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PRELIMINARY ASSESSMENT
OF
SOLID WASTE MANAGEMENT SYSTEMS
IN
MEKNES, AZROU AND SEFROU
MOROCCO

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EXECUTIVE SUMMARY

General

The overall goal of this project is to evaluate the waste management systems in the cities of Meknes, Azrou and Sefrou and make recommendations for improvements. These recommendations include collection systems, landfills and overall waste management planning.

Collection Systems

All three cities are experiencing varying degrees of problems within their existing collection systems. These problems include inadequate equipment, shortage of qualified workers, maintenance and repair problems and inefficient collection methods. To help address these problems, collection trucks should be upgraded to rear loading compactors capable of servicing waste storage containers. Significant increases in collection efficiency and neighborhood health conditions can be obtained by converting portions of the collection systems to containers, especially in the newer portions of each city where new infrastructure improvements are being made. With proper maintenance, repair and cleaning of the containers, collection frequency could be decreased to three times per week, further increasing overall equipment and manpower efficiencies.

Collections in the three cities were performed only in the morning, generally between 7:30 and 11:00. This is not an efficient use of equipment, and consideration should be given to afternoon as well as morning collections.

Collection problems are much more severe in Meknes than in the other two smaller cities. This can be seen from the ratio of collection equipment capacity as compared to total daily waste generation. A ratio of .50 would mean that each truck would have to make two trips to the landfill per day, assuming all trucks were operational. The ratio of collection equipment to waste generation in Meknes is .40, while it is .82 in Azrou and .62 in Sefrou. Considering the maintenance, repair and labor problems in Meknes it is not surprising that they are experiencing collection problems. Only one of the four municipal depots in Meknes was inspected during the field visits, but that one lacked adequate spare parts, maintenance supplies, tools and skilled mechanics.

Some of Meknes's problems arose because it became a city as four separate towns or municipalities grew and ultimately became one urban area. Although some public services have been consolidated under one City authority, others have not, including solid waste collection. A significant part of the Meknes problem is the inefficiency of four separate municipalities within the City, all operating independent collection systems. The creation of a single independent agency within the City to oversee both collection and landfill services should be evaluated. Specific recommendations for each city are made in their respective section of the report.

Landfills

The landfill in Meknes is suffering a variety of problems and should be closed. In addition to being in a very visible location, it is poorly operated and may be structurally unstable. Current problems have prevented a major housing project from being implemented. An interim three year program, designed to provide cover soil for the existing landfill while providing three years of landfill capacity, has been recommended. The report presents a discussion of regional geology and landfill siting criteria to assist the City in locating the next long term site.

Existing landfills in Azrou and Sefrou have less severe problems. These are related primarily to operating procedures, including compaction, soil cover, burning and control of blowing debris. Both landfills have remaining capacities in the 10 to 20 year range but the Sefrou landfill may be closed sooner due to the construction of a nearby market and anticipated City expansion. Section 1 of the report presents typical landfill controls to assist both municipalities in dealing with their operating problems.

Institutional/Financial Issues

Although the focus of the brief study is on technical issues, there was also an obvious need to address the institutional as well as financial needs of the three cities in dealing with their waste management. This was most obvious in Meknes where the costs of both the interim and long term programs will be significant. Reorganization and consolidation of both collection and disposal services should be evaluated in addition to potential cost recovery methods.

National Issues

The various work tasks performed have also pointed to a need for national standards for waste management, especially if privatization is to play a role in the future. In particular, standards on landfill siting, design and operation are needed. The standards should be accompanied by a realistic enforcement program through the municipal or regional governments.

Action Plans

Recommendations included in the report are summarized as follows:

Meknes:

- Maintain service records at all truck depots.
- Perform inventory of all commercial and industrial waste generators.
- Convert newer portions of the City to container service.
- Ensure that new truck purchases are 14 or 16 m^3 rear loading compactors with mechanical container filters.
- Evaluate consolidation of four separate municipal services into one City authority.

- Perform site search for interim landfill.
- Purchase larger landfill machine for compaction and covering.
- Close and cover existing landfill as soon as possible.
- Begin search for new long term landfill.
- Address medical waste disposal.
- Evaluate cement kiln for potential hazardous/medical waste disposal.
- Evaluate former compost facility.

Azrou:

- Convert newer areas of the City to container service.
- Purchase one rear loading 8 m^3 compactor with mechanical container lifter.
- Supervise existing landfill during all operating hours.
- Reduce active working area of landfill.
- Compact and cover landfill with soil or construction debris at least once per week.
- Plant cactus rows around landfill to help control blowing debris.
- Establish special areas for dumping and storing construction debris and temporary dumping/ transfer area during bad winter weather.
- Address medical waste disposal.

Sefrou:

- Convert newer areas of City to container service.
- Purchase one rear loading compactor collection truck.
- Convert open burning landfill to controlled landfill with weekly compaction and covering.
- Begin search for new long term landfill.

Follow-Up

This project includes a follow-up task to assess how each municipality has responded to the recommendations. In general, this follow-up task will address all three cities, but will concentrate on Meknes and their efforts at finding a new landfill site.

Preliminary Assessment of Solid Waste Systems in Meknes, Azrou and Sefrou, Morocco

1 INTRODUCTION

1.1 Background

The United States Agency of International Development (USAID) is assisting Moroccan municipalities through the Urban and Environmental Services Project (U&ES). Part of the U&ES project is designed to assist municipalities on improving capacities to manage a growing solid waste problem, in particular waste collection and disposal. Similar assistance was provided to the City of Tetouan several years ago. The cities of Meknes, Azrou and Sefrou have been selected to participate in this portion of the program.

The USAID technical assistance team consists of a solid waste expert under contract with the International City Management Association (ICMA) and two local consultants: an urban planner and civil engineer. The initial inspection and interview team also included two national government representatives from the Directorate of Potable Water and Sanitation (DEA/DGCL) and the FEC/Direction de Credit.

1.2 Goals and Objectives

The overall objectives of the project are to evaluate the existing waste disposal and collection systems in the three subject municipalities, assist them in making improvements and assist them in planning for the future. Although the primary emphasis of the project is on waste disposal--through controlled landfilling, recycling and composting--waste collection systems and other related issues will be addressed.

The project will be completed in three phases. The initial phase consisted of site visits, inspections and data gathering in the three municipalities. These activities were performed by the full project team, including the ICMA solid waste expert, the local consultants and the national government representatives. The second phase, the subject of this report, is the evaluation of the problems and issues observed during the inspection, data gathering, and recommendations for improvements. This task was primarily the responsibility of the ICMA solid waste expert, with assistance from the local consultants.

The final phase will include follow-up and technical assistance provided to the municipalities to assist them in implementing the recommendations of the report. This task will include a second visit by the ICMA solid waste expert and technical assistance by the local consultants. It is also anticipated that the project recommendations will include issues to be addressed at the national level, including national waste management standards, institutional and financial guidelines and a national medical waste policy.

1.3 Common Issues

Although the three municipalities differed considerably in their waste management systems, there were several issues common to all three. These will be discussed in this section while issues specific to each city will be included in Sections 2, 3 and 4.

1.3.1 Collection Procedures

All three municipalities provide collection services using curbside collection of domestic refuse or communal bins of 3 to 5 m^3 capacity serviced by a specialized bin hoist vehicle. The majority of service is provided through curbside collection using a variety of manually loaded vehicles. Waste left at the curbside by individual residents or commercial establishments is gathered in baskets by collection workers and then loaded onto collection vehicles. Most of these collection vehicles are standard flat bed dump trucks of 6 m^3 capacities. These are multipurpose vehicles and waste must be lifted approximately 1.5 meters to the bed of the truck. Only Meknes uses specialized rear loading waste compaction vehicles of 6 and 8 m^3capacity, but they are not equipped to load containers.

The curbside placement of waste without containers is creating problems in most of the urban locations, especially when waste is not placed in plastic bags. Non-containerized waste attracts insects and animals, promotes odors and makes collection more difficult.

Since all three municipalities mentioned increasing collection efficiency as a goal, the expanded use of communal containers and larger rear loading compaction trucks are appropriate options for all three municipalities. Typical containers used with compaction trucks are manufactured in several sizes. The most common size is 1.1 m^3 which is currently being used in Rabat and other larger cities in Morocco. These containers will hold approximately 495 kg of waste at a density of 450 kg/m^3. At a generation rate of .5 kg per person per day, each container can hold the daily waste generated by 990 persons or 194 families at 5.1 persons per family.

The increased collection efficiency of using containers is obtained through decreased collection time, smaller collection crews and fewer vehicles. Standard 1.1 m^3 containers can be serviced in one to three minutes each, including driving to the next container. This is compared to the curbside collection of the equivalent of 194 individual households, which may take as long as 30 to 60 minutes, depending on many variables. The increased efficiencies are obvious and will more than offset the increased cost of the containers and compactor trucks distributed over the life of the equipment.

The use of communal containers is especially appropriate in the newer areas of the three cities, where new multi-unit housing is being constructed along with infrastructure improvements and wide streets. Ideally, the containers should be located in enclosures and visually screened, features which should be designed into new road and housing infrastructure. Spacing of containers should consider convenience as well as capacity. In general, residents should not be required to walk further than 75 meters to access a waste container. The use of containers in residential

areas may also permit less frequent collections, if containers are kept clean and free of odors. Collection frequencies of three times per week, rather than daily, are possible with communal containers.

The wider streets of the new areas will also accommodate larger capacity collection trucks. If containers are considered in these areas, new compaction trucks should be at least 14 or 16 m^3 capacity, equipped with hydraulic lifting devices for the containers. The larger compaction trucks will also improve transportation efficiencies as new landfills are located farther away from the urban population centers.

The use of containers will not be appropriate for all areas of the city, and many of the older areas will still require manual curbside pickup due to narrow streets or lack of adequate locations to place the containers. Specific recommendations regarding the use of containers will be presented for each municipality in later sections of the report.

1.3.2 Medical Waste

In general, medical waste from hospitals, clinics, doctors, dentists and laboratories in all three communities is disposed of with mixed domestic waste, without any special handling or packaging. This presents a significant hazard to waste collectors, landfill operators and persons who recycle materials from the waste. A long term goal should be adopted to require all medical waste to be disinfected at the source, prior to disposal, using an autoclave, controlled incineration, or chemical treatment.

In the short term, all infectious medical waste should be placed in specifically marked containers, to alert collection workers and recyclers that the contents may be dangerous. The international standard includes the use of heavy "red" plastic bags for infectious medical waste which has not been disinfected and "yellow" bags for medical waste which has been autoclaved or chemically treated. Ashes from medical waste incinerators should be placed in ridged containers with special markings.

1.4 Technical Issues

Based on information obtained during the municipality site inspections and data gathering, there is a need to present some of the general technical issues regarding waste generation, collection and disposal and how these issues are applied to the specific conditions found in the three municipalities and in Morocco in general. This is especially important since most of the reference material on waste management is based on waste typically found in European countries and the United States. Differing waste composition, weather and geologic features found in Morocco will significantly impact the application of waste disposal systems in Morocco.

1.4.1 Waste Composition

Waste composition will vary greatly from area to area based on physical and economic conditions. Most reference material lists the various components of waste as they are generated and not as disposed. Waste characteristics, especially in poorer economic conditions, will change significantly between generation and final disposal due to sorting and recycling. The following list of typical components in Moroccan waste is presented as a general guide only and must be reviewed in more detail for each municipality.

Paper	15% to 25%
Glass	3% to 5%
Tin Cans	1% to 3%
Textiles	1% to 3%
Bones	1% to 3%
Wood	2% to 3%
Plastic	3% to 5%
Organic Food Waste	50% to 70%
Inert Fines	5% to 7%

The most important aspect of waste composition in Morocco is that it is changing. As economies develop, more and more packaging and throw-away items enter the waste stream. In particular, the increased use of plastics and metal beverage cans has had a dramatic effect on waste management in Morocco. Plastic bags are a major source of litter, and plastic containers have slowly replaced the returnable glass bottle for soft drinks, beer and water. There are several basic types of plastics, and a general understanding of them will assist waste managers in handling the problems of plastic wastes disposal and recycling.

- *Polyethylene Terapthalate (PET).* Most soda and soft drink containers holding liquid under pressure (gas) are made of PET. It has a relatively high recycle value and is used to make synthetic textiles.
- *High Density Polyethylene (HDPE).* HDPE has many applications and is used primarily for its chemical resistance and elastic strength. It is commonly used for oil, bleach, laundry detergents and milk containers. It is also one of the materials commonly used to make thin film plastic bags and has a high recycle value.
- *Polyvinyl Chloride (PVC).* This plastic is used in many structural applications, including pipes and furniture. It is also the material used most for non-gasified bottled water and other food containers. It has a good recycle value but not as high as PET or HDPE.
- *Polystyrene.* This plastic also has wide applications, including plastic utensils, dishes and toys. It is also used in most plastic foam packaging. It has a relatively low recycle value.

Plastics are inert materials, and although they create many aesthetic disposal problems they do not create an environmental problem in the landfill. However, they will create toxic gases when burned and are a significant source of air contamination in populated areas. PVC, in particular, will produce hydrochloric acid when burned.

The recycling of plastics is developing world-wide into a major industry. Environmental concerns and conservation of petroleum resources have encouraged many manufacturers to utilized recycled plastic whenever possible. This will be discussed in more detail in later sections of this report.

1.4.2 Leachate Production

Leachate is a mixture of liquid contaminants produced from waste and can be a significant problem in both waste collection and disposal. Leachate liquids are either the result of the decomposition of organic matter within the waste or liquid wastes, such as synthetic solvents, waste oil or cleaning fluids that have been disposed of along with the solid waste. This latter category of leachate is normally only associated with industrial or commercial activities. If a municipality contains only residential development, it is not likely to have a significant problem with solvents or industrial contaminants, which are a major concern in Western waste landfills.

As organic waste decomposes, it produces strong organic acids which dissolve other chemicals in the waste. These include heavy metals, which are a major contaminant in landfill leachate. While discussing heavy metals, it is important to note the sources of these heavy metals in the waste, which primarily include colored inks in magazines and newspapers and batteries of all kinds. Lead from car batteries and mercury from small watch and hearing aid batteries are common sources of heavy metal contamination in Western waste leachate. Although these sources are very common in Western waste, they are much less common in less developed economies such as Morocco. Therefore, heavy metals should be less of a problem in leachate produced from Moroccan waste.

Waste requires water to decompose and produce leachate, and therefore water control is an important aspect of landfill management. The ideal water content for organic waste decomposition is between 40 percent and 100 percent, and decomposition essentially stops at moisture levels below 20 percent. Therefore, typical Moroccan waste at 60 to 70 percent moisture will certainly begin to decompose in the landfill, but if additional water is restricted, or the waste dries, decomposition and leachate generation will stop. Since Morocco is in a semi-arid climate, with defined wet and dry seasons, leachate generation will not be as significant a problem as it is in Western areas with higher rainfall. In addition to lower rainfall, a high evaporation index will reduce moisture in the waste as it is placed in the landfill.

1.4.3 Methane Gas Production

Methane gas is another product of the decomposition of organic matter in the landfill. It is subject to the same variables as leachate generation and will increase at higher moisture contents and decrease as moisture is reduced. Methane gas is explosive at concentrations above 5 percent. It is lighter than air and will normally escape to the atmosphere above the landfill while the landfill is in active operation. When the landfill is closed and a layer of low permeability soil is placed on the upper surface, the escape of methane gas will be blocked, which could cause it to accumulate under the soil cover and possibly migrate off-site through porous layers of soil. If

houses are located nearby, the methane gas could enter the houses and possibly cause an explosion. If this potential exists, then the final cover soil should be applied along with methane gas vents, to prevent a build-up of gas and to allow the gas to escape to the atmosphere.

1.4.4 Geologic Issues

Several geologic characteristics will impact the environmental effects of the landfill. Both the physical and chemical content of the soil under a landfill will determine its ability to filter or chemically remove many, if not all of the harmful contents of landfill leachate.

In general, a fine grained sandy silt, with a permeability in the 1×10^{-5} to 1×10^{-7} cm/sec range, is the ideal landfill base soil. The fine nature of the soil will filter solid components of the leachate and promote biological growth which will remove organic by-products of leachate decomposition. Heavy metals in the leachate will also be chemically immobilized through ion exchange by fine grained soil containing adequate calcium ions. If the leachate is mainly organic in nature, a 5 to 10 meter layer of unsaturated fine grained soil, as described above, should provide adequate treatment for landfill leachate. Unfortunately, most synthetic industrial solvents will pass through the soil unchanged.

Due to the semi-arid climate of Morocco, groundwater levels are generally very deep. At one of the municipal landfill sites, groundwater was reported to be in the range of 200 meters below the surface. This large separation between the bottom of the landfill and any groundwater that may become contaminated is also a very positive characteristic of the local geology for landfill siting. Morocco has many areas with excellent soils for landfill siting, with the combination of limited leachate production due to low rainfall, fine grained soils and deep groundwater.

On the negative side, Morocco also contains many rocky areas. If the bedrock is fractured, leachate will pass through it relatively unaffected and may contaminate underlying groundwater, even at large depths. Landfills should not be located on bedrock formations.

1.4.5 Landfill Siting

From the above discussion of geology, it is obvious that landfill base soil is one of the most important landfill siting parameters. With proper location in natural clay or silty soils and deep groundwater, in excess of 5 to 10 meters, contamination of groundwater by landfill leachate should not be a problem. The combination of soil permeability and depth to groundwater is the crucial parameter. A slightly more permeable soil may still be adequate if the depth to ground water is greater. In general, sandy base soils, with permeabilities greater than 1×10^{-4} cm/sec, should not be used as a landfill base, regardless of groundwater depth.

The exception to the natural soil base is a landfill that accepts significant quantities of industrial wastes which may contain synthetic solvents or petroleum products. In this case, the landfill must be located in impermeable clay soils with permeabilities less than 1×10^{-8} cm/sec or constructed with a plastic liner and leachate collection systems. Since the evaporation index exceeds

rainfall by a wide margin, the collected leachate should be treated through evaporation in open storage ponds.

In addition to the geologic characteristics, the following siting parameters should also be considered. These are meant to be a general guide and not a rigid set of criteria. Since a solid waste landfill is a negative land use, a successful siting process will usually consist of compromises between environmental and economic issues, which will differ for each municipality.

- *Distance to surface waters:* In general, the landfill should be located at least 100 meters from a flowing or seasonal stream or river. This distance should provide an adequate buffer area to prevent waste or leachate from entering the river or stream. A hydrogeology study should confirm that there are no underground hydraulic connections between the landfill site and the surface water.
- *Distance from a well or potable water intake:* The landfill should not be located in a recharge area for a public water well or within the drainage area of a public surface water intake.
- *Wind:* The landfill should not be located in areas susceptible to sustained high winds because this may result in a chronic windblown debris problem. Prevailing wind direction should also be considered to prevent odors or smoke from blowing toward urban areas.
- *Distance to residences:* This is a difficult parameter to establish and is usually left to the local municipality to determine. Distances of 300 to 1000 meters have been used in the past. Some communities consider the density of residential development as well as the distance. Relocation of individual residences can be used to obtain adequate isolation distances.
- *Distance to public facilities, sensitive environments or archeological/historical sites:* Landfills should not be located near public facilities, where blowing debris, smoke, odors or increased traffic will negatively impact the operation or public enjoyment of the facility. Since this will include visual as well as physical impacts, this criterion will require a site specific evaluation of each site.
- *Distance from the urban center:* The distance that collection trucks must travel to access the landfill is also an important criteria. Although the landfill should be far enough away to minimize impacts, it should not be an economic burden to transport waste to the site. A distance of 5 to 10 kilometers would satisfy this criterion. Modern collection trucks are designed for stop-and-go collection routes and are not very efficient at traveling long distances to the landfill. If the landfill must be located more than 15 to 20 kilometers from the urban center, the municipality should consider the use of a transfer station to access the site. The final decision should be based on an economic evaluation.

1.4.6 Landfill Controls

In many developing countries, landfilling in towns and small cities occurs in an informal and uncontrolled manner. The term informal disposal refers to diverse disposal, on-site, along roadways, in vacant lots, in ravines or in other non-centralized locations. An uncontrolled landfill applies to informal disposal, as well as disposal at a centralized location where there are no specific management methods used to control the generation or release of contaminants to the

environment or to improve aesthetic impacts. Uncontrolled landfills are often burned on a regular basis to reduce the volume of waste and expose additional materials for recycling.

The fact that a landfill is uncontrolled does not necessarily mean that it is polluting the environment. That finding can only result from an evaluation of the waste composition, site conditions and the variables that cause waste to produce contaminants. One of the first issues to be addressed by decision makers is determining when a controlled landfill is necessary to protect human health and the environment. The answer is actually quite complex and requires a basic knowledge of waste composition and the factors which cause waste to generate pollutants, which have been presented above.

In the United States the term "sanitary landfill" is used to define the environmentally correct landfill, but in developing countries the term "controlled landfill" is more common, which the solid waste expert feels is a more appropriate term. For the purposes of this report, the various landfill procedures and functions are grouped into three categories in an attempt to clarify the definition of a controlled landfill: Design Controls, Primary Operating Controls and Secondary Operating Controls. Figure 1 illustrates controlled landfill construction.

Design Controls

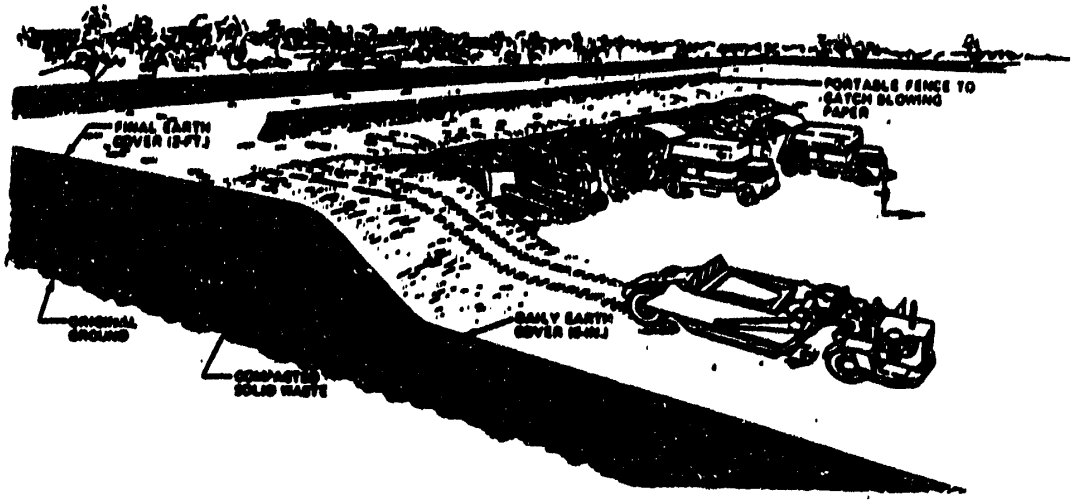
If the landfill is a new landfill, the control aspect begins in the design phase with proper site location. The location should be convenient to the waste generators but with adequate isolation from residential development. Buffer distances from surface water, and groundwater aquifers, will minimize potential impacts to water resources.

Base soils are perhaps the most important aspect of locating a landfill. If good silty clays or silty fine sands can be located with sufficient separation distance to groundwater, then landfill liners and leachate management systems can be avoided. If proper base soils cannot be located and the government determines that the groundwater quality warrants protection, then a lined landfill becomes necessary.

Primary Operating Controls

Primary operating controls are intended to control the short term impacts of landfilling, such as blowing litter, odors, flies and fires, while also reducing the factors leading to the generation of pollutants. These are the minimum controls that should be employed to convert an uncontrolled landfill to a controlled landfill.

- *Access Control:* The vehicle access to the landfill should be limited to a single entrance which can be secured during the hours when the landfill is not open or supervised. The single access ensures that all waste can be recorded and monitored.
- *Waste Monitoring:* At the entrance, all waste deliveries should be inspected to ensure that they do not include large quantities of hazardous or liquid wastes that the landfill was not designed for. Many landfills have separate areas for special wastes such as tires, metals or sludges. The



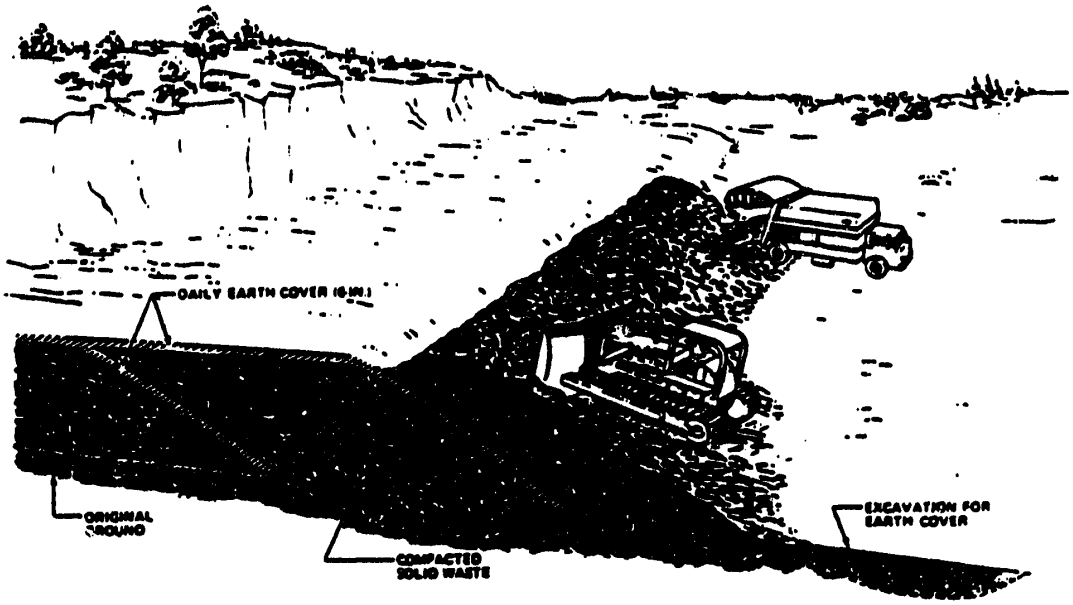


FIGURE 1

CONTROLLED LANDFILL CONSTRUCTION

initial monitoring of the incoming waste should identify these materials and direct them to the appropriate disposal location. If resources permit, a second inspection should be performed as the waste is unloaded and compacted. Depending on the administration of the landfill, a written record of all waste deliveries should be maintained.

- *Fire Control:* The burning of mixed solid waste is one of the most polluting aspects of an uncontrolled landfill and should not be permitted in a controlled site. This is especially true as waste composition changes to include more plastics which can produce highly toxic fumes when burned. Fire control begins with the initial waste inspection, since fires can start from hot coals or ashes brought into the landfill with the waste. Fires started by scavengers are another frequent source of landfill fires and must be controlled. If a fire does start, it should be extinguished as soon as possible with water or cover soil.
- *Waste Compaction:* Compaction of the waste and the building of cells is a basic requirement of controlled landfills and has many purposes. Compaction reduces waste volume and extends landfill life. Compacted waste will also be less permeable and will impede the flow of rainwater into the waste, and will burn less easily than loose, uncompacted waste. Ideally, compaction should be performed by a specifically designed landfill compactor but can also be done with a tracked bulldozer or similar earth moving equipment. Compaction should be performed in a manner which forms daily cells of waste. Ideally, these should be covered with soil at the end of each working day.
- *Cover Soil:* Like compaction, cover soil is a required landfill control which has many purposes. In addition to controlling blowing litter, insect infestation and rodents, soil cover can be used to control the infiltration of rainwater by directing it away from the landfilled waste, thereby reducing leachate formation. Covering of daily waste cells is also another method for controlling landfill fires. The frequency of soil cover is usually determined by its availability. Ideally, waste should be covered at the end of each day but this is sometimes not possible due to limited availability or cost. Covering with soil should be performed at least on a weekly basis.
- *Scavenging:* Scavenging of the landfill for food and recyclable materials is a common problem in all developing countries. Although the scavengers are exposed to many health and safety problems, they actually perform a positive function by removing materials and reducing the volume of waste requiring landfilling. Scavenging at a controlled landfill often conflicts with compaction and covering of waste, however, and should be restricted or eliminated. The objective should be to promote recycling within the collection system or through source separation programs rather than at the landfill.
- *Closure Plan:* The last primary operational control is the preparation of a closure plan to be implemented when the landfill reaches its capacity. As a minimum, the closure plan should include final impermeable cover soil and a gas venting system. The cover soil should be planted with a mixture of grasses.

Secondary Operational Controls

Secondary operating controls are defined as those control procedures that deal with managing pollutants that have been produced by the landfilled waste. Some of them may not be applicable, depending on the landfill base design and others are highly dependent on site conditions.

- *Landfill Gas Control:* The amount of gaseous emissions from a landfill will be dependent on the amount of organic decomposition that occurs in the landfill. Although methane is the component of landfill gas that is of most concern, it is only about 50 percent of the actual gas volume. The remainder is made up primarily of carbon dioxide with traces of many hydrocarbons and other gases. The gas mixture is lighter than air and will escape through the landfill during its active life but will require specific venting systems after closure.
- *Leachate Management:* If the landfill has been constructed with a liner, all leachate generated in the landfill will be collected, requiring treatment. Although treatment can be delayed by recirculating leachate back into the landfill, some form of treatment and discharge will ultimately be required. In semi-arid countries, the most economical treatment is storage and evaporation in lined evaporation ponds.
- *Environmental Monitoring:* All controlled landfills should perform environmental monitoring to assess the potential release of contaminants to the environment. Monitoring will be dependent on site conditions and what type of landfill base has been implemented. If the landfill utilizes a natural soil base then the emphasis should be on monitoring groundwater to ensure that natural filtering mechanisms are being effective. If a liner and leachate management system has been implemented, then the monitoring shifts to leachate quality and surface water sampling of the receiving river or stream. Air quality monitoring may also be required for large landfills located near residential development. All ground water and surface water monitoring programs should include the determination of background conditions prior to the landfill operation to adequately identify operational impacts from the landfill.

1.5 Waste Generation Data Bases

Prior to evaluating specific aspects of the subject landfills, a waste generation data base was prepared for each municipality from population information and reference characteristics of solid waste management components. These data bases include population, waste generation, estimated waste collection volumes and landfill requirements throughout a 20 year planning period. Although the primary intent of the data bases is to estimate future required landfill resources, they will also assist in the recommendations for waste collection systems. For each data base, two graphs have been generated.

The first graph shows estimated waste generation and collection based on 1994 population and estimated growth, and reference per capita waste generation factors. The estimated waste collected takes into account the percentage of the city provided with collection services and the degree of waste recycling and informal disposal observed during the site inspections. In Meknes the waste collected was estimated to be 70 percent of total generation, while collection was estimated at 80 percent of generation in Azrou and Sefrou.

The second graph makes several assumptions in calculating landfill requirements at five year intervals. In-place waste density was estimated at 800 kg/m^3, cover soil at 10 percent of waste volume and a landfill depth of 20 meters. The graph estimates actual landfill area in hectares, without buffer areas, which must be added to obtain the total area required for the facility. The data bases are found in Attachment A and the two graphs are included in each respective municipality report section.

2 MEKNES

2.1 General

Meknes is by far the largest city in the project group with a 1994 population of 410,852. It is located between the Zerhoun mountain range and the Central Atlas, and is one of Morocco's Imperial Cities. Meknes has a central City government as well as four independent municipalities within the City. Each municipality is responsible for waste collection within its boundaries and the central City government is responsible for the operation of the landfill.

2.2 Waste Generation and Composition

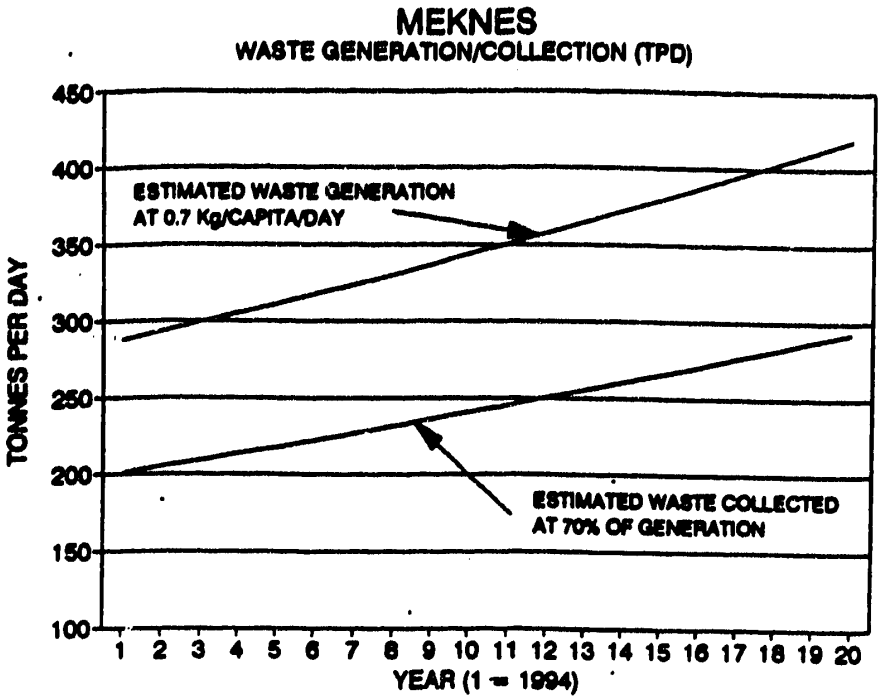
Due to its regional nature and commercial activities, a per capita waste generation factor of .7 kg was used to estimate total waste generated in Meknes. At an estimated 1994 population of 410,852 the total waste generated is estimated at 288 tonnes per day. Based on the project team's interviews with city officials, waste collection services exist for approximately 80 percent of the City. It was also estimated that approximately 10 percent of the generated waste is disposed of in informal areas, used for fill or is recycled prior to collection and disposal. Therefore, the waste actually collected is estimated to be 70 percent of the generated amount or approximately 201 tonnes per day. The waste generation and collection estimates are shown for a 20 year planning period on the upper graph found on Figure 2. A population growth of 2 percent per year was used for this estimate. For more exact figures on waste generation, the reader is referred to the waste generation data base found in Attachment A.

Because of its regional and commercial nature, waste in Meknes contains a higher percentage of paper, cardboard and plastics than is found in the other two smaller project towns. Due to the higher amounts of these materials, they are mostly recycled before reaching the collection and disposal systems. Therefore, the waste ultimately landfilled has a high organic content.

2.3 Existing Waste Collection Systems

2.3.1 General

Each of the four municipalities maintains its own fleet of collection vehicles and a repair and maintenance depot. Due to time constraints, only one of the four municipalities was interviewed during the site visit and one depot was inspected. Because of the widely varying conditions, the



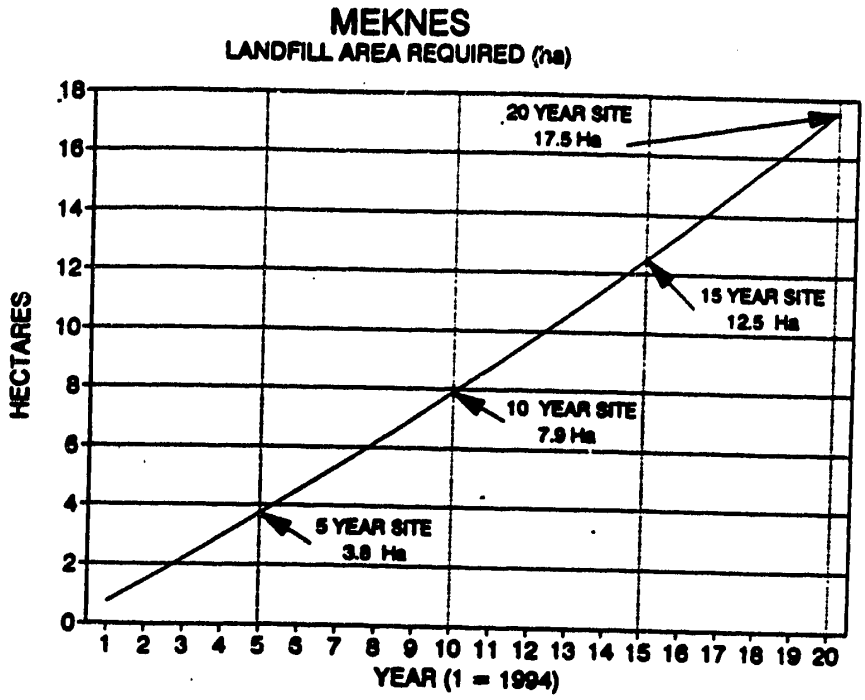


FIGURE 2

MEKNES
WASTE GENERATION
AND
LANDFILL CAPACITY

collection fleets include a mixture of vehicles including 6 to 8 m^3 compactors, 6 m^3 dump trucks, multi-benne bin hoist trucks, serving 5 m^3 bins and an assortment of smaller capacity vehicles to service older neighborhoods with narrow streets. Total capacity of all collection vehicles is 80 m^3, which when compared to the volume of waste generated in this municipality is a ratio of approximately .40. With a good maintenance and repair program, the equipment appears only marginal for the amount of waste generated in this municipality. None of the rear loading compactors were equipped with mechanical lifting devices or winches and therefore were unable to service containers. The average age of the collection vehicles was 5 to 7 years and routine maintenance and repair were cited as major problems.

Daily waste collection is performed only in the morning, between 7:00 am and 10:30 am, with all trucks returned to the depot in the afternoon. Some of the multipurpose trucks are reassigned to other activities in the afternoon.

Except for the 5 m^3 bins, all collection is performed daily at the curbside. Waste is placed at convenient locations by the residents, sometimes in small plastic bags but often just dumped loose on the ground without any container. These piles of waste are often scattered by animals or scavengers looking for recyclable materials. Waste collectors gather the uncontained waste into baskets which they then dump into the collection vehicle.

Informal dumping areas are common in Meknes as they are in other large cities throughout Morocco. These areas, which are usually vacant lots or low areas, are used as dumping areas for a variety of wastes, but mostly demolition and construction debris. The more visible areas are cleaned up by municipal workers on a periodic basis.

2.3.2 Collection Problems

The primary problems within the collection system appear to originate from a lack of both labor and financial resources. Collection vehicles are not maintained or serviced on a regular basis due to a lack of parts, supplies and skilled mechanics to perform the servicing. When a vehicle breaks down, repair parts must be requisitioned through the municipal system and then ordered from the manufacturer. Sometimes the process takes several months for a relatively minor repair. This situation is compounded by a wide variety of equipment makes and models in the same depot. With each new purchase, the municipality considers only price and as a result has many different vehicles manufactured by Renault, Hino, Mitsubishi, Fiat, etc. This makes routine maintenance and stocking of spare parts more difficult.

Records of maintenance and repairs are not kept, and therefore it is impossible to evaluate the efficiency of each piece of equipment. These records would be helpful in identifying which vehicles are over utilized or under utilized and which collection routes need to be adjusted to match the efficiency of the vehicle. It was estimated that the average availability of collection trucks was in the 50 to 60 percent range over the trucks' active life due to down time for maintenance and repair.

In the one municipality that was interviewed and inspected, 35 collection workers were monitored by only one supervisor. In addition to low wages, and health related problems, the social status of collection workers is low. These conditions result in poor collection performance and a lack of accountability for the services performed.

2.3.3 Existing Privatization

One of the municipalities has hired trucks and drivers from the private sector to augment the municipal collection vehicles. The current price is 400 DH per 8 hours for the truck and driver, with the municipality supplying the laborers. This limited form of privatization has been practiced for the past four years and is very successful. The municipality avoids the capital and operating costs of the vehicles while guaranteeing availability of the trucks.

2.4 Existing Landfill

2.4.1 General

The existing landfill is located on the north side of the city on a hillside overlooking a sparsely populated valley to the north. The location of the landfill is shown on Figure 3. Due to its location, the landfill is in full view of the main road entering the City from the north. Prevailing winds carry smoke from the ever present fires into the city.

The landfill receives all solid waste generated within the city, including residential wastes, industrial wastes and medical wastes. Although the main hospital was reported to have a small incinerator, it was not operating and all medical wastes are dumped at the landfill. A list of specific industries within the city was not available.

The landfill is being constructed from the top of the hillside by dumping refuse in a small active area and then pushing it over an embankment with a small front end loader. The front end loader was totally inadequate for the task and could not keep the area open. Other than the loader operator, there were no attendants to direct the dumping and the scavengers seemed to be in control of the site. The actual dumping area is very small and very active, with approximately 50 scavengers and a multitude of cattle, goats and sheep, all searching for materials or food in the waste as it is discharged from each vehicle.

The loose waste on the embankment dries quickly in the hot sun and fires are a constant problem. As the landfill embankment proceeds outward it will eventually become unstable and a slide failure into the lower valley is a real possibility in the future. From a structural viewpoint, this landfill may be close to becoming unstable and should be closed as soon as possible.

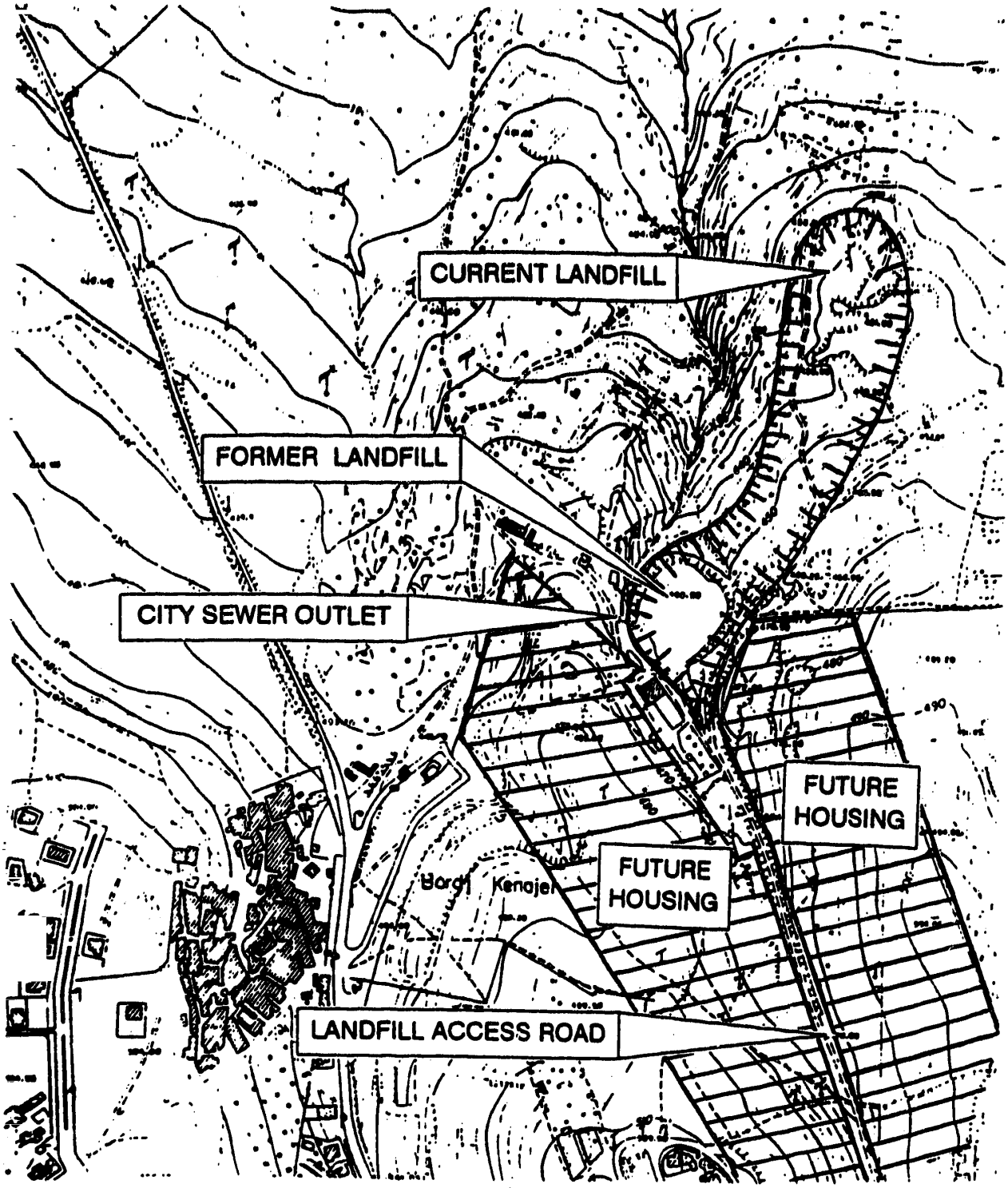


FIGURE 3

MEKNES
EXISTING LANDFILL LOCATION

2.4.2 Access

The single main access to the site is through the downtown area of the city and through a planned residential development. Due to muddy conditions experienced during the rainy season, waste has been dumped along the access road in a haphazard, informal manner. It was reported by a City official that the access road is cleaned periodically and the waste is placed in the landfill. On the day of the inspection, many of the waste piles dumped along the access road were burning.

The conditions along the access road and the landfill itself are having a severe impact on the planned residential area directly to the south of the landfill (see Figure 3). Roads and utilities have been installed but the developer has not been able to sell any lots due to the unsightly conditions associated with the landfill.

2.4.3 Environmental and Health Issues

The conditions at the existing landfill are a potential major health problem for collection workers and the waste scavengers, especially considering the untreated medical waste and unknown industrial wastes that are being placed in the landfill. In addition to physical accidents from vehicles and materials in the waste, the potential spread of infectious disease through the scavengers or animals is a real potential health problem.

Although short term environmental impacts from burning waste, odors and insects are significant to those persons working at the landfill and those unfortunate enough to live or work downwind of the site, the long term environmental impacts of the landfill are most likely minimal. This is because the landfill has burned for most of its active life so that the actual landfilled material is mostly ashes or a mixture of ashes and organic waste. When organic matter burns, it produces oxides and carbonates which are alkaline (high pH) by nature. These alkaline compounds will buffer or neutralize the acidic (low pH) conditions that result from any decomposition of organic matter that may have escaped the landfill burning. The alkaline conditions will also immobilize most heavy metals in the waste by chemically forming insoluble compounds.

In addition to the chemical conditions in the landfill, the groundwater in the area under the landfill is reported to be in excess of 20 meters and a large clay layer under lies the entire area. This clay layer becomes more pronounced to the north of the city which will be a factor in searching for a new landfill site. With these geologic factors, the landfill is not likely to be impacting ground water. The only environmental problem may be from industrial wastes that may have been placed in the landfill.

As shown on Figure 3, a major city sewer discharges immediately adjacent to the former landfill site, creating a small but polluted stream that runs along the western base of the existing landfill. Although there is a possibility of leachate flowing overland from the landfill during the peak rainy season, the impact would not be noticeable in the highly polluted stream.

Future plans call for the construction of a wastewater treatment plant for this sewer discharge. If this plan becomes a reality, the city should perform a study of the landfill to determine if leachate contamination is present.

2.4.4 Recycling

An active recycling system exists in Meknes, both in the collection system and at the landfill. An intermediate processor purchases materials from waste collection crews and scavengers at the landfill. Materials include plastic containers, glass, paper, some metals and bones. The intermediate processor cleans and prepares the materials for shipment to markets in Casablanca. As an example, he pays 1 DH per kilogram for clean plastic bottles separated by collection workers and .5 DH for bottles separated from the landfill which must be washed prior to shipment to the market. Other materials are collected and shipped but prices are lower. The operator would not reveal the price that he is paid for the materials in Casablanca.

In addition to this operator, it was reported that other recyclers are operating in the City, especially in the commercial and industrial areas where higher value materials can be found.

2.5 Compost Facility

A compost facility was constructed in Meknes in 1965 and operated between 1971 and 1992. Although the mechanical equipment has fallen into disrepair or has been cannibalized for spare parts, the major structures, including the two large covered maturation pads, appear structurally sound. The facility is typical of many earlier compost designs which relied on a high level of mechanization and incorporated size reduction and screening prior to composting. Based on a brief site visit, there did not appear to be any sorting of the waste before it was fed into two large hammer mills. In addition to the high degree of mechanization, the hammer mills were a "fatal flaw" which ultimately led to the facility closing in 1992.

As waste in Meknes changed through the 1970s and 1980s, more packaging, plastic and glass was appearing in the waste stream. Due to the design and lack of sorting, these materials were crushed or shredded by the hammer mills and became part of the compost mixture, ultimately degrading the finished compost to the point where farmers were unwilling to purchase it. Compost revenues of 60 DH per tonne in 1979 dropped to 20 DH in 1992, which was below the operating cost of the facility, forcing it to close. Although no longer operational, the facility represents a resource and should be considered in any future planning. If restored to active composting, the hammer mills should be removed and replaced with hand sorting and rough screening before composting, followed by a final screening of the finished composting.

Depending on the location of the next landfill, the site could also be converted to a transfer station. Maturation pads could either be used in a new composting operation or used for hand sorting of waste prior to transferring.

2.6 Other Issues

Meknes is the location of a major cement manufacturing plant. Although the limited time for this assignment did not permit an inspection or evaluation of the cement kiln, it may become an important resource for future waste management in Meknes and the nearby region. In the United States and many European countries, cement kilns are being used to burn a variety of waste materials, including tires, waste oil, medical waste and hazardous waste. In the United States alone, over 1.5 million tons per year of hazardous waste is burned in 33 cement kilns. The very high temperatures in the kiln and the alkaline nature of the cement dust are ideal parameters for combusting a variety of special wastes, with minimal environmental impacts. The city should contact the operators of the cement kiln to assess their interest in assisting in future waste management alternatives.

In December, 1994 the ICMA solid waste expert prepared a paper on the use of cement kilns for burning hazardous waste. Although the paper was prepared for an Eastern European country, most of the technical information is generic to all cement kilns and may be of interest to Moroccan waste managers. A copy of this paper is included in Attachment B for reference.

2.7 Recommendations

2.7.1 General

The collection systems in Meknes are suffering from numerous problems. These problems can be addressed by either upgrading the existing public systems, consolidating public systems, privatizing collection services or combinations of the above.

The existing landfill is a major problem and should be closed as soon as possible. The closure will require cover soil, and an interim three year plan is proposed during which the existing landfill can be closed while the city locates and builds a new landfill.

2.7.2 Collection Recommendations

- *Containers:* Regardless of whether the municipalities consider upgrading the public system or privatizing, they should consider converting waste collection in some areas of the city to use communal containers, especially in new areas of multi-unit housing. Containers will improve collection efficiency and health conditions. The use of containers may also permit the frequency of collection to be reduced to three times per week rather than daily.
- *Truck Size:* New truck purchases should consider increasing compactor truck capacities to 14 or 16 m^3 which should be able to negotiate wider streets in the newer sections of the City. All new compactor trucks should be equipped with mechanical lifting devices or winches to be able to service containers.

- *Common Make and Model:* When purchasing new vehicles, the municipality should attempt to purchase equipment of the same make or model to facilitate maintenance, repair and spare parts inventories.
- *Second/Third Shift:* The current schedule of collecting waste only in the morning is not an efficient use of equipment. Collection routes and crews should be re-distributed to use the trucks for an afternoon collection as well as the morning collection. A third shift should also be considered for routine equipment maintenance and minor repairs.
- *Maintain Records:* Each municipality should maintain a record of each piece of equipment under its control. A daily log of each depot should be maintained with entries for each truck including availability status, crew assignments, time in and time out, zone(s) of collection, trips to the landfill, estimated volume of waste collected per trip, maintenance performed and fuel consumed. This information can be used to calculate collection efficiencies, schedule routine maintenance, adjust collection routes and determine cost efficiencies. A depot management system was recently developed for the City of Tetouan under a USAID contract and could serve as a model for Meknes and other Moroccan cities.
- *Spare Parts Inventory:* Each municipality should maintain an inventory of spare parts and maintenance supplies for the most common vehicle repairs. These include hydraulic cylinders and hoses, brake parts, clutch parts, tires, gaskets, etc. All new equipment purchases should include an inventory of spare parts in the purchase price. A common spare parts inventory for all four municipal depots should be considered.
- *Privatization:* The municipalities have received approval to purchase new vehicles. Before making this commitment, the municipalities should consider privatization. A more detailed discussion of privatization is included in Section 5.
- *Consolidation:* The operation of four separate collection systems and depots in the same city is not the most efficient use of limited resources. The consolidation of the four municipal operations into a single entity would maximize limited resources and improve overall efficiencies. This could be accomplished by forming a new independent city department or solid waste authority with one or two centralized depots for truck maintenance and repair. This should be the subject of a future feasibility study, which would inventory all existing manpower and equipment resources and make recommendations for consolidation.

2.7.3 Landfill Closure/Interim Landfill Recommendations

The existing landfill is approaching an unstable structural condition and should be closed. Ideally the closure should include stabilization of the steep side slopes as well as covering of the entire site with a 30 to 50 cm layer of soil. The stabilization of the side slopes will require additional waste to be placed at the base of the slope, reducing the final slope to 2.5:1, which would provide structural stability and permit the placement of cover soil. The existing slope of approximately 1.5:1 is too steep for cover soil placement.

Unfortunately the placement of additional waste at the base of the side slopes will require a new access road through difficult terrain and private property. The City should investigate alternative routes to access the base of the landfill.

In the event that the base of the landfill cannot be accessed, the landfill closure should proceed with soil cover of the top of the landfill only. This will require a large volume of cover soil that is not currently available. As an interim measure the project team is recommending that a short term shallow landfill be constructed in the gently sloping area just north of the existing landfill. The excavation from this short term landfill will provide cover soil to cover the existing landfill and will provide three additional years of landfill capacity during which time the City can locate and develop a new site.

The interim site should be located in soils that are easily excavated but still meeting the characteristics outlined in Section 1.4.4 for landfill base soil. Based on the waste generation data base, a landfill volume of approximately 442,000 m^3 would be required for a three year landfill. If the landfill height were limited to 10 meters, an area of 44,200 m^2 would be required. For the purposes of this report it is assumed that the interim landfill will be 100 meters by 442 meters and located as shown on Figure 4. With these dimensions the landfill should be constructed in two phases, each 50 meters by 442 meters as shown on the cross section drawing found in Figure 5. Final interim landfill location and design should be determined by the City after a thorough evaluation of available land.

Excavated material from the interim landfill will be loaded onto dump trucks and transported to the top of the existing landfill and spread and compacted in a 30 to 50 cm layer over the completed landfill. Some areas of the landfill may require rough grading before placing the cover soil. The cover soil should be compacted with a minimum of three passes with a tracked D7 or D8 bulldozer and then seeded with a mixture of native grasses. The time frame for completing the closure of the existing landfill will depend on available resources and may be accomplished over several months or over the entire three year life of the interim landfill.

After completing the placement of cover soil, the city should test the area for the presence of methane. Due to the past burning of the landfill, methane from waste decomposition may not be a problem. If significant amounts of methane gas are detected, gas vents consisting of perforated 150 cm plastic pipe should be installed through the cover soils. The venting plan should be designed by an experienced civil engineer.

Regardless of what actions are taken by the city regarding the existing or new landfills, they should consider purchasing a new machine for operating the landfill. The existing rubber tired front loader is not adequate. Although the landfill capacity justifies a specialized landfill compactor with steel wheels, the City may consider a tracked bulldozer which may have other application. A D7 or D8 bulldozer would be the appropriate size.

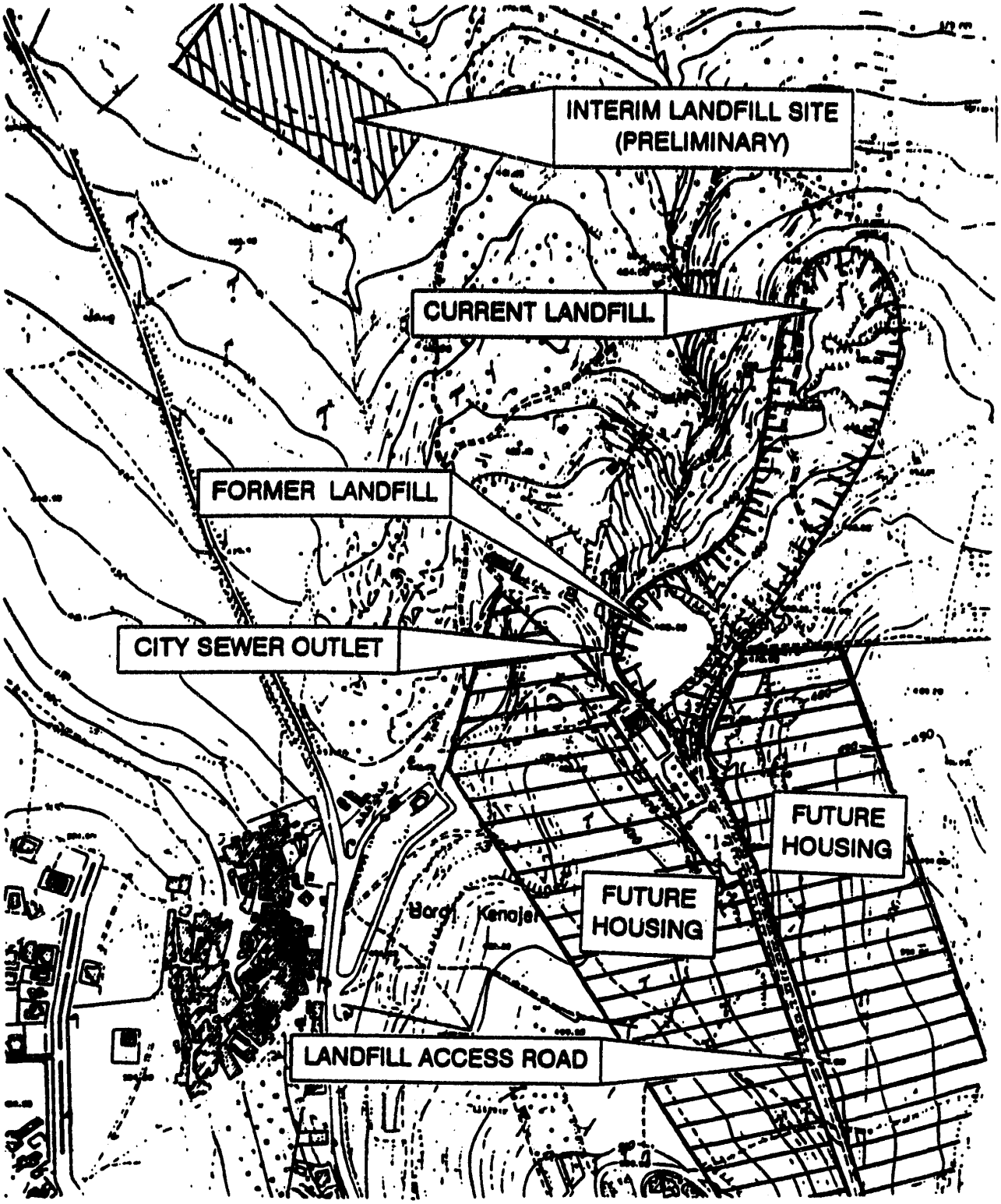


FIGURE 4

MEKNES
INTERIM LANDFILL LOCATION

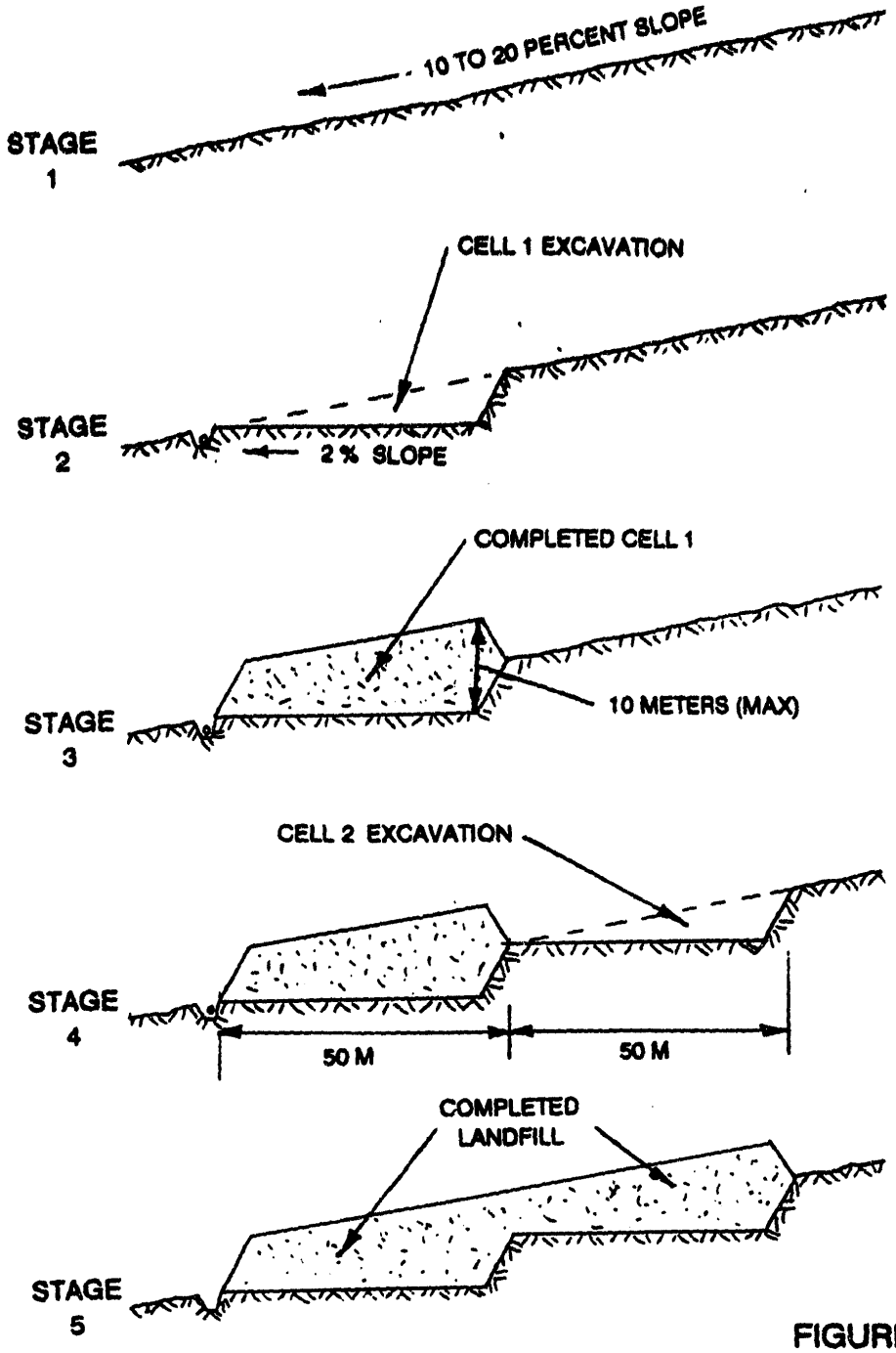


FIGURE 5
INTERIM LANDFILL SECTIONS

2.7.4 New Long Term Landfill

The problems currently facing the City are adequate justification for careful site selection for the next long term city landfill. Technical criteria for locating a new landfill have been presented in Section 1.4.5. Land requirements are presented in Figure 2 and in the waste generation data base found in Attachment A.

A review of existing data indicates that the geologic conditions for landfill siting are very favorable to the north of Meknes along the road to Sidi-Kacem. This area is underlain with an extensive layer of blue clay which is currently being mined by several brick factories. These brick quarries may become future landfill sites in 30 to 50 years but are currently active.

The hydrogeology of the area is shown in Figure 6, which is a map of the Meknes-Fez Plain and aquifer. This figure shows that the majority of the aquifer lies to the south of Meknes with massive clay deposits to the north. The piezometric groundwater contours show that the water in the aquifer flows gently to the north so that any contamination that might result from a landfill on the north side of Meknes would not likely impact the current active wells in the aquifer.

The search for a new landfill should begin with a review of all public lands in the area of favorable geology mentioned above. If public lands are not available, private lands should be reviewed. After locating one or more suitable sites, a surficial site inspection should be performed by a civil engineer or geologist familiar with landfill siting criteria. If the surficial inspection proves favorable then a subsurface investigation should be performed, identifying the characteristics of the landfill base soil and general hydrogeology of the area. If the subsurface investigation is favorable then the landfill can proceed to engineering design and construction.

The design should maximize the resources of the site and include sufficient excavation to provided adequate cover soil for the operation of the new landfill.

2.7.5 Other Recommendations

The unknown nature of the industrial waste generated in Meknes should be a concern to the city. An inventory of all industries should be performed, listing all waste products, their characteristics and where they are disposed of. All new industries should be required to list their waste materials and perform an environmental assessment of their disposal.

As mentioned above, the former compost facility represents a resource that should be considered for use. A study, reviewing the condition of the facility and possible plans for reactivating the process should be performed. The study should include a market assessment of local farmers to determine the need and price for the compost material.

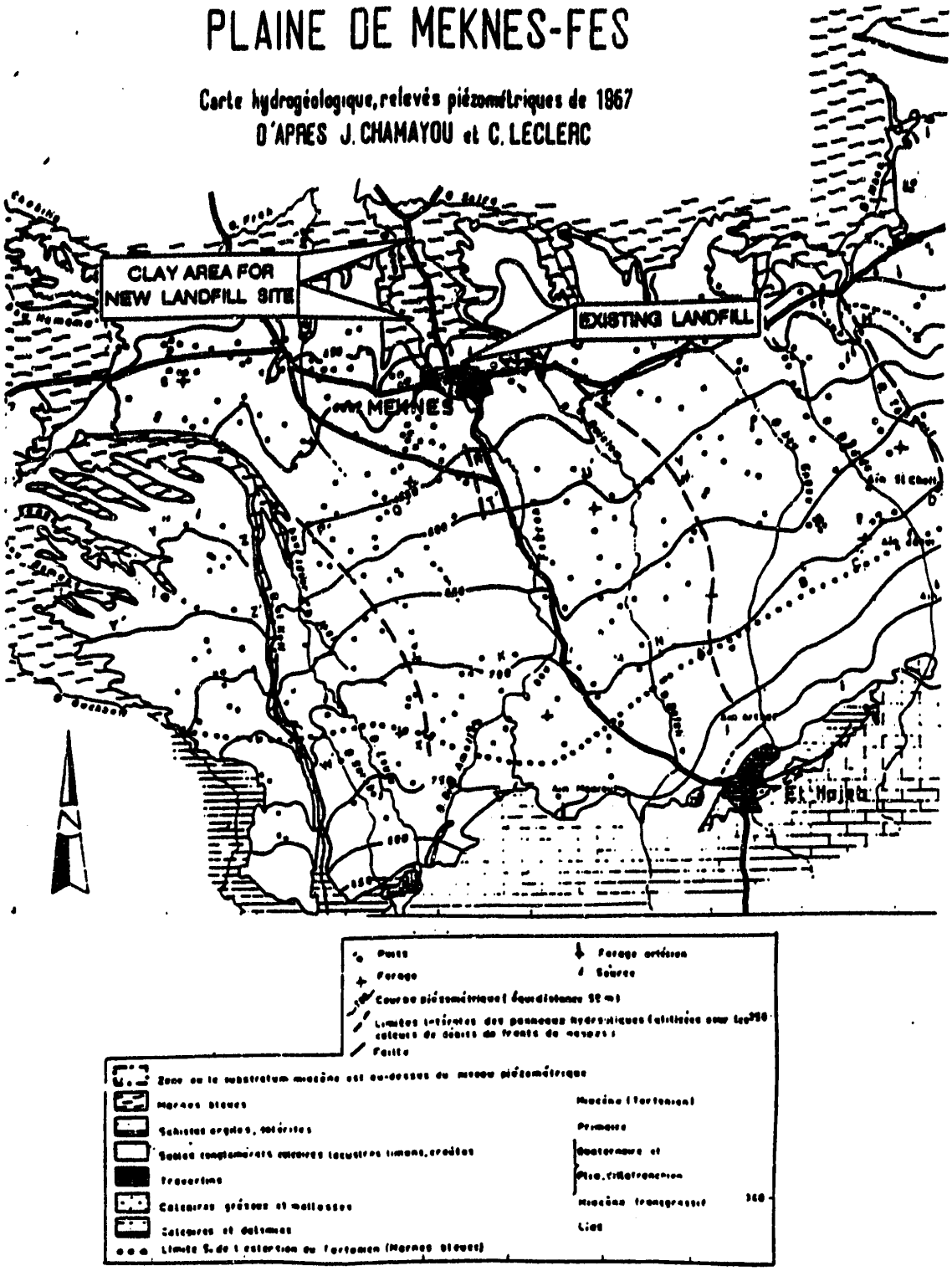


FIGURE 6

MEKNÈS HYDROGEOLOGY

3 AZROU

3.1 General

Azrou is a medium sized municipality located in the foothills of the Atlas Mountains. Due to its relatively high elevation (1,250 m) its climate is cooler and wetter than its neighbors to the west, including Meknes. Average annual rainfall in Azrou is 887 mm per year compared to 577 mm in Meknes. The city is a favorite tourist destination for residents of Meknes and Fez during the hot summer months.

3.2 Waste Generation and Composition

The 1994 population of Azrou is estimated at 40,808 and the growth rate is projected at 2 percent for the next 10 years. At a waste generation rate of .5 kg/capita/day, the total waste generated in 1994 is estimated at 20 tonnes per day. Informal waste disposal, especially during the winter months when the new landfill is not accessible during bad weather, is estimated at 20 percent, leaving approximately 16 tonnes per day for collection and disposal. Waste generation and collection estimates are shown on the upper graph of Figure 7. Assuming that the above population and waste generation figures represent permanent residents, the waste generation during the summer months can be expected to be considerably higher than the average.

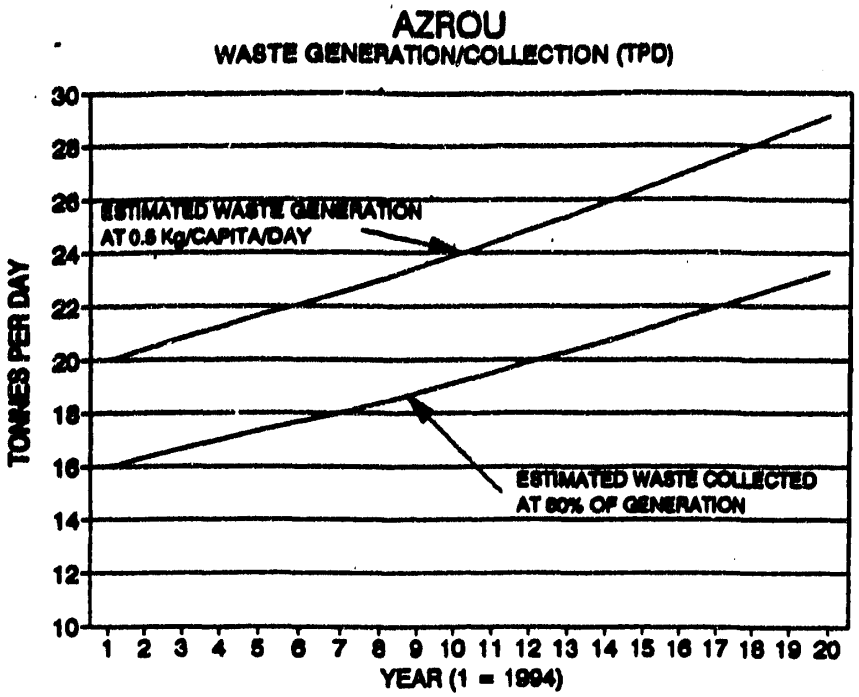
3.3 Existing Collection System

Based on the site inspection and interviews with city officials, the collection system appears to be well organized and efficiently operated. The city is divided into six sectors by geologic features. Maps of each collection sector showing streets and truck routing were presented to the inspection team for their review.

The waste collection department consists of 40 workers and six manually loaded dump trucks. Assuming an average capacity of 6 m^3 per truck yields a total truck capacity of 36 m^3 and a ratio of .82 compared to a waste generation volume of 44 m^3 (20 tonnes @ 450kg/T), which is more than adequate.

Problems expressed by City officials included waste placed at the curbside without plastic bags and six day per week collection rather than seven days. If more staff were available, the seventh day would be added. As a result of no Sunday collection, Monday's collection is often difficult. City officials also expressed problems with maintenance and repairs but were not specific.

The inspection of the repair and maintenance park found a very clean and efficient operation. Specific areas for equipment storage, repairs and administration were clean and well organized.



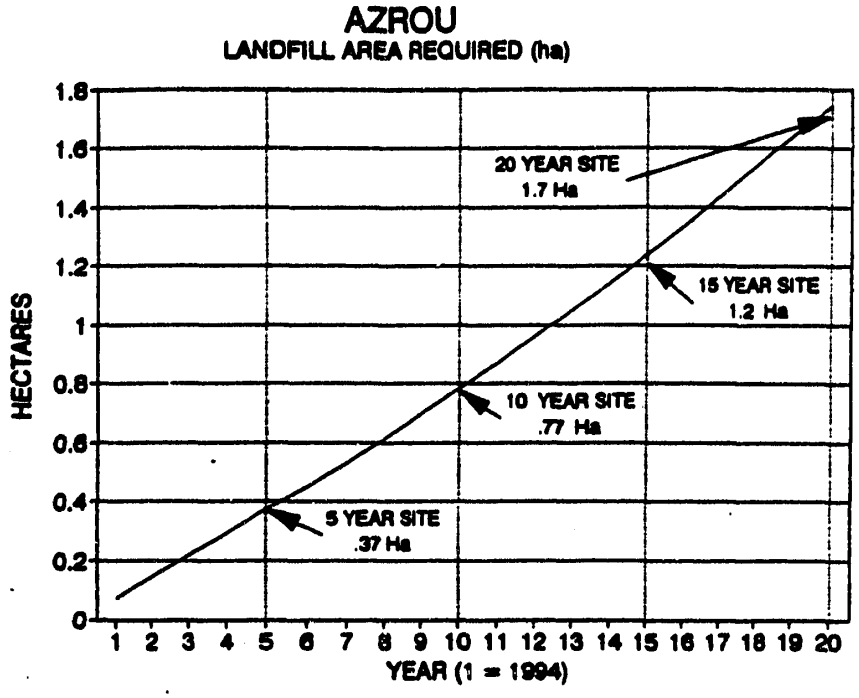


FIGURE 7

AZROU
WASTE GENERATION
AND
LANDFILL CAPACITY

3.4 Existing Landfill

3.4.1 General

The city began operating a new landfill approximately two years ago. Based on the volume calculated in the hydrogeology report and the waste generation estimates, the landfill has a capacity of approximately 15 to 20 years. The site for this landfill, which was the result of a hydrogeologic study of the region, is located about 15 kilometers from the City along the road to Fes. The road between the City and the landfill rises approximately 200 meters and has several sharp turns. This road is closed periodically during the winter months due to snow. A new access road to the site is nearly completed and a stone wall, surrounding a portion of the site as a wind break, has been built. The landfill location is shown on the map in Figure 8.

3.4.2 Site Related Problems

Although the landfill appears to be well sited from a hydrogeological viewpoint, its distance from the City and its elevation are causing several significant site related problems. The first of these problems is the lack of cover soil. The site is located in a natural depression, underlain by a 4 to 5 meter layer of clay, but there is little other soil in the area to be excavated for cover. Although the construction activity in the City generates an ample supply of construction debris, including soil, that could be used for cover soil, this material is dumped informally in the city rather than taken to the landfill because of the travel distance. The lack of cover soil is a significant operating problem.

The second site related problem is the wind. The upland location of the landfill is a very windy site. On the day of the inspection, plastic bags could be seen for at least 200 meters around the site.

3.4.3 Operational Problems

The landfill also has several operational problems that should be addressed. The first is that the site is not supervised. The city should assign an employee who will be at the landfill during all operating hours to oversee the placement of waste. At the present time, waste is spread over the entire area of the landfill, which promotes the wind blown problem. This is especially evident along the access road where piles of waste can be seen. Many of these piles contained medical waste.

Dumping should be concentrated in one small area within the landfill, until full, then moved to the next area. All dumping outside of the site along the access road should be prohibited. The landfill does not receive any compaction during the placement of waste. Compaction is a basic landfill control and should not be avoided. Consolidation of the waste and compaction, followed by cover soil, will help to alleviate the wind blown problem.

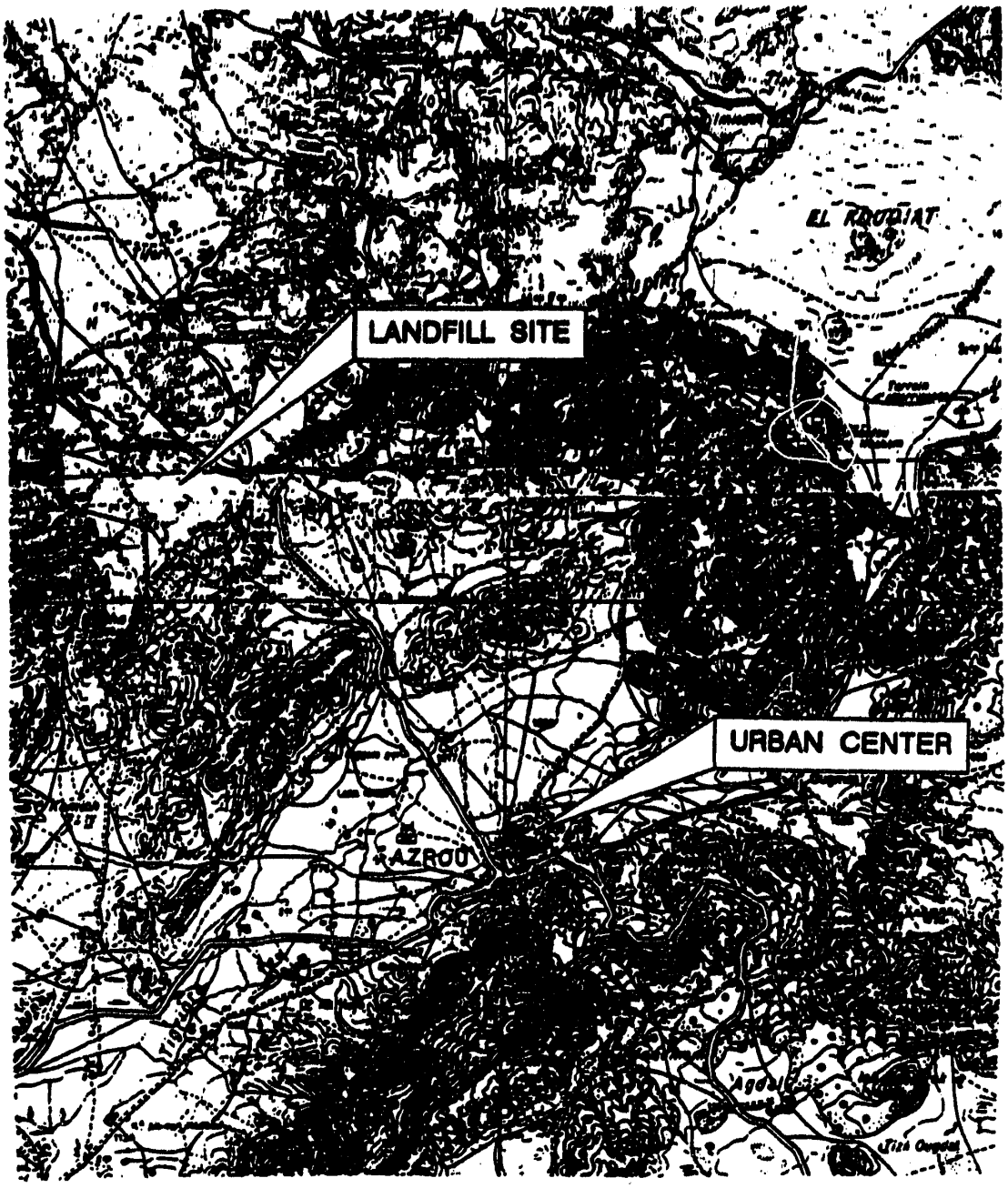


FIGURE 8

AZROU
LANDFILL LOCATION

3.4.4 Environmental and Health Issues

As stated earlier, the site has favorable hydrogeologic characteristics and the landfill will not likely have any negative environmental impacts. The 4 to 5 meter clay layer should be adequate to contain any leachate that may be formed and groundwater is assumed to be very deep due to the upland location of the site. The City generates only residential waste and therefore there should be no danger of industrial waste dumped at the site and polluting groundwater.

Several piles of waste along the access road contained medical waste. Although not confirmed by the City representative, it is assumed that these piles of waste are from the city hospital. Most of the piles had been burned. This area along the access road also is a grazing area for sheep which could potentially contact infectious medical waste. All medical waste should be placed in a clearly marked separate area of the landfill and away from grazing animals.

3.5 Other Issues

Informal dumping areas are a significant problem in the City, especially with construction and demolition materials. The inspection team visited one of the larger informal dumping areas near the north side of the town. Although most of the material was inert construction and demolition waste, there were significant amounts of resident waste. City officials indicated that this area is used to dump waste on those days when the road to the landfill is closed during the winter.

3.6 Recommendations

3.6.1 Collection System

Although the collection system is well equipped and operated, improvements could be made by converting some areas of the City to container collection. This would require the addition of at least one compactor truck with a mechanical lifter and an appropriate number of containers. The most obvious areas to convert to container collection would be the new areas of multi-unit housing. Due to the relatively small size of the city and street patterns, a compactor truck in the 6 to 8 m^3 capacity range would be sufficient.

In addition to being able to collect containers, the higher capacity compactor truck will also be more efficient at travelling to the landfill. This truck could also be used to transfer waste from smaller vehicles to the landfill.

3.6.2 Landfill

Due to its location, the new landfill will always have some problems with blowing debris. These problems however can be reduced by applying the controlled landfill operating procedures outlined in Section 1.4.6 of this report. The most important of these is to consolidate the dumping to as small an area as possible and compacting and covering the waste on a periodic basis. Due to the relatively small size of the landfill, weekly or bi-weekly compaction and covering are

recommended. This will most likely require trucking cover soil or demolition debris to the landfill from the City.

The City should maintain an employee at the landfill during all operating hours to ensure that waste is placed in the proper location. This employee could also be responsible for cleaning the area around the landfill of plastic bags and other wind blown debris.

A separate area should be established for the disposal of medical waste. This area could include an enclosure for burning the waste to ensure the destruction of potentially infectious materials. The open burning of medical waste is not recommended as a long term option, and incinerators at the hospital should be required. The ashes would then be buried in the landfill during the weekly or bi-weekly compaction and covering of the landfill.

Wind blown debris could be further controlled by planting cactus plants around the landfill in the downwind direction. The thorns on the plants will catch blowing plastic bags which can then be removed periodically by the site supervisor. This method is practiced in Tunisia, with great success.

3.6.3 Other Recommendations

Rather than allow informal dumping of demolition and construction waste to continue, the City should establish a specific site within the city to receive this waste. This site could be a low area requiring fill or simply a storage area where the material is stored and then transported to the landfill to be used as cover soil. Regulations prohibiting informal dumping should be enforced.

A temporary dumping location is also needed for solid waste on those days when the new landfill is closed because of snow. This area should be near the City but not close to residential areas. The waste stored at the site should be removed periodically and taken to the landfill.

4 SEFROU

4.1 General

Sefrou is a medium sized city with an estimated 1994 population of 55,000. Like Azrou, it is located in the foothills of the Atlas Mountains but at a lower elevation, and near the headwaters of the Sebou River. It has an average annual rainfall of 498 mm. The City has an active program of upgrading informal clandestine neighborhoods and is expanding the official city boundaries with each upgraded neighborhood. The City has a balanced economy with significant industrial and commercial areas, including a tannery and several olive oil processing factories.

4.2 Waste Generation and Composition

At the estimated 1994 population of 55,000, Sefrou generates approximately 28 tonnes per day of waste at a generation factor of .5 kg/capita/day. As in Azrou, the generation is reduced by 20 percent for informal disposal and recycling, leaving 22 tonnes per day of waste that is collected and disposed of. Sefrou is projected to grow at a 2.8 percent rate over the next ten years, a rate slightly higher than for either Meknes or Azrou. The 20 year projection of waste generation is shown in Figure 9.

4.3 Existing Collection System

The City is divided into 16 collection sectors which are serviced by 13 vehicles. The narrow streets in the medina are serviced by donkeys. The 13 collection vehicles have a combined capacity of 39 m^3 as compared to an estimated daily generation of 62 m^3 which equates to a collection capacity ratio of .62. This is more than adequate, assuming good maintenance and repair of vehicles. Five of the trucks are relatively new, purchased in 1994.

The collection system is operated by a staff of 29 who collect waste 7 days per week, between the hours of 7:00 am and 11:30 am. During discussions with City officials, they expressed a desire to optimize collection efficiency.

The existing collection system appears well maintained and operated. The staff are better paid than their counterparts in Meknes and are held accountable for their collection routes. Supervisors routinely will inspect the collection sectors after the morning collection to ensure that the services have been properly performed. The maintenance depot was clean and well organized, and records are kept of all maintenance and repair activities.

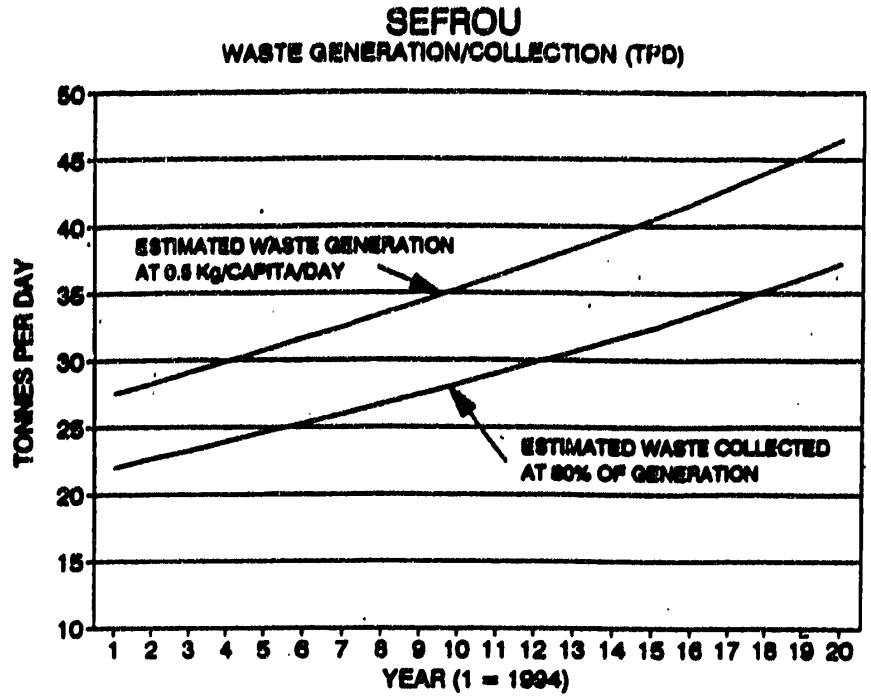
4.4 Existing Landfill

4.4.1 General

The existing landfill is located approximately three kilometers east of the urban center of Sefrou, as shown on Figure 10. Although the landfill is located near the edge of the existing city boundary, that boundary will soon be moved to include a new market area now under construction, a few hundred meters east of the existing landfill.

4.4.2 Site Conditions

The landfill is located in a depression, approximately 10 meters in depth. An access road into bottom of the landfill permits waste to be deposited at the bottom, where it is burned. During wet weather, this primary access road becomes impassable, and a secondary road along the upper edge of the site is used. Under these conditions waste is dumped from above, down a steep embankment. The landfill is surrounded by a chain link fence which is effective in catching much of the windblown debris. However, since the landfill is burned, the amount of windblown



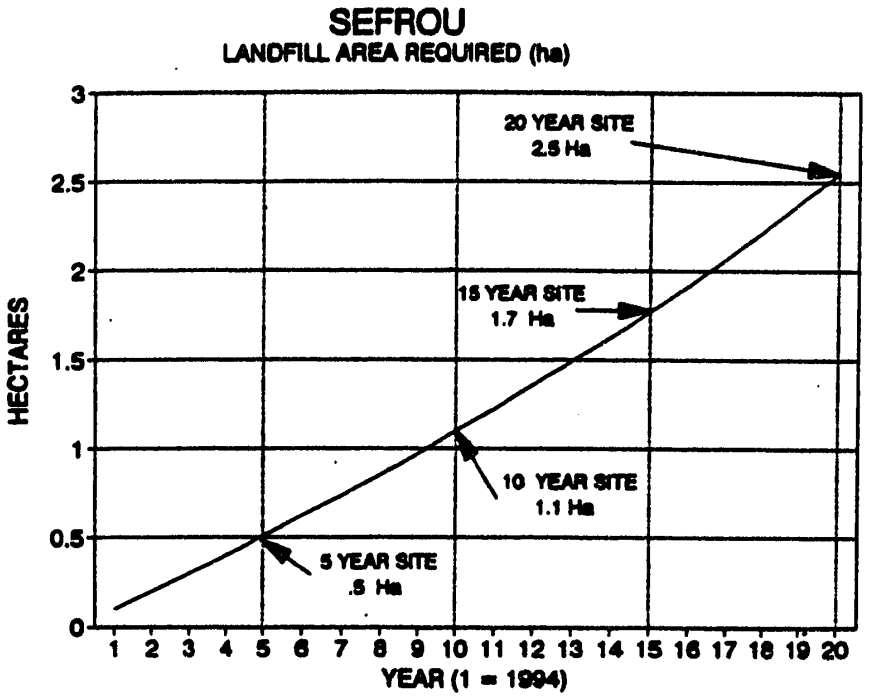


FIGURE 9

SEFROU
WASTE GENERATION
AND
LANDFILL CAPACITY

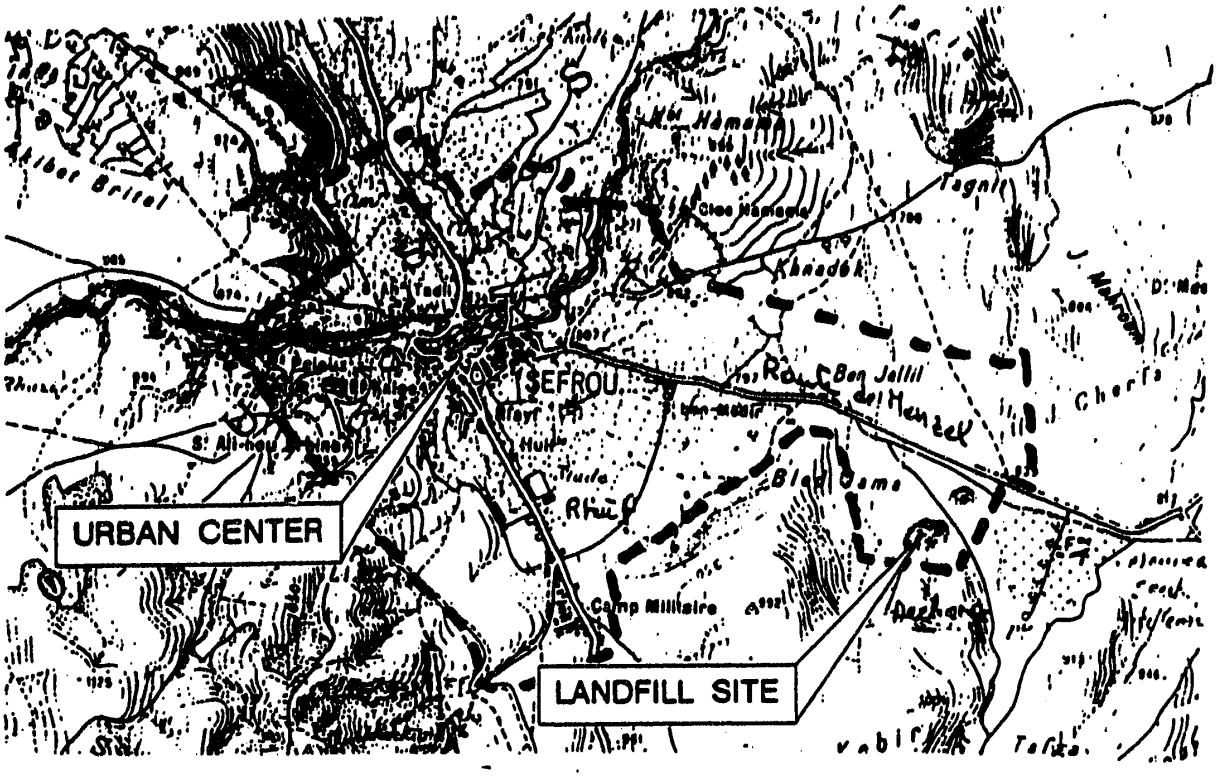


FIGURE 10

SEFROU
LANDFILL LOCATION

material is minimal, and the site, as well as the access road, is relatively clean. Periodic compaction and covering are performed by a private contractor under a broader construction contract with the City.

The remaining volume of the landfill is estimated at 150,000 to 200,000 m^3, which based on the waste generation data base found in Attachment A would be equal to another 7 to 10 years of capacity. This assumes that the landfill operation is changed in the near future to eliminate the burning of waste. If the City continues to burn the landfill, which is not recommended, the remaining capacity is in excess of 50 years.

Although no specific information was available regarding the hydrogeology of the site, excavations at the site of the new market and conversations with City personnel indicate that the soil under the landfill is a hard packed, low permeability conglomerate of silt, sand and gravel with some large boulders. This soil type is favorable for landfill location. Groundwater was reported to be approximately 200 meters below the surface but this could not be confirmed.

Adjacent to the landfill, another depression is being used to dispose of olive oil processing waste. This dark, thick liquid is a major problem waste in the region due to the large olive oil factories. Formerly, the practice of dumping this waste into the Sebou river was discontinued several years ago. The environmental problems associated with this material are being addressed by a larger project regarding the entire Sebou River valley.

4.4.3 Environmental and Health Issues

In Section 2.3.4, regarding the Meknes landfill, the environmental issues of burning waste were discussed. In Sefrou, the burning is much more deliberate and controlled than in Meknes, and the amount of organic waste remaining can be assumed to be minimal. As mentioned in Section 2.3.4, the burning has converted most of the organic matter to alkaline oxides and carbonates which will essentially neutralize any acidic conditions which may occur in the landfill and will immobilize heavy metals. Considering the combination of the burned waste, favorable soils, and deep groundwater, the landfill will not produce any significant environmental impacts to groundwater.

Although groundwater impacts are assumed to be negligible at the site, air quality is significantly impacted by the burning landfill. At the present time, the prevailing winds blow the landfill smoke away from the City and disperse it. The area downwind of the site is currently vacant but once the new market becomes operational, this area is expected to develop quickly. At that point, the potential of negative health impacts to the people working or shopping at the market will be significant and the landfill should cease burning, and begin operation as a controlled landfill as described in Section 1.4.6. In particular, the requirements for compaction and soil cover must be followed to avoid odors, blowing debris and insect infestation that may affect the new market.

Prior to converting to a controlled landfill operation, the ashes of the former operation should be evenly distributed along the bottom of the landfill. Although the base soil and depth to groundwater are favorable for landfill operation, the layer of ashes will provide an extra layer of protection against leachate that may result from the controlled landfill operation.

4.4.4 New Landfill Site

Based on a concern over the proximity of the landfill to the new market, the City formed a committee to locate a new landfill site. The committee selected a site based on geologic conditions which is 14 km from the City center, has no access and is on private land. Several City representatives indicated that this new site is not acceptable and that the site search should continue for a new landfill. Geologic and siting criteria for new landfill sites are presented in Sections 1.4.4 and 1.4.5.

4.5 Recommendations

4.5.1 Collection Recommendations

As Sefrou continues to expand and upgrade clandestine neighborhoods, the City should consider the use of rear loading compactor trucks and containers, or expanded use of open 5 m^3 bins, rather than continuing with the house to house curbside collection. As new areas are upgraded the City should incorporate container areas into the infrastructure design so that each resident in the area has easy access to a container. The collection of containers with larger rear loading compactor trucks will be more efficient than current methods and will remove wastes in a more environmentally correct manner. With proper spacing, location and maintenance of the containers, collection frequency could be reduced to three times per week, further improving collection frequency.

The use of containers may also be an alternative to using donkeys in the medina. If a sufficient number of containers could be located on the perimeter of the medina, where they could be serviced, the residents and merchants in the medina may be willing to walk the extra distance to eliminate the current curbside methods. This proposal would require a more site specific evaluation of the medina and its current collection methods.

4.5.2 Landfill Recommendations

The current operating procedures at the existing landfill will soon be unacceptable when the new market begins operation later this year. At that time, the current landfill burning should cease and the landfill should begin operation as a controlled landfill with periodic compaction and covering. Due to the potential impacts to the new market, the compaction and covering should be performed at least on a weekly or twice per week basis. If odors or fires become a frequent problem, the frequency of compaction and covering may need to become daily.

Construction debris and excavated soil from the new market should be stockpiled and stored for use as cover material. The City should formalize its agreement with a private contractor for weekly compaction and covering of the landfill or purchase a D7 tracked bulldozer and perform the compaction and covering with City personnel.

Operation of any landfill is subject to many variables and uncontrollable circumstances. Winter operation is particularly susceptible to accidental fires from hot coals placed in the waste or fires deliberately set at the landfill. Considering the proximity of the landfill to the new market and the expected growth in the area, it is recommended that the search for a new landfill be continued in accordance with the criteria established in Section 1.4.4 and 1.4.5.

5 PRIVATIZATION

5.1 General

Privatization is an important step for any municipality. Although it is widely viewed as a panacea for many problems, its implementation can be difficult and may even result in a worsening of the problems. Key issues involved with privatization must be evaluated and understood before proceeding. In many cases this preliminary evaluation reveals basic problems which will not be corrected through privatization, and operational and political changes may be required before considering privatization.

5.2 Feasibility Study

Before considering privatization of either collection or landfill operations, a feasibility study should be performed to understand the key issues involved and evaluate the true public cost of performing the service. Without this true cost estimate, the municipality will not have any basis on which to evaluate the private sector cost. In addition to evaluating existing public costs and estimated privatization costs, the feasibility study should address the following issues.

5.2.1 Service Definition

By far, the most important privatization issue is service definition. Both the existing service and the proposed private service should be well defined to ensure good, informed, competitive tenders. A poor service definition will usually result in higher costs, difficult monitoring and many contract disputes. A well defined service will allow the contractor to prepare a more precise tender, and will be much easier for the public sector to monitor and measure performance.

5.2.2 Service Measurement and Monitoring

The service must be defined in a manner that can be easily monitored and measured, in order to determine performance in accordance with the contract. As an example, a containerized collection program is by far easier to monitor and measure than the non-containerized house to house

collection program. Adequate service measurement and monitoring also depends on the government's resources and willingness to enforce contract provisions.

5.2.3 Economies of Scale

In general, the private sector can reduce costs by being more efficient in the management of equipment and manpower. This efficiency is subject to economies of scale and increases with the size of the service operation compared to the contractor's overall resources. Therefore larger private projects will potentially be more efficient than smaller projects. In general, systems involving two to three collection trucks would be considered minimal for consideration of private collection.

5.2.4 Available Private Resources

For privatization to be successful, there must be existing, experienced private companies available to perform the service. An experienced waste management contractor who employs 200 workers and maintains 25 trucks can perform a four truck collection program more efficiently than a smaller inexperienced company with only 20 workers and six trucks. In many developing countries where these resources may not exist, privatization is not likely to increase efficiency or reduce costs. If public resources are available, workshops and training seminars can be used to train private enterprises. Equipment leasing can also be used to overcome a lack of private financial resources.

5.2.5 Competition

In addition to the availability of private resources, there should also be a sufficient number of those private companies to obtain competitive tenders. Lack of competition may result in higher service costs and a monopoly of services. This may also be a problem for many developing countries, especially in remote areas. Although desirable, competition is not absolutely required, and negotiated sole source private contracts have been successful in many instances.

5.2.6 Partial Privatization

Conversion of a public service to private operation should be implemented in stages. As a general rule, less than 50 percent of the service should be included in the initial privatization. This would permit the public sector to resume performing the service in the event of a failure of the private sector to perform. Once the private sector has demonstrated its ability to perform, then the service can be expanded to the remainder of the system. Partial privatization often provides incentives to remaining public workers to increase efficiency, thus providing a better comparison of public and private performance.

5.2.7 Accountability - Control - Risk

The lack of public accountability for service performance is often used to justify a change to privatization of services. Although it is often difficult to hold public workers accountable for their actions, accountability for private performance can be obtained through contract and payment provisions. However, privatization does not remove all accountability from the public sector, since they are still ultimately responsible for the service and must maintain control and monitor the contractor's performance.

5.2.8 Regulation and Enforcement

To ensure success, a privatization project must be accompanied by a commitment of the public sector to enact and enforce regulations which will impact the contractor's performance. Regulations regarding littering, use of containers, illegal dumping and materials sorting will be necessary to define the service and to ensure service performance. Although the private sector can assist in monitoring and reporting of violations, the enforcement of regulations should always remain a public responsibility.

National regulations in many developing countries restrict local government's ability to sign long term contracts and many limit the contract length to one year. The private sector is not likely to invest its resources under those conditions. This limitation can be overcome by leasing of equipment and other physical resources to the private sector for short term operations.

5.2.9 Impacts on Recycling and Local Enterprises

Privatization may have potential negative impacts on other solid waste management practices. In many developing countries, recycling of materials occurs within the collection system, from waste generation sources, storage and transfer areas, and the landfill. This informal system of scavenging usually relies on unlimited access to the waste during the collection process. Since privatization of most larger waste collection systems will usually include containerized storage and transportation systems, the access to the waste by street scavengers will be restricted, severely reducing the amount of recycling that occurs. The containerization will relocate the recycling activities either toward the landfill or toward the generation source. Since scavenging at the landfill should be discouraged for health and safety reasons, the privatization program should consider increased recycling at the generation source with source separation programs.

Attachment A

Waste Generation Data Bases

40'

CITY:	MEKNES
1994 POPULATION:(CENSUS)	401,852
PER CAPITA GENERATION: (KG/CAP/DAY)	0.7
POPULATION GROWTH PER YEAR:	2%
LOOSE DENSITY:(KG/M)	450
TRUCK COMPACT DENSITY:(KG/M)	600
LANDFILL DENSITY: (KG/M)	800
COVER SOIL:(%)	10%

	YEAR	POPULATION	WASTE GEN (T/DAY) (100%)	WASTE COLLECT (T/DAY) (70%)	WASTE GEN (T/YR)	DAILY LOOSE VOLUME (CU.METERS)	DAILY COMPACTOR TRUCK VOLUME (CU.METERS)	ANNUAL LANDFILL VOLUME WASTE (CU.METERS)	ANNUAL LANDFILL VOLUME COVER (CU.METERS)	ANNUAL LANDFILL VOLUME TOTAL (CU.METERS)	CUMULATIVE VOLUME (CU.METERS	LANDFILL AREA @30 METER DEPTH	LANDFILL AREA (ha)	
1	1994	410,852	288	201	104,973	639	479	131,216	13,122	144,337	144,337	7,217	0.72	
2	1995	419,069	293	205	107,072	652	489	133,840	13,384	147,224	291,562	14,578	1.46	
3	1996	427,450	299	209	109,214	665	499	136,517	13,652	150,169	441,730	22,087	2.21	
4	1997	435,999	305	214	111,398	678	509	139,247	13,925	153,172	594,902	29,745	2.97	
5	1998	444,719	311	218	113,626	692	519	142,032	14,203	156,235	751,136	37,557	3.76	5 YEAR
6	1999	453,614	318	222	115,898	706	529	144,873	14,487	159,360	910,496	45,525	4.55	
7	2000	462,686	324	227	118,216	720	540	147,770	14,777	162,547	1,073,045	53,652	5.37	
8	2001	471,940	330	231	120,581	734	551	150,726	15,073	165,798	1,238,844	61,942	6.19	
9	2002	481,379	337	236	122,992	749	562	153,740	15,374	169,114	1,407,958	70,398	7.04	
10	2003	491,006	344	241	125,452	764	573	156,815	15,682	172,497	1,580,455	79,023	7.90	10 YEAR
11	2004	500,826	351	245	127,961	779	584	159,951	15,995	175,947	1,756,401	87,820	8.78	
12	2005	510,843	358	250	130,520	795	596	163,150	16,315	179,465	1,935,867	96,793	9.68	
13	2006	521,060	365	255	133,131	811	608	166,413	16,641	183,055	2,118,922	105,946	10.59	
14	2007	531,481	372	260	135,793	827	620	169,742	16,974	186,716	2,305,637	115,282	11.53	
15	2008	542,110	379	266	138,509	843	632	173,137	17,314	190,450	2,496,086	124,804	12.48	15 YEAR
16	2009	552,953	387	271	141,279	860	645	176,599	17,660	194,259	2,690,347	134,517	13.45	
17	2010	564,012	395	276	144,105	877	658	180,131	18,013	198,144	2,888,491	144,425	14.44	
18	2011	575,292	403	282	146,987	895	671	183,734	18,373	202,107	3,090,598	154,530	15.45	
19	2012	586,798	411	288	149,927	913	685	187,409	18,741	206,149	3,296,748	164,837	16.48	
20	2013	598,534	419	293	152,925	931	698	191,157	19,116	210,272	3,507,020	175,351	17.54	20 YEAR

CITY:	AZROU
1994 POPULATION:(CENSUS)	40,000
PER CAPITA GENERATION: (KG/CAP/DAY)	0.5
POPULATION GROWTH PER YEAR:	2%
LOOSE DENSITY:(KG/M)	450
TRUCK COMPACT DENSITY:(KG/M)	600
LANDFILL DENSITY: (KG/M)	800
COVER SOIL:(%)	10%

	YEAR	POPULATION	WASTE GEN (T/DAY) (100%)	WASTE COLLECT (T/DAY) (80%)	WASTE GEN (T/YR)	DAILY LOOSE VOLUME (CU.METERS)	DAILY COMPACTOR TRUCK VOLUME (CU.METERS)	ANNUAL LANDFILL VOLUME WASTE (CU.METERS)	ANNUAL LANDFILL VOLUME COVER (CU.METERS)	ANNUAL LANDFILL VOLUME TOTAL (CU.METERS)	CUMULATIVE VOLUME (CU.METERS	LANDFILL AREA @20 METER DEPTH	LANDFILL AREA (ha)	
1	1994	40,800	20	16	10,426	63	48	13,033	1,303	14,336	14,336	717	0.07	
2	1995	41,624	21	17	10,635	65	49	13,294	1,329	14,623	28,959	1,448	0.14	
3	1996	42,457	21	17	10,848	66	50	13,560	1,356	14,916	43,875	2,194	0.22	
4	1997	43,306	22	17	11,065	67	51	13,831	1,383	15,214	59,089	2,954	0.30	
5	1998	44,172	22	18	11,286	69	52	14,107	1,411	15,518	74,607	3,730	0.37	5 YEAR
6	1999	45,055	23	18	11,512	70	53	14,390	1,439	15,829	90,436	4,522	0.45	
7	2000	45,956	23	18	11,742	71	54	14,677	1,468	16,145	106,581	5,329	0.53	
8	2001	46,876	23	19	11,977	73	55	14,971	1,497	16,468	123,049	6,152	0.62	
9	2002	47,813	24	19	12,216	74	56	15,270	1,527	16,797	139,846	6,992	0.70	
10	2003	48,769	24	20	12,461	76	57	15,576	1,558	17,133	156,979	7,849	0.78	10 YEAR
11	2004	49,745	25	20	12,710	77	58	[illegible]	[illegible]	17,476	174,455	8,723	0.87	
12	2005	50,740	25	20	12,964	79	59	[illegible]	[illegible]	17,825	192,281	9,614	0.96	
13	2006	51,754	26	21	13,223	81	62	[illegible]	[illegible]	18,182	210,463	10,523	1.05	
14	2007	52,789	26	21	13,488	82	62	[illegible]	[illegible]	18,546	229,008	11,450	1.15	
15	2008	53,845	27	22	13,757	84	63	[illegible]	[illegible]	18,917	247,925	12,396	1.24	15 YEAR
16	2009	54,922	27	22	14,033	85	64	[illegible]	[illegible]	19,295	267,220	13,361	1.34	
17	2010	56,021	28	22	14,313	87	65	[illegible]	1,789	19,681	286,900	14,345	1.43	
18	2011	57,141	29	23	14,600	89	67	18,249	1,825	20,074	306,975	15,349	1.53	
19	2012	58,284	29	23	14,892	91	68	18,614	1,861	20,476	327,450	16,373	1.64	
20	2013	59,450	30	24	15,189	92	69	18,987	1,899	20,886	348,336	17,417	1.74	20 YEAR

CITY.	SEFROU
1994 POPULATION:(CENSUS)	55,000
PER CAPITA GENERATION: (KG/CAP/DAY)	0 5
POPULATION GROWTH PER YEAR.	2.8%
LOOSE DENSITY:(KG/M)	450
TRUCK COMPACT DENSITY:(KG/M)	600
LANDFILL DENSITY: (KG/M)	800
COVER SOIL:(%)	10%

	YEAR	POPULATION	WASTE GEN (T/DAY) (100%)	WASTE COLLECT (T/DAY) (80%)	WASTE GEN (T/YR)	DAILY LOOSE VOLUME (CU.METERS)	DAILY COMPACTOR TRUCK VOLUME (CU.METERS)	ANNUAL LANDFILL VOLUME WASTE (CU.METERS)	ANNUAL LANDFILL VOLUME COVER (CU.METERS)	ANNUAL LANDFILL VOLUME TOTAL (CU.METERS)	CUMULATIVE VOLUME (CU.METERS	LANDFILL AREA @20 METER DEPTH	LANDFILL AREA (ha)	
1	1994	55,000	28	22	14,053	86	64	17,566	1,757	19,322	19,322	968	0.10	
2	1995	56,540	28	23	14,446	88	66	18,057	1,806	19,863	39,185	1,959	0.20	
3	1996	58,123	29	23	14,850	90	68	18,563	1,856	20,419	59,605	2,980	0.30	
4	1997	59,751	30	24	15,266	93	70	19,083	1,908	20,991	80,596	4,030	0.40	
5	1998	61,424	31	25	15,694	96	72	19,617	1,962	21,579	102,175	5,109	0.51	5 YEAR
6	1999	63,143	32	25	16,133	98	74	20,166	2,017	22,183	124,358	6,218	0.62	
7	2000	64,911	32	26	16,585	101	76	20,731	2,073	22,804	147,162	7,358	0.74	
8	2001	66,729	33	27	17,049	104	78	21,312	2,131	23,443	170,605	8,530	0.85	
9	2002	68,597	34	27	17,527	107	80	21,906	2,191	24,099	194,704	9,735	0.97	
10	2003	70,518	35	28	18,017	110	82	22,522	2,252	24,774	219,478	10,974	1.10	10 YEAR
11	2004	72,493	36	29	18,522	113	85	23,152	2,315	25,468	244,945	12,247	1.22	
12	2005	74,522	37	30	19,040	116	87	23,801	2,380	26,181	271,126	13,556	1.36	
13	2006	76,609	38	31	19,574	119	89	24,467	2,447	26,914	298,040	14,902	1.49	
14	2007	78,754	39	32	20,122	123	92	25,152	2,515	27,667	325,707	16,285	1.63	
15	2006	80,959	40	32	20,685	126	94	25,856	2,586	28,442	354,149	17,707	1.77	15 YEAR
16	2009	83,226	42	33	21,264	129	97	26,580	2,658	29,238	383,387	19,169	1.92	
17	2010	85,556	43	34	21,860	133	100	27,325	2,732	30,057	413,444	20,672	2.07	
18	2011	87,952	44	35	22,472	137	103	28,090	2,809	30,899	444,343	22,217	2.22	
19	2012	90,415	45	36	23,101	141	105	28,876	2,888	31,764	476,107	23,805	2.38	
20	2013	92,946	46	37	23,748	145	108	29,685	2,968	32,653	508,760	25,438	2.54	20 YEAR

43

Attachment B

Burning Hazardous Waste in Cement Kilns

REPORT ON HAZARDOUS WASTE INCINERATION IN CEMENT KILNS

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INTRODUCTION

Incineration of hazardous waste is generally regarded as an acceptable method of disposal, especially liquid hazardous solvents and waste oils which have a high fuel value. Fuel blending for industrial furnaces, combining up to 50% waste products with a clean fuel, is a well established practice. Prior to the late 1980's and early 1990's, waste incineration occurred primarily in dedicated hazardous waste incinerators and some industrial furnaces using blended fuels. During the late 1980's and early 1990's cement kilns began accepting and burning larger amounts of hazardous waste materials, with an estimated 1.3 million tons of hazardous waste burned in 1991. Today, of the 211 cement kilns in the United States, 33 are burning hazardous waste derived fuel, at an increasing rate.

Similar to the United States, cement kilns in Hungary are also becoming major hazardous waste processing and disposal facilities. Due to the rapid evolution of this technology, regulatory agencies and public officials have many questions regarding this practice and what regulatory controls are necessary to insure that public health and the environment are protected.

This brief report is intended to review the key issues regarding incineration of hazardous waste in cement kilns and make recommendations for regulatory controls.

THE BASICS

USEPA considers incineration as the best demonstrated available technology for managing and destroying organic hazardous materials. Two seconds exposure to temperatures of 1,800° F (982° C) will destroy every known organic chemical, according to the USEPA. Although the hazardous chemicals are destroyed, the by-products of this process must be considered, such as heavy metals and acids, resulting from the destruction of halogenated organics.

Although there are several basic cement kiln processes, which we will review in a later section of this report, they all rely in part on a high temperature, rotating kiln to complete the conversion of raw material into the final cement product. These kilns generally operate at temperatures up to 3,500° F (1,926° C) with resonance times from 4 to 10 seconds. A logical and correct deduction is that if 2 seconds at 1,800° is acceptable, 4 to 10 seconds at 3,500° must be better. Cement kilns are very efficient at destroying hazardous waste. Although cement kilns can be efficient hazardous waste combustors, there are some limitations based on final product

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specifications and where the waste is burned in the kiln. These issues will be addressed in the report.

CEMENT KILN PROCESS

Cement is made from a mixture of raw materials containing calcium (limestone), silica, alumina (clay, shale, slate and/or sand) and iron (mill scale or iron ore). The mixture of raw materials is known as "meal". The materials are mixed, ground to a fine powder and heated to a very high temperature, producing a cement "klinker". The "klinker" consists typically of 2 inch cement nuggets which are cooled, ground to a powder and combined with gypsum to produce the final cement product.

The kilns operate in a counter-current motion, with solids and hot gases moving in opposite directions. The kiln is sloped at 3 to 6 degrees and turns slowly at 50 to 70 revolutions per hour. Meal is placed in the "cold", upper end of the kiln, and is moved toward the lower or hot end where the firing takes place. Coal or petroleum coke is usually the firing fuel which is sometimes supplemented with natural gas or fuel oil.

The process passes through 3 major stages as follows:

> *Drying and Preheating Zone*, which drys, dehydrates and begins the decomposition of clay materials. Temperatures in this phase are in the range of 70° to 1100° F.
>
> *Calcining Zone* converts the calcium carbonate in the limestone to calcium oxide (burnt lime) and carbon dioxide at temperatures of 1100° to 1650° F.
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> *Burning Zone or Clinkering Zone* combines the calcium oxide with the silicates, iron and aluminum to form the "clinker, which is a chemically complex mixture of calcium silicates, aluminates and alumoferrites. A minimum temperature of 2,700° F is required to form the "clinker".

Due to the inherent characteristics of the process, it produces a significant amount of cement kiln dust (CKD) entrained in the combustion gases. This dust is removed by either electrostatic precipitators or fabric filters prior to discharging the combustion gases to the atmosphere. Some of the dust is recycled into the kiln with the meal but due to its alkaline nature, and build-up of salts, a significant portion of it must be wasted, usually placed in a landfill.

There are three basic types of kilns with several possible variations within each type: wet, dry and semi-dry. A typical wet process is shown in Figure One to highlight the various components of the cement making process, and the different process phases.

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CURRENT US SITUATION

With the relatively rapid emergence of cement kilns as the primary hazardous waste disposal method in the United States, owners of conventional hazardous waste incinerators and other hazardous waste disposal facilities are lobbying very strongly for increased regulation of cement kilns. In their defense, the cement kiln owners have organized and formed their own organization to promote their technology.

Cement kiln dust (CKD) was exempted from USEPA, RCRA Subtitle C regulations in 1980, and waste fuel blending and use are approved under the Boiler and Industrial Furnaces (BIF's) portion of federal regulations. Due to the extensive debate between owners of cement kilns and traditional hazardous waste incinerators, the current regulatory status of hazardous waste burning in cement kilns is under review by USEPA.

The outside observer, such as regulatory agencies and public officials in Hungary are advised that this rigorous US debate is resulting in many technical, political and financial claims from both sides which must be evaluated on their own merits before applying them to situations outside the United States.

HAZARDOUS WASTE FEEDING

Since the destruction of hazardous waste is based primarily on furnace temperature and resonance time, the method of feeding waste into the cement making process is an important issue.

Liquid hazardous wastes and some light sludges are blended with the primary fuel source or injected through separate nozzles directly into the "hot" end of the kiln and travel the full distance of the kiln. Fuel blending is usually limited to 50% waste in the blended fuel. The high temperature of the burning and calcining zones and long resonance time virtually assures complete destruction of the liquid waste. Since there is little, if any additional cost to the cement kiln, the cement kiln is a very cost efficient liquid waste disposal method.

The methods of feeding solid wastes and heavier sludges into the furnace are more of a concern. In the past, solid wastes were fed into the cold end of the kiln with the "meal". Temperatures at the cold end of the kiln can be as low as 300 to 500° F. Initial gases, driven off by the start of combustion, travel out of the cold end of the kiln and into the air pollution control devices (APCD's) without encountering the high temperatures and resonance times found in the calcining and burning zones. Products of incomplete combustion (PIC's) can be formed and not destructed and may pass through the APCD's and into the atmosphere. Although this practice has been discontinued in the United States, it may still be practiced in developing or eastern European countries.

Injecting the solid waste into the final burning zone also causes problems. The chemical reactions in the burning zone, required to form the clinker, must maintain an oxidizing chemical environment. Large quantities of solid waste, placed in the burning zone may produce reducing

conditions which will hamper clinker formation. Most US cement kilns now inject solid wastes into the calcining zone where temperatures exceed 1,800° F. This usually requires special handling devices and several different methods are available.

HEAVY METALS

The fate of heavy metals is a general concern of all hazardous waste disposal methods. Heavy metals are present in many hazardous wastes and are released or volatized during combustion. They are also present in significant quantities in the cement raw materials, and cement kilns which do not burn hazardous waste can produce heavy metals emissions. Coal contains significant amounts of As, Ba, Hg, and Se. Other heavy metals such as Pb, Zn, Cr, Sb and Cd are more likely to originate from the waste components of the fuel.

Once volitized in the high temperature combustion, most heavy metals will subsequently condense at lower temperatures, typically experienced in the early calcining and drying/preheating zones. During heavy metal condensation they have a strong affinity for particulate matter (PM), and will condense onto suspended CKD which is abundant in the gaseous portion of the kiln. An efficient APCD which removes PM and will also remove the heavy metals attached to the CKD.

The exception to the above is mercury which has a much lower condensation temperature and will stay in the volatile state at most operating temperatures found in the cement making process. Temperature in the 130° F are required to condense and remove mercury from the combustion gases. Since most cement kilns operated at higher temperatures, even in the APCD's, mercury will pass through the process into the atmosphere. For this reason, mercury containing wastes should not be burned in cement kilns or any other combustion process.

Extensive testing performed by the Portland Cement Association has shown that heavy metals in the clinker are minimal and not considered an environmental problem in any products made from the cement. As stated above, most of the metals exchange takes place in the gaseous zone of the kiln and not in the solid material which produces the clinker.

ACID GASES

In addition to the acid gases formed during the combustion of sulphur containing fuels, certain waste fuels will also produce acid gases. In particular, chlorinated solvents, pesticides and PVC plastics will produce significant amounts of hydrogen chloride when completely combusted. Due to the alkaline nature of the raw materials and the amount CKD in the kiln gases, the acid gases are neutralized by the CKD, forming alkaline salts, which are removed by the APCD's. Acid gases are not a significant issue in hazardous waste burning kilns.

DIOXIN/FURANS

Dioxins and furans are a large family of complex organic chemicals and can form in many combustion processes as PIC's. Since they are considered highly toxic, even in very low concentrations, they are a potential cause for concern in any waste combustion process, especially where significant amounts of chlorinated compounds are present. Although dioxin/furans can be present in the waste derived fuel, they can also be formed in the later stages of the combustion process from PIC's in the combustion gases. Like heavy metals, dioxins and furans have a very strong affinity for particulate matter and will condense onto submicon particles after formation.

Since dioxin/furan formation has been shown to be temperature related, the key to controlling dioxin/furan stack emissions is to lower temperatures prior to the APCD, ensuring that if dioxin/furans are formed, the formation will be on the dirty side of the APCD where they will be absorbed onto the PM and removed in the APCD. Failure to reduce temperatures before the APCD, could result in dioxin/furan formation on the clean side of the APCD where they can be discharged to the atmosphere. USEPA documentation suggests that a temperature of 300° F or less should be maintained entering to the APCD as a control mechanism for dioxin furan emissions.

EMISSION LIMITS AND OTHER REGULATORY ISSUES

The current US debate is centering around several main issues, PM emission limits, dioxin/furan emission limits and disposal of CKD. The PM limit is the major emphasis since good PM control will also control heavy metals and dioxin/furan emissions. USEPA is currently evaluating data and will propose revised regulations in the near future. Existing data indicates that the limit will be in the 0.01 to 0.03 grains per dry standard cubic foot (gr/dscf) corrected to 7% oxygen. These are the levels currently being achieved by existing best controlled sources.

The dioxin levels achieved by the best controlled sources are between 0.12 and 0.17. nanograms per dscf @ 7% oxygen. Temperature limits are also being considered.

Owners of conventional hazardous waste incinerators are also calling for special landfill conditions for landfilling of the CKD. Due to the high PH of the CKD the heavy metals and organics are not likely to become mobilized and will remain chemically and physically bound to the PM in the CKD and will not leach out under normal conditions. A few special operating procedures should be implemented to insure that the CKD does not become airborne.

In March 1992, the European Economic Community (EEC) issued a directive to all its members to implement new laws, regulations and administrative procedures to regulate the incineration of hazardous wastes. This EEC directive includes recommendations of 5 mg/m^3 for total dust emissions and a dixin/furan limit of 0.1 nanograms per cubic meter @ 11% oxygen. These limits have also been adopted by Germany and the Netherlands.

PROPOSED PROCEDURES & RECOMMENDATIONS

1. Prior to proposing national regulations in Hungary, an inventory of cement kilns should be performed, recording the following:

- o Process configuration
- o Throughput production
- o Primary fuels
- o Do they burn waste materials, what kinds
- o Methods of injecting waste fuels
- o Air pollution control devices
- o Disposal method for CKD

2. All cement kilns should be required to record all waste materials burned, by type and volume, including hazardous as well as none hazardous waste. A maximum of 50% waste derived fuel should be adopted. Submit a monthly or quarterly report to the local regulatory agency.

3. Feeding of any waste or waste derived fuel into the cold end of the kiln should be prohibited. As a general rule, solid waste or sludges should only be fed where temperatures will exceed 1,800° F for 2 seconds.

4. Wastes containing mercury should be prohibited from any disposal method which includes combustion.

5. Clinker and CKD should be tested at least twice per year for heavy metals and dioxin/furans.

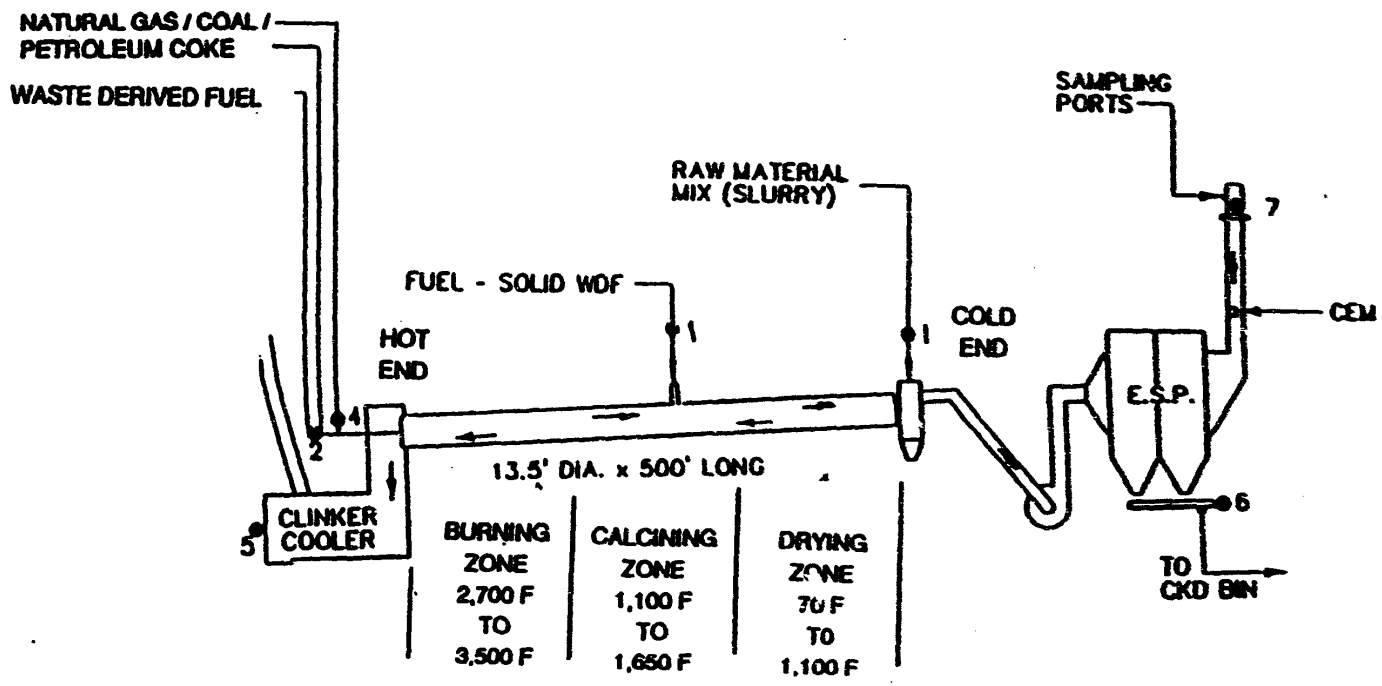
6. Require temperature recording devices at key points in the process.

7. Consider a temperature limitation of 300° F or less entering the APCD.

8. Consider adopting the EEC standards for PM and Dioxin Furans.

REFERENCES

This report was prepared from information contained in several reference documents and article/notices found in trade periodicals and the Environment Reporter. By far, the most comprehensive document is the Draft Combustion Emissions Technical Resources Document (CETRED) issued by the USEPA in May 1994. It includes most of the issues discussed above in much greater detail and should be obtained by anyone interested in this subject. Copies can be obtained through USEPA in Washington D.C. Several reports were also obtained through the Cement Kiln Recycling Coalition and the American Portland Cement Alliance.



NOTE: TEMPERATURES REPRESENT SOLID RAW MATERIALS. GASEOUS TEMPERATURES WILL BE SIGNIFICANTLY HIGHER.