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Site Selection and Estimation of a Sanitary Landfill in BIT Sindri, Dhanbad

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Abstract: This paper highlights the selection of a suitable sanitary landfill site and determines its size based on various factors, at BIT Sindri, Dhanbad campus. An overview study of the proposed landfill site, waste generated and size estimation of a landfill has been done. Historically, there have been only a few dumpsites in this campus. But with time, the rate of waste generation in this campus has increased leading to increase in dumpsites. So there is a need to construct an engineered sanitary landfill near this campus to effective dispose the solid wastes generated. However before designing and constructing the landfill, it is mandatory to select the proper landfill site in this region.

This research work thus focuses basically at selecting a proper landfill site based on soil tests at that site and determining the required landfill size considering the amount of waste generated in this area. This work is done so as to overcome the growing soil pollution everywhere. The paper also discusses about future scope in making the sanitary landfill as one of the effective means for MSW disposal in this region. It is an attempt to make a clean and hygienic environment at this campus.

Keywords: Landfill site, solid wastes, soil characteristics, size estimation, population, soil tests

I. INTRODUCTION

A harmonious and balanced relationship between nature and living beings, especially human beings, on this earth is absolutely necessary for a continued sustenance and development of both in this world. As civilization has advanced, humans have deliberately, interfered with the natural environment. This created a huge imbalance in man-nature relationship, leading to a lot of environmental problems. Most noticeable of them are: air pollution, water pollution and accumulation of solid waste. There are many factors responsible for such imbalances in nature. The most important being the huge increase in population with time.

Especially in developing countries, we have seen that although rapid on-going economic growth and urbanization has improved the living standards but has led to a significant increase in the amount of waste generated. The problem of solid waste is very serious in third world countries, where 80% of the world population lives and this often relates to a lack of financial resources (Al-Ansari, 2013 **[1]**). Segregation of waste at source results in the mixing of both biodegradable and non-biodegradable waste at the disposal units which are usually open dumps or landfills, leads to deterioration of land and its resources and eventually gives rise to environmental degradation and health impairment. Moreover, dumpsites which were located in the outskirts of a city earlier has now shifted and become part of urban landscape which is often ignored. The non-availability of land in the urban areas for a designated land for new dumps has further enhanced the need for rehabilitation or remediation of the existing dump sites. This necessity has led to the development of engineered or sanitary landfills.

A. Working of a Sanitary Landfill in Layers

1) *Layer 1:* The Liner System. The bottom of a modern landfill is typically lined with compacted clay which is dense enough to prevent liquids, especially leachate from penetrating it. Landfill engineers install a liner made of high-density plastic at the top part of the clay for added protection. The liner is a system of a lay/layers and/or geosynthetic membranes used to collect leachate and reduce or prevent contaminants to flow into the ground water.
2) *Layer 2:* The Drainage System or Leachate Collection System. Some waste produces liquid as it decomposes. And as rain and snow filter through a landfill, it can carry other contaminants to the bottom. Perforated pipes are installed at the low areas of the liner to collect these liquids (known as leachate) for storage and funnel them to treatment facilities, either onsite or at wastewater treatment plants. An alternative for collection pipes is a special configuration of geosynthetic materials that will hydraulically transmit leachate to collection points for removal.
3) *Layer 3:* The Gas Collection System. Wastes naturally produce methane as it decomposes and when methane is released into the atmosphere, it contributes to global warming. But methane is also the main component of natural gas. Modern landfills are designed to convert methane into power, using gas extraction wells that pipe it to treatment areas and then to plants that will turn it into electricity or other forms of energy.

4) *Layer 4:* The Trash or Wastes. In the area of the landfill site, trash is delivered and then compacted to take up less room. Every day, the new trash is covered with a layer of dirt which helps to control odors and deter pests.

II. AIM AND OBJECTIVES

The aim of the research is to examine the soil properties & characteristics on which waste has to be disposed, site verification and estimation of suitable landfill size at BIT Sindri campus, Dhanbad.
The objectives of the study are:

A. Proper investigation of the soil at the proposed landfill sites and conducting soil tests to find the soil characteristics
B. Calculation of solid waste generated at the campus, in efficient manner
C. Estimation of a sanitary landfill size at the campus

III. LITERATURE REVIEW

1) *M. Yazdani et al. (2015) [2]* studied the suitability of existing municipal landfill sites using GIS methods, at Tonekabon city in the west area of Mazandaran province, northern Iran, along the southern coast of the Caspian Sea. To evaluate, two guidelines were used: Minnesota Pollution Control Agency (MPCA) and regional screening method.
2) *Ali Jalil Chabuk et al. (2016) [3]* has showed the present status of solid waste management, solid waste sources, staffing for solid waste collection, machinery and equipment used in the waste collection process, finance and financial management at Babylon Governorate and its Qadhaa. There is no landfill site in Al-Qasim Qadhaa, which is situated in the southern part of the Babylon Governorate, Iraq that conforms to the scientific criteria for selecting sites for landfill. Due to this reason, 15 criteria i.e. groundwater depth, rivers, soil types, agriculture lands use, land use, elevation, slope, gas pipelines, oil pipelines, power lines, roads, railways, urban centers, villages and archaeological sites were adopted using GIS in this study. These criteria have a large ability to manage input data. In addition to this, the AHP (analytical hierarchy process) method was used to derive the relative weightings for each criterion using pair-wise comparison.
3) *Oluwadare Joshua Oyebode (2017) [4]* designed a sanitary landfill system of depth 3.6 m, width 30.3m and length 72.8 m and a model of it was fabricated. Design of sanitary land fill was done with major emphases on determination of the lifespan/target year and location of a suitable site in Ado –Ekiti, South-Western Nigeria.
4) *Trupti et al. [5]* reviewed various studies undertaken by researchers in order to implement Multiple-Criteria Decision Analysis (MCDA) and Geographical Information System (GIS) in the procedure of selecting landfill site for any region. This paper attempts to identify essential environmental, socio-economic factors that must be considered and appropriate MCDA method for selection of landfill site.

IV. METHODOLOGY

To evaluate study area for selection of a suitable landfill site, the soil characteristics of those sites are tested according to the geological criteria, i.e. soil type. Then the site best suited is selected as the proposed landfill site. After this, size of the landfill is calculated by a mathematical formula given in Sec. IV-C.
The main steps involved in this study are:
1) Selecting two sample sites in BIT Sindri campus on the basis of reconnaissance.
2) Soil from both the sites are collected and tested in the geotechnical lab to find its properties.
3) The results are compared and the best suitable soil type site is selected.
4) The parameters required to calculate the size of landfill is determined and few assumptions are made.
5) Finally, these values from step (4) are put in the formula to find the size of landfill required.

A. Study Area

On reconnaissance, two landfill sites in BIT Sindri campus has been selected for examination. Soil tests were performed from the soil samples of these regions.
The following are the sites marked as Site 1 and Site 2 (Fig. 1.):
1) *Site 1:* In front of hostel no. 14 (B-zone)
2) *Site 2:* Beside hostel no. 26
Both the sites are at compatible distance from the hostels.

Also the cost for transporting waste is minimum as the sites are located in the campus itself. The residential areas are also quite far from the sites.

Map of the BIT campus is shown in Fig. 2. indicating the proposed sites.

Site 1: In front of hostel no. 14 (B-zone); Site 2: Beside hostel no. 26

Fig. 1. Proposed landfill sites at BIT Sindri campus

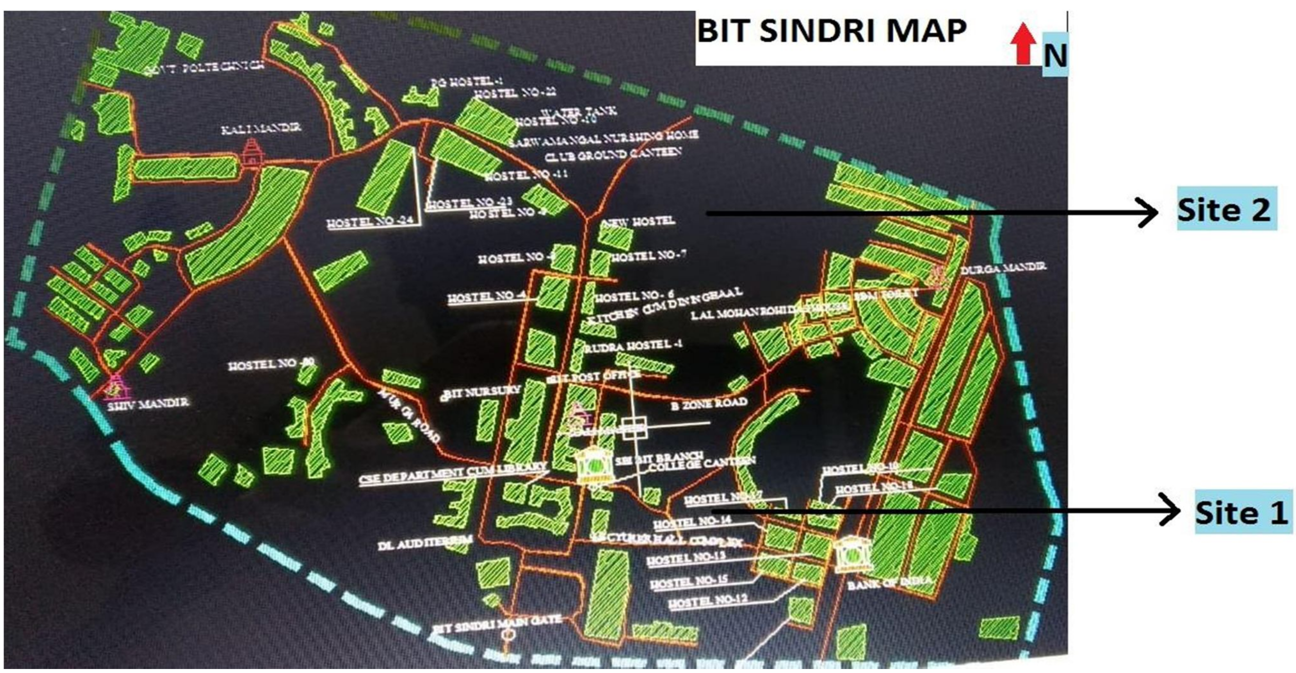

Fig. 2. BIT Sindri campus map showing the two proposed sites

B. Geological Criteria: Soil Type

A soil survey is done before designing the landfill. The soil type is directly controlled by the geology of the area. It also determines the load bearing capacity of the landfill and the migration of leachate. These factors are influenced by the nature of soil and permeability of the bed rock.

In order to compare the two sites and check the compatibility for landfilling, the following soil tests were conducted.

1) Sieve analysis
2) Liquid limit test
3) Standard proctor test
4) Specific gravity test
5) Permeability test

C. Area and Volume of a Sanitary Landfill

The most important design feature of a sanitary landfill is its volume, which in turn depends on the area available, depth at which the waste is placed and the thickness of the soil over the waste.

Mathematical/ Analytical method

The annual volume required for a landfill may be estimated using the equation proposed by Salvato:

$VSLF = (P*ms*Vr)/\rho CF$;

Where, VSLF = volume of the sanitary landfill, m3

P= population

ms = average mass (kg) of solid waste collected per person per year

Vr = volume ratio= (Vs+ Vc)/ Vs ; where, Vs = volume of solid waste, m3

Vc = volume of soil cover, m3

ρCF = compacted fill density, kg/m3

$\rho CF = \rho s*Cr$; where, ρs = mean density of solid waste, kg/m3

Cr = compaction ratio= xsu/xs ;

where, xsu = thickness of the uncompacted layer, m

xs = thickness of the compacted layer, m.

Now, daily volume of compacted solid waste at the landfill site can be estimated as:

$VSD = (P*ms)/(\rho CF*Nsw)$;

Where, VSD = volume of the compacted solid waste received daily, m3

Nsw = no. of days in a week the solid waste is delivered at the site, days/week.

Assuming that the daily volume of the solid waste is spread and compacted into a layer of thickness ‘xs’, then the area covered could be formed into a cell.

This area, Acell = VSD/xs , (m2).

After the compacted solid waste is spread, a soil layer of thickness ‘xc’ is added as cover each day. Hence the total amount placed daily as part of the cell has a thickness of (xs+xc). If ‘hc’ is the cell height and ‘xci’ is the thickness of the intermediate soil cover placed over the top of the cell, then the time it will take to complete the cell is-

$Tcell = hc - (xci - xc)/(xs + xc)$, days

& $hc = \{Nsw *(xs + xc)\} + (xci - xc)$.

Time taken to complete a stack of cells is-

$Tstack = n* Tcell$; n= no. of cells.

The volume of the solid waste per cell is-

$Vs,cell = Acell*xs* Tcell$, m3

(Acell*xs)= volume of the compacted solid waste received daily.

Total volume of solid waste in the stack, is-

$Vs = n* Vs,cell$

Similarly, volume of soil cover per cell is-

$Vc,cell = Acell[nc*xc + xci]$, m3 ; where, nc = no. of soil covers in a cell (excluding the intermediate cover).

Total volume of soil used in stack is-

$Vc,stack = n* Vc,cell$

The volume of soil cover over the stack (top cover)-

$Vc,top = Acell\ \neg(xcf - xci)$, m3 ; where, xcf = thickness of the soil cover over the top cell which includes the intermediate cover, m.

For calculating the volume of soil used in-between stacks, we assume that the soil thickness separating adjacent stacks will be the same as the thickness of the intermediate layer (xci) and that the area of the cell is a square. Then the length of the side separating adjacent stacks is-

$Lcell= \sqrt{Acell}$, m.

Therefore, volume of soil separating the stacks on both sides is-

$Vc,side= 2*xci*hc *Lcell$

Total volume of cover is-

$Vc = Vc,stack + Vc,top + Vc,side$

The volume ratio, Vr is then calculated and finally the volume of the sanitary landfill is obtained.
Since, the sanitary landfill depth 'DSLF' is known, the landfill area required annually can be estimated as-
ASLF = VSLF / DSLF.

D. Parameters Examined for Calculation

Basically the parameters examined in each primary data sources are listed below:

1) Population
- *a)* No. of boys hostels = 23
- *b)* No. of girls hostels = 3
- *c)* No. of professor quarters = 157
- *d)* No. of staff quarters = 83
- *e)* Total no. of boys (including B.Tech and M.Tech) = 2577 + 200 = 2777
- *f)* Total no. of girls (including B.Tech and M.Tech) = 508 + 12 = 520
- *g)* Average no. of members in quarters = 5

2) Solid Wastes

a) Wastes Disposed On An Average By Various Sectors In BIT Sindri (Assumed Values)
- *i)* Professors = 300 gm per head per day
- *ii)* Staffs = 250 gm per head per day
- *iii)* Canteens = 200 gm per head per day
- *iv)* Students = 150 gm per head per day

b) Physical Characterization of Disposed Waste
- *i)* Plastics
- *ii)* Paper and cardboard
- *iii)* Food packets and cans
- *iv)* Rubber and leather materials
- *v)* Wooden and glass materials
- *vi)* Construction and demolition debris

V. RESULTS AND ANALYSIS

A. Soil Tests Results

1) Sieve Analysis

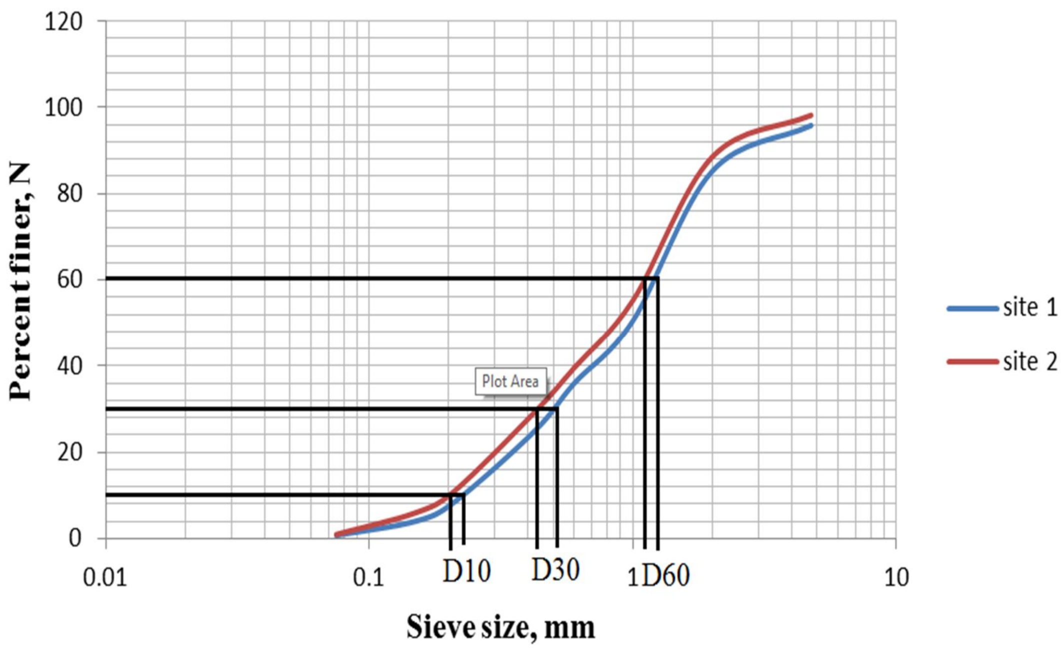

Fig. 3. Graph of sieve analysis

2) Liquid Limit Test

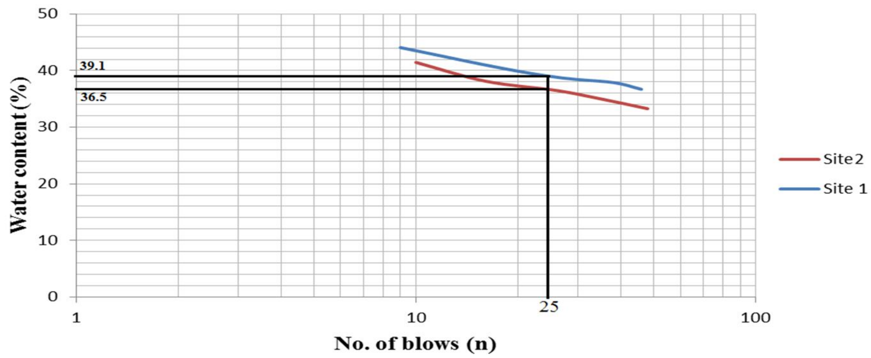

Fig. 4. Graph of liquid limit test

3) Standard Proctor Test

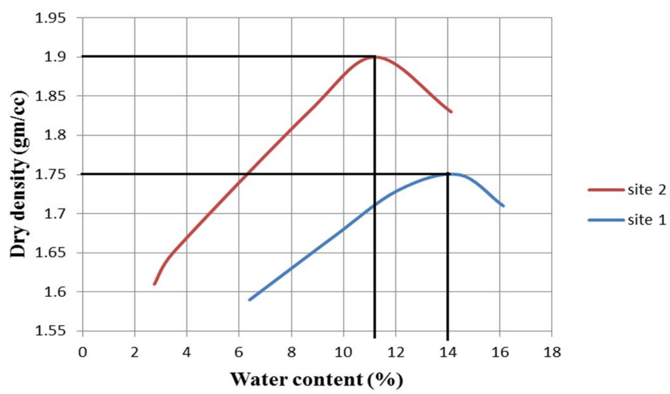

Fig 5. Compaction curve

Table 4.4 Summarized results of the soil tests

PARAMETERS	Site 1	Site 2
D60 (mm)	1.4	1.2
D30 (mm)	0.5	0.43
D10 (mm)	0.24	0.2
Cu, Uniformity Coefficient	5.83	6
Cc, Coefficient of Curvature	0.744	0.77
Liquid Limit	39.1	36.1
OMC, Optimum Moisture Content (%)	14	11.5
MDD, Maximum Dry Density (gm/cc)	1.75	1.9
Specific Gravity	2.53	2.603
Permeability (cm/sec)	$6.06 * 10^{-4}$	$5.622 * 10^{-4}$

B. Waste Generation per Head

1) Population: Total population = (157+83) * 5 + 2777 + 520 = 4497 persons.

2) Average Waste Generation per Head per Day

Professors = 300*157*5 = 235500 gm per day
Staffs = 250*83*5 = 103750 gm per day
Students = 150*(2777+520) = 494550 gm per day
Canteens = 200*1500 = 300000 gm per day
Therefore, total waste generated per day = 1133800 gm per day
Average waste generated/head/day = 1133800/4497 = 252.124 gm/head/day = 0.252kg/head/day.

C. Area and Volume of a Sanitary Landfill

1) *Problem Framed Based On This Study:* A sanitary landfill is to be designed at BIT Sindri campus, having population of 4497, to handle solid waste generated. The waste generation on the average is 0.252kg/head/day. It is expected that the waste will be delivered by a truck to the landfill site on a 2 days/week basis. The mean density of the refuse spread is assumed to be 100 kg/m^3. The solid waste is spread in 0.5 m layers and compacted to 0.25 m. The landfill will use 0.15 m of soil for daily cover. An intermediate cover of soil of 0.2 m is used to complete the cell and a final cover 1.0 m over the stack of 2 cells is recommended. Find: i) annual volume required for the landfill. ii) Annual horizontal area covered by the solid waste.
2) *Solution*

a) Total mass of waste generated in the town,

$P*m_s$ = 4497(persons) * 0.252(kg/head/day) * 365(day/year) = $41.36*10^4$ kg/year.

b) Compaction ratio, $C_r = x_{su}/x_s = 0.5/0.25 = 2$

c) Compacted field density, $\rho_{CF} = \rho_s*C_r$ = 100 (kg/m^3) * 2 =200 kg/m^3.

d) Daily volume of compacted solid waste at landfill site,

$V_{SD} = (P*m_s)/(\rho_{CF}*N_{sw})$ = ($41.36*10^4$ kg/year)/(200 kg/m^3 *2days/week*52weeks/year) = 19.88 m^3.

e) Area of cell, $A_{cell} = V_{SD}/x_s$ = 19.88/0.25 m^2 = 79.52 m^2.

f) The cell height is calculated, $h_c = \{N_{sw} *(x_s + x_c)\} + (x_{ci} - x_c)$

$= \{2*(0.25+0.15)\} + (0.2-0.15) = 0.85$ m.

g) Time it takes to complete a cell will be, $T_{cell} = h_c - (x_{ci} - x_c)/(x_s + x_c)$

$= 0.85-(0.2-0.15)/(0.3+0.15) = 2$ days

Hence, Time taken to complete a stack of cells, $T_{stack} = n* T_{cell} = 2*2 = 4$ days.

h) Total volume of solid waste in a stack, $V_s = n* A_{cell}*x_s* T_{cell} = T_{stack} * V_{SD}$

= 4*19.88= 79.52 m^3

i) Volume of soil cover per cell, n_c= 2

$V_{c,cell} = A_{cell}[n_c*x_c + x_{ci}] = 79.52(2*0.15 + 0.2) = 39.76$ m^3

So, $V_{c,stack} = n* V_{c,cell} = 2 * 39.76 = 79.52$ m^3.

j) Volume of soil cover over the stack, $V_{c,top} = A_{cell} (x_{cf} - x_{ci}) = 79.52(1.0-0.2) =$ 63.616 m^3

k) Volume of soil separating the stacks on both sides is, $V_{c,side}= 2*x_{ci}*h_c *L_{cell}$

$= 2*0.2*0.85*\sqrt{79.52}$=3.03 m^3.

l) Total volume of soil cover, $V_c = V_{c,stack} + V_{c,top} + V_{c,side}$

= 79.52 + 63.616 + 3.03 = 146.166 m^3.

m) Volume ratio, $(V_s+ V_c)/ V_s$ = (79.52 + 146.166)/79.52 = 2.84.

n) Estimated annual volume required of land, $V_{SLF} = (P*m_s*V_r)/\rho_{CF}$ = ($41.36*10^4$ kg/year *2.84)/ 200 kg/m^3 = 5873.12 m^3.

o) The landfill depth is assumed to be, D_{SLF} = 4 m.

Hence, area required annually, $A_{SLF} = V_{SLF} / D_{SLF}$ = 5873.12/4 = **1468.28 m^2**.

p) Assuming square area the length of one side would be, √1468.28 = **38.32 m**.

Thus, we can construct and design a landfill of length 40m approximately.

VI. CONCLUSIONS

Thus from the above data and information from soil tests, charts and graphs the following conclusions are derived:

1) From sieve analysis, it is seen that the soil of both the sites are well graded.
2) Liquid limit of site 1 is higher than that of site 2.
3) Comparing the OMC and MDD of both sites, site 2 has better compacting property than site 1.
4) In the specific gravity test also, soil of site 2 has higher specific gravity than that of site 2.
5) Finally, the permeability test confirms that the permeability of soil at Site 2 is less than that at Site 1.

Hence, Site 2 is best suitable for constructing a sanitary landfill.

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The final conclusions that can be inferred from this research work are as follows:

a) The soil investigations done in the campus shows that the soil is well graded having specific gravity in the range of about 5.5-6. The soil has medium permeability and the base rock is impermeable.

b) The waste generation has increased with time as many dumpsites are seen everywhere in the campus. Thus a landfill is to be designed for the campus.

c) A proper landfill site is selected on comparing the soil properties of two proposed sites in the campus.

d) Size for the landfill construction is calculated mathematically, based on various parameters needed.

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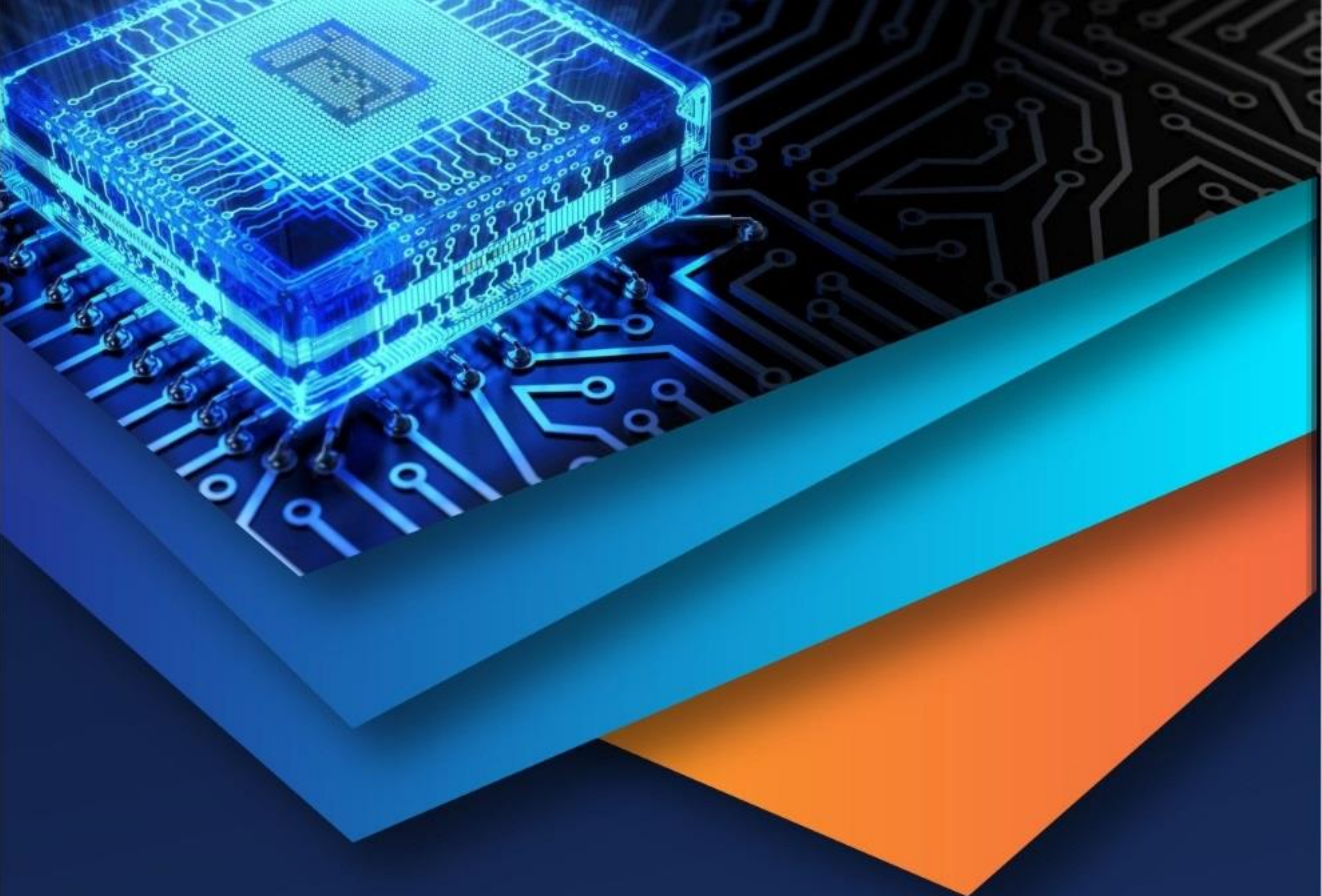

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