfill

The base of the landfill (plane) has to be prepared before the bottom liner system can be installed. In general the base has to be smooth and of homogenous bearing capacity.

Before carrying out the works, an up-to date state of the area should be recorded, e.g. the ratio of areas with vegetation or erosion channels. Furthermore the results of the field tests should be considered, especially as far as the bearing capacity is concerned, and a walk-over survey is recommended to estimate areas to be treated specifically..

The following measures are necessary for the preparation of the plane (see also SAVAGE ET AL., 1998):

- Clearing and grubbing

Clearing involves the removal of brush and vines, and other matters such as boulders or refuse. Grubbing involves the removal of tree stumps and roots to a depth of 15 to 50 cm. In Houshang this will be partially needed.

- Earth excavation and stockpiling

The excavated material generally can be used in construction and subsequent operation of the landfill. Especially the loamy, clay soil on the Houshang site is an excellent material for different purposes. The different materials which will be excavated have to be stockpiled separately before use. Drawing F7 gives an overview of the base preparation level while Chapter 12 specifies quantities.

- Grading

Preparatory grading is the process of contouring the land to create the required base gradients for the landfill once the process of clearing, grubbing, and bulk excavation of earth material have been completed. Drawing F10 and F11 show the sections.

- Compaction

The base (plane) shall be compacted to achieve a suitable density and bearing capacity. Plate load tests and proctor compaction tests will be required. This method is further described in chapter 9.2.4.

Special attention has to be paid to areas with changing composition and bearing capacity. Especially the erosion channels on Houshang site have to be considered.

Main requirements on the geotechnical quality of the plane are as follows (see DRESCHER, 1997):

- proctor density: 95%
- load-bearing capacity:  $E_{v2} = 45 \text{ MN/m}^2$

In some areas it might become necessary to exchange the soil at the surface, if the soil will not allow to achieve a sufficient bearing capacity.

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#### 4.3.4 Design of the Bottom Dams

Each landfill cell is surrounded by a bottom dam, which has to fulfill some important tasks within the bottom liner system:

- the bottom dams form the boundary of the disposal area
- the inner slopes of the dams are sealed by liners and covered by a drainage layer, which prevents untrapped outflow of leachate
- the bottom dams stabilise the slopes of the landfill body
- the surface cover or liner system is connected to the bottom liner system at the bottom dams.

Details of the bottom dams at the Houshang site are shown in Drawing F 9, using an asphalt liner system as an example:

- the bottom dams have a height of 3 m, which is a compromise between static considerations and the availability of soil material
- the outer slopes have an inclination of 1 : 3, following the inclination of the landfill bodies
- the inner slopes have an inclination of 1 : 2, which is again a compromise between static considerations and the availability of soil material
- the width of the crown is 1.50 m, the resulting total width of the dams is 16.50 m.

The quite steep inner slopes of the bottom dams are suitable for an asphalt liner, but may cause difficulties in case of geomembrane or clay liners. The friction between the asphalt liner and the drainage layer should be increased by roughening the asphalt liner (e.g. by strewing split into an additional asphalt sealing layer).

The bottom of the bottom dams is in the example shown the natural soil, but the decision on its final height in relation to the natural ground depends on the necessary shape of the bottom of the landfill cell, and the liner system chosen.

The drain pipes are running at the bottom of the dam, and lead to manholes, placed at the end of the dams.

After landfill operation, in the stage of restoration, the whole landfill slope including the bottom dams will be covered with a topsoil layer (see Chapter 6).

The bottom dams should be constructed with the material available on-site. Sandy loam or loamy sand would be suitable materials due to their limited permeability and the sufficient shear strength.

#### 4.3.5 Excavation and Back Fill

Earthworks (cuts and fills) will be needed to prepare the base of the landfill bottom as well as the dams and ponds. The landfill base will be constructed with the necessary longitudinal and transversal inclination for the bottom liner system. In general it should be tried to achieve a balance of cuts and fills, but it has to be considered, that a lot of soil is necessary for the construction of the peripheral dams, the bottom dams and the bordering dams. Furthermore the slopes and the crown of the landfill will be covered with suitable soils, too.

Soils available on-site are suitable for different purposes, therefore excavation and stockpiling before further usage of the different types of soil is recommended. A soil management system should be developed before the phase of construction begins in order to save valuable soils, to minimise transport distances, and to organise the stage of construction.

The amount of soil necessary for construction works and landfill restoration at the slopes can roughly be calculated by multiplying the specific volume ( $m^3/m$ ) with the circumference of cell 1 (app. 3380 m). The amount of soil at the top (topsoil and percolation layer) is calculated using the area of the crown ( $300,000 m^2$ ). The results of the calculation are shown in Table 2-4.8. Details concerning the dams are shown in Drawing F 8, details of landfill restoration in Drawing F 13. Further explanations concerning landfill restoration are given in Chapter 6.

	Width/ Length	Height	Specific Volume	Total Volume
	m	m	$m^3/m$	$m^3$
Peripheral dams	9.00	1.00	9.00	30,420
Bottom dams	8.75	1.00	8.75	29,575
Bordering dams	85.00	1.00	85.00	287,300
Topsoil at the slopes	95.00	0.50 · 0.67	31.83	107,600
Total				454,895
	Area	Height	Specific Volume	Total Volume
	$m^2$	m	$m^3/m^2$	$m^3$
Percolation layer	300,000	1.00	1.00	300,000
Topsoil at the crown	300,000	0.50 · 0.67	0.33	100,000
Overall Total				854,895

**Table 2-4.8: Demand of Soil for Construction and Restoration Purposes**

**Topsoil: 2/3 soil, 1/3 compost**



Table 2-4.8 shows a demand of app. 855,000 m<sup>3</sup> for construction and restoration purposes only for cell 1. Daily cover with soil is not considered here. That shows, that cutting of the hills in section 1 is useful both under the view of extensive use of the area and for the extraction of soil for construction purposes.

The Drawings F 10 and F 11 show longitudinal and horizontal sections of cell 1. The longitudinal sections follow the axes of the leachate collection pipes (northern border of cell 1) and the axes of manholes (southern border of cell 1), the cross sections follow the axes of drain pipes.

The shape of the bottom of cell 1 has developed considering the following principles:

- free drainage of leachate into the treatment ponds must be possible
- the minimum slope of drain pipes has to be 1 %
- the minimum slope of peripheral ditches has to be 1 %
- the excavations should cover the fills along a section line.

The groundplan of cell 1 (Drawing F 7) and the sections show, that the site is very suitable for the construction of a landfill in general. Large earthworks are not necessary in most of the areas of cell 1 with the exception of the southern borderline of the cell and the little hill in the south-eastern corner.

A calculation on the base of cuts and fills gave the following results:

- volume of cuts      280,000 m<sup>3</sup>
- volume of fills      250,000 m<sup>3</sup>

The surplus of earth can be used for the cover of waste with soil (see Chapter 9), which is estimated to be in a range of 1,500,000 m<sup>3</sup> for cell 1 (20 cm soil cover every 2 m).

In the period of implementation design it should be decided, if the hilly area in the south (south-east) of cell 1 will really be touched. Field investigations and soil analyses have to show, whether the extraction of soil justifies – apart from the additional disposal volume – the extensive earth works.

An exact calculation of cuts and fills – perhaps using a 3D-terrain-model – should be performed after the decision on the final bottom liner system will have been made.

Furthermore the settlements and deformations of the base of the landfill have to be considered.



#### 4.4 Recommendations on Further Investigations and Calculations

Before the implementation design the following investigations and calculations are recommended:

- Survey of the hydrological situation

The catchment areas, its properties, and the resulting discharges after intensive rainfalls are assessed only roughly at present.

In order to optimize the detailed design of the surface water collection and storage system and to determine the potentially available collected water, those tests become necessary.

- Survey of bearing capacity

A detailed survey of the bearing capacity of the natural soil is an important information for further decisions on the extent of earthworks and compaction for the preparation of the base of the bottom of the landfill.

Plate bearing tests are part of the test program which is under preparation.

- Calculation of the settlements of base of landfill (plane)

Settlements of landfill the base of the landfill are of special importance and have to be performed before the implementation design. The calculations should consider the geotechnical experience with settlements and deformations under large structures like landfills, which are collected in Western Europe and in Germany especially.

The settlement of the base has to be considered before the final design of the landfill base is performed.

The results of the geotechnical tests and the drilling program are to consider for the calculation of the settlements.

- Calculation of slope stability and overall stability (ground failure)

A slope failure analysis is recommended for the landfill body. Because less experience exists with the shear parameters of wet residual waste in Iran, it is recommended to consider data collected in other countries. Pore pressure variations which could have a significant influence on slope stability must be carefully taken into account in the calculations.

During landfill operation continuous measurements of water levels in the landfill body is useful to assess the risk of a build-up of water

The overall stability of the site (waste and surrounding ground) must be assessed by conventional stability and bearing capacity analysis.

- Investigation of the soil material in the south and south-east of cell 1  

Especially the soils in the hilly areas in the south and south-east of cell 1 should be investigated in order to decide whether they are suitable for construction and restoration purposes. In combination with the detailed calculation of cuts and fills and under consideration of changes in the disposal volume the advantages of cutting the hills can be assessed.

Soil sampling and analyses are part of the test program which is under preparation.
- Detailed calculation of cuts and fills  

An exact calculation of cuts and fills – perhaps using a 3D-terrain-model – should be performed after the decision on the final bottom liner system will have been made. This will be the base of the final decision on the shape of the base cell 1.

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## 5 Bottom Liner System

### 5.1 Introduction

The main difference between open dumping and engineered or sanitary landfills is the introduction of a base sealing system. The bottom liner system is the essence for the containment system in landfill design as it serves as the barrier which separates the internal polluted area of the landfill from the environment.

According to the Geotechnical Study, the top soil consists of clay with an average hydraulic conductivity in a range of  $1,6-3,1 \times 10^{-8}$  cm/sec in Houshang area.

This preliminary report compares different base sealing systems. They are considered as the most suitable ones regarding the local conditions, long-term international experience and the ability of the locally available workforce (see Fig 2-5.1):

Together with the bottom liner system the geological barrier beneath it would be of importance for the containment task. The geological barrier (landfill base) should consist of a natural mineral layer with low permeability (measured as  $k$ , the hydraulic conductivity) and sufficient thickness. The European Union Directive on the landfill of waste (Council Directive 1999/31/EC) defines the following requirements for geological barrier:

landfill for hazardous waste:	$k < 10^{-9}$ m/s, thickness $> 5$ m
landfill for non-hazardous waste:	$k < 10^{-9}$ m/s, thickness $> 1$ m
landfill for inert waste	$k < 10^{-7}$ m/s, thickness $> 1$ m

### 5.2 Bottom Liner Options

A decision about the recommended landfill bottom liner should be taken under consideration of following aspects:

- geotechnical stability
- hydraulic conductivity
- locally available know how in operation and installation of the liner system in secure manner
- investment and operation costs.

Figure 2-5.1 gives an schematic overview of the bottom liner options.

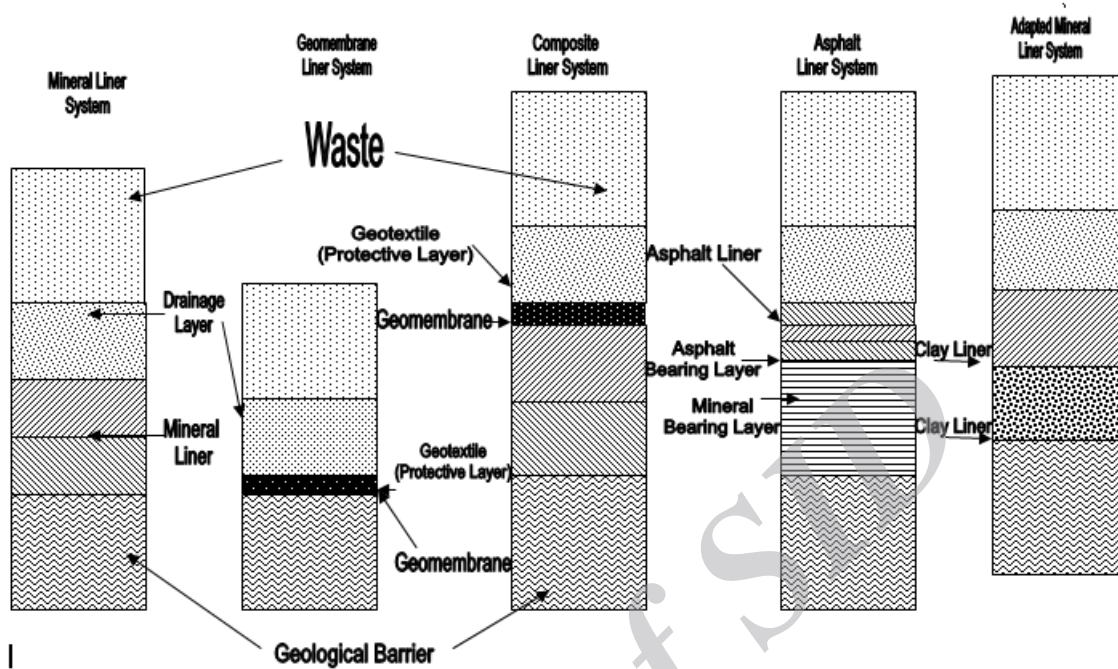


Fig. 2-5.1: Different Landfill Bottomliner Options

### 5.2.1 Improved Profiling of Subsoil

Unsuitable areas of the future landfill cell would be excavated and profiled as described in the preliminary site layout. A limitation to the clay is its **chemical consistence** and the possible reaction with the leachate (see chapter below on Natural Compacted Clay Layer).

As described in the hydro-geological chapter, there is no homogenous top soil cover. The area is rather characterised by the fluvial terrace which is interrupted by active and former erosion channels. The inhomogeneous **physical swelling** behavior of inhomogeneous soil can destabilise the underground of the landfill and may have an irreversible impact on the leachate collection system and the inclination.

A full risk analysis for this area is not possible and it is therefore not recommended to rely on the geological barrier as the only leachate containment system.

However, with reference to the multi-barrier concept introduced in chapter 1 of this study, the underground provides excellent conditions for any supplementary liner system which should be installed. Wherever layers of gravel or sand will occur while profiling the basement, these materials will be excavated and should be replaced by clay from the site nearby up to a depth of at least 50 cm.

### 5.2.2 Adapted Mineral Liner

This option contains usage of on site material and compact them as liner layer. The liner would be composed of two 30 cm layers. The lower layer is compacted in situ while the upper layer of clay, which has been screened before.

The advantages of this system are:

- low cost of construction
- availability of material on site
- local experience in earth works.

The disadvantages are as follows:

- high short-term and long-term risks of infiltration of leachate
- complex procedure of selection of material for compaction in second layer and district QC program
- The desiccation problem after construction.

### 5.2.3 Mineral Liner System

European and German regulations demand a minimum of two clay layers (e.g bentonite, kaolinite, montmorillinite, etc) to be installed to a thickness of at least 50 cm (BILITEWSKI ET AL., 1994), which are then to be compacted by heavy equipment with an optimal moisture content to gain a maximum density and lowest hydraulic conductivity.

The favourable geological barrier as described in the previous chapter, should be created in order to build a suitable and low permeable underground. This preparation works would permit the reduction of the recommended thickness from 50 cm to 30 cm. This would provide for a more cost efficient option since the major cost factor will be transportation costs for the clay.

For the material and its installation the following requirements must be considered:

- homogenous material that shows suitable water content,
- proctor density after compaction of  $D_{pr} \geq 95\%$  and
- water content (w) must be higher than the proctor water content (w<sub>pr</sub>).
- maximum content of gypsum < 5 per cent based on research carried out in Germany (Landesamt Wasser und Abfall NRW, Nr.18, 1993)
- at least 10 mass-% of clay particles with a high adsorptive capacity,

- maximum 5 mass-% of organic substances and
- maximum 15 mass-% of carbonate.

European Standards suggests a permeability of the mineral sealing layer of  $k \leq 5 \times 10^{-10}$  m/sec, due to the good geological barrier the permeability of  $k_f < 2 \times 10^{-10}$  m/sec can be considered as sufficient.

#### **Availability of suitable clay**

First investigations have shown that there are no sufficiently suitable clay pits in the direct surrounding of the landfill. Further surveys will be carried out and suitability test should be carried out. However, especially the high percentage of Gypsum (up to more than 10 %) in this particular area makes it likely to find suitable material.

Two clay pits in the further surroundings of the site were identified; one in the surrounding of Shahriar in the distance of 110 km and another closer to the site in approximately 90 km distance in the Jade Khavaran Region.

#### **5.2.4 Geomembrane Liner System**

The favourable natural geological barrier as described in the first option will serve as the lower base liner. In order to protect the sensitive geomembrane, a thin layer of 20 cm of compacted natural on-site clay or silt which is free from stones and gravel will be established. The cheaper on-site material can be used in this situation since the chemical composition of the material will not be in direct contact with the leachate. The physical composition must be free from any sharp materials which could harm the sensitive HDPE liner.

The generally recommended in European and North-American countries suggests a thickness of geomembranes ranging from 1.5 to 2.5 mm. For the purpose of protecting the clay from the potential chemical impacts, 1.5 mm of geomembrane would be sufficient. In this particular case, taking into consideration the height of 30 m but also the higher sensitiveness of the thinner material during welding, 2 mm geomembrane should be used. The cost for this upgrade would be approximately 10 % higher than for the 1.5 mm option.

Before work starts the way of placing has to be shown in a plan. For the construction of the layer the following items have to be considered:

- Geomembrane can only be installed by favorable weather conditions. Welding of the HDPE layer is only possible at temperatures of more than 5° Celsius and if the sun is shining not directly on to the HDPE layer (danger of blistering)

- welding is only to be done by experienced personnel, every welding seam has to be double checked (stability, density, thickness, visual inspection)
- no equipment must drive on the welded plastic layers (only welding equipment)

### **5.2.5 Asphalt Sealing**

In comparison to flexible membrane liners the hydraulic asphalt sealing is mechanically more resistible. Grade of deformation, durability and impermeability are in the same range as those of geomembranes or GCL. This layer is the most robust option related to mechanical impacts by heavy machinery and reacts on possible underground settlements with up to 10 % flexibility related to the original dimensions.

Construction of liners with hydraulic asphalt should have according to Central European regulations a thickness of 20 cm consisting of

1. a base liner with at least 8 cm hydraulic asphalt with a cavern content < 3.0 vol%
2. at least two times of 6 cm with a cavern content of < 3 vol. %. The sealing layer consist of a grain 0/11mm, binder contents up to 7.5 are tolerable.
3. depending on the bearing capacity, a 20 cm bearing layer may become necessary.

For both layers a good quality of gravel/sand material is needed with 50/50 ratio of split and sand. The binder material should correspond to B65 or B80 specification. For the bearing layer the grain size should be in range of 0/16 and binder content can be in range of 5.2% to 6.5%. The void ratio needed is less than 5%. For liner layer the grain size should be in range of 0/11 and binder content can be in range of 6.6% to 7.5%. The void ratio needed is less than 3%.

Studies in Germany have shown that chemical reaction will not influence permeability of the asphalt liner (Haas, 1994). Temporary fires may damage the surface of the asphalt liner but will not have a significant impact on the permeability of the entire liner (DVWK Merkblätter, 1996).

### **5.2.6 Geo-Synthetic Clay Liner in Combination With a Silt Layer**

There exist only little experience with Geo-synthetic Clay Liners as bottom liner system, since it has so far mostly being used as surface liner system. In this case, a thin layer (20 cm) of silt or natural clay will be laid on the fine leveled



surface of the landform in case of natural gravel occurs in the excavated and fine leveled landfill base. This is to be done for sheltering the sensitive GCL-layer. A Geo-synthetic Clay Liner is laid on the top of the silt. This layer consists of PP-woven geo-textile with PP-fibres needled into as structure and reinforced layer, filled with high quality sodium bentonite and a thermally bonded cover layer of a PPP-nonwoven geotextile, in order to avoid the risk of preferred pathways for liquid along penetrating fibers or threads.

The essential requirements are:

Product width:	$\geq 5$ m
Product length:	$\geq 30$ m
Total weight:	ca. 5300 g/m <sup>2</sup>
Filling of sodium – bentonite	$\geq 5000$ g/m <sup>2</sup>
Tensile strength:	$\geq 20$ kN/m <sup>2</sup>
Shear strength:	$\geq$ minimum 25°
k – value:	$\leq 5 \times 10^{-11}$ m/s

The panels have to be joined according to the guidelines of the producer or at least by 30 cm overlapping and addition of bentonite powder in the overlapping area (approx. 1kg/m).

### 5.3 Comparison of Bottom Liner Options

For the purpose of calculating the costs, prices of material were evaluated based on Iranian prices and include all necessary protective layers required either underneath or on top. All sealing options need a 30 cm drainage layer (mineral dewatering layer) made of 16/32 - 8/32 gravels to drain leachate for the whole lifespan of landfill as described in the leachate collection section.

The prices are on site prices, they include material, installation and transport to the site. As shown in the table below, the prices per square meter are all in the range from approximately USD 2 - 20. The only significantly cheaper option is the utilisation of on-site material in a 50 cm or 1 m layer.



**Costs per square meter (USD)**

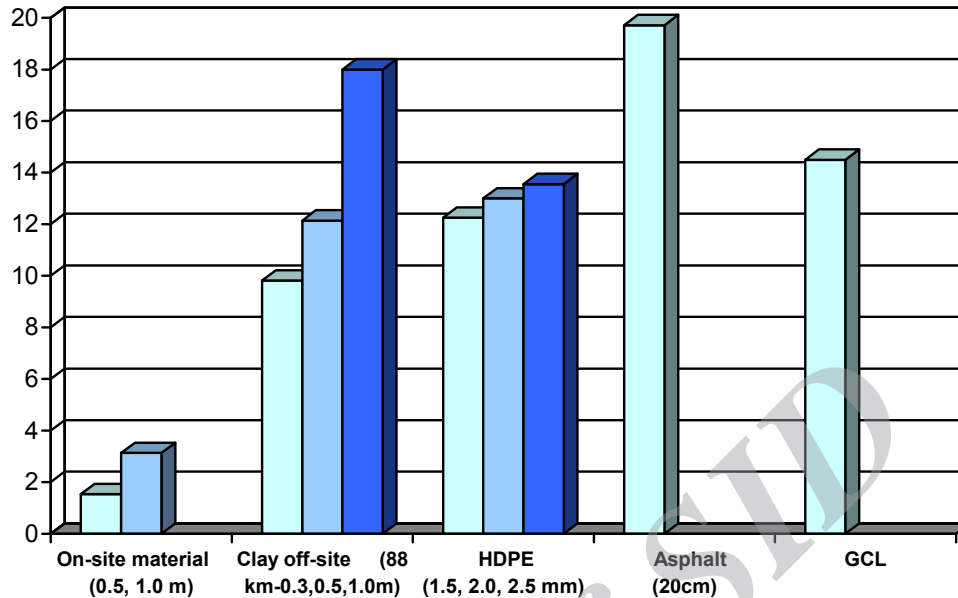


Fig. 2-5.2: Cost Comparison of Different Liner Options

In table 2-5.1 the summarized results of all aspects discussed are shown and special comments are added to completely clarify the situation.

Alternative/Criteria	Hydraulic Permeability	Long-Term Behavior	Complexity of Construction	Availability of Raw Material	Local Experience in Construction	Costs
Improved Profiling of Subsoil	--	--	0	++	++	++
Adapted-Mineral Liner System	0/-	0	-	++	+	++
Mineral-Liner System	0	0	-	+	0	0
Geomembrane Liner-System (HDPE)	++	++	0	-	0	+
Geo-Synthetic Clay Liner	++	0	+	-	0	0
Asphalt-Liner System	++	++	+	++	+	-

Table 2-5.1 Comparative Analysis of Different Options

Taking into account the environmental risks, the technical feasibility and the related costs as described above, three options can be singled out with the following priorities.

As already described, environmental considerations and technical constraints do not suggest using on-site material or the natural geological barrier as the only protective layer, although with existence of clay on site the performance of on site clay (not site soil) -adapted mineral liner system can be nearly equivalent to clay from outside (mineral layer system) but because of non-assurance exist it is not recommended at this stage. On the other hand the usage of GCLs is not recommended because of long-term performance questions. So the possible options which have sufficient and confident long-term and short-term performance are compared according to estimated cost in the Table 2.5.2.

	Cost USD per m <sup>2</sup>	Costs for Section 1 USD	Remarks
<b>Asphalt Liner</b>	19.71	61,070,000	Asphalt is the technically best option due to its robust physical composition, chemical suitability and easy installation. The price is highest, but could be reduced in negotiations following a tender. Also, all investments would stay in Iran. Tests are required.
<b>HDPE 2 mm</b>	13.00	40,300,000	The price includes all other protection against drainage layers plus installation.
<b>Off-site clay (88 km clay pit)</b>	12.14	37,634,000	The only source, which could be identified so far, is a clay pit in 88 km distance to the landfill with the related transportation costs. If closer and suitable clay deposits will be identified, the cost reduces significantly. However, the described chemical suitability and technical feasibility tests will be required.

Table 2-5.2: Recommended Bottom Liner Options

## 5.4 Conclusion

With the exclusion of the natural on site material, as the only bottom liner, the risks for have been minimized, and all options presented below can be described as impermeable if constructed according to international standards.

As described in the previous chapters, the technically best option is the asphalt liner system. This system provides the highest stability and the installation is technological very simple and common in Iran. Hence no supervision and extensive quality control is needed. The cost is the major limiting factor, but is believed that those could still be reduced during negotiations following a tender. Further, all of the money would be spent in the country, and tax benefits may apply. Initially existing concerns on the suitability

of asphalt could not be substantiated, but may be considered in additional tests.

The installation of the geomembrane needs technologically more advanced skills. The risk of malfunctioning due to incorrect installation is very high and would undermine the usefulness completely. This option would therefore require extensive quality control measures. Consequently, the option of HDPE could be considered only under international procurement procedures and international construction supervision and rigorous quality assurance procedures.

As for the off site clay material, the implementation is difficult since the compaction must be achieved during a specific and stable moisture content. However, if suitable clay pits in the closer surroundings can be identified and the water during the construction is available, the cost factor might become more decisive.

The final decision should be taken following a tendering procedure and should include the price as well as the quality assurance in the decision making. The technical design of the landfill preparation study is based on the installation of a non permeable bottom liner system and will not be significantly affected by the choice of one of those three alternatives.

Due to the unpredictable behaviour of the inhomogeneous natural on-site material and its consequent effects on the leachate collection system, no other option can be recommended.

However, the landfill operation will continue successively over the period of over 50 years. In this period, significant changes in the above mentioned price calculation may occur. The landfill is going to be constructed successively, and the bottom liner system can be chosen according to the requirements of the time. As long as the installation will be done correctly, the performance parameter are very similar.

## 6 Landfill Shape and Surface Cover

### 6.1 Final Shape of Cell 1

#### 6.1.1 General Principles of Design

The final shape of the landfill results from the following parameters and elements:

- height of landfill
- slope of landfill body
- berms and ramps.

For the general design these parameters have been used:

- height at the top of slopes 30 m  
(height above ground)
- inclination of slopes of the landfill bodies 1 : 3  
(stability of landfill body, landfill restoration, see above)
- vertical distance of berms at the slopes 10 m  
(horizontal distance 90 m + width of berms)
- maximum cross slope of surface 10 %  
(immediately after end of operation)
- minimum cross slope of surface  $\geq 5 \%$   
(to ensure discharge of surface runoff, after settlement)
- minimum longitudinal slope of surface  $\geq 1 \%$   
(parallel to slope of bottom, discharge of surface run-off)
- maximum height of landfill 41.30 m  
(immediately after end of operation)

The height of landfill must be higher immediately after the end of operation because of the settlements of the landfill body. The height of settlement is difficult to access due to the unknown amount of degradation processes.

Experience in countries in humid areas have shown that the percentage of settlement of the landfill body can reach up to 20 %.

The amount of organic waste in the municipal waste of Tehran is higher than in European countries, but the precipitation is much less, which might reduce the intensity of degradation processes.

All over all it will be assumed that settlement of the landfill body will be in a range of 20 % of the height of the landfill immediately after end of disposal.

An important design element of the landfill shape are berms, which are important

- to maintain the surface cover system
- to drill the gas wells
- to collect the surface run-off at the slopes

The berms are connected by ramps among each other and to the peripheral roads. The ramps are used in the stage of operation as well as in the stage of aftercare.

The details of design of berms and ramps are shown in drawing F 13:

- the berms should have a slope  $> 1$  % to discharge the surface run-off collected in the ditches
- the berms will have a width of 7.50 m in total, the lanes are 5.00 m wide, the shoulders 0.75 or 0.50 m, this allows oncoming traffic
- at the inner slope of the berms and ramps ditches are arranged for collection of surface runoff
- the ramps do have the same width of the lanes like the berms, but outer the shoulder is chosen a little bit wider to ensure stability (side dams)
- at the ramps ditches are positioned at the inner slopes, too
- the ramps must not have a slope  $> 7$  %, that all types of trucks can climb and leave the disposal areas.

Berms and ramps have to be paved especially when they are used for waste transfer. Above a bearing layer of construction debris a surface layer should be installed made of split and gravel, stabilized by a hydraulic binder.

This overview shows, that the system of surface runoff collection is integrated in the system of berms and ramps:

- surface water is collected by the ditches at the inner slopes of the berms
- the surface water collected will be discharged downwards by the ditches placed at the inner slopes of the ramps
- the inner peripheral ditches collect the surface water discharged downwards.

The surface cover system with its different elements is an integral part of the multi-barrier concept.

### 6.1.2 Final Shape of the Landfill

After completing the waste filling, the waste surface will be re-profiled according to the planned inclination of the surface cover system. The final shape of the landfill is shown by the schematic cross section of cell 1 (drawing F 8) and by the groundplan and longitudinal section shown in drawing F 12.

The cross section in drawing 8 shows, that the landfill body is not symmetric. This is due to the fact, that the standard cross slope of the bottom is  $\geq 1\%$ , the difference in heights between the two landfill boundaries (outer feet of bottom dams) results up to 4.85 m.

Constructing the slopes with a general inclination of 1 : 3 and berms at every 10 m of height, the “+ 30 m level” will be reached after 115 m in the horizontal. Starting at these points (end of slopes) with an inclination of 10 % and further berms at the crown, the ridge of the landfill must be left from the horizontal axes.

The berms are following the boundaries of the cell in the accompanying height. They are placed at the following heights and with the following distances:

- berms at the slopes: heights of 10, 20 and 30 m above ground level
- berms at the left side of the crown: one berm in a horizontal distance of 50 m to the “+ 30 m berm” (distance of axes)
- berms at the right side of the crown: two berms in horizontal distances of 50 m to the “+ 30 m berm” and between each other.

The berms are connected with ramps, which are placed in such a way, that the number of temporary berms in the stage of operation (when the landfill body is erected) is minimised. The arrangement of ramps followed the idea that each sub-cell should be accessible by ramps directed upwards and downward.

The standard layout of a sub-cell shows the following arrangement of ramps:

- one ramp beginning at the northern peripheral road and leading directly up to the 30 m level
- the ramp is extended (with an angle) up to the next ramp in a distance of 50 m (height of 34.25 m above ground level)
- the next ramps directed downwards (or in the south, directed upwards) starts at the opposite berm in a height of 34.25 m above ground level.

The crossroads between berms and ramps are developed to a plateau to ensure that even trucks can make a U-turn to bend inwards. Temporary ramps during operation phase are shown in drawing F 14.

## 6.2 Surface Cover System

A surface cover system or surface liner system serves several purposes, namely they (see SAVAGE ET. AL, 1998)

- provide a physical barrier over the buried refuse, this preventing human contact, minimising problems with vectors (disease carriers), and serving to control odors
- prevent erosion that could expose the waste materials
- reduce the amount of infiltration that contributes to the generation of leachate
- provide for a good foundation for possible reuse of the landfill area.

For surface liner systems of landfills (filled with municipal solid waste) European standards demand at least a single liner system.

The main components include

- a bearing layer with a high permeability to gas
- a clay liner or a geomembrane liner
- a drainage layer
- a recultivation layer (100 cm at least).

Due to low annual precipitation and high evaporation at the Houshang site a surface cover system without liner and drainage layer is suggested.

- Compensation or bearing layer with gas drainage function: 30 cm

Above the waste surface, the compensation layer made of a homogenous non-binding material will be applied. The thickness of the layer will be at least 30 cm. Within the compensation layer, gas will be directed to the gas collection system.

This layer will be installed only at the crown of the landfill, not at the slopes, because the bordering dams have the effects of a bearing layer, but there surface is not much permeable to gas.

The core of the bordering dams, dominantly made by construction waste, should be collected to the gas drainage system due to its high gas permeability.

- Percolation layer: 100 cm

The percolation layer shall store the moisture generated by precipitation during the winter months and provide the vegetation with moisture in summer.

Therefore a good (high) effective field capacity is necessary. Loamy and silty soils are most suitable for this purpose.

The percolation layer will be installed at the slopes as part of the bordering dams. Above the core made of construction debris a percolation layer with a minimum thickness of 1.00 m will be placed.

At the crown of the landfill the height of the percolation layer can be reduced, if it will be proved by a water balance model, that the layer reduced is able to store most of precipitation during winter season, and leachate generation will be in the same height like using a layer with full height.

In addition to its function as percolation layer the gas permeability of loamy or silty soils is quite low, and this layer will support the gas collection system by reducing the emissions to the atmosphere.

- Top soil layer: 50 cm

The top soil layer is needed to protect the cover from erosion due to wind and water flow. It also serves to reduce infiltration through evapotranspiration.

This layer – with a height of at minimum 50 cm – composed of nutritive and dense soil in order to support plant growth.

The soil will be mixed with compost produced by residual or organic waste to achieve the necessary soil quality.

Only if necessary - at specific limited areas - geotextiles should be installed at some locations where the static situation or extreme erosion makes it necessary.

An example might be the steep slopes at the inner sides of the ramps. For slope stabilisation geocells might be useful.



### 6.3 Vegetation

The top soil (surface cover of the landfill) has to be covered with vegetation in order

- to prevent erosion caused by wind and water
- to increase evapotranspiration in periods of high transpiration.

The selection of vegetation is a difficult task because of the very specific conditions at the site and the place of vegetation:

- the site is very arid with a long period without precipitation
- the summer season is quite hot
- the exposition to wind and sun is intensive at the surface of the landfill
- the height of top soil is limited (growth of roots).

The plants chosen for vegetation must be resistant to stress caused by temperature and wind and must be able to survive long periods without precipitation.

These species have been chosen:

- *Tamarix rammosissima*
- *Atriplex leuoclada*
- *Saxavel*
- *Sidlitzia rosmarinus*.

All of these plants are considered as shrubs. The use of grass is not possible because grass plants cannot resist to the climatic conditions.

App. 150,000 plants have to be planted at an area of about 60 ha (surface area of cell 1), the distance between the plants is about 2 m.

During the first two years app. 110,000 m<sup>3</sup>/year of water are necessary for irrigation to enable the plants to begin growing. After this period only about 4,500 m<sup>3</sup>/year are assessed to be necessary, but even the precipitation at this site might be sufficient.

In addition to this proposal some tests should be made with the plants selected to test their suitability and to optimise the height of irrigation.

The plantation of vegetation should not be started before installation and operation of the gas wells, because the plants could be damaged by emissions of landfill gas due to the replacement of air.

## 6.4 Recommendations

Before beginning the implementation design and during operation some additional measurements, tests and calculations for optimising the surface cover system are recommended:

- Measurement and control of height of landfill

The height of landfill surface and the settlement process should be controlled periodically to assess the development of settlements.

These data will allow to calculate the surcharge of waste more precise.

- Calculation of water balances of the Houshang site

The water balance of the surface cover system proposed at Houshang Abad site should be calculated using a tested model like the Help-Model, which is especially designed for the calculation of water balances of landfills.

The calculation helps to define soil characteristics more precisely, to optimise the height of the percolation layer, and to estimate leachate generation.

- Determination of effective field capacity of soils

The soils available on-site should be tested concerning their effective field capacity, because this parameter is the crucial factor for the efficiency of the surface cover system proposed.

- Test of erosion stability

Erosion stability of top soils available or especially prepared (by mixing of compost) are to be determined, because a lack of erosion stability will lead to erosion channels at the surface of the landfill, which could destroy the surface cover system and is effecting the visual impression of the site.

- Test of plants

The plants proposed should be tested concerning their stress resistance and their essential water consumption.

Most of these tests and measurements are tasks which can be performed parallel to the start of operation.

## 7 Leachate Collection and Treatment

### 7.1 Leachate Collection System

#### 7.1.1 Overview

Lining of landfill bottom requires a leachate collection system

- to collect leachate
- to discharge it at defined points out of the dumping area
- to avoid an accumulation of leachate at the bottom of the landfill

The leachate collection system basically consists of a drainage layer of inert material with a high permeability and of drain pipes which have to collect the leachate and to discharge it out of the dumping area.

In the absence of precise and detailed regulations, some general design criteria according to American, European and German research and guidelines shall be compiled here (e.g. see DRESCHER, 1997; RAMKE, 2001; SAVAGE ET AL., 1998). Further explanations can be found in Annex 1a. This research would of the material suggest the following specifications:

- drainage material: coarse material, lime content < 20 %, grain size  $\geq 8/32$  or  $16/32$  mm
- drainage layer: height 30 cm
- drain pipes: diameter 250-300 mm, made of PE-HD
- manholes: diameter  $\geq 1,5$  m

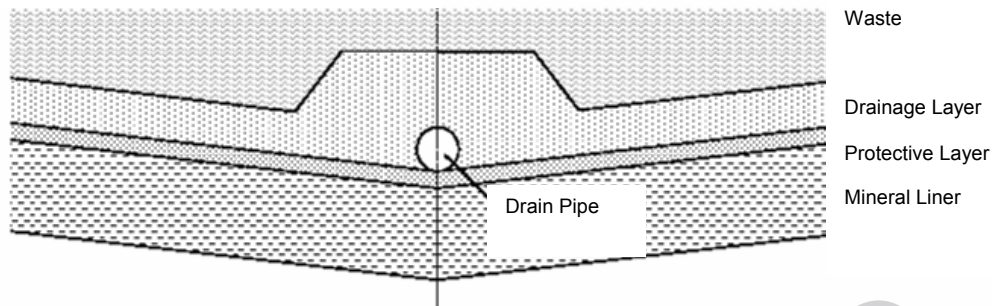
Mineral liners and geomembranes have to be protected against the coarse drainage material using geotextiles or sand layers. The whole system of drain pipes, manholes and collection pipes have to be sealed to avoid intrusion of air into the system and emissions of gas. The pipe system must allow inspection and maintenance (e.g. flushing) at each point.

Figure 2-7.1 demonstrates two different examples of design of leachate collection systems. Type 1 shows the standard system in flat areas, where the drainage layer, consisting of coarse material for long-term permeability, is placed on the roof-shaped landfill bottom with drain pipes at the low point.

The following design parameters are typical:

- cross slope:  $\geq 3$  %
- longitudinal slope:  $\geq 1$  %
- drain pipes spacing:  $\leq 30$  m

Type 1: Standard Leachate Collection System



Type 2: Leachate Collection System with Trenches of Split Gravel

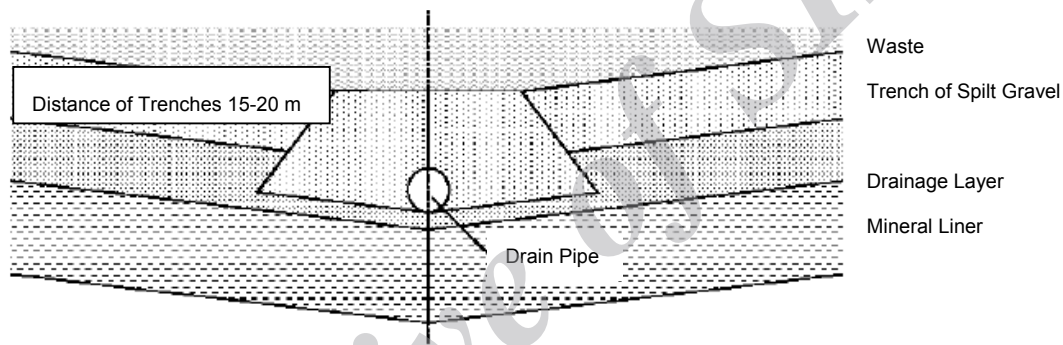
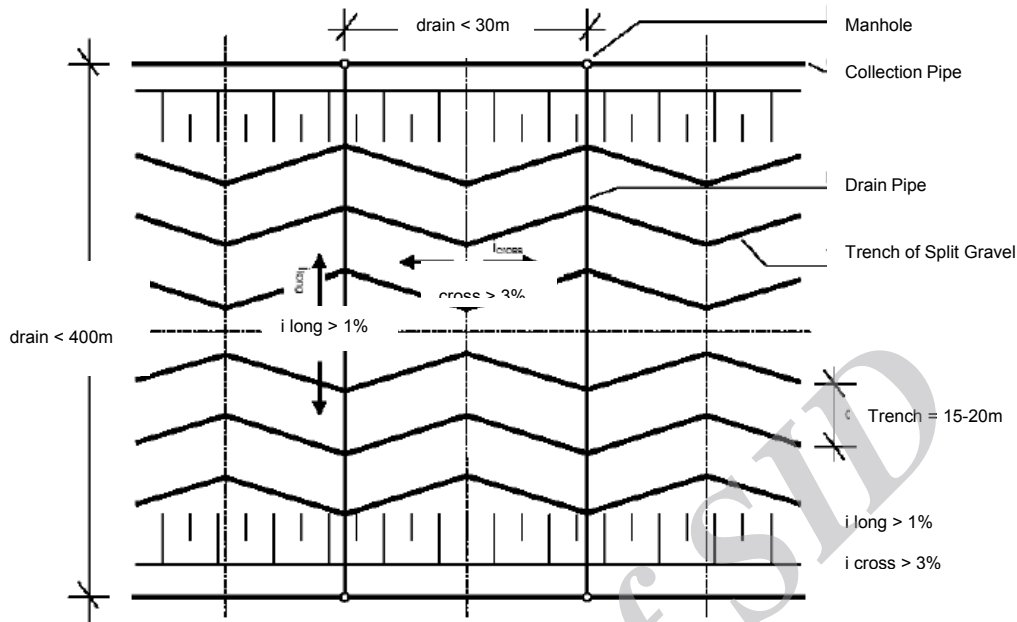


Figure 2-7.1: Leachate Collection Systems Type 1 and 2 – Cross Sections (RAMKE, 2001)

If there is no coarse drainage material available in the region of Houshang Abd, type 2 might be an alternative. In this case a combination of a drainage layer, consisting of coarse sand/fine gravel, and split gravel trenches, placed at 15 to 20 m intervals, can improve the life span of the leachate collection system (see Figure 2-7.2).

The detailed design assumes the availability of coarse drainage material and defines the following design parameters for a drainage collection system of type 1 (assuming the availability of drainage material):

- drainage material: coarse material, grain size 16/32 mm
- drainage layer: height 30 cm
- drain pipes: diameter 250-300 mm, made of PE-HD
- cross slope:  $\geq 3 \%$
- longitudinal slope:  $\geq 1 \%$



- drain pipes spacing:  $(\geq) 40 \text{ m}$

Figure 2-7.2: Leachate Collection Systems with Trenches of Split Gravel (RAMKE, 2001)

The drain pipe spacing (distance between two drain pipes) has been increased from 30 m to 40 m in order to simplify construction works and to save PE-HD pipes. The larger distance – compared to European regulations - is assessed to be suitable because of the quite low leachate generation after the first year of disposal. This reduces the risk of clogging of the drainage system.

The drainage system proposed is shown in Drawing F 7 (groundplan of cell 1) and in Drawing F 9 (details of bottom liner system).

### 7.1.2 Recommendations on Further Investigations and Tests

The following investigations and tests are necessary before the implementation design can be performed:

- investigation on availability of drainage material (gravel and split gravel (chipping))
- properties of drainage material (grain size distribution, shape, lime content).

The decision on the appropriate drainage system should be made depending on the availability of drainage material and its costs.

## 7.2 Leachate Management and Treatment

### 7.2.1 Overview of Leachate Management and Treatment Systems

The selection of a suitable leachate management and treatment system depends on three criteria:

- leachate composition
- local wastewater discharge standards
- availability of technology.

In general four management and treatment measures can be distinguished (see SAVAGE ET AL., 1998):

- Recirculation

Leachate can be effectively managed by collecting it and recirculating it through the landfill body. Recirculation of leachate results in an accelerated degradation of organic leachate constituents (BOD<sub>5</sub>, COD), especially in the acetic phase.

The design and operation of a leachate recirculation system should take into consideration the fact that recirculation results in a steadily increasing reservoir of leachate if percolation of water into the fill is greater than evaporation of collected leachate (in humid climates).

- Evaporation

Evaporation is one of the simplest alternatives for the management of leachate. In this alternative the leachate is stored in an evaporation pond, which is properly lined with an impermeable material or membrane under ideal circumstances.

The rate of evaporation is a function of climatic conditions. Periods of heavy rainfall must be considered in the design of the volume of the pond. The rate of evaporation may be increased by spraying the leachate on the surfaces of both the operated and completed fills, but this can increase the potential for the generation of odours, as well as the generation of aerosols which may contain bacteria.

- Off-site treatment

In the event that the landfill is located relatively close to a conventional wastewater treatment facility, it may be possible to discharge the leachate into the piping system for treatment at the plant. If a local sewer is not available within a convenient distance from the point of discharge at the landfill, utilisation of a tanker truck is an transport alternative.

The wastewater treatment plant must be capable of accommodating and treating the quantity and quality of leachate. In some cases, it may be necessary to install some type of pre-treatment of leachate prior to discharge.

- On-site treatment

If the alternatives presented above are not sufficient for leachate management, then some type of leachate treatment will be necessary. Several types of leachate treatment plants have been developed. Some of the processes include biological, physical, and chemical treatment.

A typical design would involve three stages of treatment:

- 1) pre-treatment
- 2) biological treatment
- 3) physical and chemical treatment.

Generally, pre-treatment involves screening, sedimentation, and pH-adjustment.

The biological treatment is designed to remove primarily the BOD, COD, and some of the nutrients. The last final stage may involve a series of processes principally designed to remove color, suspended solids, heavy metals, and any remaining COD.

Table 2-7.1 gives an overview of on-site leachate treatment systems, Table 2-7.2 compares different biological treatment methods.

For economically developing countries a proposal is made for on-site leachate treatment by SAVAGE ET AL., 1998:

*“Simple (and therefore affordable) leachate treatment systems may be the only choice for some locations. With respect to simple systems, storage and evaporation is the likely choice.*

*Where evaporative systems are not feasible, simple biological treatment systems may be a reasonable choice for leachate treatment, especially if the wastes are predominantly of domestic origin, putrescible, and cellulosic.*

*In such situations, anaerobic or aerobic systems would be the applicable form of treatment. Simple aerated systems (e.g., aerated lagoons, oxidation ponds) with hydraulic residence times of 30 to 60 days may work well, depending primarily on the BOD of the leachate.”*

No.	Method	Comments	Problems
1	Physical Methods		
1.1	Sedimentation	Low Costs	Only suitable for insoluble compounds
1.2	Evaporation	Preconcentrating constituents	Costly, corrosive, only a partial solution ( <i>in humid climates</i> ), COD is removed but not destroyed
2	Physical-Chemical Methods		
2.1	Activated Carbon Adsorption	Suitable for hydrophobic compounds in wastewater	Only provides partial treatment, regeneration of carbon necessary
2.2	Resin Adsorption	Suitable for chlorinated hydrocarbons, other hydrocarbons, aromatics	Only partial treatment, costly
2.3	Membrane Process/ Reverse Osmosis	Reverse Osmosis, good retention	Concentrated solids may require additional treatment, membrane fouling possible
2.4	Ion Exchange	Only specialised ions suitable	Organic solids and colloids are disruptive to process
2.5	Flocculation and Precipitation (with $Ca(OH)_2$ + FE salt, e.g., $Al_2(SO_4)_3$ )	Often used, partial COD elimination, not necessarily state-of-the-art anymore	Treatment/disposal of sludges and salts necessary ( $35 \text{ kg/m}^3$ leachate)
3	Chemical Methods		
3.1	Wet Oxidation with $H_2O_2$	No concentrating, elimination of residual COD and AOX	Not always appropriate for direct treatment (salinization), high energy demand
3.2	Wet Oxidation with Ozone/ UV-Treatment	No concentrating, elimination of residual COD and AOX	Not always appropriate for direct treatment (salinization), high energy demand
3.3	Wet Oxidation with Ozone/ Fixed bed catalysts	Fast reaction process	Lacking full scale implementability
4	Biochemical methods		
4.1	Anaerobic treatment	No energy needs for oxygenation, no surplus sludge	Retaining the biomass, sensitivity, not a total treatment
4.2	Anoxic treatment	Denitrification	Prior nitrification necessary
4.3	Aerobic treatment	Elimination of COD/BOD, most cost effective method	Not effective for nonbio-degradable materials, regulatory limits difficult to achieve
4.4	Nitrification	Oxidation of ammonia nitrogen from nitrite to nitrate	Sensitive method (inhibiting)

Table 2-7.1: Overview of Various Processes of Leachate Treatment (Source: BILITEWSKI ET AL., 1997)  
(italic lines: comments)



<p><b>Aerobic Biological Treatment</b></p>
<p><b>Aerated lagoons</b></p> <p>Because of their simplicity and the absence of sludge recycle facility, the aerated lagoon is the favoured method of treatment. Very high BOD<sub>5</sub> and COD removal efficiencies can be obtained for BOD<sub>5</sub>/COD ratios &gt; 0.4. Possible limits are low winter temperatures and space requirements. Floating aerators may be used an excavation within the landfill plus lining is a very simple method of lagoon construction.</p>
<p><b>Activated sludge plants</b></p> <p>This treatment, even if good performances can be obtained, may be less appropriate because it demands greater operator skill and a degree of control equipment not so compatible with landfill sites.</p>
<p><b>Trickling filters</b></p> <p>The use of trickling filters has been shown not to be appropriate for the treatment of strong leachates mainly because of filter blinding by inorganic deposition on the medium.</p>
<p><b>Rotating biological contractors</b></p> <p>These are beginning to be considered for reducing the ammoniacal nitrogen content of leachate from aged wastes. They require very little maintenance, are simple to install and use very little power.</p>
<p><b>Anaerobic Biological Treatment</b></p>
<p><b>Anaerobic lagoons</b></p> <p>This process can be successfully employed in countries with a prevailing temperate climate. It is not a complete method of treatment but could be used for storage, balancing and as a rough pre-treatment stage.</p>
<p><b>Anaerobic digesters</b></p> <p>This process has proved to be an effective means of removing both the organic load and heavy metals. Limits of the treatment plant costs if high removal efficiency is required (reactor size and heating facilities).</p>

Table 2-7.2: Assessment of Biological Leachate Treatment Methods (Source: Cossu et al., 1989)

A further appropriate method of simple leachate treatment using aerated lagooning is described by OELTZSCHNER/MUTZ, 1996:

- *at the lower end of the landfill three ponds with a sealed bottom should be constructed*
- *the first pond will serve as a settling pond,*
- *the second pond could get an artificial aeration (if possible)*
- *the third pond would serve as a final settling pond with natural aeration*

These both examples are assessed to be very useful and will be considered while selecting the proper leachate treatment for the Houshang landfill.

### 7.2.2 Wastewater Discharge Standards

Existing environmental legislation in Iran contains general requirements and bans to prevent irreversible changes and damage to the environment. The Agenda for Water Pollution Prevention (approved 1994) prohibits any activity that would result in water pollution.

In particular, it prohibits discharge of wastewater exceeding pollution limits. Table 2-7.3 shows the wastewater discharge standards, which are defined in an annex to the agenda.

Parameter	Unit	Discharge to Surface Water	Discharge to Absorption Pits
pH		6.5 – 8.5	5.0 – 9.0
COD	mg/l	60	60
BOD	mg/l	30	30
Iron	mg/l	3	3
Zinc	mg/l	2	2
Cadmium	µg/l	100	100
Ammonia	mg/l	2.5	1
Chloride	mg/l	1	1

Table 2-7.3: Wastewater Discharge Standards in Iran, (Source: Agenda for Water Pollution Prevention)

No significant difference can be seen between the requirements on water quality in case of discharge to surface water and in case of discharge to absorption pits.

### 7.2.3 Selection of a Leachate Management and Treatment System

The suitability of leachate management and treatment measures for the Houshang landfill can be assessed as follows:

- Recirculation

A recirculation of the whole leachate quantity to the landfill body seems not to be a sufficient solution, because of the very high moisture content of waste. Despite the high evaporation leachate accumulation inside the landfill body is quite probable under these circumstances.

Recirculation should be used as an additional method, especially in periods of very high leachate discharge and inadequate treatment capacities.

- Evaporation

Evaporation is extremely high in the area where Houshang landfill is sited and has to be used as a natural and inexpensive possibility. Evaporation will reduce leachate quantity significantly, sludge or dry solid matter can be disposed of at new landfill cells.

Changes of height of evaporation during the year following the seasons has to be considered.

- Off-site treatment

Off-site treatment is only an additional solution for specific types of leachate with specific characteristic, e.g., from cells with hospital waste or hazardous waste. Too much leachate will be generated in the dumping areas for MSW, and distances to treatment plants for municipal sewage in Tehran or Qom are very far, thus a transport via tanker truck will not be economical, and pipes do not exist.

- On-site treatment

In addition to the use of evaporation a simple biological on-site treatment system is recommended to avoid strong odour of the highly concentrated leachate. Without treatment the handling of the concentrated leachate with its high rates of organic substances may become very difficult, especially during the summer season.

Apart from these general considerations the requirements on leachate discharge have to be taken into account (see Chapter 7.2.2). Surface water does not exist in the neighbourhood of the landfill, therefore discharge of treated leachate into pits seems to be the only possibility to dispose of non-evaporated leachate.

But facing the strong discharge standards this would require a full leachate treatment plant meeting state-of-the-art standards. This includes a biological stage, a physico-chemical stage, and perhaps a second biological stage (for elimination of nitrogen and COD). Unit costs for such a treatment plant can be assumed in a range of USD 10-20 per cbm, even considering quite low energy costs. Therefore a wide use of evaporation and recirculation of the non-evaporated parts seems to be the best choice.

Summarising the reflections above, the local situation, and the economic demands the requirements on the leachate management system for Houshang landfill could be defined as follows:

- consideration of sporadic and changing leachate generation
- use of high evaporation and partial recirculation of leachate
- sufficient treatment capacity for high organic load (reduction of organic components)
- low to moderate investment costs
- low to moderate operation costs
- low rate of spare parts not produced in Iran.

The resulting concept is described by Figure 2-7.2. The system combines leachate evaporation with anaerobic and aerobic pre-treatment and considers leachate recirculation to landfill.

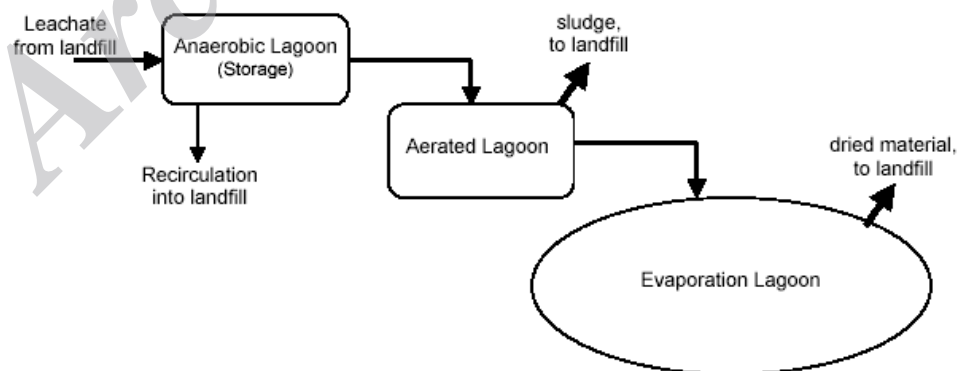


Figure 2-7.3: Leachate Management System for Houshang Landfill

The leachate collected will be pumped (or flows with gravity) to an anaerobic lagoon, which also serves for intermediate storage.

A partial anaerobic treatment of leachate is useful due to the very high concentrations of organics and the warm climate in summer. Anaerobic pre-treatment will reduce the number of aerators to be installed and energy consumption for aeration. A total anaerobic pre-treatment of leachate seems not to be possible because of the cold temperatures in winter.

According to the measurements of the stations Mehrabad and Qom temperatures below 10 °C are normal in December, January and February. Anaerobic lagoons will not work sufficiently below temperatures of 15 °C, and considering the high concentration of volatile fatty acids, the process of methane generation will stop in winter times. Therefore a combination of anaerobic and aerobic lagoons is assessed to be the best solution.

Intermediate storage is recommended to buffer changes in leachate discharge. The outlet for leachate recirculation can be installed here.

Behind the anaerobic lagoon the aerated lagoon is placed. An aerated lagoon is the best choice for biological treatment under the following circumstances:

- sufficient space available
- moderate temperatures in winter
- high BOD<sub>5</sub>/COD-ratios
- no strong discharge standards.

All these circumstances are applied here. Advantages of aerated lagoons are – in opposite to most of the other (aerobic) biological techniques :

- easy to operate
- low investment costs
- low operation costs.

An artificial aeration is required due to the high organic load of the leachate. Floating aerators should be used for aeration, because they are easily to install and to remove.

The anaerobic lagoon and the aerated lagoon have to be sealed with geomembranes, because leachate will have the most high concentrations here.

The whole treatment capacity should be distributed to two “lines”, that means two anaerobic and two aerobic lagoons, to be able to disrupt operation for maintenance or to optimise leachate pre-treatment.

The evaporation lagoon is a flat pond without artificial aeration. The low surface/volume-ratio guarantees a maximum of evaporation. The liner of the evaporation lagoon could be a mineral liner, but it has to be considered, that during the summer season the likelihood is very high, that the lagoon will run dry, and the soils will get cracks. An asphalt liner might be an interesting alternative. Finally it might be possible that low rates of percolation are acceptable, and that a compaction of the natural soil in combination with self-lining by clogging will lead to a certain impermeability, but this may not take place from the very beginning.

Therefore a geomembrane is recommended, but it requires very careful operation emptying the lagoon. By these reasons the sealing of the evaporation ponds should be performed using the natural soil available on-site for lining (30cm) in combination with a geomembrane.

The capacity for evaporation should be split into two lagoons, too, to get the opportunity to empty the lagoons without disruption of operation.

#### **7.2.4 Pre-Dimensioning of a Leachate Management and Treatment System**

The dimensioning of the leachate treatment depend on the objectives of leachate management, and can be ranked in this order:

1. reduction of leachate quantity by evaporation
2. in addition leachate re-circulation (in seasons with lower evaporation)
3. leachate treatment is necessary to reduce odour and improve the handling this can only be achieved by a significant reduction of BOD

The relationship between BOD-reduction and odour reduction is as follows:

- the odour is caused by compounds of H<sub>2</sub>S and Ammonia and by Volatile Fatty Acids, esp. butyric acid
- these compounds can be reduced by biological treatment
- leachate with high concentrations of organics (like the leachate of Kahrizak) normally cause odour problems
- therefore a reduction of BOD (and of COD as well) will reduce odour of leachate
- a clear relationship depends of the specific leachate and can only be developed by degradation tests

An alternative to the proposed lagoons are aquatic systems (wetlands), which are large basins filled with wastewater undergoing some combination of physical, chemical, and/or biological treatment processes that render the wastewater more acceptable for discharge to the environment. They are not widely used because they tend to be very large in area, require some form of fencing to minimize human health risk, often require supplemental treatment before discharge or reuse (e.g. aeration), and are rarely approved or implemented. The composition of the leachate in Kahrizak with a high content of VFA would not create a suitable basis for the creation of wetlands. This possibility should therefore be assessed in future; after the landfill is operating successfully a small scale pilot project might be started.

Due to the insufficient data situation and the stepwise construction of the whole landfill (a sub-cell with appr. 15 ha every year) it seems to be recommendable, to consider the leachate quantity calculated in Chapter 3 for the overall design of the whole landfill, but to start with leachate treatment facilities for 1/3 of the leachate quantity calculated.

Measurements of leachate discharge during operation will show, whether further treatment capacities will be necessary, but sufficient capacities will have been constructed to cover a significant ratio of leachate with the beginning of landfill operation. The part of leachate which cannot be treated at once can be re-circulated.

Therefore the pre-dimensioning will be performed for a leachate discharge of 500 m<sup>3</sup>/day. Furthermore a BOD<sub>5</sub>-concentration of 40,000 mg/l will be assumed (see Chapter 3).

The data resulting of the pre-dimensioning of the anaerobic lagoon are compiled in Table 2-7.4 The recommendations of the EPA, 2002 on anaerobic lagoons have been considered.

Parameter	Unit	Value	Remarks
Daily Input	m <sup>3</sup> /day	250 m <sup>3</sup>	half of relevant discharge
Residence Time	days	40	first proposal
Volume	m <sup>3</sup>	10,000	
Height/Depth	m	4.0	
Surface Area	m <sup>2</sup>	2,500 m <sup>2</sup>	
BOD <sub>5</sub>	mg/l	40,000	
BOD <sub>5</sub> -Load	kg/day	10,000	250 m <sup>3</sup> · 40 kg/m <sup>3</sup>
Volume Load	kg BOD <sub>5</sub> /m <sup>3</sup> /d	1.0	10,000 kg/day / 10,000 m <sup>3</sup>
BOD <sub>5</sub> -reduction	% BOD <sub>5</sub> -Input	50	assumed

Table 2-7.4: Predimensioning of One Anaerobic Lagoon

During the summer season a BOD-reduction of about 50 % might be achievable. The COD will be reduced in the same ratio due to the high BOD<sub>5</sub>/COD-ratio.

Mixing of the anaerobic lagoon is necessary to avoid zones of different concentrations of sludge and dissolved constituents. Therefore 10 swimming stirrers per lagoon with a nominal power of 5.5 kW are suitable.

Most important design criteria for dimensioning the aerated lagoon are the residence time and the volume load. For leachate treatment in aerated lagoons some recommendations are given by different authors:

- SAVAGE ET AL., 1998: hydraulic residence time 30 to 60 days  
general recommendation
- COSSU ET AL., 1989: hydraulic residence time > 10  
BOD<sub>5</sub>/COD-removal efficiency > 90 %  
for BOD<sub>5</sub>/COD-ratios > 0,4
- STEGMANN  
(see COSSU ET AL., 1989) organic load: 0.025 – 0.050 kg BOD<sub>5</sub>/m<sup>3</sup>/d  
for complete treatment, BOD < 25 mg/l  
in German climatic conditions

If a complete ammonia removal is intended, sludge retention times of more than 20 days are necessary.

Due to the high concentration of organics (BOD<sub>5</sub> and COD) a hydraulic residence time of 40 days seems to be a first realistic approach for a partial treatment. The resulting volume load will be 0.5 kg/m<sup>3</sup>/day (after anaerobic pre-



treatment). This load is 10 times higher than proposed for complete treatment, but seems to be acceptable considering the high average temperature in Houshang. The design parameter of the aerobic lagoon resulting are compiled in Table 2-7.5.

Parameter	Unit	Value	Remarks
Daily Input	m <sup>3</sup> /day	250 m <sup>3</sup>	half of relevant discharge
Residence Time	days	40	first proposal
Volume	m <sup>3</sup>	10,000	
Height/Depth	m	3.0	
Surface Area	m <sup>2</sup>	3,333 m <sup>2</sup>	
BOD	mg/l	20,000	
BOD-Load	kg/day	5,000 kg/day	250 m <sup>3</sup> · 20 kg/m <sup>3</sup>
Volume Load	kgBSB <sub>5</sub> /m <sup>3</sup> /d	0.5 kg/m <sup>3</sup> /day	5,000 kg/day / 10,000 m <sup>3</sup>
BOD <sub>5</sub> -Reduction	% BOD <sub>5</sub> -Input	50	assumed

Table 2-7.5: Predimensioning of One Aerated Lagoon

The BOD<sub>5</sub>-reduction is assumed again in a range of 50 %, facing experiences with highly loaded aerobic lagoons for the treatment of sewage of food processing industries.

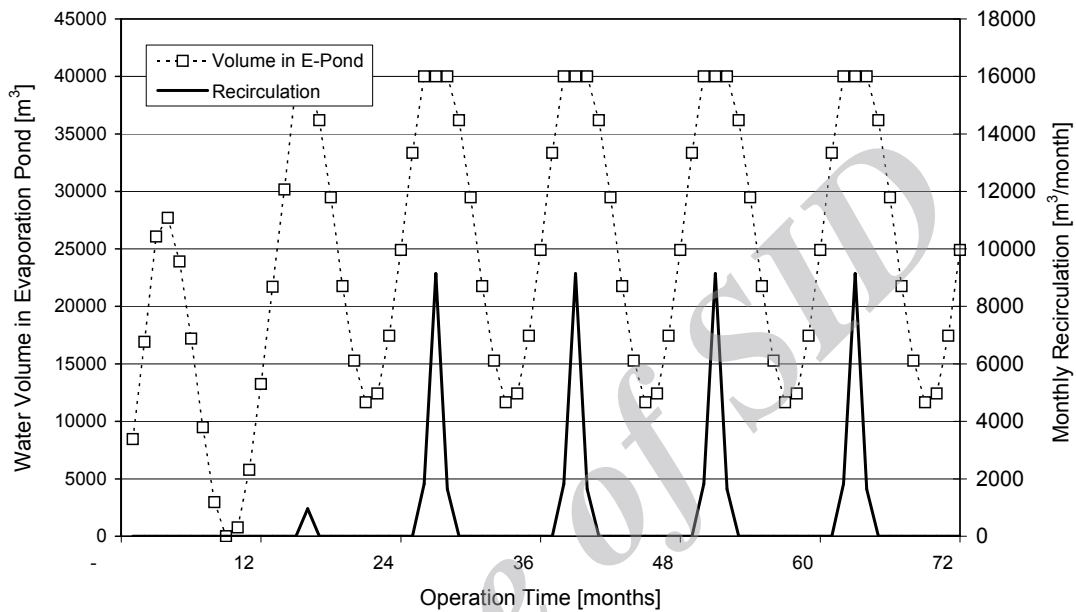
Two of these lagoons with a volume of 10,000 m<sup>3</sup> and a surface area of 3,333 m<sup>2</sup> should be constructed first, to ensure sufficient pre-treatment capacity.

The aerobic lagoons must be equipped with aerators. Due to their easy installation and handling floating aerators are useful. Considering the low anaerobic pre-treatment capacity during the winter season one of the aerated lagoons should be fully equipped with aerators for a wide decay of the organic load. For this purpose a number of app. 16 floating aerators with a nominal power of app. 22 kW are assessed to be necessary at present for full COD-removal in winter times. The second aerobic lagoon should be equipped with eight of these aerators (partial BOD-removal in summer times).

The advantage of floating aerators is that they can easily be installed and removed. This allows a flexible adjustment to the oxygen consumption in different ponds. Apart from this the input into the ponds might be adjusted to the oxygen input capacity installed (serial or parallel operation).

The dimensioning of the evaporation lagoon requires the consideration of seasonal differences in precipitation and evaporation.

Using the average data of precipitation and evaporation (diminished at 20 %) the necessary surface area for a wide evaporation of leachate can be calculated. Figure 2-7.4 shows the volume stored in the evaporation lagoon and the necessary quantity of leachate recirculation per month, if the evaporation and the free storage capacity cannot take the input.



**Figure 2-7.4: Water Volume in One Evaporation Lagoon and Monthly Recirculation**

The figure demonstrates steady states after the second year. The lagoon will run dry at the end of the summer (or will have the lowest volume), and its capacity will be exceeded at the end of the wet season. In total 12,000 m<sup>3</sup> water of 91,250 m<sup>3</sup> (365 days · 250 m<sup>3</sup>/day) input have to be recirculated per year (recirculation rate < 15 %). A more simple calculation, using average monthly values, confirms these dynamic calculations (see Table 2-7.6).

The construction of one of the evaporation ponds and the preparation of a second one are recommended for the first stage of landfill development. Drawing F 15 shows the general design of the leachate treatment area, considering 2 anaerobic ponds, 2 aerobic ponds and 2 evaporation ponds for a leachate discharge of 500 m<sup>3</sup>/day.

Furthermore the space for 4 further anaerobic and 4 further aerobic ponds in the leachate treatment area is considered. Landfill operation and measurements will show whether they are necessary in total.

Parameter	Unit	Value	Remarks
Daily Input	m <sup>3</sup> /day	250	
Monthly Input	m <sup>3</sup> /month	7,500	
Mean Evaporation V <sub>E</sub>	mm/month	200	average value for the whole year
Mean Precipitation N	mm/month	15	average value for the whole year
Net Evaporation V <sub>net</sub>	mm/month	185	V <sub>net</sub> = V <sub>E</sub> - N
Surface required	m <sup>2</sup>	40,500	7,500 m <sup>3</sup> /mon / (185 mm/mon · 1/1000 m <sup>3</sup> /(m <sup>2</sup> ·mm))
Depth h	m	1.0	h < 1,0 to avoid anaerobic conditions
Volume	m <sup>3</sup>	40,500	

Table 2-7.6: Pre-dimensioning of One Evaporation Lagoon

If additional evaporation ponds will be necessary, they could be installed in section 2 (to be separated by a dam from the main road, too) or perhaps at the top of the readily filled up landfill bodies.

The leachate pre-treatment system shown above combines a sufficient level of operational safety with high flexibility. Its stepwise adaptability to operational requirements allows economical use of investments.

Finally it shall be emphasised, that additional investigations, compiled in the next chapter, are necessary during the final stage of design, to achieve a result best fitted to the local situation.

### 7.2.5 Recommendations for Further Investigations and Tests

The following tests are beneficial for the further design process and might especially lead to an improved layout of treatment process in the stage of implementation design:

- Aerobic degradation tests with leachate, taken from Kahrizak landfill
- Anaerobic degradation tests with leachate, taken from Kahrizak landfill

These tests can verify the assumptions on the rate of decay and can help to optimize the design of the pre-treatment facilities (residence time, volume load etc.).

### 7.2.6 Considerations on Landfill Design and Operation

These considerations might be of interest in the next steps of landfill design:

- The two lines of leachate treatment facilities, each consisting of an aerobic lagoon, an aerobic lagoon and an evaporation lagoon, should be

sited at the deepest point of area 1. The total area required is app. 10 ha. Landfill operation will show, whether additional pre-treatment and evaporation lagoons are necessary.

- The additional evaporation lagoons necessary could be constructed on the top of the landfill cells, which are finally filled. This requires energy for pumping, but will save many hectares of land.
- Furthermore additional evaporation lagoons could be sited at other areas designated to future landfill development, e.g. at section 2 (proposed)

Beginning landfill operation at the Houshang landfill site further measurements are useful to develop the landfill site according the real requirements:

- Measurements of leachate quantity during operation will show, whether further treatment capacities will be necessary.
- In case of sufficient water storage capacity in the landfill body the rate of recirculation can be increased without the risk of accumulating water in the landfill body beyond its storage capacity.
- The observation of the evaporation ponds – especially of leachate discharge, evaporation, and the height of fill – is a pre-condition for an improved design of further treatment facilities.
- Analyses of leachate discharge of the first cells and of the effluent quality of the lagoons will help to optimise the pre-treatment capacities and to find a sufficient split between anaerobic and aerobic treatment capacities.
- In addition to the observation of leachate treatment during operation technical tests with anaerobic reactors are recommended to verify whether an increased ratio of anaerobic pre-treatment might be possible (volume load, decay rates, stability of process etc.).

Finally some advice for leachate management will be given:

- The start of the anaerobic lagoon might cause difficulties due to the high ratio of volatile fatty acids. Therefore it might be useful to start with aerobic pre-treatment of leachate and to fill the anaerobic lagoon with partial pre-treated leachate. Furthermore an increase of the pH-value by addition of bases or alkaline materials might be useful.
- Leachate recirculation of can be performed with tanker trailers driving over the non-recultivated landfill and spreading the leachate over the waste.

## 8 Gas Collection and Treatment

The anaerobic decomposition of organic substances causes landfill gas. To avoid influences, which are harmful to the environment, a degasifying system of the new Tehran landfill is strongly recommended. An active degasification system with suction is the most efficient system for recovering the gas out of the landfill. Only an active system is able to collect more than 50 % of total amount of produced landfill gas for incineration in a high temperature flare.

There are 3 main reasons to collect and incinerate landfill gas:

- 1: Methane is a strong ozone killer, more than 28 times as strong as carbon dioxide.
- 2: Safety for the working staff on the landfill body, reduce of bad odour
- 3: Prevention of fire in the landfill body.

### 8.1 Gas Forecast

The prognosis of landfill gas volumes can be calculated according to a specific formula, e.g. the Rettenberger model (see Production Manager Manual for Landfill Gas, Trier, 1995), which requires accurate baseline data, e.g. the TOC in the future delivered waste.

In this case, during the whole lifespan of the landfill the potential of gas generation is according to this Rettenberger formula:

$$G = 1.868 \times \text{Carbon total} (0.014 \times \text{Temperature in } ^\circ\text{C} + 0.28)$$

$$G = 1.868 \times 200 \text{ kg of total carbon per ton} (0,014 \times 30 \text{ C} + 0.28)$$

$$G = 260 \text{ m}^3/\text{t of waste}$$

A passive degasification system with horizontal and vertical gas drainage layers has only a small potential of collecting gas of the theoretical amount of landfill gas generation, depending on the permeability of the covering material of the waste. In general, it will not exceed 10%.

Long-term experiences shows that a part of 50 % of this theoretical amount can be collected by an active degasification system. The rest is not collectable (10 up to 20 %) or will not be produced due to an inhomogeneous milieu inside the landfill body (30-40%).

Based on experience, these theoretic calculations and experiences can be complemented by a gas forecast in relation to the landfill volume. Hence a gas forecast as a result of experience from hundreds of active landfill degasification examples defines a reliable gas production quantity. 100,000 m<sup>3</sup> of waste are generating 50-75 m<sup>3</sup> of gas per hour after reaching the stable methane phase.

Due to its high content of biodegradable material the Tehran waste is estimated to generate gas at the maximum end in the range of gas production rates.

After a few months the way through the first 3 phases of degradation of organic matter is finished and the production of methane by methanogenic bacteria will increase fast. During operation and decomposition of waste in phase 4 the gas production is increasing proportional to the quantity of waste. The output of landfill gas depends on the following input data:

- Total waste quantity
- Total Organic Carbon
- Temperature
- Decomposition parameter
- Presence of water

The main point which causes fluctuation in the total rate of gas production is the humidity in the waste body. If there is not enough water inside the landfill, gas production decreases immediately. The calculation of gas production by one of the calculation models can be elaborated with sufficient information about content of total organic carbon and the other factors mentioned above.

Based on the above mentioned experience, cell 1 of Houshang landfill with 13.1 million m<sup>3</sup> content of waste will generate up to 9,825 m<sup>3</sup>/h landfill gas. This gas will contain at least 50 % of volume of methane during the first years in the stable methane phase (phase 4, Christensen/Kjeldsen, 1989, see also Chapter 3). The yearly volumes for each cell are calculated in Table 2-8.1.

Cell	Volume m <sup>3</sup>	Gas Production Max. m <sup>3</sup> /year	Years of occurrence	Total Capable Emission of Methane in m <sup>3</sup>	Emission of Methane after Treatment
Cell 1	13,100,000	86.067 million m <sup>3</sup>	2005 – 2030	808.93 million m <sup>3</sup>	323.57 million m <sup>3</sup>
Cell 2	10,100,000	66.357 million m <sup>3</sup>	2009 – 2034	623.68 million m <sup>3</sup>	249.47 million m <sup>3</sup>
Cell 3	14,600,000	95.922 million m <sup>3</sup>	2012 – 2037	901.55 million m <sup>3</sup>	360.62 million m <sup>3</sup>
Cell 4	12,600,000	82.782 million m <sup>3</sup>	2015 - 2040	778.05 million m <sup>3</sup>	311.22 million m <sup>3</sup>
<b>Total</b>	<b>50,500,000</b>	<b>351,128 million m<sup>3</sup></b>	<b>2005 – 2040</b>	<b>3112,21 million m<sup>3</sup></b>	<b>1,244.88 million m<sup>3</sup></b>

**Table 2-8.1 Gas Production Estimate and Reduction of Greenhouse Gases**

The Table 2-8.1 shows that the application of the proposed active degasifying system will significantly reduce the emission of methane in the atmosphere.

## 8.2 Gas Management

An active degasifying system with vertical gas collection wells is proposed. This capable degasifying system with suction is the only option able to collect about 50 % or more of the produced gas. A passive degasification instead is only

able to collect about 10 % of generated gas. In combination with a gas permeable top cover without a lining system as a top sealing, the performance of a passive system is even lower and therefore not recommendable.

Despite of proper landfill operation, different settlements cannot be avoided, especially the rapid growth of the foreseen landfill will cause considerable settlements. Different settlements inside the landfill body are a constrain to the efficiency of horizontal gas collectors, consequently this method is not used in new landfill planning anymore. A horizontal venting system for temporary degasification, realized in several landfills with a slow growth towards the final capping, is not feasible. In this particular landfill the subcells will be filled in a short time, and the active degasification system will be installed at the beginning of methane gas generation in the landfill body.

Therefore, it is proposed that after filling the landfill, several vertical gas wells will be drilled into the waste body. Each well has a collection radius of approximately 25 m. The gas wells will be installed subsequently after reaching the top level of landfilling waste before capping the surface with low permeable material. The gas wells will be led out of the landfill body as non perforated pipes. Because of the non perforated pipes and the sealing in the near area around each gas well, a penetration of the degasification system from outside air is minimized (see Drawing F17). This is absolutely necessary to gain a gas quality with a high content of methane for a durable und safe incineration in a high temperature flare.

To operate the degasification system the monitoring of every gas well is necessary. In the first phase of operation weekly monitoring is recommended, if the landfill is in the stable methane phase, the repetition of monitoring should be extended up to one or two times in a month.

There are two options for monitoring, measuring at the bottom of the gas well or at the gas collector station, which is more usual. The parameters of measurement are: Flow rate, content of methane, temperature and moisture. If the content of methane decreases, the negative pressure for this gas well has to be reduced, so every each gas well is to be adjusted separately to get the whole system run in an optimal way. Usual negative pressure ranges are from 3 to 4 Pa.

The active system for gas collection and gas discharge will consist of 278 vertical gas wells built inside the landfill body with prevailing gas wellheads; gas suction lines connecting gas wells with the 10 gas collection stations. Every gas collection station is connected with up to 30 gas wells (see Drawings F16 and F17).



The gas management system consists of

- measuring and control systems, positioned in the collection stations,
- condensate collection chambers
- a collection system for gas condensate with connection to leachate discharge
- a main gas transport line between the collection stations
- the booster station and the flare

Due to the very low energy prices in Iran a use of landfill gas for energy recovery is not recommended. Gas filters and scrubbing technologies are expensive in operation and invest, a return on invest by increasing energy prices is not foreseeable

### 8.2.1 Gas Wells

The gas wells will be installed in the waste body after finishing a first area of the whole landfill cell, approximately  $\frac{1}{4}$  of the whole volume.

With a poly-grip the holes with a width of 80 cm will be dug up to 15 m depth into the waste. A slotted HDPE gas collection pipe of 280 mm diameter will be installed into the borehole. A gravel bed will be filled into the ring space between borehole rim and slotted pipe. The right position of the pipe will be fixed with distance keepers in the gravel (see Drawing F17).

The ring space around the HDPE-pipe will be filled with lime free gravel (16/32 mm) up to 3.5 meters to the surface. A 50 cm layer of lime free gravel (8/16) gives filter stability against the clay on top of the gravel. The last 3 meters to the top the gravel will be sealed with clay in the ring space between the not perforated pipe and the waste to avoid entrance of oxygen by suction process into the well.

Each pipe will be connected to the collection stations with suction pipes. Towards the surface the gas well must be sealed with impermeable clayish material with  $k_f < 10 \text{ E-6 m/s}$ .

### 8.2.2 Gas Suction System

The suction lines will connect the gas wells to the gas collection station. One separate line will be installed from each gas well to a separate branch at the gas collecting station. The HDPE suction pipes will have a diameter of 90 mm and will not exceed 200 m length to avoid too much pressure loss.

A shut-off flap (diameter 80 mm) will be flanged directly at the socket and a hose will be installed as flexible transition behind the shut off flap. The corrugated steel hose will be connected to the suction pipe installed in the soil covering with a flange connection (see Drawing F 17). For cell 1 of Houshang



landfill site 30,000 m are calculated of suction pipes between the wells and the collection station.

### **8.2.3 Gas Collection Stations**

The gas collection stations will be installed nearby the internal roads on the landfill surface. The individual suction lines will be connected in it to a central manifold. Furthermore, valves in the suction lines, pressure and sample inlet tabs will be installed on each pipe. The condensate will be drained into the water traps at the lowest point of the manifold after leaving the collection station (see Drawing F 17).

The entire piping has to be made of galvanised steel to prevent electrostatic charging. All pipe passages into the construction will be made gas-proof by installed sealing inserts.

### **8.2.4 Condensate Discharge**

The condensation water arising in the gas collection station manifolds will be discharged from the negative pressure area of the degassing system with the water traps according to the siphon principle (see Drawing F 17).

The collected gas condensate will discharge to the leachate collection system by a closed pipe (HDPE DA 100). The water traps are equipped with a central socket pipe, which can also be used for soil sludge suction and flushing (during operation), as well as for condensate level measurement. Filling level indication will be implemented by a measuring board mounted on a floater. The water traps will be placed accessible on the slope at the base of the gas collecting station.

Discharge of the condensate will be made via an overflow socket into the condensate collecting line, leading around the landfill at the bottom of the slope to the main leachate collection pipe (see Drawing F 17).

## **9 Landfill Operation**

### **9.1 Development of Cell 1**

#### **9.1.1 Bordering Dams**

Each landfill cell will be surrounded by a bordering dam, when the height of the bottom dam is reached. The bordering dams have several distinct tasks in the concept of a sanitary landfill:

- bordering of the sub-cell areas to define exactly the zone of disposal
- preventing of crashing down of trucks, compactors and dozers
- covering of the landfill slopes to minimise open waste areas
- retention of landfill gas in the phase of aftercare
- bearing and percolation layer within the surface cover system.

The bordering dams are constructed together with the growing of height of the landfill. Drawing F 9 shows the details of those bordering dams.

Construction of the dams begins when the waste level has reached a height of 0.5 m below the present crown of bottom or bordering dam.

The outer slope of the dams follows the inclination of the slopes of the landfill (1 : 3), the inner slopes have an inclination of 2 : 3. The height of the bordering dams is approximately 2.5 m. The total bottom width results – considering the width of the crown with 1.5 m – in a range of 9 – 11 m.

The bordering dams will be constructed by two different materials:

- The core and the inner slope of the dam will be constructed by construction debris, which is delivered to the landfill and ensures a high stability of the dam.
- The outer part of the dam will be covered with loam with a height of 1 m. Loam can be excavated on-site and is available unrestricted.

The loam cover prevents releasing of landfill gas and serves as percolation layer within the surface cover system.

The bordering dams should be constructed by a special team, which belongs to the landfill operation group.

This team (1 technician, 3 drivers, 3 workers) should be equipped with an excavator (shovel), mid- and low-size compactors, a loader/bulldozer and 2 trucks.

### 9.1.2 Development of Sub-Cells

The sub-cells of a cell are divided from each other by a separating dam. The construction of every sub-cell has to be finished some weeks before it is needed for operation.

A sub-cell will be developed in five steps:

- Step 1 – Starting up of the sub-cell

The new constructed sub-cell consists of the bottom liner, the drainage layer (and the drain pipes), the bottom dam, and the peripheral dam and ditches.

The drainage layer has to be covered with household waste in a height of 2 m without compaction in order to protect the liner from destruction. Therefore only a minor part of the waste streams should be delivered to the new sub-cell to avoid jams and uncontrolled traffic at the site. The waste has to be pushed with a dozer on the site starting at the edge and tipping the waste over the top.

- Step 2 – Full operation of the first working level

After covering the drainage layer with waste completely, standard operation of the first working level can be started. The waste transporters enter the sub-cell by a ramp at the begin of the sub-cell, and drive on temporary roads, made of construction waste, to the present working area. The trucks will unload the waste at the front of the compaction zone, afterwards the waste will be spreaded and compacted in thin layer (see below).

The trucks leave the sub-cell at a ramp at the opposite site of the sub-cell. Ramps should not be used for the entrance and the exit at the same time, even they are wide enough, to avoid oncoming (contraflow) traffic. This seems to be of special importance because most of the waste will be delivered during the night.

- Step 3 – Preparation of the next working level

The preparation of the next working level starts with the construction of the ramps, before the bordering dams will be erected. The erection of the bordering dams begins as soon as the height of waste reaches 2 m. The ramps have to be extended into the working areas by ramps inside the disposal area to bridge the differences in heights between the new ramps and the level of present working areas/ tipping floors (see below).

The bordering dams and ramps of the outgoing working level will be finished, and the working level has to be covered with soil.

After these measures of preparation – which are running simultaneously to the normal disposal procedure – the new working level is ready for operation, and the next working period can begin.

- Step 4 – Operation at higher working levels

Working step 3 – preparation of the next working level - will be repeated every time when a working level is filled completely.

In case that ramps have to change their direction – because the length of the baseline of a sub-cell is too short - a plateau of construction waste has to be built so, that the trucks can make a U-turn to use the next ramp. But a better solution is the preparation of temporary berms and ramps, which is shown for sub-cell 1.

Preparing the weekly plan of disposal the disposal managers have to consider the decreasing size of sub-cell 1, when landfill body becomes higher. The reason for the decreasing size of sub-cell 1 is the slope at the edge neighbored to sub-cell 2. This temporary slope should also have an inclination of 1 : 3, despite the fact, that waste bodies in general could be stable for some month with much steeper slopes. But apart these general experience the specific local conditions (risk of earthquakes, high content of moisture) require a more careful construction.

Sub-cells 2 – 4 in cell 1 will have all the same surface area, because they are covering parts of the preceded sub-cells.

- Step 5 – Closure of the sub-cell

At the end of operation of a sub-cell (especially of sub-cell 1.1) waste delivery to the ongoing sub-cell and the number of compactors operating there have to be reduced with respect to the decreasing working area. When full operation of the next sub-cell begins, the former sub-cell under operation can be closed.

Specific tasks to be performed fast after closure are covering with topsoil and drilling and installation of gas wells. The final height of the landfill body has to consider the settlement of waste, caused by degradation and consolidation processes.

Drawing F 14 shows the plan of landfill operation illustrated by sub-cell 1. This plan includes specific information concerning operation like boundaries between sub-cells , temporary berms, and temporary ramps.

These plans of landfill operation have to be developed for every sub-cell.

### 9.1.3 Working Area

The definition of the “standard working area”, which is used for unloading of the waste transporters and for waste disposal depends on two criteria:

- size of the cell/sub-cell
- daily/hourly waste transports

Considering the high amount of waste which is delivered to the Houshang Abad Site, the number of daily trips of municipal waste transporters (app. 400), and the number of transporters of private companies (approximately also 400) the working area must not be chosen too small.

Each of the sub-cells in cell 1 has an area of app. 16 ha at the begin of operation. The minimum size of one sub-cell – at the top of a cell at a height of 30 m above ground - is in a range of 4 ha. This size – 4 ha – seems to be a little bit too small to allow simultaneous operation of several compactors and dozers as well as the delivery of waste by many waste transporters. Therefore a zone of at minimum 6 ha for compaction and an additional tipping zone in front of the compaction area is recommended.

Each sub-cell should be divided into two working areas, which include zones for compaction and tipping, with the following properties:

- height of one working area in one period: 2.0 m
- total size of one working area 80,000 m<sup>2</sup>
- length of compaction area 200 m
- width of compaction area 300 m
- length of tipping edge 200 m
- width of tipping floor (maneuver of trucks) 100 m
- volume of one working period 160,000 m<sup>3</sup>
- density after compaction 0.95 Mg/m<sup>3</sup>
- daily amount of waste 7,000 Mg/day
- waste disposal volume per day 7,400 m<sup>3</sup>/day
- duration of one working period 22 days

The working period of 22 days – app. 4 weeks if 5 - 6 working days per week are assumed – is a reasonable value. Within this period all the temporary installations like temporary roads inside the working area and temporary access roads to the ramps of a sub-cell area can be constructed.

## 9.2 Techniques of Waste Disposal

### 9.2.1 Theoretical Background

Waste delivered to the landfill has to be disposed of in the dumping area and should be compacted strongly. Waste compaction has different objectives:

- saving of landfill volume by increasing the density of waste
- reduction of the risk of fire by minimising the intrusion of air
- less vermin spreading, less blowing of waste, less attractive to birds

Apart from these operational advantages waste compaction increases the economical benefits due to the longer life span of the landfill and the larger mass of waste dumped on the same area.

The density which can be achieved depends on many different factors such as

- waste properties (material size, composition, moisture content)
- technique of disposal  
(thin layer operation, tipping edge operation, number of passes)
- compaction engine  
(compactor or bulldozer, operating weight, wheel concept)
- shape of the site (pit site or dump site, height of site)
- weather conditions (precipitation, temperature).

At the Houshang site the working conditions are described by the high content of organics of municipal waste with a high moisture content, a large working area and dry and hot weather conditions (in general).

Three different types of densities shall be defined:

- **Compaction Density**

Density of the waste immediately after waste disposal and compaction, only influenced by the kind of waste and the disposal technique

- **Disposal Density**

Average density of waste in all depths of the landfill during landfill operation, influenced by biochemical degradation, settlement, caused by static pressures and consolidation effects

- **Post Operation Density**

Final density of waste after operation, most of decomposition and consolidation processes are nearly finished

Four different types of waste disposal techniques can be distinguished (see Figure 2-9.1):

- thin layer operation
- operation with extended tipping edge (downwards)
- operation with extended tipping edge (upwards)
- tipping edge operation only.

The best disposal technique is the thin layer operation because of the highest possible compaction densities which can be achieved by this method. The unloaded waste is distributed by the compactor, crushed, compressed and then compacted by several passes. The compaction layers are varying between 20 and 50 cm in depth in general.

The tipping edge operation leads to quite low compaction densities, because the influence of the compactor stresses sharply decreases after some decimetres. This kind of operation should only be used when bulky waste or sludge must be disposed of.

Practical experiments showed that even when no compactor can be used, thin layer operation using a bulldozer is much more efficient than tipping edge operation.

The compaction density which can be achieved with a compactor is furthermore a direct function of the number of passes, but also clearly influenced by the type of operation. A really satisfying compaction density is only to achieve with the thin layer operation.

The advantage of high compaction densities is demonstrated by the following example: When the compaction density increases by about  $0.2 \text{ t/m}^3$  – relating to an initial value of  $0.8 \text{ t/m}^3$  - the necessary volume decreases by about 20 %. That means that the landfill can be used 20 % longer, considering equal delivery of waste during all the time. This demonstrates the necessity of good landfill practice including adequate procedures of waste compaction.

According to these theoretical principles the following parameters have to be varied to optimise landfill operation:

- height of waste layers
- number of passes
- pre-separation of waste.

In general thin layer operation is to be recommended, but local conditions like waste properties and amount of waste delivery must also be taken into consideration.



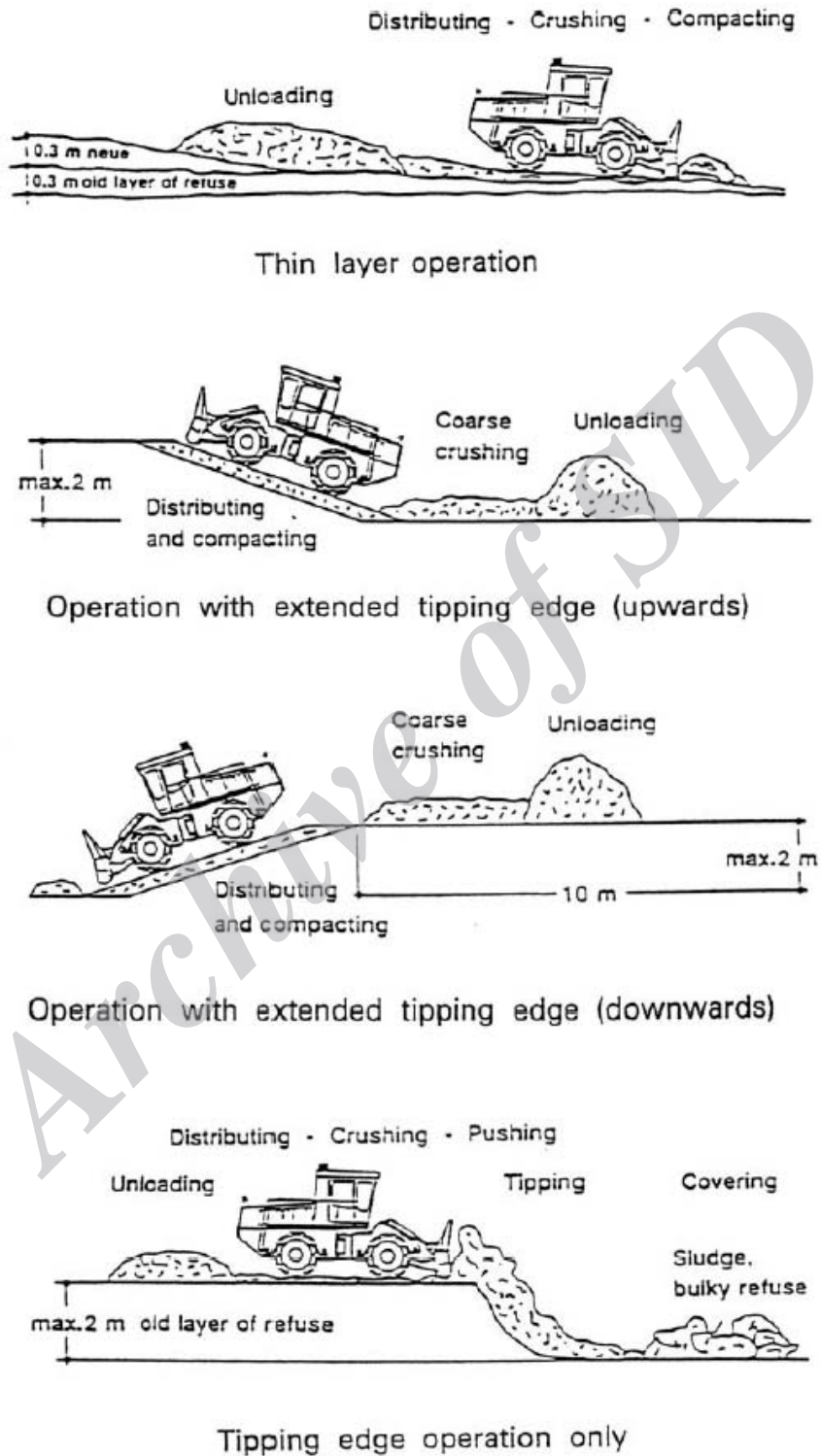


Figure 2-9.1: Techniques of Waste Disposal



### 9.2.2 Example of Practical Experience with Waste Compaction

Compaction tests have been performed by RAMKE/WEWETZER, 1997 in Poland on a landfill near Katowice, and this experience might be transferable to the situation on the Houshang site to some extent.

The following observations could be made:

- It is possible to increase the density of the dumped waste by compaction with a modern compactor from 0.70 t/m<sup>3</sup> (without compaction) to about 1.20 t/m<sup>3</sup> (after compaction). The compaction density after compaction can be 70 % higher than the spreading density without compaction.
- Before compaction the waste has to be spreaded in layers with heights of 30 cm or 50 cm and has to be compacted by at least 6 roller passes.
- The compaction density of 1.20 t/m<sup>3</sup> can be achieved by a layer with a height of 30 cm and 6 to 10 roller passes.
- Spreading the waste with a height of 50 cm and compacting it by 6 to 10 roller passes will result in a compaction density of about 1.00 t/m<sup>3</sup>.
- It can be recommended to use a waste layer of 30 cm during the spreading, and to compact it by 6 roller passes at minimum and to try to make 10 roller passes.
- A rough economic calculation has proved that - even taking into consideration a very low level of specific costs of landfill volume - the benefits by saving landfill volume are significant.
- In addition the positive effects on the environment are evident. Beginning with the extended period of landfill operation (about 50 - 70 %), going on with the improvement of landfill operation (smaller open dumping areas, better handling of bulky waste) up to minimisation of dust, litter and the risk of fire.

This practical experience show that thin layer operation in combination with intensive use of compactors will guarantee a high compaction density.

But on the other hand it has to be considered, that waste properties in Katowice and at the Houshang landfill are quite different, especially related to the content of moisture.

### 9.2.3 Recommendations for Disposal Technique at the Houshang Site

The design of organisation and technique of disposal at the Houshang site has to cover the following aspects:

- selection of equipment
- technique of disposal
- organisation of working areas
- covering of waste with soil
- management of waste streams.

These items will be discussed below in this order, considering that most of them are linked.

Table 2-9.1 shows the relationship between weight, performance and mass of waste, which can be compacted by one compactor, according to the information of a compactor supplier.

<b>Weight [Mg]</b>	<b>Performance [kW]</b>	<b>Compactable Mass of Waste [Mg/day]</b>
28	226	800
32	314	1000
<b>36</b>	<b>330</b>	<b>1200</b>
46	381	1400
54	400	1500

**Table 2-9.1: Weights and Performances of Compactors**

*Source: Internet-Homepage of BOMAG, [www.bomag.com](http://www.bomag.com)*

For proper operation at the Houshang site 6 compactors with a weight of 36 Mg and a performance of 330 kW are recommended. The use of compactors with a higher weight seems not to be recommendable for two reasons:

- the compaction density will not increase very much by use of compactors with higher weights
- compactors with too high weights might raise difficulties in operation (wet waste) and stability

In addition to the six compactors used for operation one compactor should be bought as replacement for compactors in maintenance or under repair.

Two compactors should be supported by 1 bulldozer, which can assist the compactors in spreading the waste. This seems to be necessary because

much waste will be delivered in a short period, therefore the expected bulks of waste must be divided and spread. In total 3 bulldozers for waste disposal and compaction should be used.

The technique of waste disposal will be determined by five factors:

- available equipment
- properties of waste
- hourly/daily amount of waste
- available working area
- requirements on compaction density.

Considering the maximum of compaction density only, thin layer compaction has to be performed in any case, because this method of waste disposal ensures the highest compaction density and therefore the most economic way of landfill operation.

Thin layer operation will be possible at the Houshang Abad site as far as the available equipment (provided it will be bought) and the available working area are concerned. Both factors have been determined above and will ensure a sustainable landfill operation. Furthermore trained staff at site are a precondition for advanced landfill operation (see Annex 4 – Institutional Strengthening and Implementation Support).

Despite these positive conditions attention has to be paid to the high amount of waste, the peak hours of waste delivery, and its high moisture content at the site. Discussions with landfill managers at the Kahrizak landfill have shown, that driving on the top of waste without soil cover may cause the trucks getting stuck, especially when the waste has been highly compacted.

This excludes a direct transport of the waste to the compaction zone. A tipping edge or a tipping floor, paved with construction debris and soil, is necessary. The length of such a tipping edge should be about 200 m to meet the requirements of the peak hour of waste transfers during the night. The tipping floor should have a width of about 100 m to allow maneuver of the trucks and their semi-trailers.

The potential of waste compaction in thin layers cannot be assessed totally at present. Despite the often mentioned high content of organics and the resulting high content of moisture thin layer operation might be possible. A field test with a modern compactor is recommended before the implementation of landfill operation at the Houshang site.

Facing the potential problems of very wet areas after compacting the waste of Tehran in very thin layers and the necessity of a tipping edge/tipping floor due

to the very high traffic in the night hours and the necessity of temporary paved tracks/maneuver zones the following procedure is recommended for the start of operation at the Houshang site:

1. After preparation of a cell and covering of the drainage layer with a “protection layer” of 2 m of waste, this layer has to be prepared as “tipping and maneuver floor” over a length of 200 m and a width of 100 m using construction waste and soil.
2. The waste transporters will start unloading the waste at the tipping edge – the borderline between the compaction zone and the maneuver zone.
3. The bulldozers will spread the waste rectangular to the tipping edge, and the compactors will start compaction in thin layers. The objective of this phase will be to prepare a maneuver zone upwards in a height of two meters.

This phase of operation can be defined as extended tipping operation, directed upwards.

4. When the tipping floor has achieved a height of 2 m and a width of 100 m at the opposite site of the sub-cell, the trucks will be directed to this tipping floor, which will be paved before.
5. At the upper tipping floor waste transporters will start unloading at the tipping edge again.

The principle of disposal starting here is an extended tipping edge operation, directed downwards.

6. When the whole working area has achieved the final height of two meters, the next working area will be put into operation.
7. The previous working cell will be covered with soil in total.

The whole procedure could be called as “upwards and downwards (swinging) extended tipping operation”. It ensures a maximum of compaction density – as far as possible – and minimises problems of operation.

The width of the compaction area should be at minimum 100 meters, the tipping edge (and pavement of tipping floor) should follow the front of the compaction area to optimise length of transportation of waste with bulldozers.

The height of the layers compacted depends on the properties of waste. It is recommended to begin with heights of layers of 50 cm, and to minimise the height if a sufficient density can be achieved without swampy zones.

If the waste does not allow compaction in thin layers their height has to be increased up to the height necessary for operation and perhaps the layers have

to be covered with soil (see below). Each of the waste layers spreaded at the extended tipping edge should be passed 6 times at minimum.

The compactors should be under operation in three shifts, to ensure a sufficient compaction density and landfill operation.

The final density of compaction depends on the height of the layers, the number of passes and the composition of waste. Taking into account the recommendations above and the high moisture of waste, the compaction density which is used for calculation of lifetime of cells of  $0.95 \text{ Mg/m}^3$  is a very reasonable approach and should be achievable.

The extent of soil cover of waste depends on its purpose. In general the extent of daily cover with soil should be reduced because this takes a lot of disposal volume. Depending on the landfill operation process a ratio of up to 20 % is possible. The following purposes and stages can be distinguished:

- Pavement of tipping floor/maneuver zone

The tipping floor/maneuver zone at the front and end of each sub-cell needs a pavement made of construction waste and sand. The height of the pavement has to be in a range of 30 cm considering Kahrizak experience.

Due to the high amount of construction waste delivered to Kahrizak and likely to Houshang site disposal volume will not be wasted. Construction waste is and has to be stockpiled out of the compaction areas.

- Daily cover of compaction zones

Daily cover with soil meets good landfill practice, in case the compaction density of waste is not very high. In this case daily cover with soil is recommended to avoid strong odour, blow of litter, attack of vermin, and attraction of birds.

In case of good waste compaction most of these problems will be minimised. Therefore daily cover should only be applied when necessary. The high moisture content of the waste may cause the need of a daily cover to ensure compactability. In this case a daily cover in a height of 15 – 20 cm must be applied.

- Final cover of working areas

When the final height of a working area within a working period will have been achieved, the working area should be covered with soil. The height of soil should be in a range of 20 cm. The whole working– out of operation for app. 4 weeks - should be covered when the actual final height is met.

Finally some operational recommendations are made to decrease the problems of landfill operation caused by the high traffic during the peak hours:

- Intermediate storage of waste in semi-trailers/containers

The transport of waste with semi-trailers from the transfer stations in Tehran within a few hours will cause difficulties if an intensive waste compaction shall be achieved. Especially because the delivery of waste happens during the night an organised operational procedure including spreading and thin layer compaction will be quite difficult.

Therefore, an increase of the number of semi-trailers or containers in order to reduce the number of emptyings during the night can be considered.

Assuming that 300 containers will be delivered during the night, an additional number of 100 containers would allow to unload 1/3 of the waste (delivered normally during the night) at daytime.

The full semi-trailers/containers could be stored at a separate parking place and could be driven with landfill-owned trucks to the disposal areas. It is assumed that 3 trucks will be sufficient for this task. The transport trucks will pick up an empty container.

- Intermediate storage of waste on a tipping floor

An alternative could be the intermediate storage of waste on a tipping floor sited between cell 1 and cell 4. Once again 1/3 of the waste delivered during the night (app. 1,750 Mg) could be store at such a tipping floor and transported by dumpers on the disposal area during the day. This alternative might be much cheaper in the investments (asphalt pavement of the tipping floor only), but requires the use of 1 - 2 loaders and some dumpers.

- Limitation of opening hours

The opening hours for waste transports not coming from the transfer station of the municipality of Tehran should be limited to avoid an additional traffic load in peak hours.

Therefore it is proposed to limit the opening hours for non-municipal waste transports from 08.00 – 18.00 hours.

During landfill operation the management and technique of disposal have to be developed in order to achieve a maximum of compaction density while improving smooth operation.

#### **9.2.4 Compaction of Special Types of Waste**

Special types of waste should be treated on the landfill in the following ways:

- Bulky waste must be compacted very carefully to crush it intensively. Large pieces of metals must be removed before compaction.
- Tires, refrigerators and other large or non-compactable pieces must be removed before compaction.
- Very wet zones (water saturated) have to be avoided. They should be drained and stabilised with debris before compaction.
- When sludge is delivered, it must be spread horizontally in thin layers for dewatering purposes, and then this layer has to be covered with a layer of household waste. Measures against odour are necessary (mixing with calcium or covering with soil).

#### **9.2.5 Recording of Disposal Areas**

It is recommended to record daily the location, height level and volume/type of waste, which actually is disposed of. A determination of these data is possible by using a measuring grid. When recording is performed properly it will later be possible to identify the place of waste dump when required (i.e. investigating potential contaminants).

But besides that, recording is helpful in controlling and managing the landfill.

#### **9.2.6 Recommendations**

Before implementing the operation plan a field test concerning the disposal technique is strongly recommended.

A compactor should be used to test the suitability of waste from Tehran for thin layer operation. The tests can be performed at the landfill of Kahrizak.

It is recommended to use a separate area for such a test, and to vary the following parameters:

- height of layers
- number of passes

In addition the compaction density achieved should be estimated.

## **9.3 Further Tasks of Landfill Operation**

### **9.3.1 Introduction**

An adequately organised landfill site is necessary to ensure a long-term technical safety of waste disposal and to avoid relevant impacts on or damages to the environment. The organization of a landfill has to cover the following topics apart from waste disposal:

- definition of waste admitted to disposal
- entrance control on landfills for municipal solid waste
- handling of special types of waste
- documentation and recording of landfill activities.

All site-specific regulations have to be recorded with in a "Basic Operation Manual", and the whole staff should have training related to its tasks.

### **9.3.2 Definition of Waste Admitted to Disposal**

For the Houshang site landfill a list of wastes will be defined giving information about the types of waste admitted to disposal. This list will enclose

- the key number of the waste  
(according to a waste classification system)
- a short description
- characteristic parameters.

At present it is understood that the Houshang site will be a landfill for municipal solid waste, which includes

- household waste (delivered by the transfer stations)
- commercial waste (like household waste, delivered by private companies)
- other municipal waste like street sweepings and construction waste
- non-municipal, non-hazardous industrial waste  
(after acceptance by the local administration and screening by the landfill operator)

The non-municipal waste is admitted to disposal has to be defined and listed. In addition a list of industrial and hazardous wastes should be made which names the waste not admitted to disposal on the municipal landfill site.

The types of waste listed there will be in accordance with the national or an international waste classification system.



### 9.3.3 Entrance Control

The type of waste delivered has to correspond with the list of waste admitted to disposal. This list must be available on the landfill site and must be part of the operation manual.

Delivered waste which is doubtful due to the yardmen will be unloaded on a paved small place near the entrance area for further check (sampling etc., see Drawing F 15).

The waste will be checked at the entrance as well as at the dumping place (to detect hidden components). The landfill workers are to carry mirrors with long sticks and ladders (to check the open vans and containers), and walky-talkies for the communication between the entrance and the dumping place.

For municipal waste delivered with the semi-trailers from the transport stations an entrance control is usually not necessary.

At the entrance the waste is to be registered and recorded. The following reception procedures are to be respected by the operator:

- checking of the transport papers (company, vehicle, licence) in case of municipal waste and in addition checking of the waste documentation in case of non-municipal waste
- determination of weight of the waste (two weigh bridges are designed)
- check of the waste by its properties (odour, colour, consistency, components etc.) at the entrance and at the point of deposit to verify the conformity with the description provided in the documentation of the waste generator
- for any kind of undetermined waste of unknown and suspicious origin, a temporary storage area for critical waste has been established.
- keeping a register of the quantities and characteristics of waste deposited.

In particular waste delivered by private industrial and waste management companies have to be checked.

The transport vehicles which are used for waste transport from the transfer stations (semi-trailers) or from the pre-treatment plants (perhaps dumpers) should be registered and their weight should be determined. This allows that the semi-trailers are to be weighed at the entrance only, but not at the exit.

Therefore a bypass at the weigh-bridge is installed, which makes it possible for the semi-trailers to pass the weigh-bridge without waiting.

#### 9.3.4 Handling of Special Types of Waste

The following recommendations are given for the handling of special types of waste, keeping in mind that the measures proposed are a matter of an integrated waste management concept:

- Bulky Waste

The disposal of specific types of bulky wastes (such as refrigerators or iron materials) should be organised in a way that dumping on the landfill is not necessary.

- Debris or Construction Waste

The disposal of debris or construction waste on the Houshang site landfill should be reduced to a minimum. Debris should only be accepted for construction of the bordering dams, the temporary operation roads, or for covering of dumping areas. If debris cannot be used as recycling material, a special landfill (area) for inert materials should be established.

- Sludge

The disposal of sewage sludge may cause problems. Often the contamination of the sludge has the consequence that the acceptance criteria are not fulfilled. In addition layers of spreaded sludge can cause problems for the stability of the landfill (risk of sliding etc.). A practical rule is that sludge should not exceed 10 % of the total weight of waste disposed of.

- Industrial Waste and other Non-Hazardous Waste of Non-Municipal Origin

Industrial waste and non-hazardous waste of non-municipal origin (mining waste, slag etc.) has to be rejected from disposal on the municipal landfill Houshang. There is just one exception for the generator who has the allowance from the local administration and from the operator, which have to consider waste properties and landfill capacities.

- Hazardous Waste

Hazardous wastes should not to be allowed to be disposed of on the Houshang site, since this landfill is designed and will be operated as a landfill for municipal solid waste.

It might be a reasonable approach to develop the Houshang site to an arrangement of different landfills, which contains next to the municipal solid waste landfill a landfill for construction waste and a sector for hazardous waste.

### 9.3.5 Recording and Documentation

Recording and documentation are necessary to check, that:

- waste has been accepted for disposal in accordance with the criteria defined
- the processes within the landfill proceed as desired
- the environmental protection systems are in working order
- the permit conditions for the landfill are fulfilled

A detailed recording is necessary as an evidence of compliance towards the controlling administration and to inform the people, living in the region. In a case of environmental impact it is possible to prove whether the impact is caused (or not caused) by emissions or by insufficient operation of the landfill site (according to the polluter pays principle).

Recording starts with the documentation of the permanent conditions of landfill operation:

- documentation of the installed technical protection measures (fence, collection and treatment of surface water, measuring equipment)
- documentation of the constructional measures during operation (covering of dumping areas, bordering dams, surface capping activities, recultivation)
- responsible operator and controlling administration
- situation of staff, working schedule
- operating instructions (landfill and equipment)
- updated emergency plans (fire protection, hospital etc.)
- maintenance of equipment
- laboratory, equipment and activities.

Daily recording is necessary will allow for:

- mass and cost balance
- control of landfill operation
- documentation of emissions
- documentation of unexpected events.

The daily recording must enclose

- atmospheric conditions  
(temperature, rainfall, evaporation, wind direction)
- delivery and disposal of waste  
(type and amount of waste delivered, places of disposal)
- usage of staff and machinery  
(staff, machinery, expenses for fuel, maintenance of equipment)
- maintenance of landfill structure  
(building of ramps, bordering dams, construction works etc.)
- measurements of emissions  
(leachate, landfill gas, litter, dust)
- documentation of special events  
(accidents, fire, machine failures).

Within the monthly and annual reports the results of the daily reports have to be compiled and presented in suitably arranged tables and figures.

All records have to be kept until the landfill is closed and the phase of aftercare is finished. The data of the records should be evaluated, in form of diagrams, tables and maps.

#### **9.4 Mobile Equipment**

Since there will be 400 to 500 vehicles (depending on the selected transfer and pre-treatment technology) every day, five steel wheeled compactors will be working permanently on site. Due to the extreme workload and the high weight of the compactors wear and tear will be high, and a maintenance circle of 2:1 is recommended, resulting to 7 compactors in total. Because of the increasing rate of waste input to the landfill the number of compactors should be increased by one in the beginning of operation of cell 3; but it depends on the experience gained during operation to see the need for such increase. Two bulldozers will be used for soil works and the preparation of waste compaction, whereas the other one contributes to dam building in addition to above mentioned activities.

7 tipper trucks will be used for transportation of various construction materials on site for daily cover, dam building and ditch and road maintenance activities (including needed redundancy for maintenance). This number would be added during operation because of increase in waste stream to 9 in total including redundancy. Wheel loader will be used for various loading activities related to landfill operation and recycling measures. 3 Pick-up trucks will be used for transportation of staff and equipment in different shifts and for internal trips in

the landfill. A water tank will be used e.g. for the minimisation of dust via watering of paved areas and is also used for site cleaning activities.

The leachate tube cleaning truck will be used for cleaning of the drainage system.

A middle-size roller compactor and a short-size one are to be used for compaction activities needed for dam building.

A shovel is necessary to build the peripheral dams with suitable slope and ditch maintenance.

In table 2-9.2 the equipment and necessary water supply for each of the activities in the landfill are shown.

In this table all landfill operations are divided to 14 main tasks and the equipments and water supply for each is mentioned in the beginning of operations and the 15<sup>th</sup> year (the estimated year for section 1 closure). The experience gained during years of operation will modify the current estimate of equipment needed. The equipment described in this table is needed to be operational. For the purpose of cost estimation a 5 years working age is assumed for machinery involved in waste placement and dam construction.

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	<i>Equipment and supply</i>	<b>1st year</b>	<b>15th year</b>
<b>Task 1</b> <b>Waste Placement</b>	Compactor	7	8
	Bulldozer	2.5	2.5
	Trucks	5	7
<b>Task 2</b> <b>Dam Building</b>	Middle Size Compactor	1	1
	Short Size Compactor	1	1
	Trucks	2	2
	Bulldozer	0.5	0.5
	Shovel	1	1
	Water(m <sup>3</sup> /day)	20	25
<b>Task 3</b> <b>Pipe Flushing</b>	Pipe Washing Truck	1	1
	Water(m <sup>3</sup> /day)	5	30
<b>Task 4</b> <b>Leachate Treatment</b>	Light Tools		
<b>Task 5</b> <b>Road and Ditch Maintenance</b>	Light Tools		
<b>Task 6</b> <b>Site Maintenance</b>	Light Tools		
<b>Task 7</b> <b>Green Area Maintenance</b>	Light Tools		
	Water(m <sup>3</sup> /day)	500	150
<b>Task 8</b> <b>Entrance Control- Weigh Bridge</b>	Office Tools		
<b>Task 9</b> <b>Administration and Management</b>	Office Tools		
<b>Task 10</b> <b>Repair and Maintenance Equipment</b>	Light Tools		
<b>Task 11</b> <b>Utility Services and Maintenance</b>	Light Tools		
	Water(m <sup>3</sup> /day)	31.4	36.2
	Sewerage Discharge	23.55	27.15
<b>Task 12</b> <b>Cleansing of the Site</b>	Cleansing Machine	1	
	Light Tools		
	Water(m <sup>3</sup> /day)	10	40
<b>Task 13</b> <b>Gas Collection Maintenance</b>	Light Tools		
<b>Task 14</b> <b>Internal Services</b>	Light Tools		

**Table 2-9.2: Equipment and Water Supply Needed for Each Operation Task**

### **Landfill Staff and Related Tasks**

An operator of a sanitary landfill has to ensure sufficient and suitable staff at any time. The operator has to ensure that adapted training and further training related for different tasks during a landfill operation is offered. The required staff landfill operation are:

Landfill manager with the following main tasks:

- Technical, organisational and financial overall management
- Personnel administration and training
- Counterpart for request of the disposal of waste from other sources (e.g. non-hazardous waste from industry)

Determination of a plan describing the exact location of the waste to be placed at the different location at the site (for each construction stage); final control and forwarding of all reports covering the landfill

The supervisors are responsible for the further landfill staff and the security regulations. In addition they are responsible for the preparation of the "landfill diary" (daily and monthly) and the annual report. They are taking care of the required control and are supporting the further landfill staff. Four supervisors for the landfill are proposed:

- 1- Disposal manager responsible for waste placement and dam building
- 2- Technical deputy responsible for maintenance of site and equipment and any operational activities (leachate and gas treatment)
- 3- Internal Deputy responsible for any safety measures, security, entrance control activities, material supply and waste acceptance or refusal in landfill
- 4- Financial and office affairs deputy responsible for any tariff reception or financial issues and supportive services for administration (dormitories, canteen) and employees.

**The engineers** are responsible for conducting main activities on the landfill and for helping supervisors to prepare and for execute "landfill diary" with their specialty in the respective fields. They should manage the staff needed and be completely involved in detailed operations.

**The technicians** are responsible for the maintenance, wear and tear of the mobile equipment and other equipment like, e.g., leachate collection, gas collection and treatment. In case of emergency (weekend and holidays), they are available for repairs on waste collection vehicles.

**The drivers** are responsible for the operation of the mobile equipment (compactor, bulldozer, wheel loader, truck, pick-up and special truck for the leachate pipes).

**The workers** are supporting the drivers and entrance control staff in guiding the waste collection trucks to the envisaged location for placing their load.

**The entrance control** staff are responsible for registering and controlling (weighing and registering of entering and leaving waste collection trucks; this includes date, hour, load, kind of waste, verification of a disposal permission based on a computerised list of permitted waste deliverers). In addition they will check the kind of waste by spot checks (at the waste inspection area) in the case that they have doubts that the permission covers the loaded waste.

**Employee** is an official who is responsible for different aspects of administration and supportive acts and working under the supervision of landfill deputies.

**Security agent** is responsible for the site security and should be equipped with firearms. This security agent should always be present of the landfill full time and in concordance with local legal and security authorities. In special situations (e.g. Anti-Scavenger acts) the number of security agents should be increased temporarily.

The disposal and dam building, security (two shifts) and entrance control are full time in three shifts and other staff are working in one shift. In Table 2-9.3 the numbers of staff needed in each position are shown.

	<b>Staff</b>	<b>1st year</b>	<b>15th year</b>
<b>Task 1 Waste Placement</b>	Compactor Driver	18	21
	Bulldozer Driver	9	9
	Loader Driver	3	3
	Truck Driver	15	21
	Disposal Manager(Supervisor)	3	3
	Technicians	3	3
	Worker	21	24
<b>Task 2 Dam Building</b>	Shovel driver	3	3
	Compactor driver	6	6
	Truck driver	6	6
	Technicians	3	3
	Workers	6	6
<b>Task 3 Pipe Flushing</b>	Technician	1	1
	Worker	2	2
	Driver	1	1
<b>Task 4 Leachate treatment</b>	Engineer	1	1
	Technician	1	1
	Worker	2	3



<b>Task 5</b>			
<b>Road and Ditch Maintenance</b>	Engineer	0.5	0.5
	Technician	1	1
	Worker	3	6
<b>Task 6</b>			
<b>Site Maintenance</b>	Engineer	0.5	0.5
	Technician	1	1
	Worker	2	3
<b>Task 7</b>			
<b>Green Area Maintenance</b>	Technician	1	1
	Worker	2	2
<b>Task 8</b>			
<b>Entrance Control</b>	Worker	6	6
<b>Weighbridge</b>			
<b>Task 9</b>			
<b>Administration and Management</b>	Landfill Manager	1	1
	Technical Deputy(Supervisor)	1	1
	Financial and office affairs Deputy(Supervisor)	1	1
	Internal Deputy(Supervisor)	1	1
	Secretary	1	2
	Employee	5	6
	Security	2	3
	Worker	2	2
<b>Task 10</b>			
<b>Equipment Maintenance</b>	Technician	2	3
	Worker	2	3
<b>Task 11</b>			
<b>Utility Services- maintenance</b>	Technicians	1	1
	Workers	2	2
<b>Task 12</b>			
<b>Cleansing of the site</b>	Technicians	1	1
	Workers	5	5
<b>Task 13</b>			
<b>Gas Collection System Maintenance</b>	Engineer	1	1
	Technician	1	1
	Worker	2	4
<b>Task 14</b>			
<b>Internal Services</b>	Employee	1	1
	Chef	1	1
	Worker	3	3
	<b>Total</b>	157	181

Table 2-9.3: Staff Allocation to Each Task

## 9.5 On-Site Safety Measures

A landfill like Kahrizak or – in future – the Houshang site requires several safety measures to protect the workers on-site, especially during the night.

Of special importance are the following recommendations:

- Equipment of the workers:  
uniform working clothes, protective clothings (safety boots, safety gloves, warning vests), helmets with light
- Equipment of the disposal area  
lighting of the whole area, clear signposting, blocking of areas
- Equipment of the vehicles  
fully operating lights, horn signals at driving backwards
- Prohibition of scavenging  
no scavenging at the disposal area due to the high traffic

Furthermore some measures of landfill operation are recommended to improve on-site safety:

- soil material of a volume of at least 100 m<sup>3</sup> will be stored near the waste filling area for fire fighting
- two trucks for fire fighting, one of them a tanker truck, should be available nearby the disposal area
- smoking is only to allow in the administration and social buildings, in all buildings fire extinguisher have to be fixed

These measures will help to reduce the risk of heavy accidents and to minimize the consequences of accidents.

## 10 Entrance Area

### 10.1 Access

The access to the site in section 1 is handled through a right turn ramp for entrance and an underpass of Tehran-Qom road for return. The less important access to Qom is delivered through a right-turn loop for entrance and a ramp for return. The entrance area is sited in a manner that it can be used for section 2 of the landfill with minor further constructions. For more detailed information on site access see chapter 4 on site development and related drawing.

The central entrance area consists of one control room between the two weigh bridges. Outside the control and entrance area, a parking lot is created to park cars who do not have the permission to enter the landfill. In this way, the entire traffic which is entering the landfill has to pass through this gate. For the cars of employees and the administration, a separate lane with a barrier is built, so to avoid conflicting traffic with the large semi-trailers. This gate is also controlled from the control room, which ensures the central recording of all vehicles and easy replacement of staff during the breaks and changing shifts.

There is a special access for the compactors which can not pass over the main entrance area after the weigh bridge.

### 10.2 Weigh Bridge

The weigh bridge is located after the entrance area and before the disposal area to block any unchecked waste transport vehicle passing to the landfill, and to avoid interference with the traffic of other vehicles. There is a by-pass besides the weight bridge to let the identified transport vehicles exit after unloading.

After the weigh bridge an area with asphalt liner is proposed so that the vehicles with waste types being potentially hazardous and not to be disposed in the landfill can be stored for classification. For more information on waste input procedure see chapter 9 on landfill operation.

### 10.3 Green Area

For the Houshang landfill a green area has been designed. For the green entrance area, there are 2 surfaces: one is around 3,780 m<sup>2</sup> and the second one around 42,000 m<sup>2</sup>. The total surface is approx. 46,000 m<sup>2</sup>. For this arid area 3 types of shrubs and 3 types of trees have been chosen. The trees are *Eucalyptus camaldulensis*, *Fraxinus pendula* -and *Tamarix aphylla* and the shrubs are *Atriplex leucoclada*, *Artemisia Escobar* and *Pennisetum orientale*.

These are all suitable for the landfill climate and all have low need for irrigation, will be able to cover the site properly and give a pleasant view to the site. For plantantion them a hole must be dug and filled with suitable soil for vegetation which can be a mixture of 1/3 compost and 2/3 clay and loam. During the first 2 years after planting, a permanent irrigation is needed for all the plants, but after that it is just needed for *Eucalyptus* and *Fraxinus*.

#### **10.4 Water, Sewerage and Electric Supply**

Water in the landfill during operation is needed for following purposes:

- dam construction and compaction
- pipe flushing
- human services
- irrigation
- site cleansing.

As the existence of water in the underground is not proved even with deep boreholes, the usage of underground water seems not to be possible. The other option is to use surface water. Hence a surface water pond is proposed in the entrance area to store surface water for usage. On the other hand the high evaporation rates and low rainfall does not preserve certain resource of water. Therefore transported water will be is the source of water supply in the landfill. A 120 cubic meter storage tank is proposed to store the transported or pumped water for usage.

Electricity supply can be provided by two means: power generators and use of the national electricity supply network. Investigations demonstrate that the investment costs for first the option are lower. But looking at the long-term usage of the site, will be more economical to use the electricity from the national network.

A transformation station is proposed near the boundary of the entrance area. But the place might change depending of the way that the authorities in charge for electricity will lead the electric lines to the site.

For the sewerage system a sewage tank with 120 m<sup>3</sup> capacity is proposed in the entrance area. This tank will be discharged from time to time and the sewage will be transported to a safe treatment and disposal facility.

#### **10.5 Other Entrance Area Facilities**

There are other general facilities in the entrance area like administration building to place administration staff and communications facilities. The dormitory is proposed also to be used for bathing and change of clothes.The

canteen will offer food for each shift of workers. A sheltered parking is proposed for heavy equipment and a workshop for repair activities. A storage building will provide capacity to store materials and instruments necessary for operations.

A fuel station is an optional item to let the transport vehicles fuel up within the landfill and minimize the time need for gasoline taking. The fuel needed for landfill equipment can be delivered to the site and stored in containers.

A fire station is a necessary item to extinguish any potential waste fire.

In Table 2-11.1 the buildings in the entrance area and the relative dimensions are shown.

<b>Building and facilities</b>	<b>Dimension</b>
Control building	20 m <sup>2</sup>
Administration	300 m <sup>2</sup>
Laboratory	120 m <sup>2</sup>
Staff Building	300 m <sup>2</sup>
Canteen Building	120 m <sup>2</sup>
Sheltered for parking	600 m <sup>2</sup>
Workshops	504 m <sup>2</sup>
Storage building	240 m <sup>2</sup>
Fire station	60 m <sup>2</sup>
Fuel station	60 m <sup>2</sup>
Electric power receiver	60 m <sup>3</sup>
Water storage tank	120 m <sup>3</sup>
Sewage water tank	120 m <sup>3</sup>

**Table 2-11.1: The Buildings in the Entrance Area and Corresponding Dimensions.**

## 11 Monitoring

### 11.1 Objectives

Landfill monitoring has to cover the source of emissions (landfill body) and the environment. In order to assess the influence of a landfill on its environment monitoring activities should comprise:

- meteorological data (if water balances shall be prepared)
- leachate emissions (quality and quantity)
- landfill gas emissions (quality)
- groundwater and surface water monitoring
- data on landfill body (type of waste, height, volume etc.)

A clear definition of the responsibility for landfill monitoring is recommended.

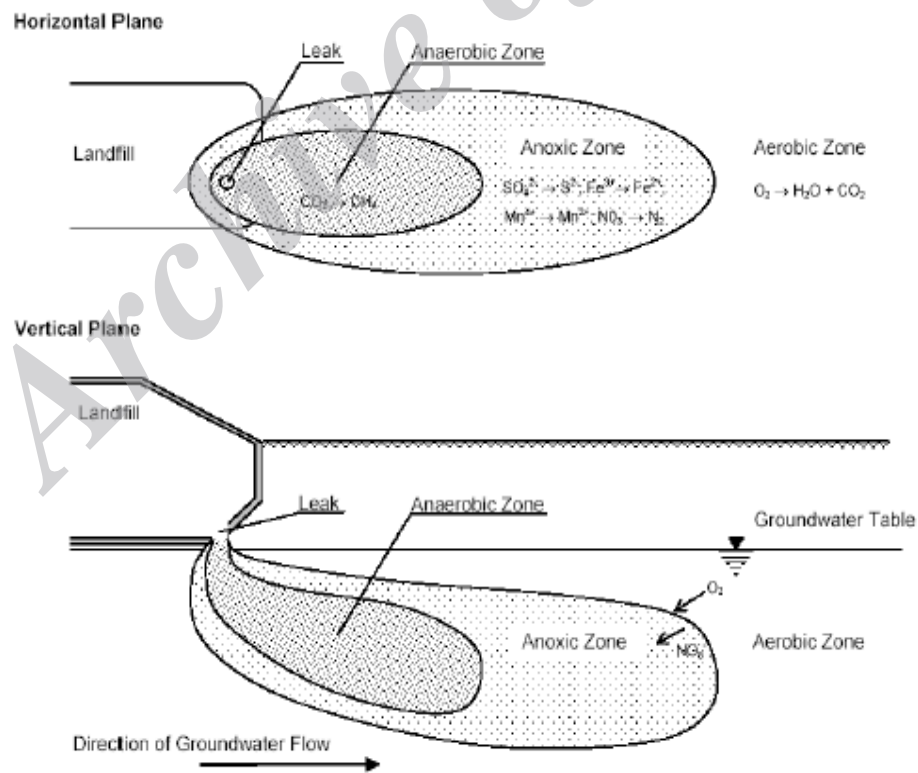


Figure 2-12.1: Long-term Impacts of Landfills

## **11.2 Monitoring Practice**

During landfill operation the following parameters have to be measured:

### **11.2.1 Meteorological Data**

The main objective of measuring meteorological data is the preparation of water balances of the landfill. The necessary parameters, which have to be measured daily, are precipitation, average daily temperature and evapotranspiration. In general evapotranspiration has to be calculated by data such as humidity, solar radiation and temperature.

### **11.2.2 Leachate Emissions**

Leachate is the main emission of the landfill. If a leachate collection system exists, periodical measurements of leachate quality and quantity are necessary for design and operation of treatment plants. In addition leachate quality clearly shows the phase of degradation of a landfill.

Important parameters for quality control are pH value, electrical conductivity, BOD (biological oxygen demand), COD (chemical oxygen demand), TOC (total organic carbon) and the content of cations (e.g. Na, K, Ca, Fe and NH<sub>4</sub><sup>+</sup>) and anions (esp. Cl<sup>-</sup> and SO<sub>4</sub><sup>--</sup>)

### **11.2.3 Landfill Gas Emission (Composition)**

Measurement of landfill gas is recommended to avoid explosions (dangerous range: 5 – 15 % of methane in normal air), to design landfill gas collection systems and to calculate potential benefits of gas utilisation. The measurement must be representative for each section of the landfill.

Monitoring of landfill gas production inside the landfill can be done with probes, combined with methane, carbon dioxide and oxygen detectors. If a landfill gas collection system exists, gas samples can be extracted from the system.

Landfill gas emission at the surface is measured with a FID (flame ionisation detector) which can detect methane (hydrocarbons) down to a range of 1 ppm.

### **11.2.4 Groundwater and Surface Water Monitoring**

The measurement of groundwater must provide information on groundwater likely to be affected by disposal of waste with at least one measuring point in the groundwater inflow region and two measuring points in the outflow region. Figure 9 gives an example for the impact of a landfill on groundwater. Apart from groundwater sampling and analysing the hydrogeological situation has to

be described, the direction of groundwater flow must be determined and the transport of contaminants in groundwater (if there are any) is to be assessed.

Monitoring of surface water (if relevant) shall be carried out at not less than two points in the river, one upstream from the landfill and one downstream.

Monitoring parameters are the same as in the case of leachate analyses. Some “target” parameters can be used to identify the influence of waste disposals on groundwater (boron, NH<sub>4</sub>, SO<sub>4</sub>, chlorinated hydrocarbons).

#### 11.2.5 Data on Landfill Body (Type of Waste, Height, Volume etc.)

Data on landfill body have to be collected by the entrance control (type and mass of waste delivered) and by the landfill staff during operation.

#### 11.2.6 Frequency of Sampling

No.	Media	Frequency of Sampling	
		Operating Phase	Aftercare Phase
<b>1.</b>	Leachate		
1.1	Leachate Quantity	Monthly	Every six months
1.2	Leachate Quality	Quarterly	Every six months
<b>2.</b>	Surface Water		
2.1	Volume of Surface Water	Quarterly	Every six months
2.2	Quality of Surface water	Quarterly	Every six months
<b>3.</b>	Landfill Gas		
3.1	Potential gas emissions	Monthly	Every six months
<b>4.</b>	Groundwater		
4.1	Level of groundwater	Every six months	Every six months
4.2	Groundwater quality	Site specific	Site specific
<b>5.</b>	Data on Landfill Body		
5.1	Structure and Composition	Yearly	
5.2	Settlement of Landfill Body	Yearly	Yearly reading

Table 2-12.1: Recommendations on the Frequency of Sampling, Given by the Annex III of the EC Directive



## 12 Volumes and Cost Estimates

### 12.1 Comparison of Costs with Benchmarks

The estimated construction costs are based on the local experience of Iranian contractors and the comparison with the governmental official costs for construction. Due to lack of standard construction and operation experience for landfills in Iran, the costs were estimated using similar activities like road and channel construction in Iran as well as internationally applied benchmarks.

For estimating the operation costs the exact number of staff, equipment, energy and material supply for each operation tasks was the basis for the calculation. The expenses were then derived from the unit costs of supply.

To make sure that the costs are precisely determined, the results are collated to benchmarks in addition to the investigation of the costs with local contractors (excavation, transport, asphalt and geomembrane liner etc.). The summary of this comparison is shown in Table 2-12.1.

Item	Bench Mark	Estimation
Operation to construction cost ratio	40%	36%
Ratio of equipment maintenance costs to equipments value	15-20%	18%
Liner cost	USD 6-14/m <sup>2</sup>	USD 20 m <sup>2</sup>
Gate fee	USD3-10 /ton	USD 5.71/ton

Table 2-12.1: The Comparison of Cost Estimate results with benchmarks (Cointreau-Livine 1995)

### 12.2 Waste Reduction and liner option related costs

As requested by client, the consultant investigated the reduction of input waste by 25% after 3 years from starting the operation. The investigations showed that the decrease in the amount of waste has no significant effect on the gate fee but extends the operation time of landfill from 15 to 19 years. The increasing effect of some fixed cost on gate fee has been compensated with the delay of investment in the 25% input reduction scenario.

The alternative option to the asphalt liner system is the HDPE liner which has different price for procurement and installation and causes the 17.4% decrease in the net construction costs.

In the table 2.12.2 the different related construction costs and gate fee for different options are shown.

<b>Cost Item</b>	<b>Landfill with Asphalt Liner</b>	<b>Landfill with HDPE liner</b>	<b>Landfill with 25% Reduction Scenario- Asphalt Option</b>
Investment (USD)	141,776,635	117,168,835	139,753,862
Gate Fee (USD)	5.72	4.94	5.69

**Table 2-12.2: The corresponding investment and gate fee costs for different options**

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## Cost Estimates and Specifications for Landfill Section 1

### 12.2.1 Investment Costs

No.	Item	Description	Reference	Unit	Qty.	Unit price in USD	Subtotal in USD	Total in USD
<b>1</b>	<b>Site Facilities</b>							4,999,947
1.1	Entrance Control	20 m <sup>2</sup> -one room-one floor-Control window & space for 2 people-2.5m height	Ch. 4.1 Dwg. F4	m <sup>2</sup>	20	350.00	7,000	
1.2	Weigh Bridge	With minimum 55 Tons capacity-Compactable with fully computerized system of data management	Ch. 10.2 Dwg. F15	pc.	2	100,000.00	200,000	
1.3	Sheltered Parking Area	The sheltered parking area for compactors, loaders, bulldozers and shovel- the shelter is steel structure with light weight roof	Ch. 10.5 Dwg. F15	m <sup>2</sup>	288	95.00	27,360	
1.4	Storage Building	240 m <sup>2</sup> -on floor building with portal system and no columns between-3.25 height	Ch. 10.5 Dwg. F15	m <sup>2</sup>	240	175.00	42,000	
1.5	Access Roads		Ch. 4.2.3					
1.6	Ar-G Roads	See drawing F-5	Ch. 4.2.3	m	1,500	140.00	210,000	
1.7	ITR Roads	See drawing F-5	Ch. 4.2.3	m	10,450	125.00	1,306,250	
1.8	IMR Roads	See drawing F-5	Ch. 4.2.3	m	7,810	70.00	546,700	
1.9	Underpass	See drawing F-15	Ch. 4.1.4	lump sum	1	350,000.00	350,000	
1.10	Water Tank, Water Pipeline	120 cubic meter steel water tank with 10 meters height- conveyance pipes are galvanized steel	Ch. 10.5 Dwg. F15	lump sum	1	70,000.00	70,000	
1.11	Power Supply (National Network)	Transformation room(40 m <sup>2</sup> -3 meter height-1.5 meter deep)-distribution room(20 m <sup>2</sup> -3 meter height) both suitable for 2MGV electricity)	Ch. 10.4 Dwg. F15	lump sum	1	750,000.00	750,000	
1.12	Sewage System, Septic Tank	Reinforced concrete septic tank with 120 m <sup>3</sup> capacity and HDPE pipes	Ch. 10.4 Dwg. F15	lump sum	1	30,000.00	30,000	

1.13	Fire Station	with two distinguisher trucks, canteen and dormitory for staff, 290 m <sup>2</sup> 3.5 high building including 120 m <sup>2</sup> parking for truck which is 4 meter high	Ch. 10.5 Dwg. F15	lump sum	1	250,000.00	250,000
1.14	Terrain Preparation & Pavement of Entrance Area	Including Fill-Cut activities, Pavement and Parking and storm water drainage system construction	Ch. 10 Dwg. F15	m <sup>2</sup>	11,400	45.00	513,000
1.15	Laboratory	Equipped with tools to determine: dry solid matter, loss on ignition, Toc, PH, EC, NH4-N, BOD5, COD-poetable meter for O2, CO2, CH4 and portable flammable ionization detector-see drawing F-16b	Ch. 10.5 Dwg. F15, F16b	m <sup>2</sup>	1	150,000.00	150,000
1.16	Administration	300 m <sup>2</sup> one floor building with 31 office stations and general facilities, 2.75 m high	Ch. 10.5 Dwg. F15	m <sup>2</sup>	300	230.00	69,000
1.17	Staff Building	300 m <sup>2</sup> one floor building for cloth exchange of up to 70 staff and dormitory for up to 20, 3 m high	Ch. 10.5 Dwg. F15	m <sup>2</sup>	300	290.00	87,000
1.18	Canteen Building	120 m <sup>2</sup> one floor building serving 100 people for one meal-Each meal time is 1.5 hours, 3m high	Ch. 10.5 Dwg. F15	m <sup>2</sup>	120	230.00	27,600
1.19	Office and Light Tools	Computers, Printers, Desks, and Other Office Facilities	Ch. 10.5	lump sum	1	100,000.00	100,000
1.20	Workshop	504 m <sup>2</sup> building with 4 meter height-see F16c	Ch. 10.5 Dwg. F15, F16c	m <sup>2</sup>	504	175.00	88,200

1.21	Fence	10cm*10cm Steel Fence- with Steel Pipe 8mm Diameter Each Five Meters as a Post-2.5 m high-3 Lines of Barbed Wire	Ch.10 Dwg. F15	m	1,235	50.00	61,750	
1.22	Entrance Area Dam	3 m high compacted soil dam of local soil-side slopes 1:2	Ch. 4.3.4, 4.3.5 Dwg. F15	m	1,049	63.00	66,087	
1.23	Temporary Storage for Critical Waste	An Asphalt liner platform with light roof and leachate control system	Ch. 9.3.3 Dwg. F15	m <sup>2</sup>	400	120.00	48,000	
1.24	Fuel Station**		Ch. 10.5 Dwg. F15	lump sum	1			

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No.	Item	Description	Reference	Unit	Qty.	Unit price in USD	Subtotal in USD	Total in USD
<b>2</b>	<b>Mobile Equipment</b>		Ch. 9.2 - 9.5					10,470,000
2.1	Waste Compactor	36 ton- 36 HP power		pc.	22	200,000.00	4,400,000	
2.2	Bulldozer	110 HP power		pc.	15	120,000.00	1,800,000	
2.3	Shovel	54 HP power		pc.	3	100,000.00	300,000	
2.4	Minibus			pc.	1	40,000.00	40,000	
2.5	4x4 Pick-up			pc.	3	25,000.00	75,000	
2.6	Loader	110 HP-wheel loader		pc.	6	130,000.00	780,000	
2.7	Little Compactor	30 HP- 1 ton weight		pc.	6	2,500.00	15,000	
2.8	Trucks for Road Surface Wetting	15000 liters storage capacity		pc.	1	40,000.00	40,000	
2.9	Leachate Pipe Cleaning Truck	450 HP diesel driver unit for two parallel HP pumps(450 l/min and 220 bar pressure-vacuum pump with 1500 m3/hour capacity- 800 meter ultra-light 1 1/4 inch hose on reel-ceramic nozzle with optimized flow properties-flow accelerator		pc.	1	600,000.00	600,000	
2.10	Trucks for Material Transport	18 m <sup>3</sup> capacity- 80 HP		pc.	22	110,000.00	2,420,000	

No.	Item	Description	Reference	Unit	Qty.	Unit price in USD	Subtotal in USD	Total USD
<b>3</b>	<b>Landfill Sealing System</b>							62,300,000
3.1	Liner (with Protection layer)	2mm-HDPE liner- 15 cm protection beneath-500 gr/m <sup>2</sup> geotextile- see drawing F.9.1	Ch. 5 Dwg. F9	m <sup>2</sup>	3,100,000	20	62,000,000	
No.	Item	Description	Reference	Unit	Qty.	Unit price in US \$	Subtotal in USD	Total in USD
<b>4</b>	<b>Earthworks</b>		Ch. 4.2, 4.3, 9.1, 12 Dwg. F4, F7, F10, F11					4,575,000
4.1	Cut and Haul to Temporary Storage			m <sup>3</sup>	1,500,000	2.00	3,000,000	
4.2	Fetch from Temporary Storage and Fill			m <sup>3</sup>	700,000	2.25	1,575,000	
No.	Item	Description	Reference	Unit	Qty.	Unit price in US \$	Subtotal in USD	Total in USD
<b>5</b>	<b>Leachate Drainage System</b>		Ch. 7.1 Dwg. F9					15,511,300
5.1	Drainage Layer	16/32 gravel-less than 5% lime		m <sup>2</sup>	3,150,000	3.30	10,395,000	
5.2	Perforated Pipes	30 cm- HDPE pipe- specially perforated for landfill usage- RSC>1.4 kN/m		m	61,000	65.00	3,965,000	
5.3	Non-Perforated	30 cm- HDPE pipe-32 kg/m bearing capacity		m	6,150	14.00	86,100	
5.4	Manholes	manholes made of HDPE with density 0.995 gr/cm <sup>3</sup> and flexural modulus more than 110000 psi- built on 30 cm of soil compacted to 95% proctor density		pc.	130	8,000.00	1,040,000	
5.5	Sumps	sumps made of HDPE with density >0.995 gr/cm <sup>3</sup> and flexural modulus more than 110000 psi- built on 30 cm of soil compacted to 95% proctor density		pc.	4	6,300.00	25,200	

No.	Item	Description	Reference	Unit	Qty.	Unit price in USD	Subtotal in USD	Total in USD
<b>6</b>	<b>Leachate Treatment System</b>		Ch. 7.2 Dwg. F18					6,123,000
6.1	Evaporation Lagoon Liner	2 mm thick HDPE geomembrane-30 cm protection sand		m <sup>2</sup>	252,000	8.00	2,016,000	
6.2	Evaporation Lagoon Excavation			m <sup>3</sup>	240,000	2.00	480,000	
6.3	Aerated Lagoon Liner	2 mm thick HDPE geomembrane-30 cm protection sand		m <sup>2</sup>	23,000	8.00	184,000	
6.4	Aerated Excavation			m <sup>3</sup>	60,000	2.00	120,000	
6.5	Storage Lagoons Liner	2 mm thick HDPE geomembrane-30 cm protection sand		m <sup>2</sup>	20,000	8.00	160,000	
6.6	Storage Lagoons Excavation			m <sup>3</sup>	60,000	2.00	120,000	
6.7	Swimming Stirrers	minimum 55 kW power		pc.	60	14,000.00	840,000	
6.8	Pumps			pc.	12	12,500.00	150,000	
6.9	Pipes	30 cm- HDPE pipe-32 kg/m bearing capacity		m	1,500	14.00	21,000	
6.10	Manholes			pc.	20	8,000.00	160,000	
6.11	Floating Aerator	minimum 22 kW power		pc.	72	26,000.00	1,872,000	
No.	Item	Description	Reference	Unit	Qty.	Unit price in USD	Subtotal in USD	Total in USD
<b>7</b>	<b>Gas Management System</b>							13,240,000
7.1	Gas Extraction Wells	see drawing F-17		pc.	1,200	4,000.00	4,800,000	
7.2	Flare and Booster	see drawing F-17	Ch. 8.2.6 Dwg. F16, F17	pc.	8	250,000.00	2,000,000	
7.3	Condensation System	see drawing F-17	Ch. 8.2.4	pc.	60	4,000.00	240,000	
7.4	Gas Pipes	see drawing F-17	Ch. 8.2	m	120,000	30.00	3,600,000	
7.5	Main Gas Pipe	see drawing F-17	Ch. 8.2.5	m	20,000	100.00	2,000,000	
7.6	Condensate Line	see drawing F-17	Ch. 8.2.5	m	20,000	30.00	600,000	



No.	Item	Description	Reference	Unit	Qty.	Unit price in USD	Subtotal in USD	Total per directory in USD
<b>8</b>	<b>Storm water Drainage System</b>		Ch. 11.2.4 Dwg.F9					1,671,500
8.1	Sedimentation Ponds	Reinforced concrete pond with 500m <sup>2</sup> net volume with floating cover		lump sum	2	90,000.00	180,000	
8.2	Main Drainage Channels	With 10cm of non-reinforced concrete as liner and stabilizer-see drawing F-9		m	12,500	100.00	1,250,000	
8.3	Cell Drainage Channels	with 10 cm of non-reinforced concrete as liner and stabilizer-see drawing F-9		m	16,100	15.00	241,500	
No.	Item	Description	Reference	Unit	Qty.	Unit price in USD	Subtotal in USD	Total per directory in USD
<b>9</b>	<b>Landfill Surface Sealing System</b>		Ch.6 Dwg.F13					4,976,258
9.1	Cover Layer	See drawing F-13		m <sup>2</sup>	2,488,129	2.00	4,976,258	
No.	Item	Description	Reference	Unit	Qty.	Unit price in USD	Subtotal in USD	Total per directory in USD
<b>10</b>	<b>Monitoring</b>		Ch. 11.2					65,000
10.1	Weather Station	facilities for measurement of precipitation , temperature, humidity and solar radiation, wind speed and direction		pc.	1	40,000.00	40,000	
10.2	Monitoring Wells			pc.	10	2,500.00	25,000	

No.	Item	Description	Reference	Unit	Qty.	Unit price in USD	Subtotal in USD	Total per directory in USD	
<b>11</b>	<b>Green Area</b>							1,391,483	
11.1	Green Area on Cells	Sustainable species such as Tamarix rammosissima, Atriplex leucoclada, Saxavel and Siedlitzia rosmarinus has been recommended for this according to the climate and just 1.5m soil depth. 2 meters between each shrub has been considered.	Ch. 10.3 Dwg.F6.1, F6.2			0.28	1,341,483		
11.2	Entrance area gardening activities	Eucalyptus camaldulensis, Fraxinus pendula, Tamarix aphylla, Atriplex leucoclada, Artemisia Escobar and Pennisetum orientale are the recommended	Ch. 10.3 Dwg.F6.1, F6.2	lump sum	1	50,000.00	50,000		
<b>TOTAL</b>							16,661,625	3,685,378.83	125,023,487

Table 2-12.2: Investment Cost Estimates

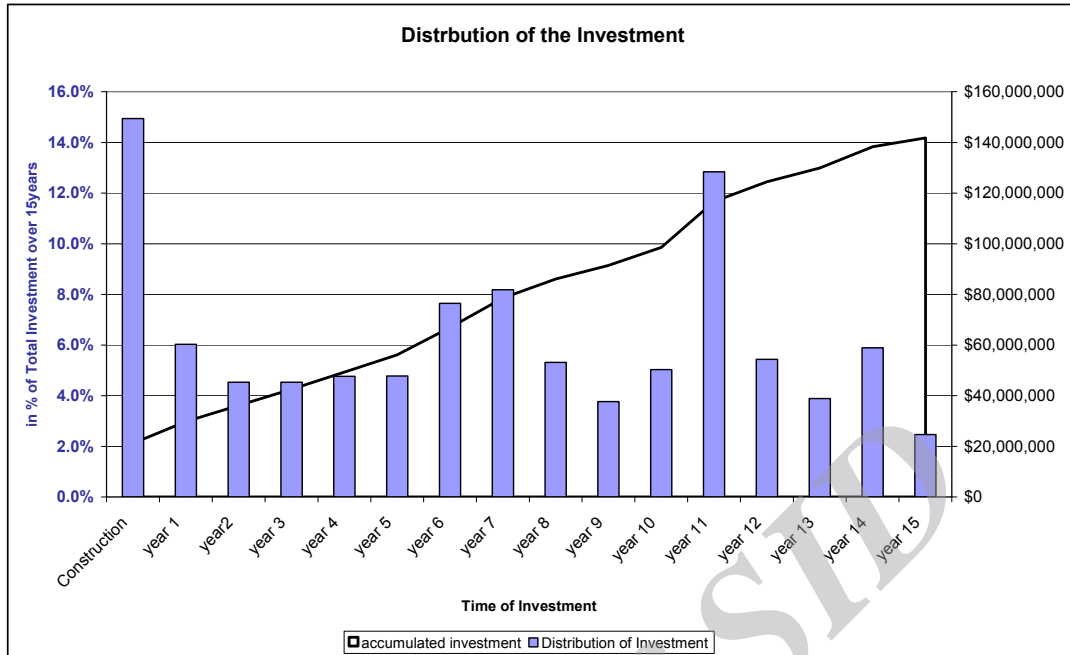


Figure 2-12.1: Distribution of Investment

The investment distribution is shown in Figure 2-12.1. The peaks can be explained by the increased need for replacement of equipment and starting of new cells which need more investment on liners in first year. The investment schedule was calculated without taking into account the time value of money.

### 12.2.2 Operational Costs

Operation Costs Items		Construction	year 1	year 2	year 3	year 4	year 5	year 6	year 7	year 8	year 9	year 10	year 11	year 12	year 13	year 14	year 15	Subtotal per Item	
Staff			-1,200,000	-1,200,000	-1,200,000	-1,216,000	-1,216,000	-1,216,000	-1,236,000	-1,236,000	-1,236,000	-1,320,000	-1,320,000	-1,320,000	-1,340,000	-1,340,000	-1,340,000	-18,936,000	
Gasoil/Gas			-100,000	-100,000	-100,000	-100,000	-100,000	-100,000	-100,000	-100,000	-100,000	-115,000	-115,000	-115,000	-115,000	-115,000	-115,000	-1,590,000	
maintenance and part replacement of machinery			-572,400	-572,400	-572,400	-572,400	-572,400	-572,400	-572,400	-572,400	-572,400	-628,200	-628,200	-628,200	-628,200	-628,200	-628,200	-8,920,800	
Material Supply (Maintenance of site and light tools)			-50,000	-50,000	-50,000	-60,000	-60,000	-60,000	-70,000	-70,000	-70,000	80,000	-80,000	-80,000	-90,000	-90,000	-90,000	-1,050,000	
laboratory and testing			-30,000	-30,000	-30,000	-30,000	-30,000	-30,000	-30,000	-30,000	-30,000	-30,000	-30,000	-30,000	-30,000	-30,000	-30,000	-450,000	
Electricity			-95,000	-95,000	-95,000	-140,000	-140,000	-140,000	-200,000	-200,000	-200,000	-260,000	-260,000	-260,000	-310,000	-310,000	-310,000	-3,015,000	
Sewerage			-25,000	-25,000	-25,000	-26,500	-26,500	-26,500	-28,000	-28,000	-28,000	-29,000	-29,000	-29,000	-30,000	-30,000	-30,000	-415,500	
Water			-115,000	-120,000	-127,000	-135,000	-145,000	-150,000	-158,000	-166,000	-175,000	-182,000	-190,000	-197,000	-205,000	-214,000	-222,000	-2,501,000	
Gas Treatment facility Maintenance			0	-79,300	-158,600	-237,900	-317,200	-317,200	-443,300	-569,400	-569,400	-687,700	-806,000	-924,300	-924,300	-1,112,150	-1,300,000	-8,446,750	
contingencies	8%		-174,992	-181,736	-188,640	-201,424	-208,568	-208,968	-227,016	-237,744	-238,464	-266,552	-276,656	-286,680	-293,800	-309,548	-325,216	-3,626,004	
<b>Total Cost of Operation</b>			<b>-2,362,392</b>	<b>-2,453,436</b>	<b>-2,546,640</b>	<b>-2,719,224</b>	<b>-2,815,668</b>	<b>-2,821,068</b>	<b>-3,064,716</b>	<b>-3,209,544</b>	<b>-3,219,264</b>	<b>-3,598,452</b>	<b>-3,734,856</b>	<b>-3,870,180</b>	<b>-3,966,300</b>	<b>-4,178,898</b>	<b>-4,390,416</b>	<b>-48,951,054</b>	
<b>Cashflow from Investments</b>			<b>-21,181,679</b>	<b>-8,536,571</b>	<b>-6,416,305</b>	<b>-6,416,305</b>	<b>-6,753,926</b>	<b>-6,769,812</b>	<b>-10,835,997</b>	<b>-11,605,770</b>	<b>-7,538,600</b>	<b>-5,340,332</b>	<b>-7,130,626</b>	<b>-18,200,306</b>	<b>-7,703,455</b>	<b>-5,508,773</b>	<b>-8,351,602</b>	<b>-3,486,575</b>	<b>-141,776,635</b>
<b>Total Cash outflow before Interest</b>			<b>-21,181,679</b>	<b>-10,898,963</b>	<b>-8,869,741</b>	<b>-8,962,945</b>	<b>-9,473,150</b>	<b>-9,585,480</b>	<b>-13,657,065</b>	<b>-14,670,486</b>	<b>-10,748,144</b>	<b>-8,559,596</b>	<b>-10,729,078</b>	<b>-21,935,162</b>	<b>-11,573,635</b>	<b>-9,475,073</b>	<b>-12,530,500</b>	<b>-7,876,991</b>	<b>-190,727,689</b>
<b>Cashflow form Gate Fee</b>			<b>14,562,646</b>	<b>14,815,191</b>	<b>15,067,736</b>	<b>15,320,280</b>	<b>15,572,825</b>	<b>15,825,370</b>	<b>16,077,915</b>	<b>16,330,459</b>	<b>16,583,004</b>	<b>16,835,549</b>	<b>17,088,093</b>	<b>17,340,638</b>	<b>17,593,183</b>	<b>17,845,727</b>	<b>18,098,272</b>	<b>244,956,888</b>	
Total operative Cashflow before Interest and Amortisation		incl. Construction	-17,517,996	5,945,450	6,104,791	5,847,131	5,987,345	2,168,305	1,407,428	5,582,315	8,023,408	6,106,471	-4,847,069	5,767,003	8,118,109	5,315,227	10,221,281	54,229,199	
Accumulated operative Cashflow before Interest			-17,517,996	-11,572,545	-5,467,754	379,377	6,366,722	8,535,027	9,942,455	15,524,770	23,548,178	29,654,648	24,807,579	30,574,582	38,692,692	44,007,918	54,229,199	54,229,199	
Interest on Construction Phase (50% of initial Investment)	10% p.a.		-1,059,084															-1,059,084	
Initial Working Capital			-4,854,000															-4,854,000	
Total Cashflow before Interest and Amortisation		incl. Construction	-23,431,080	5,945,450	6,104,791	5,847,131	5,987,345	2,168,305	1,407,428	5,582,315	8,023,408	6,106,471	-4,847,069	5,767,003	8,118,109	5,315,227	10,221,281	48,316,115	
Accumulated Cashflow before Interest			-23,431,080	-17,485,629	-11,380,838	-5,533,707	453,638	2,621,943	4,029,371	9,611,686	17,635,094	23,741,564	18,894,495	24,661,498	32,779,608	38,094,834	48,316,115	48,316,115	
Interest Payments on accumulated cashflow before interest and working capital	10% p.a.			-2,343,108	-1,748,563	-1,138,084	-553,371	0	0	0	0	0	0	0	0	0	0	-5,783,125	
<b>total Cashflow after Interest and Amortisation</b>		incl. Construction	<b>-23,431,080</b>	<b>3,602,342</b>	<b>4,356,228</b>	<b>4,709,047</b>	<b>5,433,974</b>	<b>2,168,305</b>	<b>1,407,428</b>	<b>5,582,315</b>	<b>8,023,408</b>	<b>6,106,471</b>	<b>-4,847,069</b>	<b>5,767,003</b>	<b>8,118,109</b>	<b>5,315,227</b>	<b>10,221,281</b>	<b>42,532,990</b>	
<b>Accumulated Cashflow after Interest</b>			<b>-23,431,080</b>	<b>-19,828,737</b>	<b>-15,472,509</b>	<b>-10,763,462</b>	<b>-5,329,488</b>	<b>-3,161,183</b>	<b>-1,753,754</b>	<b>3,828,561</b>	<b>11,851,968</b>	<b>17,958,439</b>	<b>13,111,370</b>	<b>18,878,373</b>	<b>26,996,482</b>	<b>32,311,709</b>	<b>42,532,990</b>	<b>42,532,990</b>	
<b>Waste Volume handled (t)</b>			<b>2,544,120</b>	<b>2,588,240</b>	<b>2,632,360</b>	<b>2,676,480</b>	<b>2,720,600</b>	<b>2,764,720</b>	<b>2,808,840</b>	<b>2,852,960</b>	<b>2,897,080</b>	<b>2,941,200</b>	<b>2,985,320</b>	<b>3,029,440</b>	<b>3,073,560</b>	<b>3,117,680</b>	<b>3,161,800</b>	<b>42,794,400</b>	
Resulting Gate Fee	\$5.72	<b>Table 2-12-3: Operational Costs, Gate fee and Cash flow</b>																	

Aftercare	\$42,532,990
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### 12.2.3 Cash Flow – Gate Fee Ratio

The operational cost table bases the annual cash flow on an assumed gate fee of USD 5,72 to cover the costs for the landfill operation, the aftercare which is normally calculated at about 30 %. The costs for the aftercare will most likely be lower, since most of the operation will continue on the southern area in section2. Figure 2-12.2 shows the dependency of the accumulated cash flow from the gate fee to be defined by OWRC.

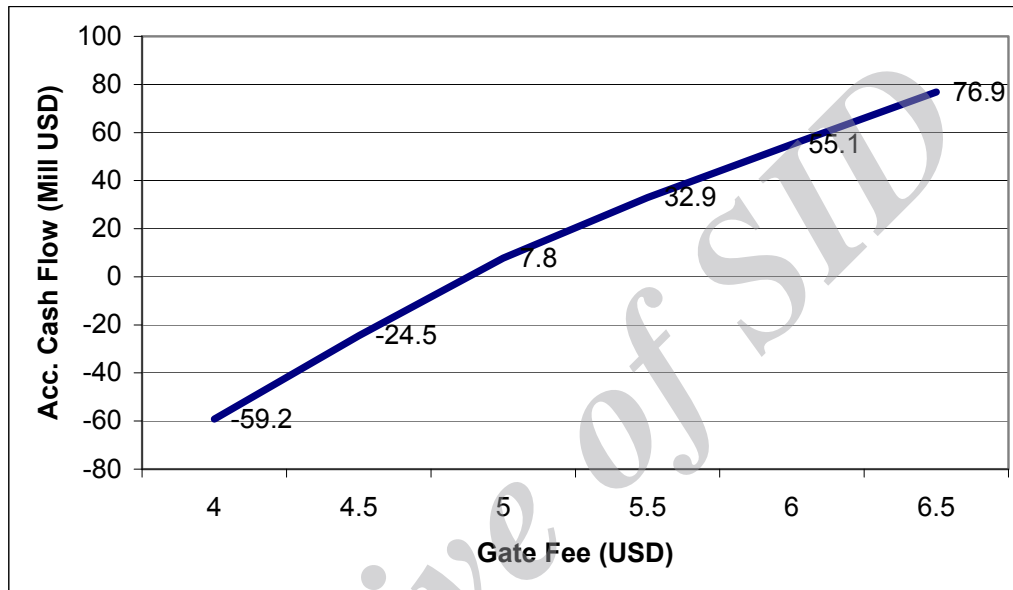


Fig 2-12.2: Cash flow - Gate fee dependency for the landfill costs

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## Part 3

### Comparative Transportation Analysis

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# 1 Baseline Data and Current Situation

## 1.1 Transport Volumes and Distances

There are 12 active transfer stations in the Tehran metropolitan area that handle the most part of the household waste generated in the city. A negligible amount of waste is carried directly to the landfill of the city which is currently sited in Kahrizak. In Table 3-1.1 the coding of transfer stations and their exact address is noted.

Station	Station No.	Address
Darabad	TS.1	Ozgol Ave., Ooshan Blvd.
Bani Hashem	TS.2	Khaje-Abdollah Ansari Ave. , Banihashem St.
Chitgar	TS.3	Karaj Highway, Koohak Blvd., Nassim 4th.St. next to Chitgar park
Beihaghi	TS.4	Argentina Sq. , Next to Shahrvan Shopping center
Golbarg	TS.5	Narmak ,West Golbarg St. between Kerman & Madani St.
Hakimieh	TS.6	Damavand Ave. Hakimieh St. Next to Water Organization (sazman-e-Ab)
Zanjan	TS.7	North Zanjan Ave. Next to Police parking
Harandi	TS.8	Shoush Ave., between Shoush Sq. & Harandi Sq.
Azadegan	TS.9	Afsarieh Sq. ,Azadegan Highway, In front of Touska park
Mive-Va-Tarebar	TS.10	Azadegan Highway , Jihad Sq. , South Nour St.
Jade Saveh	TS.11	Beginning of saveh Rd. , Before the Gas station
Shahr-e-Rei	TS.12	Shahid Avini Highway , Infront of Ahmadvar village

Table 3-1.1: Code and Address of Each Transfer station

The transfer stations are scattered all over the city and so the distances between transfer stations and the landfill vary a lot. On Map M5 the location of transfer stations is shown and in Table 3-1.2 the distances between every active transfer station and the new landfill are shown.

The amount of waste delivered to Kahrizak shows minor changes in different seasons, of course, some peak points have been observed that are temporary and should not be considered as a base for studies. The amount of waste transferred to the Kahrizak landfill from transfer stations is 1,900,000 Mg when the amount of waste which Kahrizak received is 2,550,000 Mg in the recent year (1382 Hejri Shamsi).The main reason of this difference is direct transport (not via transfer stations) to Kahrizak. The amount of waste which is basically sludge and wood that can not be handled by semi-trailers (65 m<sup>3</sup> volume) in transfer stations is estimated to be 94 Mg in recent year which shows a considerable amount of waste (22% of total waste received in Kahrizak) is transported directly to Kahrizak. In this study we made an assumption that this part will be directly transferred to new landfill.

**Insert Map M5: Location of Transfer Stations**

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Station No.	Name	Distance (km)
TS.1	Dar Abad	85.5
TS.2	BaniHashem	76.0
TS.3	Chitgar	80.0
TS.4	Beihaghi	76.5
TS.5	Golbarg	75.0
TS.6	Hakimiyeh	78.0
TS.7	Zanjan	69.5
TS.8	Harandi	61.7
TS.9	Aazadegan	61.0
TS.10	Miveh-va-Tarebar	59.0
TS.11	Jade Saveh	62.5
TS.12	Shahr-e-Rei	53.4

Table 3-1.2: Distance of Each Transfer Station to the New Landfill

## 1.2 Transfer Stations

All transfer stations in Tehran except one are classified as large transfer stations according to the amount of waste transferred from each one. Current waste turnover of each active transfer station is shown in Table 3-1.3 According to the forecast of waste increase that has been agreed upon with OWRC as baseline indicator anticipated for year 2019 is also shown in table 3-1.3. This amount would be used as a basis for studies.

All transfer station in Tehran have a considerable amount of spare capacity according to the studies conducted in OWRC. These studies have been checked during this study and proven to be correct. The main point that limits the capacity of current transfer station is the number of semi-trailers available and the absence of waste storage system which increase the waiting time of collection vehicles.

Station	Station No.	Turnover (2004)	Turnover (2019)
		Mg/year	Mg/year
Darabad	TS.1	145,978.75	225,975.11
Bani Hashem	TS.2	47,510.41	73,546.12
Chitgar	TS.3	231,166.52	357,845.78
Beihaghi	TS.4	214,080.38	331,396.43
Golbarg	TS.5	128,100.00	198,298.80
Hakimieh	TS.6	194,920.82	301,737.44
Zanjan	TS.7	191,786.87	296,886.07
Harandi	TS.8	146,686.19	227,070.22
Azadegan	TS.9	230,914.85	357,456.18
Mive-Tarebar	TS.10	146,317.36	226,499.27
Jade Saveh	TS.11	164,675.42	254,917.56
Shahr-e-Rei	TS.12	92,964.78	143,909.48
Total		1,935,102.36	2,995,538.45

Table 3-1.3: Turnover of Each Transfer Station

The method used in transfer stations is the direct haul method which is based on usage of more semi-trailer than tractors as the storage capacity. No storage has been foreseen for transfer stations although the waste would be stored in transfer station yard in emergency conditions. No classical compaction is implemented in transfer stations but some manual compaction or using shovels and pushing blade to compact the waste has been observed during site visits. At the landfill the pushing blade method is used by semi-trailers to unload the waste.

Management of waste transport is done by private sector contractors and is supervised by the Motor Pool Department. The semi-trailers are owned by the Motor Pool Department and are lent to the contractor under conditions of contract.

The circle time varies from each transfer station to another and is highly dependent on the timing of the transportation, technology of tractors and containers and the technology used in transfer stations.

The datasheet of each transfer station and the corresponding pictures are to be found in Annex of this report.

### 1.3 Transportation Fleet

In the current year 179 semi-trailers are used. Although the total number of vehicles used is 715 but because of the high frequency of semi-trailer usage, most part of the waste is transported by semi-trailers which include almost all of domestic waste (not sludge or wood type wastes). As there is no data available about the fleet age, but some unofficial information from contractors and OWRC staff and site visits: is assumed that the current fleet lifetime will exhaust in the near future. The fleet tends to be replaced in coming years, which corresponds to unofficial data gathered.

Depending on waste turnover and distance to Kahrizak landfill different numbers of fleet elements have been allocated to each transfer station. In Table 3-1.4 the number of tractors and semi-trailers in each transfer station is shown. The number of each tractor trips from transfer stations to Kahrizak is varying from 2 to 6 trips per tractor.

Station	Station No.	Number of Semi-Trailers	Number of Tractors
Darabad	TS.1	12	9
Bani Hashem	TS.2	5	4
Chitgar	TS.3	13	7
Beihaghi	TS.4	25	20
Golbarg	TS.5	6	6
Hakimieh	TS.6	15	10
Zanjan	TS.7	10	10
Harandi	TS.8	10	6
Azadegan	TS.9	14	9
Mive-va-Tarebar	TS.10	7	4
Jade Saveh	TS.11	10	7
Shahr-e-Rei	TS.12	6	2

Table 3-1.4: Number of Semi-Trailers and Tractors in Each Station

The unofficial data gathered show that between 25 % - 35 % of fleet are currently in repair, which indicates the expired lifetime of the fleet. The repairs are usually delayed due to the of large number of repair works needed.

#### 1.4 Development Scenario

The scenario underlying the transportation study is based on the main assumed scenario for the landfill design. In recent years the density of waste in semi-trailers fell from 325 kg/m<sup>3</sup> to 280 kg/m<sup>3</sup>, thus providing that the waste density is decreasing in Tehran. This makes the compaction more favourable. In addition the amount of waste is increasing due to increasing population and public welfare, also supporting the compaction principle. Because of lack of yearly and continuous data on waste density it is assumed that with the increasing percentage of non-degradable materials in waste the density of waste in the horizon of study would be 250 kg/m<sup>3</sup> that would be a middle range reported for a middle income country.

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## 2 Alternatives for Transfer Systems

### 2.1 Comparison of Different Transfer Technologies

Transfer station alternatives include an extensive range of facilities from a simple soil platform to a multi-story building with sophisticated instruments. Consequently, the potential technologies used for these transfer stations vary considerably.

There are three main domains in the field of transfer system for which different alternatives can be described:

- 1- Waste storage alternatives
- 2- Transfer container and vehicle loading alternatives
- 3- Transfer container and vehicle unloading alternatives

These three domains are discussed in this sub-chapter and a general comparison is made.

#### 2.1.1 Waste Storage Alternatives

The first component of a transfer activity is waste storage in transfer stations. There are three basic transfer technologies to be used in stations:

- Direct dump into transfer vehicle or storage container
- Tipping floor waste storage
- Surge pit

In Table 3-2.1 the advantages, disadvantages and the common usage of these alternatives are discussed.

Waste storage Alternatives			
Technology	Advantages	Disadvantages	Application
Tipping floor waste storage	<p>Simple arrangement; little potential for equipment breakdown.</p> <p>Generally less expensive and provides more operational flexibility than pits.</p> <p>Storage provides "disconnect" between waste receipts and waste loading. (Shortage of empty trailers does not shut down facility.)</p> <p>Allows for easy screening and removal of unacceptable wastes.</p> <p>Allows for the breaking up of bulky items and the compacting of waste to increase density for more economical shipping.</p>	<p>Garbage on tipping floor can be messy and slippery (fall hazard).</p> <p>Potential for accident between customers and transfer station mobile equipment (e.g., wheel loader) that moves/stacks waste (safety issue).</p> <p>Requires roll-out space for trucks to pull forward when discharging their loads.</p> <p>Equipment is needed to reload the waste into the transfer trailer.</p> <p>Requires additional fire control equipment (e.g., fire hoes, water cannon) to control fires in waste piles on tipping floor.</p>	<p>Suitable for small and large transfer station; can manage nearly all waste types.</p>



Surge pit	<p>Storage provides "disconnect" between waste receipts and waste loading. (Shortage of empty trailers does not shut down facility).</p> <p>Allows for the breaking up of bulky items and the compacting of waste to increase density for more economical shipping.</p> <p>No roll-out space required for unloading vehicles; waste falls from back of truck into pit.</p> <p>Eliminates potential for collision between transfer station equipment and customers.</p>	<p>Expensive to construct.</p> <p>Fall hazard for people and vehicles.</p> <p>Hazards to equipment operator working in pit when waste is being unloaded by customers.</p> <p>Can be difficult to remove unacceptable waste founding the pit.</p> <p>Extra building level (three stories instead of two might increase building above grade, increasing building profile.</p> <p>Equipment is needed to reload the waste into transfer trailer.</p> <p>Requires additional fire control equipment (e.g., fire hoses, water cannon) to control fires in waste piles in surge pit.</p>	<p>Most suitable for large transfer stations with high peak flows.</p>
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**Table 3-2.1: Transfer Container and Vehicle Loading Alternatives**

One of the main points that should be considered in waste storage is the leachate generation. In tipping floor and surge pits systems - because of significant amount of waste moisture - there would be considerable amount of leachate to collect and treat and unless a sewerage system exists. This will create substantial cost of leachate treatment in order to release it to the surface water runoff drainage system.

### 2.1.2 Loading and Container System Alternatives



**Fig. 3-2.1: Preload Waste Compaction into Conical Containers, With Container Shift System**

The process of loading transport vehicles is the main issue of waste transfer which has a great effect on the whole transportation system. There are four basic options for loading and the container system to be employed:

- Top-loading trailers and containers
- Compaction into trailer and container
- Preload compaction into rear-loading trailer or container
- Baling

In Table 3-2.2 the advantages, disadvantages and the common usage of these alternatives are discussed.

Transfer Container and Vehicle Loading Alternatives			
Technology	Advantages	Disadvantages	Application
Top-loading trailers and containers	<p>Simple, gravity-loading method.</p> <p>Might be supplemented with compaction by using equipment that reaches into the top of the trailer to tamp down and level the load.</p> <p>Suitable for a wide range of waste types, including construction debris and bulky materials.</p>	<p>Generally involves imperfect, permeable closure (screen or tarp) on top of trailer. Odours and litter can escape, and precipitation can make the load heavier.</p> <p>Trailers can be damaged when dense or sharp materials fall into an empty trailer.</p> <p>Sound of waste falling into trailers can be noisy.</p>	<p>Suitable for small and large transfer stations.</p>
Compaction into trailer and container	<p>A trailer or container can be completely closed to prevent rainwater entry and odour and liquid from escaping.</p>	<p>A heavy trailer or container decreases effective payload. (Trailer must be structurally reinforced to withstand the pressure of the compactor.)</p> <p>Capital cost of trailer fleet is greater.</p> <p>Tail end of trailer or container (near compactor) tends to become overloaded. Front end of trailer tends to be light. Rear axle loading tends to limit effective payload.</p> <p>Hydraulic power equipment for compactor can be noisy.</p>	<p>Not commonly used for new transfer stations.</p>
Preload compaction into rear-loading trailer or container	<p>Allows use of lightweight trailer or container to increase effective payload.</p> <p>Trailer or container can be completely closed to prevent rainwater entry and liquid from escaping.</p> <p>Payload can be measured as it is compacted, with ability to optimise each payload.</p>	<p>High capital costs (but can be offset by reduced transportation costs).</p> <p>Relatively complex equipment; when it breaks down can shut down transfer station after short-term storage capacity is full.</p> <p>Less suitable for certain types of waste (oversize materials, concrete, wire, cable).</p> <p>Hydraulic power equipment for compactor can be noisy.</p> <p>A heavy electrical power consumption system.</p>	<p>Most suitable for high-volume transfer stations, particularly those that need to haul waste over a long distance.</p> <p>Container alternative ideally suited for intermodal transfer to rail system.</p>
Baling	<p>Allows for efficient transportation due to density of waste and ability to use light-weight trailers.</p> <p>Trailer can be completely closed to prevent rainwater entry, and odour and liquid from escaping.</p> <p>Compatible with balefills, which allow filling a large amount of waste in a small space, might be best in difficult (extreme weather or windy) environments.</p> <p>Baler can also be used to prepare recyclables for transport and sale.</p>	<p>High capital cost.</p> <p>Relatively complex equipment; when it breaks down, it can shut down transfer station after short-term storage capacity is full.</p> <p>Hydraulic power equipment for baler can be noisy.</p> <p>Special equipment needed at landfill.</p>	<p>Suitable for large transfer stations, particularly those that need to haul waste over long distances.</p> <p>Required for delivering waste to a balefill.</p>

Table 3-2.2: Transfer Container and Vehicle Loading Alternatives

Top loading into semi-trailers is the method which is currently in practice and the introduction of any alternative will need significant amounts of capital investment.



**Fig. 3-2.2: Tehran Waste Transfer: Current Practice**

With a longer distance to the new landfill than to the Kahrizak landfill, the option of minimization of volume of waste has to be evaluated.

Baling will not be considered further, because of unstable bales due to large amounts of high density and moist organic waste, high capital and operational costs for balers in transfer stations and the need of a totally new technical and operational system to unload bales. Each bale of approximately 1t of weight should be unloaded and stapled in the landfill. This would result in 8000 bales a day to be stapled in the landfill, which is not feasible.

Compaction on semi-trailers after filling is not a good practice because of the low compaction rate and the delay for transport vehicles.

Compaction directly into containers is a rarely applied practice for transfer stations and is not recommended for Tehran. Press water will remain in the containers and the container is especially enforced to absorb the direct pressing power.



**Fig 3-2.3: Land Filling of Bales**

The only alternative to the currently successfully applied system is the pre-load compaction into containers. This study will, in addition to the current system describe different container types and sizes in chapter 4-2.3 for both rail and road transport.

### 2.1.3 Transfer Container and Vehicle Unloading Alternatives

The unloading procedure is highly dependent on the technology in use and the type of container to be used. There are four options to unload vehicles:

- Push-out blade transfer trailer
- Walking floor transfer trailer
- Trailer tipper for transfers trailers and trailer- mounted containers
- Open-top railcar tippers.

In Table 3-2.3 the advantages, disadvantages and the common usage of these alternatives are discussed.

Among all alternatives using the trailer tippers for trailers is used in current situation and will have less needed capital cost to modify current system. It is also compatible for container-type railway transfer. If there would be operation problems due to short tipping front to cause some delays for transport trailers open top railcar tippers would be considerable.

Transfer Container and Vehicle Unloading Alternatives			
Technology	Advantages	Disadvantages	Application
Push-out blade transfer trailer	Allows for unloading anywhere (not just at a landfill with a trailer tipper).	Some trailer capacity (both volume and weight) used for the push-out blade, which reduce effective waste payload. Material can become stuck behind push-out blade. Blade can bind during extension or retraction.	Most suitable for short-distance, low-volume hauling.
Walking floor transfer trailer	Allows for unloading anywhere (not just at a landfill with a trailer tipper).	More prone to leak liquids from the bottom of the trailer. More prone to damage from dense or sharp objects that fall into an empty trailer.	Suitable for a range of volumes and distances.
Trailer tipper for transfers trailers and trailer mounted containers	Allows use of light-weight trailer to maximise payloads.  Ideal for rail-based container intermodal system	High reliability or redundancy required. No way to unload trailer at the landfill if the tipper fails.  Tippers can be unstable if placed over waste at landfill.	Most suitable for long-distance, high-volume hauls. Most suitable for hauls to large landfill (small to medium-sized landfills most likely to have a tipper).
Open-top railcar tippers	Extremely rapid, large-volume unloading.	Fixed unloading point requires reloading and some other form of transport from unloading point to final destination.	Most suitable for a fixed disposal method such as at a solid waste incinerator.

Table 3-2.3: Transfer Container and Vehicle Unloading Alternatives

From the Table above, two possible options derive: either the trailer tipper, for smaller containers (e.g. 30 m<sup>3</sup>) by a hook-lift system, or the pushout blade for larger containers (up to 65 m<sup>3</sup>). Both options will be compared and described in chapter 4-2.3.

## **2.2 Comparison and Best-Practice Analysis for Tehran Transfer Stations**

With regard to aforesaid different options introduced in previous sections, some different alternatives can be considered. The objective of this section is to delineate some alternatives with best-practice characteristics among all other choices and use these alternatives as an input to comparative transportation analysis.

### **2.2.1 Characteristics of the Transfer Stations**

The datasheets extracted from gathered data from all station are attached with other transfer station datasheets in the Annex 6a and 6b.

### **2.2.2 Recommendations to Improve Current Practice**

All transfer stations except one (Bani-Hashem) are large capacity transfer stations with more than 500 Mg/d waste turnover. The direct dump system is not ideal for large transfer stations mainly because of the delay of collection vehicles.

According to the two years old "*Optimization of Current Transfer Stations and Site Selection for New Transfer Stations Report*" and recalculation done in this study, the structural capacity of the Tehran transfer stations is sufficient for transferring two to three times of the current amount of waste. In contrary to this fact, the waiting time of collection vehicles is the main problem of all transfer stations. As already mentioned before due to direct tipping into semi-trailers, which is suitable for small transfer stations only. So the first and most fundamental modification in transfer stations is to switch to tipping-floor waste storage whenever the land is available. The surge pit option is not recommended since it needs to build an extra (third) level in transfer stations.

The main recommendations can be summarised as follows:

- To close the top of semi-trailers
- To have separate entrance and exit ways for collection vehicles as first priority and transfer vehicles
- To give higher priority to vehicle driving patterns by removing unnecessary obstacles in the drive way
- To outline a specific guideline in each transfer station for collection vehicle drivers and operation staff to avoid unnecessary interferences

- To provide a septic tank for storage of leachate and for carriage to landfill, and a separate leachate storm water drainage system in each transfer station

### 3 Comparative Analysis of Transportation Systems

#### 3.1 Option 1: Open Semi Trailer

##### 3.1.1 Description

This transportation model continues the existing way of transportation to the landfill with some minor changes (Top closing, cleaner transfer...). In this case the available transfer stations will be used further on, without building a new one. The same trailers and tractors as currently used will transport the waste and therefore no compaction is possible, at least not to an efficient level.

The only system which could be considered for open trailers in this respect is the



power roller. The investment costs for this system are around USD 20,000 and the compaction rate is only significant for light densities such as packaging and paper. So with no recycling it is not recommended to use this approach.

Fig. 3-3.1: Roller Packer for Light Density Waste

Because of the longer distance to the new landfill the cycle times will increase and additional vehicles will be necessary. Accordingly by more drivers will be needed. The vehicles will also have a higher rate of wear and will not last as long as the currently used vehicles.



### 3.1.2 Circle Time and Investment

Assumed average speed of vehicles:	30 km/h
<i>Circle time:</i>	
Loading:	30 min
Driving to landfill:	140 min
Unloading:	30 min
Driving back to transfer station:	140 min
<b>Total circle time:</b>	<b>5.7 h</b>

Resulting circles per vehicle and day:	4 circles
Container volume:	65 m <sup>3</sup>
Payload:	16.4 tons
Waste transported by one vehicle per day:	66 tons
Number of vehicles needed for daily transport of waste:	130 vehicles
Safety percentage of vehicles needed (including spare vehicles):	35 %
Number of extra vehicles needed:	46 vehicles
Vehicles in total:	176 vehicles

Investment In USD:	
Semi-trailer and Container:	7,661,176
Pushing-Blade:	8,800,000
Tractor vehicles:	20,705,882
Workshop:	153,158
Trailer cleansing facility:	19,439
<b>Invest sum:</b>	<b>37,339,656</b>

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### 3.2 Option 2: Container With Compaction on Road

In this option, the waste is compacted before loading into containers. The objective is to reduce the size of the transportation fleet, which in turn means reduction of the number of trips and overall investment. The option works with using sticks to the present way of waste delivery to the landfill using the road.

#### 3.2.1 Option 2a: 50 m<sup>3</sup> containers on Semi-Trailers

The containers of 50 m<sup>3</sup> volume are put on semi-trailers, the loading is via the compaction unit (see chapter 5), the unloading via push-out blade. Compaction of waste is performed by installation of compactors at the existing transfer stations.

Assumed average speed of vehicles:	30 km/h
Circle time:	
Loading:	20 min
Driving to landfill:	140 min
Unloading:	20 min
Driving back to transfer station:	140 min
<b>Total circle time:</b>	<b>5.3 h</b>
<hr/>	
Resulting circles per vehicle and day:	4 circles
Container volume:	50 m <sup>3</sup>
Payload:	21 tons
Waste transported by one vehicle per day:	84 tons
Number of vehicles needed for daily transport of waste:	102 vehicles
Safety percentage of vehicles needed (including spare vehicles):	35 %
Number of extra vehicles needed:	36 vehicles
Vehicles in total:	138 vehicles
<hr/>	
Production of one press per day:	960 tons
Number of transfer stations:	12 stations
Number of compactors needed per station:	2 compactors
Compactors in total:	24 compactors
<hr/>	
Investment in USD:	
Semi-trailer:	2,435,294
Container:	2,846,250
Tractor vehicles:	16,235,294
Push-out blade:	6,900,000
Compactor:	7,913,700
Workshop:	120,170
Trailer cleansing facility:	15,242
<b>Investment amount:</b>	<b>36,465,951</b>



### 3.2.2 Option 2b: Two 30 m<sup>3</sup> Flexible Containers

This option is increasing the transported amount of waste by using two 30 m<sup>3</sup> containers: one each on the chassis and the trailer. Loading and un-loading will be done with the help of a hook-lift (see Figure 3-3.2). The hook lift will also be used to lift the container from the trailer and to empty it too.

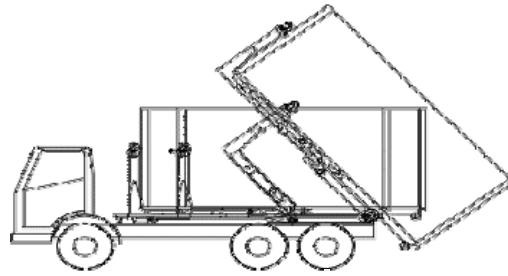


Fig. 3-3.2: Two 30 m<sup>3</sup> Flexible Containers

Assumed average speed of vehicles:	30 km/h
Circle time:	
Loading:	40 min
Driving to landfill:	140 min
Unloading:	40 min
Driving back to transfer station:	140 min
<hr/>	
Total circle time:	6.0 h
Resulting circles per vehicle and day:	3,33 circles
Container volume:(2*30)	60 m <sup>3</sup>
Payload:	30 tons
Waste transported by one vehicle per day:	100 tons
Number of vehicles needed for daily transport of waste:	85 vehicles
Safety percentage of vehicles needed (including spare vehicles):	35 %
Number of extra vehicles needed:	30 vehicles
Vehicles in total:	115 vehicles
Production of one press per day:	960 tons
Number of Compactors needed:	9 compactors
Safety percentage of compactors needed (including spare compactors):	10 %
Number of extra compactors needed:	1 compactors
Compactors in total:	24 compactors
Investment in USD:	
Semi-trailer:	2,029,412
Container and rail:	2,702,500
Tractor vehicles:	13,529,412
Hook lift:	3,450,000
Compactor:	7,913,700
Workshop:	100,142
Trailer cleansing facility:	12,702
<hr/>	
<b>Investment amount:</b>	<b>29,737,867</b>

### 3.2.3 Option 2c: 65 m<sup>3</sup> Containers on Semi-Trailers

This option is the continuation of option 1 after addition of compaction facilities at the existing transfer stations. Also, it utilizes 65 m<sup>3</sup> fully closed containers fixed on semi-trailers which are filled with compacted waste at the transfer stations and pulled to the landfill by tractors. The process of unloading waste at the landfill is made through installation of push-out blades at each container.

Assumed average speed of vehicles:	30	km/h
Circle time:		
Loading:	20	min
Driving to landfill:	140	min
Unloading:	20	min
Driving back to transfer station:	140	min
<hr/>		
Total circle time:	5,3	h
Resulting circles per vehicle and day:	4	circles
Container volume:	65	m <sup>3</sup>
Payload:	26	tons
Waste transported by one vehicle per day:	104	tons
Number of vehicles needed for daily transport of waste:	82	vehicles
Safety percentage of vehicles needed (including spare vehicles):	35	%
Number of extra vehicles needed:	29	vehicles
Vehicles in total:	111	vehicles
Production of one press per day:	960	tons
Number of Compactors needed:	9	compactors
Safety percentage of compactors needed (including spare compactors):	10	%
Number of extra compactors needed:	1	compactors
Compactors in total:	24	compactors
Investment in USD:		
Semi-trailer and container:	4,831,765	
Push-out blade:	5,550,000	
Tractor vehicles:	13,058,824	
Compactor:	7,913,700	
Workshop:	96,607	
Trailer cleansing facility:	12,260	
<hr/>		
<b>Investment amount:</b>	<b>31,463,156</b>	

### 3.3 Container With Compaction on Rail

At the new transfer station with railway connection compactors will be installed. The delivered waste is tipped into the compaction hopper and pressed into enclosed 30-ft container. The delivery from nearer districts is directly done by collection vehicles, from far-away districts the existing transport vehicles transport from the existing transfer station to the new one. In this mode a part of the existing transfer stations can be closed to save space and personnel.

The full container is removed from the compactor and an empty one is linked by an automatic container change system. For continuous work of the compactors a container stock is necessary to have empty containers available in time when no train is at the station. The containers are loaded on the train by movable cranes or stationary cranes with automatically moving locomotives to tug the train and position the waggons under the crane.

The train transports the container to the landfill station, where other cranes lift the container onto semi-trailers. Semi-trailers are tugged to the deposit site by tractor units with installed hydraulic equipment to unload the container by pressing the front shield through it. The empty container is brought back to the station and loaded on the train again by crane. This variant is similar to the transfer station in Berlin-Gradestraße (Fig 3-3.3).

### 3.3.1 Option 3a: 50 m<sup>3</sup> Containers on Semi-Trailers

This option builds on the characteristics of option2a for deliveries to the rail transfer station. The rail transport cannot take place from each transfer station, and the waste needs to be transported to and from the two rail-container terminals.



Fig. 3-3.3: Rail Transfer Station in Berlin-Gradestrasse Built by BC-Berlin

Container volume:	50 m <sup>3</sup>
Container payload:	21 tons
Containers to be transported per day:	407 containers
Containers per waggon:	2 containers
Waggons per train:	15 waggons
Transported payload per train:	630 tons
Train circle time:	
Loading:	120 min
Train to landfill:	60 min
Unloading:	120 min

Train back:	60 min
<hr/>	
Total train circle time:	6 h
Circles per train and day:	4
Trains needed:	3
Containers needed (incl. Container stock and spare):	150
Railway waggons (incl. spare):	50
Container transport vehicles:	0
Cranes:	4
Compactors:	24
Assumed average speed of vehicles (Tehran side):	30 km/h
Vehicle circle time:	
Loading:	30 min
Driving to train station:	60 min
Unloading:	30 min
Driving back to transfer station:	60 min
<hr/>	
Total vehicle circle time (teheran side):	3 h
Resulting circles per vehicle and day:	7 circles
Waste transported by one vehicle per day:	147 tons
Number of vehicles needed for daily transport of waste:	58 vehicles
Safety percentage of vehicles needed (including spare vehicles):	35 %
Number of extra vehicles needed:	20 vehicles
Vehicles in total(teheran side):	78 vehicles
Assumed average speed of vehicles(landfill side):	30 km/h
Vehicle circle time:	
Loading:	30 min
Driving to landfill:	2 min
Unloading:	30 min
Driving back to rail station:	2 min
<hr/>	
Total vehicle circle time(landfill side):	1.1 h
Resulting circles per vehicle and day:	19 circles
Waste transported by one vehicle per day:	399 tons
Number of vehicles needed for daily transport of waste(landfill site):	21 vehicles
Safety percentage of vehicles needed (including spare vehicles):	35 %
Number of extra vehicles needed:	7 vehicles
Vehicles in total (landfill site):	28 vehicles
Number of vehicles needed for daily transport of waste:	79 vehicles
Vehicles in total:	106 vehicles
Investment in USD	
Tractors:	12,470,588
Semi-trailers:	1,870,588
Containers:	3,093,750
Push-out blades:	7,500,000
Workshop:	93,073
Container cleansing facility:	16,568

Building of rails, 5 km	2,058,824
Container transport vehicles:	0
Cranes:	1,472,674
Transfer station incl. building, tipping pits, walking floors, container changing equipment:	5,890,696
Compactors:	7,913,700
Streets:	147,267
<b>Total investment amount:</b>	<b>42,527,728</b>

### 3.3.2 Option 3b: 30 m<sup>3</sup> Flexible Containers

This option builds on characteristics of option2b for deliveries to the rail transfer station. In this case, the containers are transported by heavy-duty lifters instead of cranes.

Container volume:	30 m <sup>3</sup>
Container payload:	15 tons
Containers to be transported per day:	570 containers
Containers per waggon:	2 containers
Waggons per train:	15 waggons
Transported payload per train:	450 tons
Train circle time:	
Loading:	120 min
Train to landfill:	60 min
Unloading:	120 min
Train back:	60 min
Total train circle time:	6 h
Circles per train and day:	4
Trains needed:	5
Containers needed (incl. container stock and spare):	250
Railway waggons (incl. spare):	80
Container transport vehicles:	6
Cranes:	0
Compactors:	24
Assumed average speed of vehicles:	30 km/h
Vehicle circle time:	
Loading:	30 min
Driving to train station:	60 min
Unloading:	30 min
Driving back to transfer station:	60 min
Total vehicle circle time:	3 h
Resulting circles per vehicle and day:	7 circles
Delivery vehicle container volume:(2*30)	60 m <sup>3</sup>

Payload:	30 tons
Waste transported by one vehicle per day:	210 tons
Number of vehicles needed for daily transport of waste:	41 vehicles
Safety percentage of vehicles needed (including spare vehicles):	35 %
Number of extra vehicles needed:	14 vehicles
Vehicles in total(Tehran site):	55 vehicles
Assumed average speed of vehicles(landfill site):	30 km/h
Vehicle circle time:	
Loading:	30 min
Driving to landfill:	2 min
Unloading:	30 min
Driving back to rail station:	2 min
<hr/>	
Total vehicle circle time (landfill site):	1.1 h
Resulting circles per vehicle and day:	19 circles
Delivery vehicle container volume:(2*30)	60 m <sup>3</sup>
Payload:	24 tons
Waste transported by one vehicle per day:	456 tons
Number of vehicles needed for daily transport of waste(landfill side):	19 vehicles
Safety percentage of vehicles needed (including spare vehicles):	35 %
Number of extra vehicles needed:	7 vehicles
Vehicles in total(landfill side):	26 vehicles
Number of vehicles needed for daily transport of waste:	60 vehicles
Vehicles in total:	81 vehicles
Investment in USD:	
Tractors:	9,529,412
Trailers:	1,429,412
Containers:	2,937,500
Hook-lifts:	2,430,000
Workshop:	70,688
Container cleansing facility:	27,613
Building of rails, 5 km	2,058,824
Container transport vehicles:	2,209,011
Transfer station incl. building, tipping pits, walking floors, container changing equipment:	5,890,696
Compactors:	7,913,700
Streets:	147,267
<hr/>	
<b>Total investment amount:</b>	<b>34,644,122</b>

### 3.3.3 Option 3c: 65 m<sup>3</sup> Containers Fixed on Semi-Trailers

This option builds on characteristics of option2c for deliveries to and from the rail transfer station.

Container volume:	65 m <sup>3</sup>
Container payload:	26 tons
Containers to be transported per day:	329 containers
Containers per waggon:	2 containers
Wagons per train:	15 waggons
Transported payload per train:	780 tons
Train circle time:	
Loading:	120 min
Train to landfill:	60 min
Unloading:	120 min
Train back:	60 min
<hr/>	
Total train circle time:	6 h
Circles per train and day:	4
Trains needed:	3
Container needed (incl. Container stock and spare):	150
Railway waggons (incl. spare):	50
Container transport vehicles:	0
Cranes:	4
Compactors:	24
Assumed average speed of vehicles:	30 km/h
Vehicle circle time:	
Loading:	30 min
Driving to train station:	60 min
Unloading:	30 min
Driving back to transfer station:	60 min
<hr/>	
Total vehicle circle time:	3 h
Resulting circles per vehicle and day:	7 circles
Waste transported by one vehicle per day:	182 tons
Number of vehicles needed for daily transport of waste:	47 vehicles
Safety percentage of vehicles needed (including spare vehicles):	35 %
Number of extra vehicles needed:	16 vehicles
Vehicles in total (Tehran site):	63 vehicles
Assumed average speed of vehicles(landfill side):	30 km/h
Vehicle circle time:	
Loading:	30 min
Driving to landfill:	2 min
Unloading:	30 min
Driving back to rail station:	2 min
<hr/>	
Total vehicle circle time (landfill site):	1.1 h
Resulting circles per vehicle and day:	19 circles
Waste transported by one vehicle per day:	494 tons
Number of vehicles needed for daily transport of waste(landfill side):	17 vehicles
Safety percentage of vehicles needed (including spare vehicles):	35 %
Number of extra vehicles needed:	6 vehicles
Vehicles in total (landfill site):	23 vehicles

Number of vehicles needed for daily transport of waste:	64 vehicles
Vehicles in total:	86 vehicles

Investment in USD:	
Tractors:	10,117,647
Semi-trailers and containers:	6,529,412
Push-out blades:	7,500,000
Workshop:	75,401
Container cleansing facility:	16,568
Building of rails, 5 km	2,058,824
Container transport vehicles:	0
Cranes:	1,472,674
Transfer station incl. building, tipping pits, walking floors, container changing equipment:	5,890,696
Compactors:	7,913,700
Streets:	147,267
<b>Total investment amount:</b>	<b>41,722,188</b>

### 3.4 Option 4: Open Semi-Trailer on Rail

In this option the waste transport vehicles drive on the railway waggons (railway-owned waggons) via a ramp. When the whole train is loaded it is driven to the landfill. At the landfill other drivers take over the vehicles and drive from the station to the deposit site, unload the vehicles and bring back the empty vehicles to the railway waggons which are driven back to the loading station where the regular drivers take back the vehicles.

In this option the working times of the drivers for the transportation period are saved and only loading and unloading stations without further equipment are needed. The benefit of railroad transport is generally the less environmental impact by reducing noise and pollution and the saving of traffic movements.

But the number of vehicles increases as well as the number of drivers and the transportation of vehicles causes a loss of payload on the railway waggons.

Assumed average speed of vehicles on road:	30	km/h
Circle time:		
Vehicle loading:	30	min
Vehicles driving to rail station(teheran side):	60	min
Vehicles on train:	75	min
Train to landfill:	60	min
Shunting:	30	min
Vehicles driving to deposit site, unloading and going back to train:	30	min
Vehicles on train:	75	min
Train back to city station:	60	min
Shunting:	30	min
Vehicles back to transfer stations:	60	min
<b>Total circle time:</b>	<b>8,5</b>	<b>h</b>



Resulting circles per vehicle and day:	3
Container volume:	65 m <sup>3</sup>
Payload:	26 tons
Vehicles needed for daily transport of waste:	110 vehicles
Percent of extra vehicles:	35 %
Extra vehicles (incl. Spare vehicles):	39 vehicles
Vehicles in total:	149 vehicles

Wagons per train:	15
Transported waste per train:	390 tons
Circles per train and day:	3
Trains needed:	7

Investment in USD:	
Tractor vehicles:	17,529,412
Pushing-out blade:	7,450,000
Semi-trailer and container:	6,485,882
Workshop:	129,595
Trailer cleansing facility:	16,457
Railway waggons:	rent
Building of rails, 5 km:	2,058,824
Building of streets and ramps at the stations:	220,901
<b>Total investment amount:</b>	<b>33,891,071</b>

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### 3.5 Comparison of Costs

The comparison of costs will consider not only the investment costs but also the operating costs and the preferences of the OWRC which may contain also ecological and other reasons.

Therefore an enormous amount of information is required to cover the local situation as exactly as possible and to proof the conditions for each individual transportation system.

If options no. 1 or no. 2 are considered to be implemented, a bypass of approximately 3 km for the city of Hassan Abad is recommended. The investment cost of this bypass is estimated at USD 1,100,000.

The following table shows the comparison of costs in 2019 in USD for different variants.

COST ITEMS	OPTION#1	OPTION#2			OPTION#3			OPTION#4
		A	B	C	A	B	C	
<b>Total investment sum:</b>	<b>37.339.656</b>	<b>36.465.951</b>	<b>29.737.867</b>	<b>31.463.156</b>	<b>42.527.728</b>	<b>34.644.122</b>	<b>41.722.188</b>	<b>33.891.071</b>
Depreciation	3.726.308	3.639.824	2.968.780	3.141.485	3.366.684	3.016.509	3.628.126	3.230.646
Capital Costs	1.306.888	1.276.308	1.040.825	1.101.210	1.488.470	1.212.544	1.460.277	1.186.187
Staff Costs	5.937.750	5.659.875	7.171.125	5.196.750	5.859.750	5.416.125	5.713.500	6.127.875
Repair&Maintenance	2.233.475	2.182.541	1.779.758	1.883.435	2.190.315	1.717.752	2.142.690	1.421.931
Insurance	568.377	727.423	593.178	627.739	585.665	529.551	569.801	494.861
Fuel	123.653	97.020	67.375	77.996	42.732	30.475	34.626	34.752
Tires	3.257.647	2.556.000	1.770.000	2.054.824	1.122.000	800.471	909.176	892.941
Tax	0	0	0	0	0	0	0	0
Rail Transportation	0	0	0	0	24.447.124	40.745.206	24.447.124	42.782.466
<b>Total operation sum:</b>	<b>17.154.098</b>	<b>16.138.991</b>	<b>15.391.041</b>	<b>14.083.439</b>	<b>39.102.740</b>	<b>53.468.634</b>	<b>38.905.319</b>	<b>56.171.660</b>
<b>Annual cost per Ton:</b>	<b>5,74</b>	<b>5,40</b>	<b>5,15</b>	<b>4,71</b>	<b>13,08</b>	<b>17,88</b>	<b>13,01</b>	<b>18,79</b>

Table 3-3.2: The Operation Cost of Different Transport Alternatives

The implementation of a successful waste reduction strategy by 25% would result in

- 20% less investment costs and a 10% increase of the costs per Mg for the transportation system with compaction;
- 25% less investment costs and a 5% increase of the costs per Mg for the road transportation system without compaction, and
- 10% less investment costs and a 5% increase of the costs per Mg for the transportation system by rail

The differences can easily be explained by the different impact of the reduction on the investments and the related operation.

### **3.6 Conclusion on Best Transportation Option**

#### **Current System**

As a result of the comparative transfer analysis the current option should be phased out. The current system does create pollution on the way due to the open semi-trailers, and causes the highest number of vehicle movements through the city. Moreover, calculating the needed investment of all the options, it becomes clear that the current option is - due to the higher number of vehicles needed – not the most cost-efficient alternative.

#### **Rail Transport**

As it has also been shown that the railway option is not recommendable. Firstly, expensive new tracks towards the landfill should be planned. Secondly the transport is several times broken, since waste is to be transported from the transfer stations to a rail terminal by truck and also from the final terminal at the landfill towards the dumping site. Due to the settlement of the landfill no rail tracks can be considered for direct disposal. Two additional transfer stations with container movement facilities are needed and the need of more containers as buffer or while in the train. This requirement increase the price for the rail option significantly. Finally, the rent for the rail wagon adds up to the higher price of the railroad option.

Due to these disadvantages in terms of transfer time, needed equipment and costs the rail option is not recommended.

#### **Road Transport**

The transportation by road has as described above several environmental and social impacts. Those impacts can be reduced by reducing the number of daily trips for the transportation of the waste to the landfill. This will be achieved by compacting the waste prior to the loading. The direct compaction into the containers is not recommended since the amount of liquid as a result from the pressing can not be collected externally and has to remain in the container.

From the three researched options, two 30 m<sup>3</sup> container on a truck and a trailer are considered as less favourable: Firstly, the system is less efficient due to higher investment costs and longer loading and unloading procedures. Secondly, this systems is different to the existing equipment.

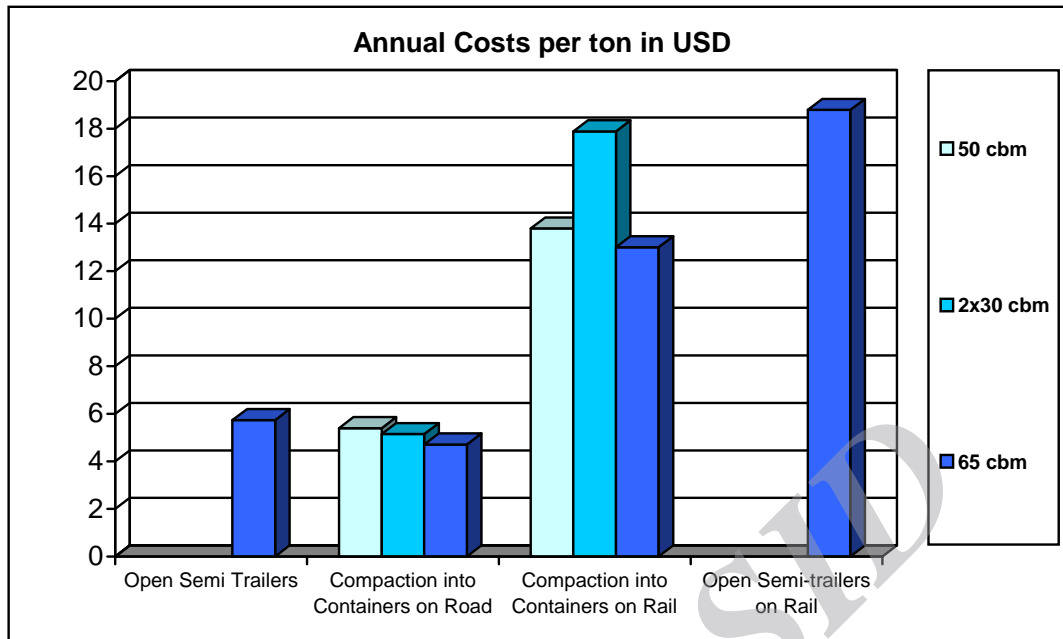


Fig. 3-3.4: Annual Costs per Ton of Transferred Waste (Incl. Depreciated Investment)

### Recommended Option

As Figure 3-3.4 and the related tables demonstrate, due to the greater distance from the new landfill to the transfer stations the compaction system is more effective in both terms of capital and operation costs. The lower numbers of vehicles for the compaction alternative and especially the container system result even in less capital costs.

Consequently, the most preferred option is the 65 m<sup>3</sup> closed container system attached to semi-trailers with push out blade and pre-load compaction. This refers to the previous system with one decisive advantage: the containers are fully closed and permit pre-compacting and pose no environmental impacts during the transportation. This will permit to use the possible payload to 100 %.

The compaction will have another positive side effect: during the pressing of the waste, a significant amount of moisture will be squeezed out. In order to determine the exact amount, either the proposed waste consolidation test should be performed or the press water must be monitored during the operation of the pilot station. In any case, the waste arriving at the landfill will content less moisture and thus ease the operation and compaction. The press water at the transfer station should be analysed, and the way of disposal determined. Either it must be transported directly to the leachate treatment facility of Houshang site, or it could be discharged locally. The equivalent amount of required transport of

press water will reduce the weight of the waste transport. Depending on the amounts and the way of disposal, a septic tanker should be considered.

In the same way, the 50 m<sup>3</sup> container system might be considered, since neither the operation nor the cost do not differ significantly. The final price can be determined by the tendering procedure. If the compactors are all of the same made all type of containers should be compatible to the compaction unit. This will, however, depend on the supplier of the material.

As a general rule the following can be stated: The costs for pre-load compaction are estimated at 10 to 15 % of the total investment sum, while the resulting reduction in transportation equipment will be more than 20 to 40 %.

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## 4 Implementation of Optimised Transfer Technology

### 4.1 Organisational Improvements

As Figure 3-4.1 shows, priority is to reduce the waste as close as possible to its source. For achieving waste reduction recycling should be considered as a major priority, since the recyclables would – if already separated at the transfer station – not be transported by OWRC to the landfill.

The higher density of the organic waste suggests a continuation of the transport of the organic waste over the shorter distance to the Tehran compost plant by the currently used open semi-trailers. In the long run, the semi-trailers should be replaced by a water-proof transportation system where no leachate can drop out.

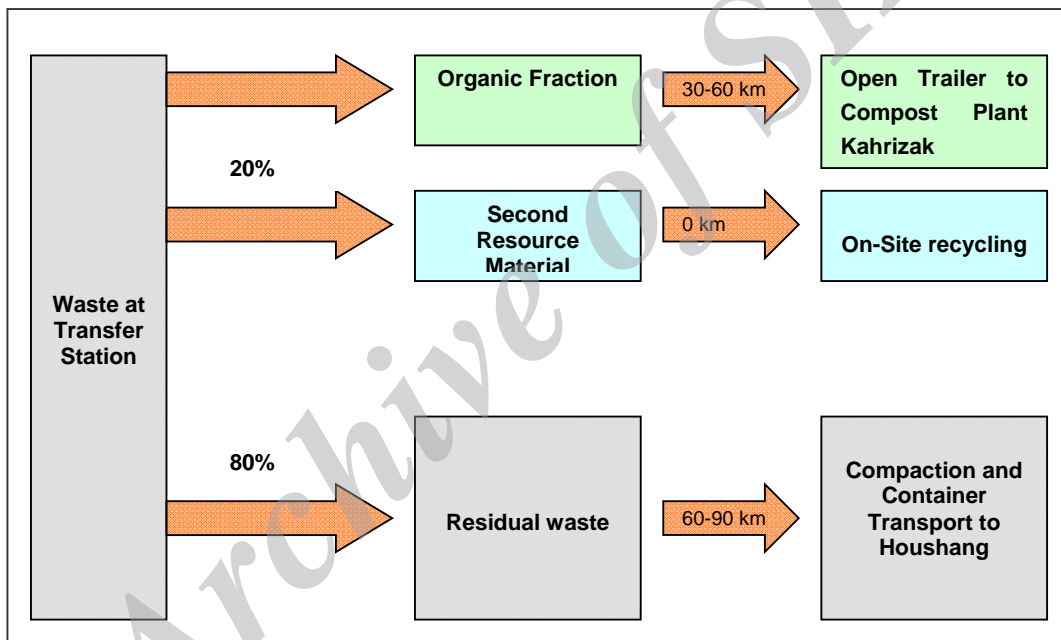


Fig. 3-4.1: Waste Streams from Transfer Station

Obviously, the result from the pilot project at transfer station 15 and the Tehran waste strategy will be important in this aspect and will make more elaborated proposals.

The following Table gives an overview of all transfer stations in Tehran and describes some possibilities for future improvement.

Transfer Station	Tipping Floor	Compaction	Composting	Leachate Management	Storm Water Collection System
TS.1 Dar-Abad	No suitable space	Fair: due to waste high variety	Fair: due to waste high variety	Septic tank and system needed	Separate storm water collection should be constructed
TS.2 Bani Hashem	No available free space	Fair: due to waste high variety	Fair: due to waste high variety	Septic tank and system needed	Separate storm water collection should be constructed
TS.3 Chitgar	Free space exists	Good: quite near industrial areas	Fair	Septic tank and system needed	Separate storm water collection should be constructed
TS.4 Beihaghi	Free space exists	Good: quite near commercial areas	Fair	Septic tank and system need to be rehabilitated	Separate storm water collection should be constructed
TS.5 Golbarg	No free space exists	Fair	Fair	Septic tank and system needed	Separate storm water collection should be constructed
TS.6 Hakimieh	It is already a tipping floor type of station	Fair	Fair	Septic tank and system needed	Separate storm water collection should be constructed
TS.7 Zanjan	No free space exists	Fair	Fair	Septic tank and system needed	Separate storm water collection should be constructed
TS.8 Harandi	Free space exists	Fair	Fair	Septic tank and system needed	Separate storm water collection should be constructed
TS.9 Azadegan	Free space exists	Fair	Fair	Septic tank: in good condition- not complete system	Need to be completed
TS.10 Miveh-va-Tarebar	Free space exists	Not good: due to high share of organic waste	Good: because of the fruit market nearby	Septic tank and system need to be rehabilitated	Separate storm water collection should be constructed
TS.11 Jadeh Saveh	No free space exists	Almost suitable- quite near industrial areas	Fair	Septic tank and system need to be rehabilitated	Separate storm water collection should be constructed
TS.12 Shahr-e-Rei	No available free space	Not good: due to high share of organic waste	Almost good: near agricultural fields	Septic tank and system needed	Separate storm water collection should be constructed

Table 3-4.1: Management Practice for Tehran Transfer Station

The waste which has not been pre-selected at the transfer station has to be transported to the landfill over a distance ranging from 53 to 85 km. This residual waste will be pre-load compacted and thus the first leachate will be collected as a result of the compaction (which also contributes to weight reduction). The in this compacted waste is then transported in containers to the landfill. Until the press water can be discharged in a sewage treatment system, it will be transported separately to the landfill by collection tankers.

## 4.2 Technical Specification for Transfer Stations with Pre-Load Compaction

### 4.2.1 Technical Parameters

The description of a model a transfer station is based on the following parameters.

Daily amount of waste to be handled	1000 Mg/d
Current density of waste	280 kg/m <sup>3</sup>
Density of waste after compaction	400 kg/m <sup>3</sup>
Maximum payload of container	26 Mg
Volume of container	65 m <sup>3</sup>
Type of trailer	three axis semi-trailer
Operation time of press	20 hours
Effective operation time of press	40 %
Peak hours	11:00 h - 01:00 h (delivery of 25 % of waste)

Based on these data, it is recommended to install 2 compaction units for the pilot transfer station. Due to cleansing, maintenance and other factors the construction of a third unit should be considered, taking into account the specific conditions of Tehran: there will be no other way to fill the containers than via the compaction unit through the rear door.

Under normal operation, one unit can handle up to 700 m<sup>3</sup> per hour. Due to change of the container other operational requirements it will be in fact only be in use for 40 % of the installed capacity. Consequently, for the peak hours the following requirements arise:

Waste per day	1000 Mg
Waste delivered in peak hours 11 h - 01 h	250 Mg
Theoretical capacity of press	500 m <sup>3</sup> /h
Waste density after compaction	400 kg/m <sup>3</sup>
Effective operation of capacity of press	40 %
Maximum capacity of press	80 Mg/h
Capacity of TS in peak hours	320 Mg
Buffer of TS in peak hours	70 Mg



#### 4.2.2 Compaction Units

The press consists of a body in sturdy welded steel construction and a horizontally-operating pressure ram mounted on adjustable polyamide rails. The bottom is exchangeable and is made of a special wear-resistant material. As figure 3-4.2 shows, the compaction unit is placed in the centre with the container attached on the left and the press with the ram on the right.

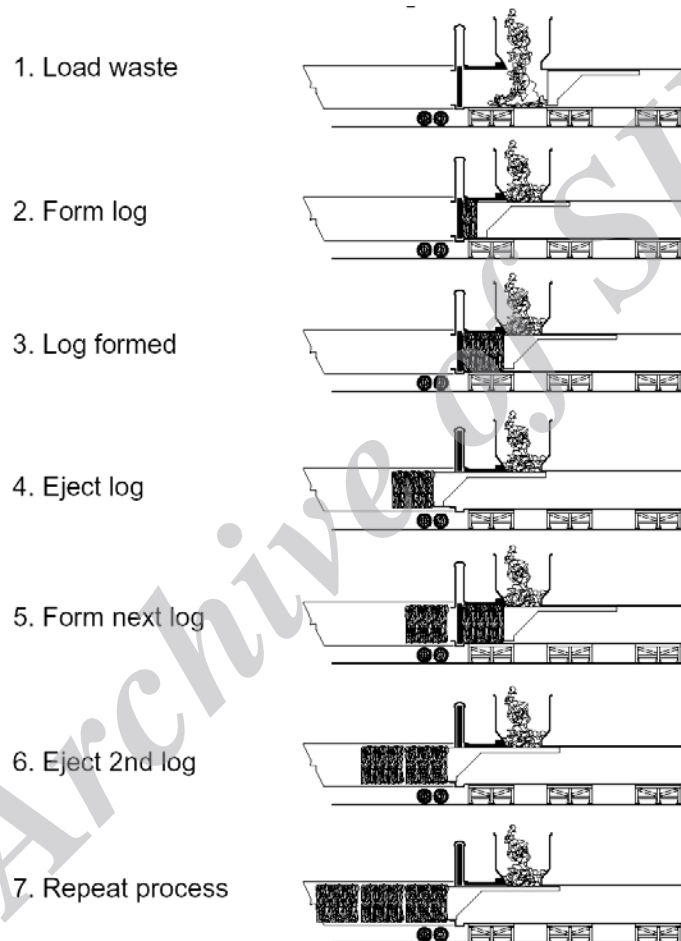


Figure 3-4.2: Waste Compaction Circle

The drive operates via a hydraulic unit with axial reciprocating pump and a horizontally mounted hydraulic cylinder. The auxiliary equipment is driven by a gear pump. The hydraulic unit stands separately and contains the complete control unit as well as a pressure relief valve and maximum pressure switch. The complete control unit is accommodated in the unit housing (see picture 3-4.3).



Figure 3-4.3: Hydraulic Unit of Waste Compaction Unit

The control voltage is 24 V and is switched by a limit switch into automatic mode. Standard are a time switch and optical pre-warning which indicate that the coupled container has reached approximately 80 % of its maximum load. Switching over the pressure ram is done by a limit switch with a protective circuit. When reaching the load limit the machine is switched off by means of a pressure-operated switch.

Length of stroke:	4000 mm
Press force:	700 kN
Pressing power:	29 N /cm <sup>2</sup>
Drive output:	30 kW/400 V
Double stroke:	40 sec.
Press plate:	2000 x 1200mm
Press chamber volume	7.7 m <sup>3</sup>
Technical press capacity	500 m <sup>3</sup> /h
Oil volume:	800 l
Length approx.	8110 mm
Width approx.	2360 mm
Height approx.	2084 mm
Weight approx.	14200 kg

Each press has a **hydraulic compaction container connection** which pulls the container up to the press by means of a hook and secures it during the complete

filling process. The action is carried out by the press hydraulic system. Control is by pushbutton switching. In the press a hydraulic vertical locking mechanism of the container press-in aperture closes the containers by means of a plate. After the container is loaded the locking device mounted on the press forces the plate belonging to the container down from above into the press-in aperture and locks it. Operation is via pushbutton switching.



Figure 3-4.4: Pre-Compaction Chamber and Container Docking System

The press has a **hydraulic low-pressure device as a bulge remover** on the press edge, which works in cycle with the pressure ram and frees the compaction chamber from material bridges and bulges. The bulge remover works by the press hydraulics. It is operated via press-button switching. A hydraulic horizontal



Figure 3-4.5: Hopper, Ram and Compaction Chamber

hopper partitioning is installed for cleaning the compaction chamber and preventing waste from falling into the pressing area during container changing and to allow a delivery vehicle to off-load even during the container change. This guarantees that the container press-in aperture can be locked without problem by the hydraulic locking device. Control is via press button switching.

The top-mounted hopper on the press compaction chamber, in sturdy welded steel construction incl. all necessary bracing, is installed in situ and adapted to conditions of the building. Its contents is approx. 24 m<sup>3</sup>.

If necessary, the hopper can be complemented by extended concrete slopes in order to permit more than one collection vehicle to discharge the waste during peak hours.

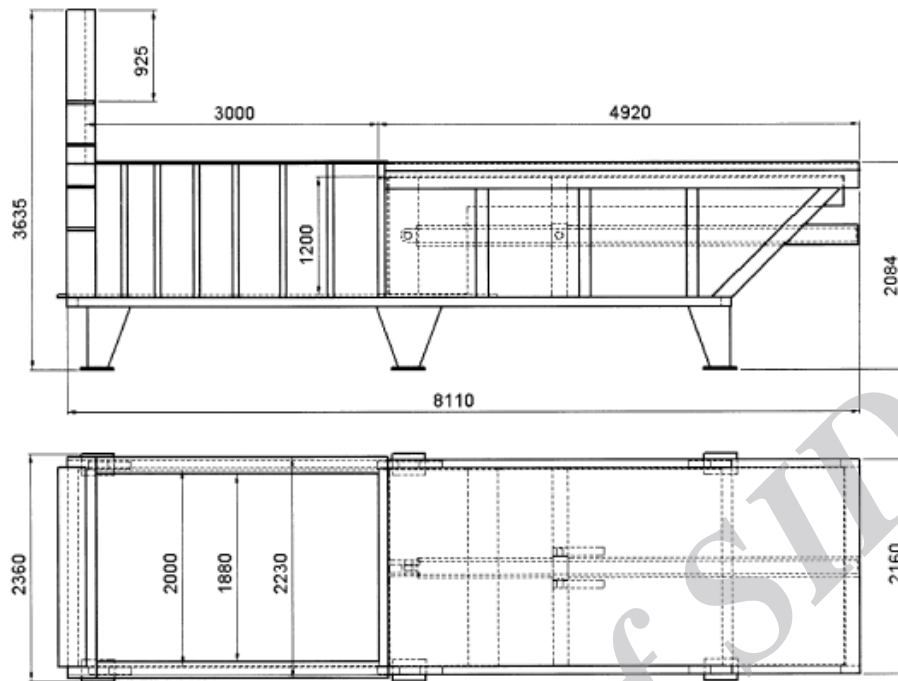


Figure 3-4.6: Dimensions of Compaction Unit (e.g. Wagner Press WP 700)

The dimensions of the press are shown in Figure 3-4.6. Those can differ according to the type of press finally chosen, but are basically determined by the size of the container and the ram.

#### 4.2.3 Container Discharging Unit with Container Weighing System

The design foresees the usage of a container discharge system which handles 3 semi-trailers. The displacement control system is directly linked to the machine control, whereby differentiation is possible between empty and full containers. The advantage of the system is that empty containers can already be placed on the discharge devices to be ready for filling once the first container is full. In turn the full container can be moved sideward once it is full and does not need the immediate transfer by means of a truck.

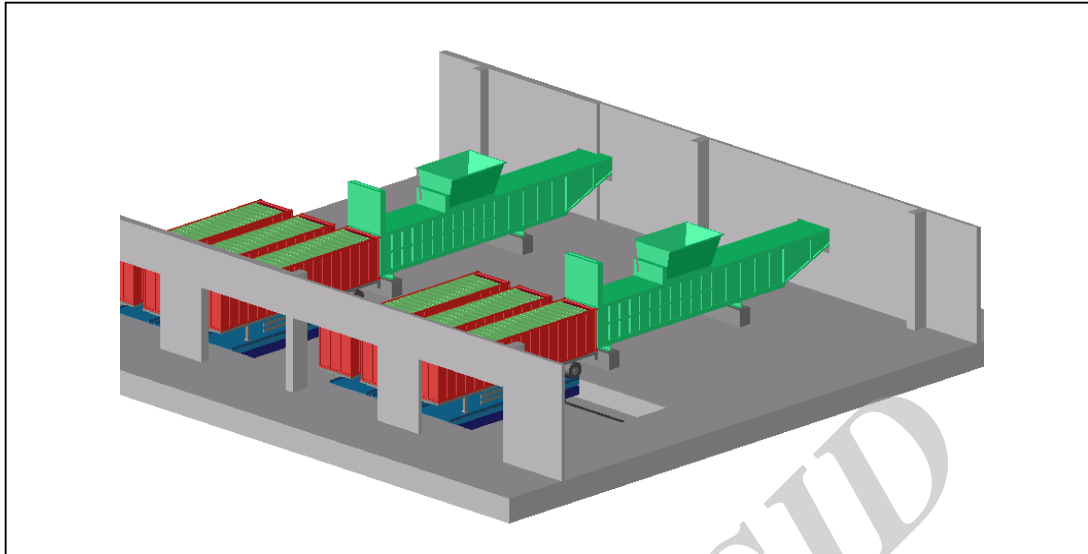


Figure 3-4.7: Dimensions of Compaction Unit

The unit should be equipped with **electronic weighing cells** that control the filling status of the container. Once the preset weight of 26 Mg has been achieved, the weigh cells indicate the press to automatically stop in the closing position. A second safety device is a pressure control, which stops the loading of the container, once a preset pressure has been reached.

This module is recommended for all transfer stations, it is considered as essential during the pilot project period in order to monitor the waste flows and to be in the position to reach quantifiable results which can be applied for the other transfer stations.

#### 4.2.4 Press Containers

The transfer station should be equipped with 65 m<sup>3</sup> containers mounted on semi-trailers to go with the press, built for conveying of semi-trailers, with guidance and hydraulic locking of the semi-trailer. The container and the semi trailer is in principle a similar system as currently in place, it uses the push-out blade, 65 m<sup>3</sup> and three axis. The significant difference to the current system is the full closure or the top of the container in order to make it suitable for compaction and the single-panel door for container emptying, designed also for connection to the heavy-duty press.

A closing plate is built into the container door, which is pressed downwards after loading by the press's locking device and locks the press-in aperture. The clearing blade, together with the bulk goods, are pressed back into the normal rear position by the loading of the container.

#### 4.2.5 Environmental Installations

Specific waste water collection and treatment is required for the transfer station. Any water that will leak out of the press will be collected and transferred to a collection bin (20-40 m<sup>3</sup>). The collected water will be transported by a waste water tanker or, after a thorough testing or the possibility for treatment, it can be discharged in the public sewage system.

The containers are insulated and have a leakage proof rear sealing in the lower third of the rear door. In order to maintain the well-functioning, the sealing must be cleaned.

#### 4.2.6 Unit Costs for Compaction System

Item	No of Units	Sum of Costs
Compactor	1	92,500
Hydraulic compaction container coupling	1	7,250
Cleansing facility	2	5,000
Electronic equipment	1	1,250
Funnel	1	9,000
Hydraulic closing blade	1	7,375
Container distribution system (3 semi-trailers)	3	116,250
Shelter for weather and noise protection	1	18,750
Supports for Presses	1	600
Hydraulic push-down device	1	6,125
Oil shortage and temperature watchdog	1	850
Oil cooler	1	2,100
Hydraulic-oil heater	1	738
Ram end position, back	1	400
Infrared light barrier control	1	1,225
Top-mounted hopper for heavy-duty press	1	5,625
Hours-run counter	1	325
Flash-light, alarm	1	613
Switchboard	1	7,000
Remote control in switchboard	1	1,400
PLC control system	1	13,625
Control and monitoring system	1	9,500
Protective barrier at the opening of the filling hopper	1	5,938
Additional control desk mounted at the press hopper	1	150
Flash light on the upper edge of the hopper	1	363
Safety light barrier in front of the filling hopper	1	3,288
Presswater collection system	1	12,500
<b>Total Compaction Unit</b>		<b>329,738</b>

Table 3-4.2: Cost Calculation for Compaction Unit in USD (based on German Supplier)

### 4.3 Selection of Pilot Transfer Station for Pre-Load Compaction

#### 4.3.1 Baseline Data

Station		Waste Production(2004)		Distance to Kahrizak	Waste Production(2019)		Distance to Houshang site	Daily Ton-km
NAME	NUMBER	TONS/YR	TONS/DAY	KM (2004)	TONS/YR	TONS/DAY	KM (2019)	TON-KM (2019)
Dar Abad	ST1	145,978	417	45	225,975	646	86	55,202
Bani Hashem	ST2	47,510	136	36	73,546	210	76	15,970
Chitgar	ST3	231,166	660	40	357,846	1,022	80	81,793
Beihaghi	ST4	214,080	612	36	331,396	947	77	72,434
Golbarg	ST5	128,100	366	35	198,299	567	75	42,493
Hakimiyeh	ST6	194,920	557	38	301,737	862	78	67,244
Zanjan	ST7	191,786	548	30	296,886	848	70	58,953
Harandi	ST8	146,686	419	22	227,070	649	62	40,029
Azadegan	ST9	230,914	660	21	357,456	1,021	61	62,300
Miveh-va-Tarebar	ST10	146,317	418	19	226,499	647	59	38,181
Jade Saveh	ST11	164,675	471	23	254,918	728	63	45,521
Shahr-e-Rei	ST12	92,964	266	13	143,909	411	53	21,956
<b>SUM</b>		<b>1,935,096</b>	<b>5,529</b>	<b>AVERAGE =30</b>	<b>2,995,538</b>	<b>8,559</b>	<b>AVERAGE =70</b>	<b>599,108</b>

Table 3-4.3: Baseline Data for Transfer Stations

#### 4.3.2 Selection Criteria

The first criteria is the cost (investment) involved as calculated for each transfer station. Secondly, spatial and technical feasibility of transfer stations are assessed based on the availability of required space for installation of the compaction facility as well as the easy manoeuvre of delivery vehicles to unload their load into the funnels and also semi-trailers which transport the waste to the landfill. A rating (in the scale of 1 to 4) is assigned to each transfer station

Other factors like projected transportation performance of each transfer station (in terms of ton-kilometers, which combines weight and distance measures) are also taken into account. This criterion, in essence, determines the significance of each transfer station from the pure transportation point of view. Composition suitability of the waste disposed at each transfer station as well as the social impact of introducing compaction to transfer stations located at the vicinity of residential areas are also considered as decisive at this stage.

Note: the methodology used in ranking transfer stations against various criteria is based on the identification of three critical boundary points, that is to say the average, the average minus standard deviation, and the average plus standard deviation.



Station		Ratings								Priority
Name	Number	Weight	Distance	Ton-Km	Composition	Space	Technical	Social	Average	
Dar Abad	ST1	3	1	2	3	2	1	2	2.0	4
Bani Hashem	ST2	4	2	4	3	1	2	2	4.2	9
<b>Chitgar</b>	<b>ST3</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>3</b>	<b>1.4</b>	<b>1</b>
Beiaghgi	ST4	2	2	1	1	4	1	2	1.8	3
Golbarg	ST5	3	2	3	3	3	1	1	2.2	5
Hakimiyeh	ST6	2	2	2	3	1	1	1	1.6	2
Zanjan	ST7	2	3	2	3	3	1	2	2.2	5
Harandi	ST8	3	3	3	3	2	1	3	2.4	6
Azadegan	ST9	1	3	2	3	1	1	3	2.0	4
Miveh-va-Tarebar	ST10	3	4	3	4	1	2	3	2.6	7
Jade Saveh	ST11	2	3	3	2	1	1	3	2.0	4
Shahr-e-Rei	ST12	4	4	4	4	2	1	3	2.8	8

Table 3-4.4: Ranking of Transfer Stations

#### 4.3.3 Monitoring Requirements

In order to transfer this system after a trial period to all the other transfer stations, the following data should be monitored:

- Peak hours (vehicles, waste amounts)
- Peak days
- Press water amounts and composition
- Incoming density of waste
- Outgoing density of waste
- Time for container loading
- Maintenance and cleansing cycle
- Reporting and interviews with the workers on incidents.

#### 4.3.4 Criteria for the Conversion of Further Transfer Stations

According to the data as described above, further transfer stations could be converted to the new system. In general, it is recommended to use three presses for all transfer stations of approximately 1000 Mg per day. Only in case the amount of waste is below 500 t per day and of availability of are alternative ways for loading the transfer vehicles (e.g. in a transfer station nearby), one press is considered as sufficient.



The residual waste which will be transported to the landfill is considered in the scope of this study. However, due to the ongoing design in terms of pre-treatment and recycling, future waste streams can not yet be quantified exactly for each transfer station. Until such reliable quantification will be available, this study counts with the current option in terms of waste volumes.

In relation to the final design of the landfill operation, the exact amount of daily incoming waste and the handling at the transfer stations (e.g. due to changes in the operation of the transfer station), extra storage capacity might be required.

In this case, the 50 m<sup>3</sup> container option will be taken into consideration, since the containers are easily detachable and can so be stored at the transfer station or the landfill.

This option would use the same way of compaction, a similar container shift system and would use the hook-lift as tipper for unloading the waste. Hence, the design of the transfer station or the landfill unloading area would be least affected.