"MUNICIPAL SOLID WASTE MANAGEMENT OF SOLAN CITY USING ENGINEERED LANDFILL"

A Thesis

Submitted in partial fulfillment of the requirements for the award of the degree

of

MASTER OF TECHNOLOGY

IN

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Under the supervision of

Mr. Saurabh Rawat

By

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to

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WAKNAGHAT, SOLAN – 173234
HIMACHAL PRADESH, INDIA

June, 2016

CERTIFICATE

This is to certify that the work which is being presented in the project title **"Municipal solid waste management of Solan city using engineered landfill"** in partial fulfillment of the requirements for the award of the degree of Master of Technology in Environmental Engineering and submitted in Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by **Neeraj Kumar** during a period from July 2015 to June 2016 under the supervision of **Mr. Saurabh Rawat** Assistant Professor, Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of my knowledge.

Date: -

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the dissertation entitled **"Municipal solid waste management of Solan city using engineered landfill"** in partial fulfillment of the requirements for the award of the degree of Master of Technology and submitted in Civil Engineering Department, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by **Neeraj Kumar** during a period from July 2015 to June 2016 under the supervision of **Mr. Saurabh Rawat** Assistant Professor, Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

I have not submitted the matter embodied in this dissertation for the award of any other degree.

Date: **Neeraj Kumar**

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Neeraj Kumar

142756

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γ_b	Bulk density
γ_d	Dry density
e	Void ratio
ρ_w	Water density

ABSTRACT

Municipal solid waste management of Solan city using engineered landfill in place of non-engineered landfill. In this study we estimate the landfill capacity, landfill height, landfill area and infrastructure area. Provide liner system, cover system, leachate collection system, gas collection system, surface water drainage system, environmental monitoring system and in situ testing was carried out to study the properties of the landfill soil. By using visual HELP tool we check the hydrological landfill performance. Using an engineered landfill increase the capacity of the waste collection in the non-engineered landfill being currently used in the area. The current capacity of the landfill is 6070 m^2 and engineered landfill capacity is 10319 m^2.This shows that the capacity of the landfill is increased by 58.82%, if engineered landfill is used for the MSW management. The height of the engineered landfill is 18m. The specific gravity of the soil is 2.6 with in limit (2.6 to 2.8) as per as IS code 2720-1980. The permeability of the soil is 1.21×10^{-4} cm/sec. This signifies that the soil is mainly silty sand.

Keywords: *Engineered landfill, liner system, cover system, surface water drainage system, environmental monitoring, visual HELP.*

CHAPTER 1

INTRODUCTION

1.1 General

There are many problems associated with landfills occurred as a result of non-engineered facilities and poor management. It is imperative that issues outlined in this manual and the other landfill manuals are considered in full in the design and the development of the landfill. There are many potential environmental problems associated with the land filling of waste. These problems are often long-term and include possible contamination of the groundwater and surface water regimes, the uncontrolled migration of landfill gas and the generation of odour, noise and visual nuisances.

The primary objective of landfill site design is to provide effective control measures to reduce as far as possible negative effects on the environment, in particular the pollution of surface water, groundwater, soil and air, as well as the resulting risks to human health arising from land filling of waste. The design concept for a landfill depends on the ground conditions, the geology and hydrogeology of the site, the potential environmental impacts and the location of the landfill. The investigations for a landfill should provide sufficient information to enable the formulation of a site specific design. Landfill practice is dynamic in that it will change with both advances in technology and changes in legislation. To incorporate such advances and changes a periodic review of the design should be carried out, as the life span of a landfill site from commencement to completion is long compared to other construction projects.

1.2 Design Life

A landfill design life will comprise of an ‘active’ period and an ‘closure and post-closure’ period. The ‘active’ period may typically range from 10 to 25 years depending on the availability of land area. The ‘closure and post-closure’ period for which a landfill will be monitored and maintained will be 25 years after the ‘active period’ is completed.

1.3 Landfill Layout

A landfill site will comprise of the area in which the waste will be filled as well as additional area for support facilities. Within the area to be filled, work may proceed in phases with only a part of the area under active operation. The following facilities must be located in the layout access roads, equipment shelters, weighing scales, office space, location of waste inspection and transfer station, temporary waste storage or disposal sites for special wastes, areas to be used for waste processing. (eg. shredding), drainage facilities, location of landfill gas management facilities, location of monitoring wells.

1.4 Landfill Section

Landfills may have different types of sections depending on the topography of the area. The landfills may take the following forms above ground landfills, below ground landfill, slope landfills, valley landfills. The area landfill is used when the terrain is unsuitable for the excavation of trenches in which to place the solid waste. In hilly regions it is usually not possible to find flat ground for land filling. Slope landfills and valley landfills have to be adopted. In a slope landfill waste is placed along the sides of existing hill slope. Control of inflowing water from hillside slopes is a critical factor in design of such landfills.

1.5 Liner System

Liner systems comprise of a combination of leachate drainage and collection layers and barrier layers. A competent liner system should have low permeability, should be robust and durable and should be resistant to chemical attack, puncture and rupture. A liner system may comprise of a combination of barrier materials such as natural clays, amended soils and flexible geomembranes. A liner is an engineered system to contain and control the pollution of the land and water environments surrounding the land disposal operation. The design of a bottom liner, in the case of economically developing countries, will vary depending on a number of factors, including: the potential of the landfill polluting the land and water environments, the local hydrogeology and meteorology, and the availability of suitable materials and monetary resources.

1.6 Landfill Gas Management

The gas management strategies should follow one of the following three plans. Controlled collection and treatment/use will be adopted only after the feasibility of such a system is established and proven by an agency having experience in this area. Gases generated in the fill can either be allowed to disperse and migrate beyond the confines of the fill without any effort being made to control them, or they can be collected. Collected gases may be put to some use, may be flared, or may simply be vented into the environment. Venting into the environment provides undesirable contributions to global warming. However, the collection and use of landfill gas entails significant capital and operating costs that must be compared to alternative sources of energy. Accumulated gases and uncontrolled dispersal and migration can lead to the development of undesirable or hazardous conditions due to flammability, asphyxiating properties, and trace organic composition of the gases. The slightly positive pressure usually existing within a landfill permits gases to flow uncontrolled from the fill to areas of lower gas pressure by convective gas transport.

1.7 Final Cover System

A landfill cover is usually composed of several layers, each with a specific function. The final cover system must enhance surface drainage, minimise infiltration, vegetation and control the release the landfill gases. The landfill cover system to be adopted will depend on the gas management plan controlled passive venting, uncontrolled release, controlled collection and reuse.

1.8 Surface Water Drainage System

Surface water management is required to ensure that rainwater run-off does not drain into the waste from surrounding areas and that there is no water logging on covers of landfills. Rainwater running off slopes above and outside the landfill area should be intercepted and channeled to water courses without entering the operational area of the site. This diversion channel may require a low permeability lining to prevent leakage into the landfill. Rain falling on active tipping areas should be collected separately and managed as leachate, via the leachate collection drain and leachate collection sumps to the leachate treatment and disposal system.

1.9 Environmental Monitoring Systems

Ground water monitoring wells, air quality monitoring systems and vadose zone monitoring instruments are periodically inspected to check that all systems are functioning satisfactorily and that well caps and sampling ports are not subjected to damage due to excessive settlement or vandalism. Environmental monitoring systems have to be maintained during the entire post-closure period as per the requirements of the local environmental regulatory agencies. Wherever possible, monitoring instruments must be periodically recalibrated. Sampling devices must be routinely detoxified and also regularly checked for proper functioning of the opening and closing of valves or spring loaded mechanisms.

1.10 Visual HELP Model

The HELP model (Hydrologic Evaluation of Landfill Performance), is a versatile program used to design, evaluate and optimize landfill hydrology and groundwater recharge rates. The HELP model is used and recognized all over the world as the accepted standard for modeling landfill hydrology, and has become an integral component for projects involving landfill operating and closure permits. The HELP model is a quasi-two-dimensional, multi-layer hydrologic model requiring the following input data for each model profile weather data (precipitation, temperature, evapotranspiration parameters) and soil properties.

The landfill profile structure can consist of a combination of natural (soil) and artificial materials with options to install horizontal drainage layers. The HELP model also accounts for the change in slope for different parts of the landfill profile. HELP uses numerical solution techniques that account for the effects of surface storage, snowmelt, runoff, infiltration, evapotranspiration, vegetative growth, soil moisture storage, lateral subsurface drainage, leachate recirculation, unsaturated vertical drainage, and leakage through soil, geomembranes, or composite liners. Visual HELP for Windows 2000/XP is the most advanced hydrological modeling environment available for designing landfills, predicting leachate mounding. Visual HELP combines the latest version of the HELP model (v.3.07) with an easy to use interface and powerful graphical features for designing the model and evaluating the modeling results. Visual HELP's user-friendly interface and flexible data handling procedures provide you with convenient access to both the basic and advanced features of the HELP model. This completely-integrated modeling environment allows the user to graphically create several profiles representing different parts of a landfill. Automatically generate statistically reliable weather data. Visualize full-color, high-resolution results. Prepare graphical and document materials for your report. An International Weather Generator for synthetic generation of up to 100 years of daily values of precipitation, air temperature and solar radiation. For professional applications in landfill design, Visual HELP is the only software package you will ever need! After running through this demonstration tutorial, we trust you will agree that Visual HELP is now the most complete and easy-to-use modeling tool for designing & optimizing landfill hydrology.

Ref. Sharholy, M. & Trivedi, R.C. (2007). “Municipal solid waste management”.

CHAPTER 2

LITERATURE REVIEW

2.1 General

A number of research papers are available on the topic of municipal solid waste management and landfill. Some of the most important research papers in the context of landfill have been reviewed here in the present study.

M.Alekhya and N.Divya research that A landfill is a facility which is designed for the safe disposal of solid wastes. The bottom liners and a top Cover, of the landfill are considered as the most critical components. Penetration of leachate in to the soil is the major problem in landfills. For existing landfills the main factor affecting the quality of liners/covers is its permeability. Alternative materials which can be used as liners are compacted ball clay, vitrified ceramic tiles, limestone slabs which have permeability relatively less compared to compacted clay. The compacted ball clay in the form of tiles (green) had undergone heavy compaction which in turn reduces permeability and the thickness of the liners/covers. By reducing the thickness of liners more amount of municipal solid waste can be accommodated. Usage of alternative materials will reduce the overall thickness of liner system by about 40-50 cm. Solid waste may be defined as generation of undesirable substances which is left after they are used once. They cannot be reused directly by the society for its welfare because some of them may be hazardous for human health. At present, the annual generation is approximately 1.6×10^9 ton in India .Land filling has been the most common method of solid waste disposal .The central problem in landfill disposal is leachate control and thickness of liners and covers. A surface seal landfill design is recommended for maintaining the dry state of solid hazardous wastes and for controlling leachate. Bottom liner and top cover plays very important role in reducing the leachate quantity.

Sudhakar Yedla research on waste management, being one of the most important aspects of urban development, is gaining importance among developing nations. Landfills, which were initiated for hazardous waste management and subsequently transformed into sanitary landfills, have been the most widely adapted practice for municipal solid waste management worldwide. However, the conventional design of landfills not only fails to fulfill the needs of waste management but also fails to target optimal resource recovery and energy generation. In the present study, modified design was proposed for partially engineered landfill system based on theoretical considerations. Its potential for energy generation and resource utilisation was analysed with a case study of Mumbai municipal solid waste. It was found that the system with modified design could yield 0.157 million tons of landfill gas (0.145 million tons of coal equivalent) out of one year of solid waste. Rapid population growth and urbanization results in increasing environmental concerns and municipal solid waste (MSW) management is of prime importance in such rising urban issues. The state of economy, to a large extent influences waste generation and MSW in particular. Unlike other solid wastes, namely industrial solid waste, hazardous waste, hospital waste, MSW involves waste generation from various sources. The generation being the non-point/area source, collection and disposal poses a serious problem to the local municipalities and other regulatory bodies.

Joyti Rani study that for a better environment, proper collection of solid waste, its treatment and its final disposal with the minimum possible risk to public health is a necessity. Though many methods are available for refuse disposal but sanitary land filling has its own advantages over other methods. The importance of this method over other methods of disposal lies in the fact that no matter what source reduction/refuse/recycling or incineration option is necessary element of integrated solid waste management. Solid wastes are those waste materials, which arise from human and animal activities and which are not easily carried away with water or air i.e. these are solid or semi– solid in nature. However this term solid waste does not include human excreta but it may have some hazardous material as its subset. Solid waste includes rubbish- the waste that does not decompose rapidly like paper, textile, plastic, cardboard, rubber, leather, wooden items, glass, crockery, tin cans etc. and garbage – the waste which decomposes rapidly being organic in nature. It generally arises from food related activities e.g. Fruit and vegetables peels, meat, bones, leftover etc. The quality of solid waste generated by a nation is highly variable and its function offs its geographic location, season and economic status. In general, developed and rich countries tend to produce more solid waste as compared to developing or poor ones. Similarly, urban household produce more solid waste than rural ones.

Sharifah Ismail and Latifah Abd. Manaf work on land filling is the most frequent waste disposal method worldwide. It is recognised as being an important option both now and in the near future, especially in low- and middle-income countries, since it is the easiest and the cheapest technology available. Owing to financial constraints, landfills usually lack of environmental abatement measures, such as leachate collection systems and lining materials. As a result, a lot of contamination is inflicted upon the environment. Importantly, even with proper abatement measures in landfills, there is no guarantee that contamination will be prevented. Another major concern is the appropriate location for landfills to ensure the impact towards the environment is minimised.This paper highlights the challenge to find suitable place for future landfill in Malaysia. There is a tendency of landfill to be built on unsuitable area such as near to residential area or on agricultural land where most of the land are grading as high prospect value to be developed as business or industrial area that are more profitable.

K.Hadjibiros studies that Municipal solid waste (MSW) collection and disposal is a major problem of urban environment in the world today. MSW management solutions have to be technologically feasible, legally and socially acceptable and environmentally and financially sustainable. European policy is pushing to a rational management of natural resources; a promising technological perspective today is waste valorization, a process that becomes possible through sorting at the source, combined with material recycling and waste-to-energy methods. On the other hand, technologies like mechanical sorting, or disposal of MSW in landfills do not really improve MSW management efficiency. Landfills should become the ultimate disposal site of a few inert residuals from MSW valorization. Despite all this, conventional landfills for disposal of mixed MSW are still being constructed, with landfill site selection being a major social problem due to the lack of public acceptance; objectivity in landfill site selection is therefore extremely important. In Greece, we find several examples of inefficient MSW management and curious landfill site selection. In this paper, we criticize environmental policy issues for MSW management in Greece and identify weak points in the criteria used for the selection of landfill sites. We conclude that there is a real need for rational MSW management based on high quality scientific input. Municipal solid waste (MSW) collection and disposal is a major problem of urban environment in the world today. Lack of appropriate MSW management leads to significant soil, water, air and aesthetic pollution, associated human health problems, as well as an increase in greenhouse gas emissions. In advanced, environmentally-conscious societies, MSW management is dealt with as an integrated issue, leading to MSW management solutions that are technologically feasible, legally and socially acceptable and environmentally and financially sustainable.

Km Alim Al Razi, study that leachate is the aqueous effluent generated as a consequence of rainwater percolation through wastes and the inherent water content of wastes themselves. Its quality is the result of biological, chemical and physical processes in landfills combined with the specific waste composition and the landfill water regime. In Khulna city, municipal solid waste is dumped in the Rajbandh landfill site where large amount of leachate is produced every day. This leachate is pretreated by anaerobic process in a pond and pumped out to the surface water from three wells. This pretreated leachate has great impact on surrounding surface water and environment. The aims of this study are to asses and evaluate the environmental impact of the pretreated leachate. In order to do this, some parameters including pH, BOD, COD, Iron content, Alkalinity, TC etc. of the collected leachate and surface water are determined. Obtained values of the parameters are compared with the standard value. Amount of greenhouse gas emission and their effects on human health are also determined and reviewed. Therefore, this paper provides insight regarding how the leachate puts impact to the environment.

H. Abu Qdais the purpose of this paper is to estimate the amount of methane emitted from Al Akeeder landfill which is the second largest landfill in Jordan. To achieve that Gas-Sim model was used in predicting the amount of methane emissions. It was found that the methane emission will reach its peak value of 12 Million m^3/year by the year 2021, one year after the landfill closure. Furthermore, the power that can be obtained from the landfill in case methane recovery was estimated to be 5.6 MW in 2021. Utilizing the biogas will not only generate a green energy, but also will create a source of revenue through selling the CERs regulated by Clean Development Mechanism of Kyoto protocol. Landfills are remaining and will remain a common method for landfill disposal . Unless properly managed, landfills will pose serious environmental and health risks. Several gases are generated by decomposition process of organic materials in a solid waste landfill. The composition, quantity, and generation rates of the gases depend on several factors such as refuse quantity, density and composition, placement characteristics, landfill depth, refuse moisture content, temperature and amount of oxygen present.

Unsecure landfill areas are contributors of soil, air and water pollution around the site. Beside that greenhouse gases (GHG) emission from landfill areas is concern to the global warming. In the present study the methane and nitrous oxide were analysed in Ghazipur landfill area of Delhi. The Ghazipur landfill area is one of the biggest and oldest landfill areas of Delhi. The municipal solid waste is indiscriminately disposed here since last 30 years and the landfill area has become mountain of waste. Landfill mining is process of recovering valuable recyclable materials, which have previously been land filled. This landfill area is being converted into waste to energy plant, where garbage will be mined to convert into refuse derive fuel (RDF) to be used for energy generation and the ten acre of landfill area is given to Gas Authority of India (GAI) for mining methane and other gases to be used as fuel.

Landfill is considered as one of the most popular method of disposal of Municipal solid waste (MSW) in India. The typical composition of MSW in India is around 40-60% of organic waste, 30-40% of earthen materials, paper, metals, plastics, leather etc. Every city in India has one or two MSW disposal landfills. Most of these landfills in metro cities are operational since more than 10 years or more. The municipal solid waste dispose in most of the landfills is done without segregation so it contains large amount of valuable materials in it. As, the MSW in India has around 40-60% of biodegradable waste under anaerobic condition it generates methane, which has almost 21 times more global warming potential (GHP) than CO_2 equivalent. With the nitrification and denitrification process results in formation of N_2O, this has global warming potential as 310 times higher than CO2 equivalent. In landfills the organic components in the municipal refuse results in GHG emission (3%) under aerobic and anaerobic condition. The average composition of landfill gases is 45-60% methane and 40-60% carbon dioxide, 2-5% Nitrogen gas, < 1% hydrogen sulphide and non-methane organic compounds (NMOCs) and there composition.

D.R Manandhar research aims to estimate water balance for landfill on quantitative basis using a pilot scale Landfill Lysimeter Model in Nepal. The main objective of this research is to have estimation of water balance on quantitative basis for designing and operating landfills in developing countries with different climatic conditions. The research focuses particularly on the leachate production in a landfill. The use of computer software like Hydrological Evaluation of Landfill Performance, HELP model will be tested in Nepalese context. The outcome of the research work will be beneficial in addressing waste management issues especially landfill design and operational aspects in Nepalese context. Water management is governed by water input and output from landfill. Consideration and general conclusions shall be drawn from a research work using pilot scale lysimeter in Nepal, which serves as a case study for better understanding. The Hydrologic Evaluation of Landfill Performance (HELP) model is used to compute estimates of water balances. Simulation of the model indicates that the evapotranspiration (ET) is nearly constant and do not follow the precipitation and percolation trend. Also the evapotranspiration component in this case, is not high. This may be due to the small surface area of lysimeter and larger portion of the leachate percolated before evaporation could take place. The model has been calibrated for the local situation with the limited observed data of leachate generation from the lysimeter. However the trend of leachate generation on HELP simulation and Actual Data seem to be similar during month of October to December season, but during June to September, the trend shows higher actual percolation rate compared to the model output. This may be due to the higher value of permeability of barrier soil (in the range of 10-5 cm/s), which should be generally in the range of 10-7 cm/s or lower. The rainy season during June to September may be another reason, when soil is wet most of the time. The annual data shows that percolation is about 81-84% of precipitation amount, whereas evapotranspiration is about 15-19%. The application of the model may be a valuable tool to determine.

2.2 Observation from literature review

The following observation is drawn from the literature review collect the data of the municipal solid waste management. To know the sources of waste are domestic waste, commercial and office, hazardous waste, debris etc. Field study including review of existing conditions, assessing the quantity and quality of waste, their composition and status of waste processing and disposal. For landfill design we know the properties of soil of the landfill site. To study the design of landfill and components of the landfill for the engineered landfill. The bottom liners and a top cover of the landfill are considered as the most critical components. Penetration of leachate in to the soil is the major problem in landfills. For landfills the main factor affecting the quality of liners or covers is its permeability. A surface water drainage system which collects and removes all surface runoff from the landfill site. An environmental monitoring system which periodically collects and analyses air, surface water, soil-gas and ground water samples around the landfill site.

2.3 Objective of the present work

Based on the critical observation the following objectives were determined.

a. Designing and analysis of an engineered landfill for MSW of Solan city.
b. Analysis and hydrological performance of the engineered landfill by using software tool Visual HELP.

2.4 Scope of the work

1. The scope of the present work can be determination of the end-use of engineered landfill site Solan. This is an important part of the plan for landfill closure and post closure maintenance.

2. The study of emission of gases has not been covered in the project. Hence it can be an important to analyze in the counted of the future of landfill and its environmental impact.
3. Study of the slope stability of the engineered landfill has also not been incorporated in the present work. Slope stability analysis can be carried out to predict the durability of the landfill and stability of liner and cover system.

CHAPTER 3

MATERIALS AND METHODOLOGY

3.1 General

In this chapter we discuss the study area of the landfill, meteorological data of Solan city, municipal solid waste of the Solan city, site visit of the landfill, field survey, methodology of the waste characterization, geotechnical investment, in situ testing of the landfill site, design step of engineered landfill, weather data, plan of the landfill using AutoCAD.

3.2 Study Area

Solan is the district headquarters of Solan district created on 1 September 1972. At an average elevation of 1,600 meters. Solid waste management plant Salogra, Solan was set up in 1998.The waste collected from Solan city, Rajgarh, Arki, Kandaghat, Dharampur, Badog, Salogra as shown in the fig. 3.1.Salogra plant till date being maintained by a non-government organization (NGO) known by the name of "Jan Seva Ashram" which has its head office in New Delhi. The aerial map of the Solan as shown in the fig. 3.2.

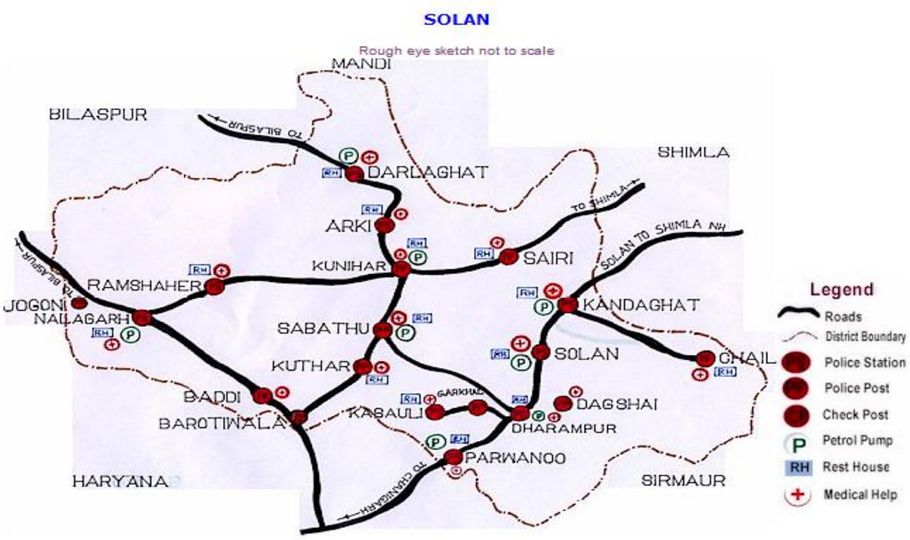


Figure 3.1 Map of Solan

Ref: Commissioner, D. “Official website of Solan.” Map, <http://hpsolan.nic.in> (2016).

Figure 3.2 Aerial map of Solan

Ref: Commissioner, D. “Official website of Solan.” Map, <http://hpsolan.nic.in> (2016).

3.3 Meteorological data of Solan City

The maximum precipitation and average temperature of Solan city as shown below:

Table 3.1 Meteorological data of Solan

Month	Precipitation(mm)	Temperature('C)
January	55.3	12.8
February	14.4	14.8
March	31	19.4
April	10.6	26.7
May	5.2	31.1
June	31.5	33
July	66.6	30.5
Aug	21.9	28.8
September	62.5	28.5
October	6.9	24.9
November	2.7	19
December	3.2	14.1

Ref. Meteorological department Shimla

Average wind speed	9.36 km/h
First quarter relative humidity	83%
Second quarter relative humidity	15%
Third quarter relative humidity	50%
Fourth quarter relative humidity	90%
Latitude	30°51'11.9"
Longitude	77°10' 14.8"

3.4 Municipal solid waste of Solan city

The municipal solid waste of Solan contains waste from different sources. The sources of waste are domestic waste, commercial and office, hazardous waste, debris etc. Domestic waste contains waste from kitchen refuses which contain organic matters, ashes from fires, packing materials paper polythene etc. Commercial and offices waste contain matters papers, wood, rags etc.

Table3.1 Data of municipal solid waste Solan

Sources	Type of waste	Total no of units	Total waste
Domestic	Kitchen refuse which contain organic matters, ashes from fires, packing materials paper polythene etc.	9632 Household	17 tons per day
Commercial &offices	Matters papers ,wood, ashes from fires, rags etc.	13232	5 tons per day
Hazardous (Hospitals, nursing homes)	Hospital waste	11	0.75 ton per day
Debris	Stones, broken bricks, sand, soil etc.	N/A	3 tons per day
Hospital waste	Hazardous waste of hospital	Go to Shimla and collects private clinics a private institution Parvanu collects named SUDDHI	0.75 ton per day
Detail of processing of MSW Solan			
Domestic (HHs)	Bio-degradable	50% W/W	8.50
Produced compost	From organic materials	5-8%	400-600kg/day
Cost of compost	@ Rs. 1.75/kg		Rs. 1700/day
Rejection & inert	For safe landfill	10% W/W	1.70 tons/day
Inert like stone ,soil, Sand & debris	For general landfill	10%W/W	1.70 tons/day
Density of the waste	0.60 ton/m^3	N/A	N/A
Increase in generation of waste per year	0.5 ton/d	N/A	N/A
Area of the plant	12140 m^2	N/A	N/A

Ref. Municipal Corporation Solan

3.5 Site Visit

A visit to solid waste plant Solan was made on September, 2015 and detailed field study was conducted including interaction with the concerned agencies for formulation of this report. Field study including review of existing conditions, assessing the quantity and quality of waste, their composition and status of waste processing and disposal were studied. To initiate the process, visit to the landfill site was conducted as shown in fig. 3.3 and 3.4. The site was assessed in terms of its accessibility and to study the topography.

Figure 3.3 MSW plant Solan

Figure 3.4 Landfill site of Solan

3.6 Field Survey

Waste Characterization

Information on the nature of wastes, its composition, physical and chemical characteristics and the quantities generated are basic requirements for devising solid waste management plans. Quantity and characteristics of solid waste generated varies with income, socioeconomic conditions, social developments and cultural practices. Thus, information on the nature of wastes, its composition, physical and chemical characteristics and quantities generated are basic needs for the planning of a solid waste management and disposal system of project area. Detailed Survey of municipal area was carried out in 1st week of August to define the sampling points, waste was collected from: Residential, Commercial, Slums, Hotel, and Dumping site.

3.7 Methodology of Waste Characterization

The methodology adopted for sample collection to assess the physical and chemical composition of the waste is as described. Studying the area map of the Solan and location of the garbage bins. Analysis of present condition at the dumpsite at municipal solid waste management plant Salogra.

3.8 Geotechnical Investigation

The geotechnical investigation was carried out for designing landfill. For which laboratory tests was conducted on representative samples to determine permeability, bulk density, dry density, specific gravity, moisture content and void ratio of the landfill soil. Approach road to landfill will be designed as per the IRC Codes. Geological investigation of soil and subsoil conditions, analysis of physical, chemical and geotechnical properties of the subsoil.

3.9 In situ testing of landfill site

In order to study the in situ density of the landfill soil core cutter test was performed at the test site as shown in the figure 3.5. The method for core cutter test was adopted from IS: 2720-1975.

Figure 3.5 In situ core cutter at site

Procedure

The core cutter was extracted from the surface of the landfill site at Solan. Three core cutter samples were taken. The cutter shall then be dug out of the surrounding soil care being taken to allow some soil to project from the lower end of the cutter. The ends of the soil core shall then be trimmed flat to the ends of the cutter by means of the straight edge. Special care was taken while transporting the samples to the JUIT lab.

The bulk density that is, the weight of the wet soil per cubic centimeter shall be calculated from the following formula:

$$\gamma_b = \frac{W_s - W_c}{V_c} \text{ in g/cm}^3$$

W_c = Weight of core-cutter in g

W_s = Weight of core-cutter + Wet soil in g

V_c = Volume of core-cutter in cm^3

The dry density canbe calculated from the following formula:

$$\gamma_d = \frac{100\gamma_b}{100 + w} \text{ in g/cm}^3$$

γ_b = bulk density

w = water content of the soil

Water content in percent (w) = $\frac{(W_2 - W_3)}{(W_3 - W_1)} \times 100\%$

W_1 = Weight of container in g

W_2 = Weight of container + Wet soil in g

W_3 = Weight of container + Dry soil in g

Table 3.3 Observation table of in situ testing of landfill site

S.NO.	DETERMINATION NO.	1	2	3
1	Weight of core-cutter + Wet soil (W_s) in g	2870	2700	2520
2	Weight of core-cutter (W_c) in g	920	920	870
3	Weight of wet soil (W_s-Wc) in g	1950	1780	1650
4	Volume of core-cutter (V_c) in cm^3	1020.5	1020.5	1020.5
5	Bulk Density = (W_s-W_c)/V_c in g/cm^3	2	2	2
6	**WATER CONTENT CONTAINER NO.**	**1**	**2**	**3**
7	Weight of container (W_1) in g	19.3	19.3	20.6
8	Weight of container + Wet soil (W_2) in g	209.8	200	163.5
9	Weight of container + Dry soil (W_3) in g	192.8	173.9	136.2
10	Water content in percent w = (W_2-W_3)/(W_3-W_1) ×100	10	16.88	23
11	Dry Density = (100 γ_b)/(100+w) in g/cm^3	1.99	1.99	1.99

From the core cutter the bulk density of landfill soil is $2 g/cm^3$ and dry density is $1.99 g/cm^3$

3.10 Specific gravity test

In order to study the specific gravity of the landfill soil pycnometer test performed at the lab as shown in fig. 3.6 and 3.7. The method for specific gravity test was adopted from IS: 2720-1980.

Procedure

Collect the sample of landfill soil. Three sample of landfill soil were taken. Clean and dry the pycnometer. Tightly screw its cap. Mark the cap and pycnometer with a vertical line parallel to the axis of the pycnometer to ensure that the cap is screwed to the same mark each time.

$$\text{Specific Gravity}\,(G_s) = \frac{W_2 - W_1}{(W_2 - W_1) - (W_3 - W_4)}$$

W_1 = Mass of empty pycnometer in g

W_2 = Mass of pycnometer + Soil in g

W_3 = Mass of pycnometer + Soil + Water in g

W_4 = Mass of pycnometer + Water in g

Figure 3.6 Empty pycnometer   **Figure 3.7 Pycnometer filled with sample**

Table 3.4 Observation table of Specific gravity test

SPECIMEN NO	1	2	3
Mass of empty pycnometer in g (W_1)	463.8	463.8	463.3
Mass of pycnometer + Soil in g (W_2)	529.3	525.3	529.1
Mass of pycnometer + Soil + Water in g (W_3)	1227.4	1221.7	1227.2
Mass of pycnometer + Water in g (W_4)	1186.7	1182.2	1186.4
Specific Gravity (Gs) = (W_2-W_1)/((W_2-W_1)-(W_3-W_4))	2.64	2.7	2.6

The average value of the specific gravity is 2.6.

3.11 Permeability Test

The permeability of the landfill area was determined by variable head permeameter.The coefficient of permeability is given by

$$k = \frac{2.30aL}{At}\log_{10}\left(\frac{h_1}{h_2}\right)$$

Where h_1 = initial head, h_2 = final head, t = time interval, a = cross-sectional area of the liquid stand pipe, A = cross-sectional area of the specimen, L = length of specimen.

Procedure

Three sample of the landfill soil can be taken. Connect the stand pipe of suitable diameter to the inlet at the top. Fill the stand pipe with water. Remove the upper section of the chamber tie rods and place the upper porous stone on the specimen. Open the stop cock at the top and allow the water to flow out till all the air in the mould is removed. Open the valve and start the stop watch. Record the time interval for the head to fall from h_1 to $\sqrt{h_1h_2}$ and also from $\sqrt{h_1h_2}$ to h_2.

Figure 3.8 Permeability test

The following are the sample properties used in the determination of permeability of soil sample from the landfill site.

Length of specimen (L)	12.7 cm
Diameter of specimen	10 cm
Volume of specimen	996.95 cm^3
Water content	10%
Diameter of stand pipe	2 cm
Area of stand pipe (a)	3.14 cm^2

Table 3.5 Observation table of Permeability test

S No	Observation and Calculation	1	2	3
1	Mass of empty mould with base plate (kg)	9.24	9.24	9.24
2	Mass of mould, soil and base plate (kg)	11.02	11.2	11.1
3	Initial head h_1 (cm)	100	100	100
4	Final head h_2 (cm)	71	69	72
5	Head $\sqrt{h_1 h_2}$ (cm)	84.26	83.06	84.85
6	Time interval t (min)			
	h_1 to $\sqrt{h_1 h_2}$	15	18	16
	$\sqrt{h_1 h_2}$ to h_2	10	9	12
	h_1 to h_2	25	27	28
	Calculations			
7	Mass of soil = (2)-(1) (k)	1.8	1.9	1.9
8	Bulk Density γ_b = (Mass of soil)/(Volume of specimen) (g/cm^3)	1.8	1.9	1.9
9	Dry Density $\gamma_d = (\gamma_b/1+w)$ (g/cm^3)	1.6	1.7	1.7
10	Void Ratio $e = (\rho_w G)/\gamma_d - 1$	0.625	0.588	0.529
11	$k = 2.3aL/At \log_{10}(h1/h2)$ cm/sec	1.21×10^{-4}	1.33×10^{-4}	1.18×10^{-4}

3.12 Design for engineered landfill

The design of a secure landfill largely depends upon the hydro geological characteristics of the site. The Division of filling area in filling sections each with a life time of 10 years. Calculation of the landfill volume taking into consideration the possible slopes. Planning of access roads for the respective filling sections. Design the landfill capacity, landfill height, landfill phases, landfill infrastructure and layout, liner system, cover system. Design of leachate collection system (leachate collection pipes, drainage layer etc.) and design of surface drainage system environmental monitoring system.

3.13 Assessment of Waste Volume

Based on the detailed field investigations, it is estimated that Solan generates about 25 tons of solid waste every day and is projected to generate about 30 tons of solid waste every day by the year 2025. The quantum of bio-degradable MSW, to be processed at the bio-conversion facility before Land filling in 2015, has been estimated at approximately 25 T/day. The quantum of non-biodegradable MSW and the inert rejects of the bio-conversion facility for land filling has been estimated at 8.5 tons per day.

Estimation of landfill capacity

Estimate the landfill capacity and height

Current waste generation of MSW Solan using table 3.1 (W_1) = 25 ton/d

Estimated waste generation after 10 years of MSW Solan (W_2) = 25+ 5

= 30 tons/d

Proposed life of landfill MSW Solan (n) = 10 yr

Total waste generation in 10 years MSW Solan (T) = $1/2[W_1+W_2]n$

= 100375 tons

Density of waste of Solan = 0.60 tons/m^3

Total waste volume (V_w) = T/Density of waste

= 167292 m^3

Volume of daily cover (on the basis of 15 cm soil cover on top (V_d) = $0.1V_w$

= 16729 m^3

Volume of liner and cover system (on the assumption of 1.5m thick liner system (including leachate collection layer) and 1.25 m thick cover system (including gas collection layer)

(V_c) = $k.V_w$

k-0.25 = 0.125 - 0.25/20-10 (18-10)

k = 0.15

= 0.15 ×167292

= 25094 m^3

(k = 0.25 for 10 m high landfill, 0.125 for 20 m high landfill and 0.08 for 30 m high landfill. This is valid for landfills where width of landfill is significantly larger than the height)

Volume due biodegradation of waste (V_s) = m.Vw

= 16729 m^3

Using m = 0.05 for biodegradable waste (Ref. EPA guidelines)

Estimate capacity of landfill (C_i) = V_w+V_d+V_c-V_s

= 192386 m^3

Estimate height and area of landfill

Restricted area available of MSW plant Solan (A_r) = 12140 m^2

Area required for infrastructural facilities at site = 0.15×A_r

= 1821 m^2

Area available for land filling the solid waste = 0.85×A_r

= 10319 m^2

Average landfill height required (H_i) = Ci/0.9×A_r

= 18 m

Area required for land filling = C_i/height of landfill

= 10410 m^2

Total area required including infrastructure and landfill area = 1.15 A_i

= 11972 m^2

Landfill phases

Active life of landfill of MSW Solan = 10 yrs.

Duration of one phase of the engineered landfill = 1 yr.

Number of phases in landfill = 10

Volume of one phase in landfill = landfill capacity/10

= 19239 m^3

Plan area of one phase of the landfill = Volume of one phase/landfill height

= 1041 m^2

Number of daily cells = 365

Volume of one cell in the landfill = volume of one phase/365

= 52 m^3

3.14 Landfill Section and Plan

Landfill Section and Plan is evaluated on the basis of (U.S. EPA, 1989) guidelines. General 3:1 side slope for the above ground portion of the landfill for cover system. General 3:1 side slope for the below ground portion of the landfill due to natural slope of hill in landfill. Material balance for daily cover, liner and final cover material through excavation at site. Extra space around the waste filling area for infrastructural facilities.

3.15 Landfill infrastructure & layout

The approx. plan dimension of the engineered landfill Solan is 110×110 m. Steel sheets fencing all around the landfill. Access to the landfill site should be controlled preferably by building a fence around the entire perimeter of the site or, at the very least, around the locations of easy access to equipment and wastes by unauthorized individuals. The area of the administrative office is 300 $m^{2.}$ Weighbridge of 60T capacity is required for the accurate weighing of incoming waste. The area of the site control office is 4×4 m. Access road in the municipal solid waste management plant is 3.5 m wide. The area of equipment workshop & garage is 400 m^2. The leachate holding tank 400 m^2 for storage of leachate.

3.16 Liner System Design and Leachate collection system

1. Leachate evaluation

Average total precipitation in Solan = 1500mm/yr (Ref. Indian Meteorological department Shimla)

Area of one phase of the landfill = 1041 m^2

Assuming 80% precipitation in 4 months (monsoon period) = 1200 mm/d

Peak leachate Quantity (c) = 1.2*1041/120 = 10.41 m^3/d

2. Leachate collection pipe

The piped bottom collection system design includes the placement of clay barriers and perforated leachate collection pipes at the bottom of the site. Typically, the barriers have a defined form and a width similar to that of the solid waste cell. A geomembrane is placed on top of the clay surface. After the barriers have been installed, slotted pipes are placed on top of the geomembrane.

Material of HDPE pipe = 0.95 g/cc

Leachate flow to determine pipe size Q_{req} = c × area of the phase

= 10.41× 1041

= 30 m/yr

Size of pipe (Trial error method) = assume pipe size 2 cm to 16 cm

Diameter of the HDPE pipe is 7 cm

Pipe Spacing

The pipe spacing may be determined by the mound model. The slope of ground surface between the pipe is 3:1. In the Mound Model the maximum height of fluid between two parallel perforated drainage pipes is equal to (U.S. EPA, 1989)

$$h_{max} = \frac{1}{2}\frac{L}{c}\left[\frac{\tan^2\alpha}{c} + 1 - \frac{\tan\alpha}{c}\sqrt{\tan^2\alpha + c}\right]$$

L = Distance between the pipes (31.96 m)

c = Peak leachate quantity

α = Slope of ground surface between the pipe

The spacing of the pipe is h_{max} = 17.44 m

Leachate holding tank = 40×10 m

3. Base Liners

The bottom portion of the landfill directly rests on stable compacted specially prepared soil bed. The various layers of liners from bottom to top which are required as per the EPA guidelines.300 mm thick crushed material blended with bentonite. 90 cm clay liner layer for single compose liner. 1.5 mm thick high density polyethylene. (HDPE) geomembrane. 20 cm geotextile layer. 30 cm thick granular soil drainage layer. (Leachate Collection Layer).

4. Top Cover Design

The final cover is the layer that is placed on the completed surface of the fill. The functions of the final cover are several. It controls infiltration of water, controls landfill gas migration, serves as a growth medium for vegetation, provides a support for post-closure activities, and is a barrier between the waste. The top cover of the landfill directly rests on compacted waste surface. The various layers of liners from bottom to top are vegetation soil is 15 cm, top soil is 45 cm, HDPE Layer 1.5 mm, clay or amended soil 60 cm, soil cover is 150 mm.

Table 3.6 Layer of the liner system

	Liner System	
1	Geotextile	200 cm
2	Leachate Drainage Layer	30 cm
4	Geomembrane	1.5 mm
5	Thick Clay Liner	90 cm

Table 3.7 Layer of the cover system

	Cover System	
1	Native Soil Layer for Vegetation	45 cm
2	Drainage Layer	150 cm
3	Clay or Amended Soil	60 cm
4	Gas Collection Layer	15 cm

3.17 Surface Water Drainage System

To minimise the generation of leachate and the prevent pollution of surface water sources at the site, each phase of the landfill shall be provided with adequate drainage system. The drainage has been designed to the maximum rainfall intensity. Further to avoid the entry of leachate into the stream flowing across the landfill site. The surface water drainage system is designed by using rational equation simplest method to determine peak discharge from drainage basin runoff. It is used to determine peak discharge flow of drainage system.

Rational Equation: $Q = c.i.A$

Q = Peak discharge m^3/s

c = Rational method runoff coefficient (0.4)

i = Rainfall intensity, mm/yr

A = Drainage area, sq.m

i = 1500 mm/yr

Dimension of drainage channel

Depth = 0.9 m Width = 0.9 m slope = 2:1 as per as mention in EPA guidelines.

$A = 0.9 \times 0.9 = 0.81\ m^2$

$Q = 1.52\ m^3/s$

3.18 Environmental Monitoring System

Ground Water Monitoring Wells per cell. These are used to check the groundwater. Numbers = 2 (1 up gradient well; 1 wells along the sides in down gradient direction) as shown in the plan of the landfill. Lysimeters 1 it is a measuring device which can be used to measure the amount of actual evapotranspiration which is released by plants, usually crops or trees as shown the plan of the landfill. Gas Monitors one portable gas monitors for landfill gas. These are used to check the gas emission rate as shown in the plan of the landfill. Samplers for the groundwater sample and leachate samples in vertical wells.

3.19 Facilities at the Site

Landfill site shall be fenced and provided with proper gate to monitor incoming vehicles or other modes of transportation. The landfill site shall be well protected to prevent entry of unauthorized persons and stray animals. Approach and other internal roads for free movement of vehicles and other machinery shall exist at the landfill site. The landfill site shall have wastes inspection facility to monitor wastes brought in for landfill, office facility for record keeping and shelter for keeping equipment and machinery including pollution monitoring equipment's. Provisions like weigh bridge to measure quantity of waste brought at landfill site, fire protection equipment's and other facilities as may be required shall be provided.

3.20 Landfill Equipment

Equipment falls into three functional categories: waste movement and compaction, earth cover transport and compaction, and support functions. The following equipment is required at a landfill site:

(a) Dozers are used for spreading waste and daily cover.

(b) Landfill Compactors are used for compaction of waste.

(c) Loader Backhoes are used for loading of waste, for excavating trenches etc.

(d) Tractor trailors are used for internal movement of waste or daily cover soil.

3.21 Determination of nitrate and sulphate concentration in leachate

The concentration of nitrate and sulphate in leachate for engineered landfill can be determined by combine advection diffusion equation.

$$\frac{C(z,t)}{C_0} = 0.5 erfc\left[\frac{z - v.t}{(4D)^{0.5}}\right] + \left[\exp\left[\frac{v.z}{D}\right] erfc\left[\frac{z + v.t}{(4D.t)^{0.5}}\right]\right]$$

Where C = Initial concentration nitrate = 27 mg/l, sulphate = 50 mg/l, C_0 = Final concentration, z = Depth 18 m, v = velocity 1.39 m/sec, D = Diffusion coefficient $3*10^{-10}$ cm^2/sec

For nitrate $27/C_0 = 81.4$ For sulphate $50/C_0 = 81.4$

$C_0 = 3.01$ mg/l $C_0 = 1.62$ mg/l

3.22 Weather Data by using visual HELP

The graph below shows the outcome of the simulation using monthly averages data. The HELP model requires three different types of meteorological data that must be provided as daily values for a year precipitation, temperature. The Weather Generator is a built-in component for generating statistically reliable weather for virtually any location in the world for periods of up to 100 years.

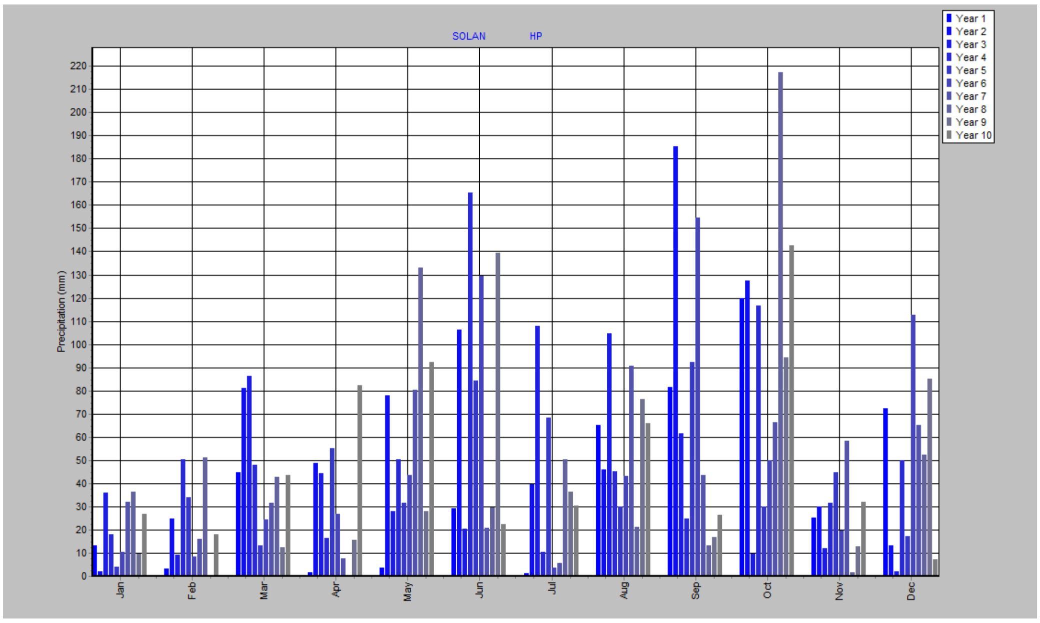


Figure 3.9 Precipitation per month

This graph shows that maximum rainfall in June, September and in October month. This can effect on the stability of the landfill. The runoff produced from the landfill leachate can affect the water quality in a significant way in the rainy months. The strength of leachate within the landfill sites was found to increase after the rainfall month.

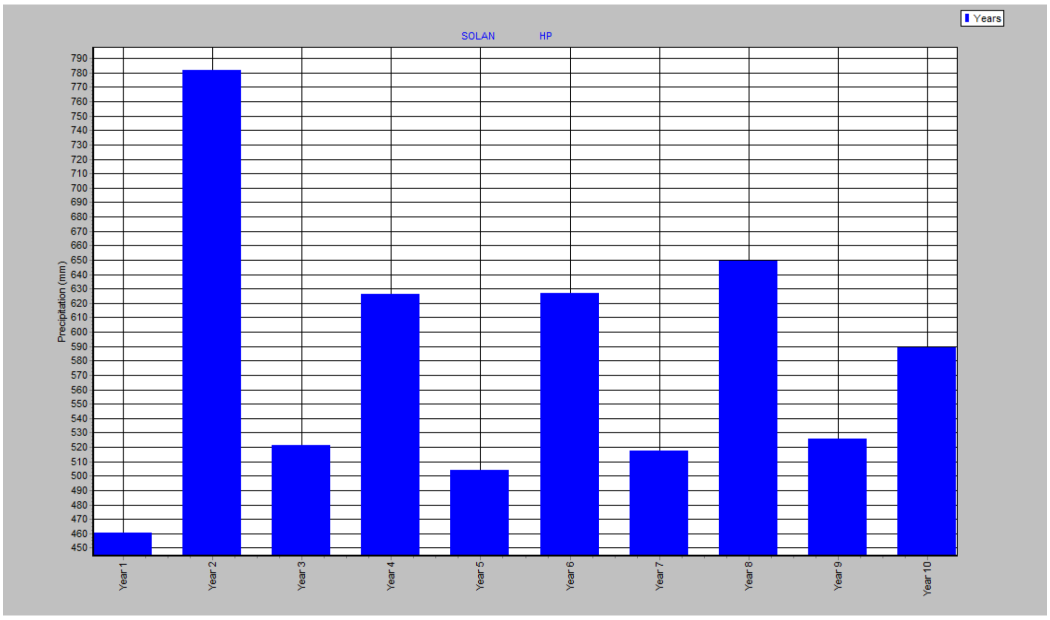


Figure 3.10 Precipitation per year

This graph shows that precipitation in year 2 is 780 mm and in year 1 precipitation is 460 mm. The maximum precipitation in year 2 and minimum precipitation in year 1. The increase of leachate temperature may be because of the reaction that is taking place due to availability of water that is getting mixed up. The reaction rate of physical, chemical and biological processes within the landfill may be increased in rainfall month.

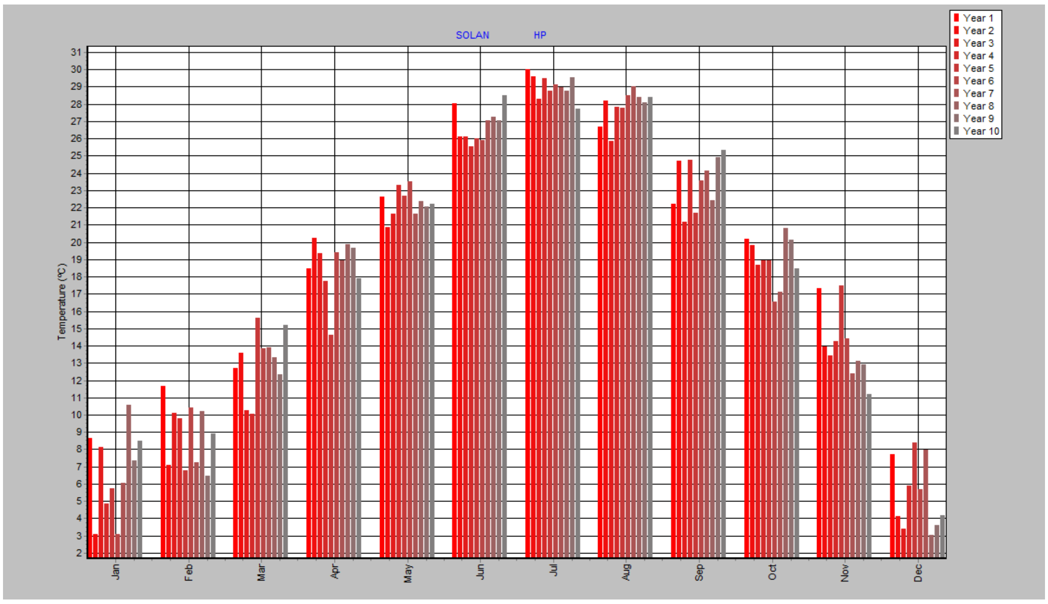


Figure 3.11 Temperature per month

This graph shows that maximum temperature in May, June, July and August. Due to high temperature in the landfill the waste can decompose early.

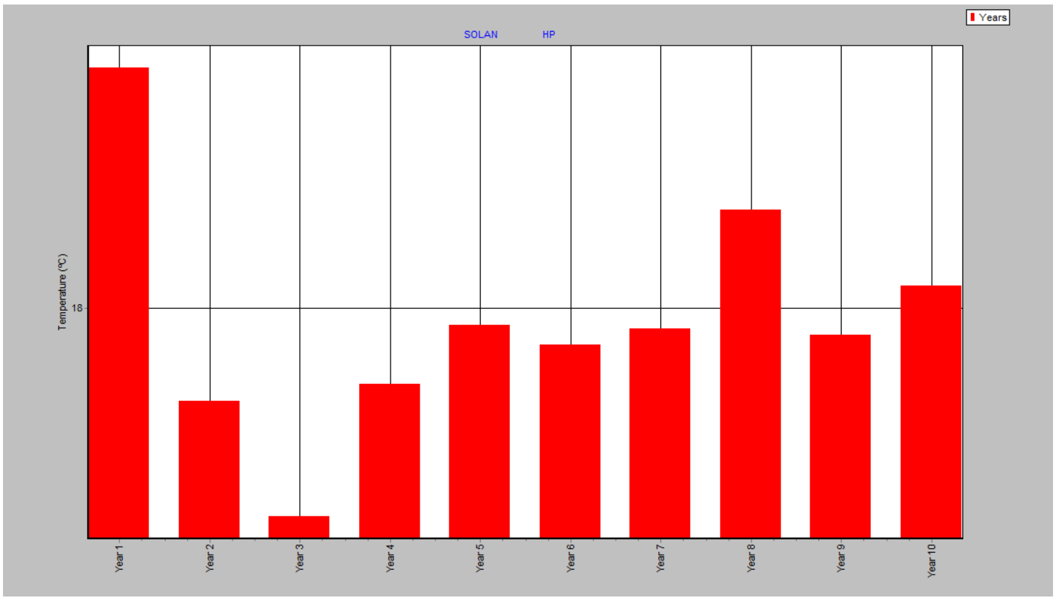


Figure 3.12 Temperature per year

The 10 yearly data also indicates that evapotranspiration seems to be almost constant and is following the trend of rainfall and it is a dependent parameter. The temperature maximum in the year1 and minimum in the year 3.The evapotranspiration is not dependent on rainfall.

3.23 Plan of Landfill using AutoCAD

AutoCAD is a computer-aided drafting software program used for creating blue prints for buildings, bridges and computer chips. There is different commands use for the landfill plan such as line, arryrect, trim, hatching, extend, move, mirror, rotate, fillet, circle. The landfill plan includes infrastructure area, land filling area, road, site fencing, lysimeter, ground water monitoring wells.

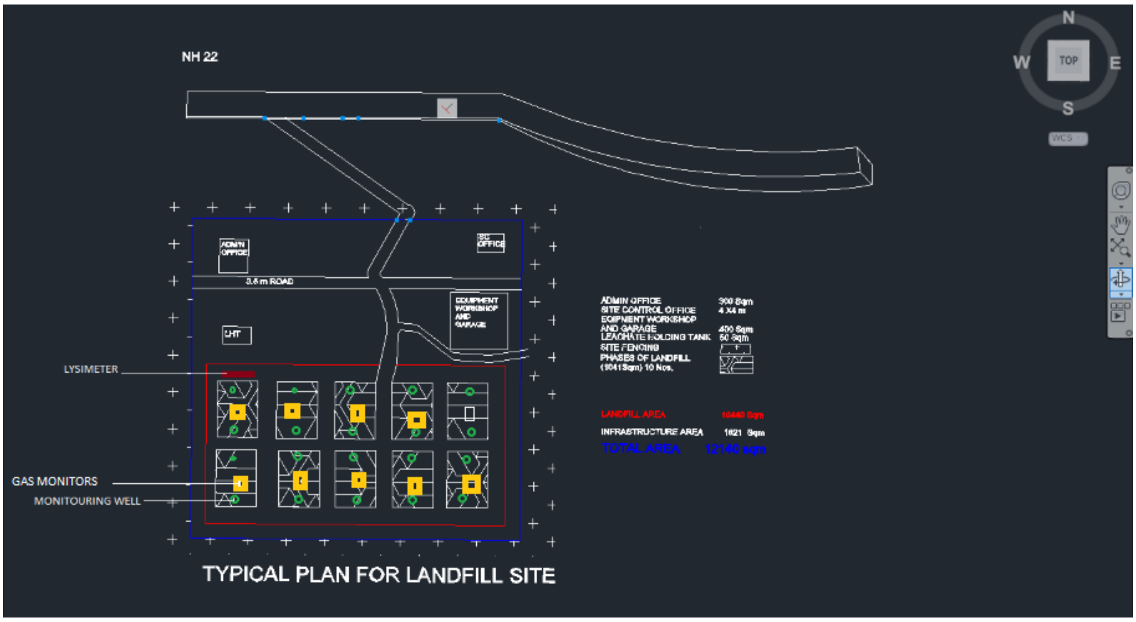


Figure 3.13 Top view of engineered landfill

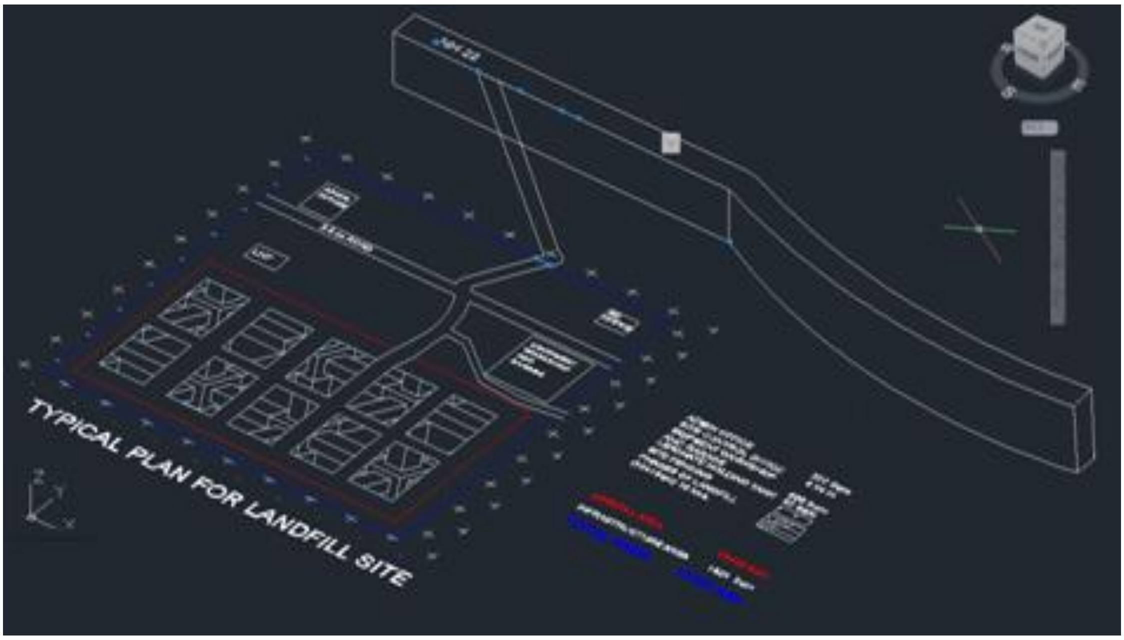


Figure 3.14 Side view of engineered landfill

CHAPTER 4

RESULTS AND DISCUSSION

4.1 General

Municipal solid waste management data collected from the municipal corporation Solan and detailed field study was conducted. Study the in situ properties of the landfill soil. Provide liner system, cover system, leachate collection system, surface drainage system, environment monitoring system. By using visual HELP evaluate leachate mounding or leakage problems with current landfills.

4.2 Results and Discussion

Specific gravity of the soil is 2.6 within limits as per as IS code 2720-1980. The bulk density of the soil is 2 g/cm^3 and dry density is 1.99 g/cm^3. It means the soil is silty sand whereas that of organic matter is about 0.5. Bulk density normally decreases, as mineral soils become finer in texture. The bulk density varies indirectly with the total pore space present in the soil and gives a good estimate of the porosity of the soil. Soils with a bulk density higher than 1.6 g/cm^3 tend to restrict root growth. The permeability of soil is 1.21×10^{-4} cm/sec in silty sand condition.

The liner system should consist of the following a minimum 0.5m thick leachate collection layer having a minimum hydraulic conductivity of $1\text{x}10^{-3}$ m/s, the upper component of the composite liner must consist of a flexible membrane liner. At minimum a 1.5 mm HDPE or equivalent flexible membrane liner should be used, as it is sufficiently robust but at the same time not prone to excessive cracking and construction difficulties; base and side wall mineral layer of minimum thickness 5m having a hydraulic conductivity less than or equal to $1\text{x}10^{-9}$ m/s; and a minimum 1.5m of the 5m thick mineral layer should form the lower component of the composite liner and should be constructed in a series of compacted lifts no thicker than 250 mm when compacted.

The design of surface water drains is usually based on storm events with specified return period and duration of rainfall. A common return period for design purposes is 10 years. The return period may be selected based on site characteristics, the risk of failure and the consequences of failure of the drainage system. It should be noted that longer return periods will lead to systems with greater capacities but at a higher cost. The peak discharge rate and run off volume during peak discharge should be determined. Design methods used include rational method. The surface water management systems should be designed to collect and control at least the water volume resulting from a specified duration and return period.

The leachate management system should include the following components. A drainage layer constructed of either natural granular material (sand, gravel) or synthetic drainage material (e.g. geonet or geocomposite). Synthetic drainage material may be used on side walls of the landfill cells, where the construction and operation of granular material may be difficult. perforated leachate collection pipes within the drainage blanket to collect leachate and carry it to a sump or collection header pipe; a protective filter layer over the drainage blanket, if necessary, to prevent physical clogging of the material by fine grained material.

The drainage layer piping is the component that is most vulnerable to compressive strength failure. The design of leachate collection pipes should consider required capacity and pipe size and maximum slope and structural strength of the pipe. A network of perforated smooth bore 200 mm minimum diameter (generally high density polyethylene, or polypropylene) laid to a self-cleansing gradient. The intake area of at least $0.01m^2/m$ length of pipe.

Monitoring is required to ensure the leachate head is being successfully controlled. A minimum of two monitoring points should be provided in all cells. Each cell should be monitored at its leachate collection point, which is the lowest point in the cell and at two additional locations per hectare of cell area.

The purpose of a landfill gas management system is to minimize the impact on air quality and the effect of greenhouse gases on the global climate to minimize the risk of migration of landfill gas beyond the perimeter of the site, minimize the risk of migration of landfill gas into services and buildings on site and minimize the damage to soils and vegetation within the restored landfill area.

This graph shows that the maximum runoff was not preceded by very intensive precipitation. However, after reviewing the weather data, it appears that day 18 was the first warm day with an average temperature of 4 degrees C after a long span of frosty days. The peak runoff was caused by the intensive thaw of snow accumulated during the previous cold period.

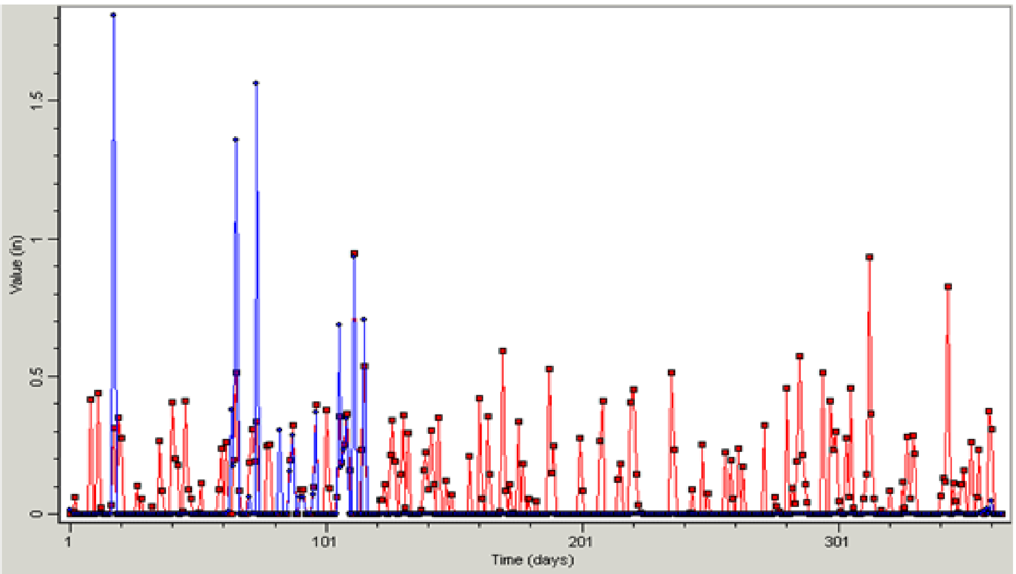
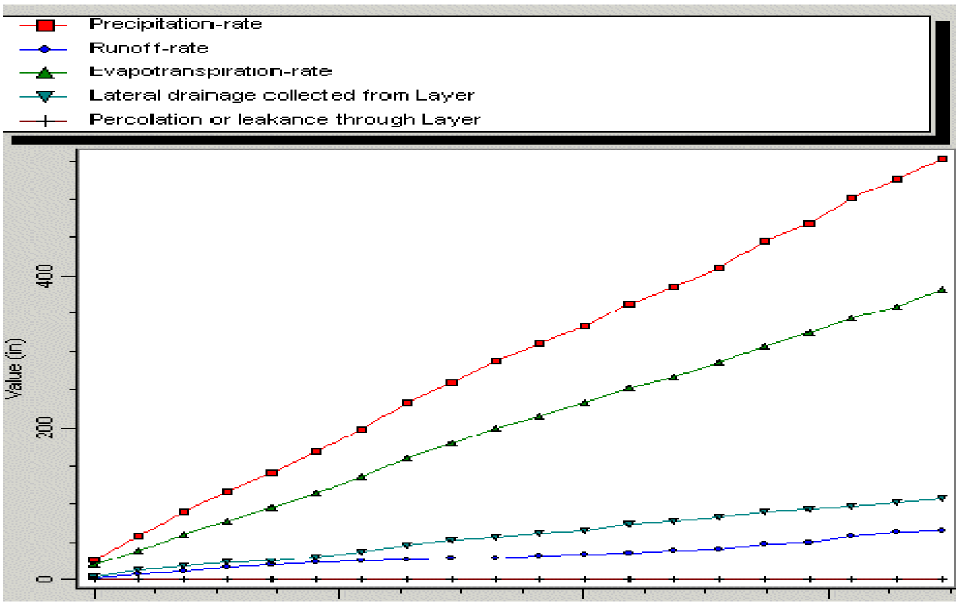


Figure 4.1 Precipitation vs. time graph

Landfill's moisture conditions and runoff parameters



1 3 6 9

Time in year

Figure 4.2

From the graph, we conclude that Runoff, Evapotranspiration, and Lateral drainage collected from layer play an important role in the landfill balance while percolation through layer is equal to 0.

The final values for accumulated volumes are:

Precipitation 11430 mm

Runoff 1270 mm

Evapotranspiration 6223 mm

Lateral drainage collected from layer 2540 mm

Percolation or leakage through Layer 0 mm

These values show that the landfill design provides good ground water protection for our project location.

CHAPTER 5

CONCLUSION

1. In the current work the management of municipal solid waste of Solan city was done by replacing the used non-engineered landfill with engineered landfill. In the present study, in situ study of soil properties was carried out. The specific gravity of the soil is 2.6 with in limit (2.6 to 2.8) as per as IS code 2720-1980. The permeability of the soil is 1.21×10^{-4} cm/sec. This signifies that the soil is mainly silty sand. The low permeability of the in-situ soil will not make the pore water drain out easily. Hence contamination of the in-situ soil is a problem of concern. This problem can be minimized by constructing an engineered landfill with a leachate collection system. This leachate collection system will regulate and channelize the leachate formed into leachate collection drains. Hence the contamination of the in situ soil can be reduced effectively.
2. It is observed that if the Solan MSW is managed using an engineered landfill it will increase the capacity of the waste collection in the non-engineered landfill being currently used in the area. The current capacity of the landfill is 6070 sq.m and engineered landfill capacity is 10319 sq.m. This shows that the capacity of the landfill is increased by 58.82%, if engineered landfill is used for the MSW management.
3. It is observed concentration of the leachate is significantly reduced. When non-engineered landfill used the concentration of nitrate 27 mg/l and sulphate 50mg/l. It is found that by using engineered landfill the concentration of nitrate is reduced to 3.01 mg/l and sulphate is reduced to 1.62 mg/l.
4. The major components of non-engineered landfill gas are methane and carbon dioxide with 45 to 60%, oxygen with 0.1 to 1%, nitrogen 2 to 5%, sulfides 0 to 1% and hydrogen 0 to 0.2%. Oxygen emitted approximately 21% in the atmosphere, nitrogen emitted approximately 79% to the atmosphere, carbon dioxide concentration is emitted in the atmosphere 0.03% and methane emitted 5% in the atmosphere. It is observe that by using engineered landfill reduce all these gases by gas collection system.
5. After the post closure period, if the leachate is recirculated it is found that the stabilization of the MSW is increased. Thus the existing landfill area can be used to

accept a higher amount of MSW. Moreover the post closure of the landfill is found to open new opportunities for landscaping, parking lots and infrastructure.

6. By using visual HELP we conclude that the engineered landfill design provides good ground water protection and there is no percolation through the drainage collection layer.

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