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Investigation of Existing Solid Waste Disposal Site in Chikmagalur City

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Abstract

Soil waste management involves activities associated with generation, storage, collection, transfer and transport, processing and disposal of solid waste, which are environmentally compatible, adopting the principles of economy, aesthetics, energy and conservation. It encompasses planning, organization, administration, financial, legal and engineering aspects involving interdisciplinary relationships. Disposal of solid waste is primarily an urban problem and waste disposal facilities are necessary if society is to function smoothly. Chikmagalur city generates about 40 tonnes of solid waste per day which is presently being disposed in site located near Indavara village and there is a growing concern for the safety of people living in close proximity of the disposal site. Investigation of existing solid waste disposal site was carried out based on geological, hydrological and geophysical investigations. Grain size analysis, permeability test, compaction tests were also carried out for the soil sample collected from the disposal site.
Key words : Solid waste disposal, Chikmagalur city, Grain size analysis, Permeability test, Compaction test.

Solid waste management is one of the essential obligatory functions of the urban local bodies in India. This service is falling too short of the desired level of efficiency and satisfaction resulting in problems of health, sanitation and environment degradation. Most urban areas in the country are plagued by acute problems related to solid waste. Due to lack of serious efforts by towns and city authorities, garbage and its managements has become a tenacious problem and this is not withstanding the fact that the largest part of municipal corporation in the country, most of the local bodies suffer due to non availability of adequate expertise and experience, there by the solid waste is not properly handled resulting into creation of environmental pollution and health hazards (1). The common methods of solid waste disposal include on site disposal, composting, incineration, open dumps and sanitary landfills. The physical factors are most significant in siting, disposal location. Without careful consideration of soil, rocks and hydrogeology the disposal of waste may cause environmental pollution and health hazards. Factors controlling the feasibility of solid waste disposal site include topography, location of ground water table, amount of precipitation, type of soil and rock, surface water and good ground water flow system. The best sites are those in which natural conditions insures reasonable safety in disposal of solid waste. Determining sites where hazardous waste may be disposed off requires careful geologic and hydrologic considerations.

Geophysical Survey

Geophysical survey refers to the systematic collection of geophysical data for spatial studies, which may use a great variety of sensing instruments and data may be collected from above or below the Earth's surface or from aerial or marine platforms, and have many applications in earth science, archaeology, mineral and energy exploration and engineering. Geophysical surveys are used in industry and for academic research.

There are many methods and types of instrumentation and technologies used in geophysical surveys which include : Seismic methods, such as reflection seismology, seismic refraction, and seismic tomography ; magnetotellurics ; transient electromagnetic (EM) ; radio frequency electromagnetic propagation (e.g., ground penetrating radar) ; electrical techniques, including electrical resistivity, induced polarization, and spontaneous potential ; magnetic techniques, including aeromagnetic surveys and magnetometers ; gravity and gravity gradiometry ;

Table 1. Resistivities of some common rocks and minerals.

Materials	Resistivity (Ω.m)
Igneous and Metamorphic Rocks	
Granite	5×10^3—10^6
Basalt	10^3—10^6
Slate	6×10^2—4×10^7
Marble	10^2—2.5×10^8
Quartzite	10^2—2×10^8
Sedimentary Rocks	
Sandstone	8—4×10^3
Shale	20—2×10^3
Limestone	50—4×10^2
Soils and Water	
Clay	1—100
Alluvium	10—800
Ground water (Fresh)	10—100
Sea water	0.2

geodesy ; remote sensing ; and seismoelectrical method (2).

Electrical Resistivity

Electrical resistivity is a geophysical method in which an electrical current is injected into the ground through steel electrodes in an attempt to measure the electrical properties of the subsurface.
Electrical resistivity *p* (Greek : rho) is defind by,

$$p = \frac{E}{J}$$

Table 3. Specific gravity test by pycnometer method.

Trial no.	1	2	3
Weight of Pycnometer bottles W_1 (g)	685	685	685
Weight of dry soil + Pycnometer bottle W_2	982	999	987
Weight of soil + water + Pycnometer bottle W_3	1738	1739	1739
Weight of water in Pycnometer bottle W_4	1563	1563	1563
$G = W_2 - W_1 V (W_2-W_1)-(W_3-W_4)$	2.35	2.27	2.39

Where *p* is the static resistivity (measured in volt-meters per ampere, V m/A) ; *E* is the magnitude of the electric field (measured in volts per meter, V/m) ; *J* is the magnitude of the current density (measured in amperes per square meter, A/m^2). Most soils and non-ore bearing rocks are electrically resistive, (i.e., insulators). Soil moisture and ground water are often electrically conductive due to contained dissolved minerals. Therefore the resistivity measured in the ground is predominantly controlled by the amount of moisture and water within the soil and rock (a function of the porosity and permeability), and the concentration of dissolved solids (salts) in that water.

The basic method requires at least four steel electrodes be driven into the ground. An electrical current is then applied to the outer electrodes by a battery or generator. A voltage is measured between the two inner electrodes using a simple voltmeter. Through Ohm's Law (V = IR) and by knowing the input current, the measured voltage and the geometry of the electrode array, a value known as resistance can be calculated. Resistivity, measured in Ohm-meters, is resistance time's area divided by distance.

Table 2. Grain size analysis by mechanical method.

	IS sieve	Particle size 'D' in mm	Weight of particles retained in grams	% of retained	Cumulative % weight retained (x)	% finer (100-x)
1	4.75	4.75	292.00	29.2	29.2	70.8
2	2.36	2.36	59.50	5.95	35.15	64.85
3	1.18	1.18	68.00	6.80	41.95	58.05
4	600	0.600	29.50	2.95	44.90	51.1
5	425	0.425	46.50	4.65	49.55	50.45
6	300	0.300	26.00	2.6	52.15	47.85
7	150	0.150	73.50	7.35	59.5	40.5
8	75	0.075	14.50	1.45	60.95	39.05
9	pan	—	390.50	39.05	100	0

Table 4. Liquid limit by cone penetrometer method.

Particulars	1	2	3	4
No. of penetration	15	21	27	33
Container no.	209	213	207	221
Weight of container W_1 (g)	26.24	26.98	26.93	28.92
Weight of container + Wet soil W_2	41.01	54.52	48.76	52.27
Weight of container + Dry soil W_3	36.75	46.44	41.97	44.67
Weight of water Ww (W_2-W_3)	4.26	8.08	6.79	7.6
Weght of dry soil Wd (W_3-W_1)	10.51	19.46	15.04	15.75
Water Content W% = (Ww/Wd) × 100	40.53	41.52	45.14	48.25

Because the actual current flow is highly influenced by conductive layers, the value measured is known as the "apparent resistivity". In its simplest terms, it represents an average value encompassing all of the different materials within the volume (half-space) of materials being measured. Most modern resistivity meters calculate apparent resistivity once the geometric parameters are input.

The electrical resistivity method involves measuring the apparent resistivity of soils and rock as a function of depth or position. The resistivity of soils is a complicated function of porosity, permeability, ionic content of the pore fluids, and clay mineralization. The most common electrical methods used in hydrogeologic and environmental investigations are vertical electrical soundings (resistivity soundings) and resistivity profiling.

During a resistivity survey, current is injected into the earth through a pair of current electrodes, and the potential difference is measured between a pair of potential electrodes. The current and potential electrodes are generally arranged in a linear array. The apparent resistivity is the bulk average resistivity of all soils and rock influencing the current. It is calculated by dividing the measured potential difference by the input current and multiplying by a geometric factor specific to the array used and electrode spacing (2).

Table 5. Plastic limit.

	Particulars	1	2
1	Container No	102	105
2	Weight of empty container W_1 (g)	15.92	16.56
3	Weight of container + Wet soil W_2	22.39	23.42
4	Weight of container + Dry soil W_3	21	21.94
5	Weight of water Ww (W_2-W_3)	1.39	1.48
6	Weight of dry soil Wd (W_3-W_1)	5.08	5.38
7	Water content W = (Ww/Wd) × 100	27.39	27.50
8	Average = Water content plastic limit (Wp)	27.44%	

Relationship Between Geology and Resistivity

Resistivity surveys give a picture of the subsurface resistivity distribution. To convert the resistivity picture into a geological picture, some knowledge of typical resistivity values for different types of subsurface materials and the geology of the area surveyed, is important. The resistivity values of some common rocks, soils and other materials are given below (Table 1). Igneous and metamorphic rocks typically have high resistivity values. The resistivity of these rocks is greatly dependent on the degree of fracturing, and the percentage of the fractures filled with ground water. Sedimentary rocks, which usually are more porous and have higher water content, normally have lower resistivity values. Wet soils and fresh ground water have even lower resistivity values. Clayey soil normally has a lower resistivity value than sandy soil. However, note the overlap in the resistivity values of the different classes of rocks and soils. This is because the resistivity of a particular rock or soil sample depends on a number of factors such as the porosity, the degree of water saturation and the concentration of dissolved salts (2).

Table 6. Shrinkage limit by mercury displacement method.

1	Weight of shrinkage dish W_1 (g)	123.56
2	Weight of shrinkage dish + Wet soil W_2	164.49
3	Weight of shrinkage dish + Dry soil W_3	152.06
4	Weight of dry soil pot Wd = (W_3-W_1)	28.5
5	Weight of water Ww = (W_2-W_3)	12.43
6	Water content of soil pot W = (Ww/Wd) × 100	43.61%

Table 7. Standard proctor compaction test of water content and dry density.

Crucible no.	218	216	101	112	110
Empty weight of crucible W_1 (g)	26.22	26.48	19.17	15.26	17.38
Weight of crucible + soil W_2	60.63	57.55	36.86	39.25	43.89
Weight of crucible + Dry soil W_3	54.62	51.72	33.26	34.10	38.12
Weight of water Ww = $(W_2\text{-}W_3)$	6.01	5.83	3.6	5.15	5.77
Weight of dry soil Wd = $(W_3\text{-}W_1)$	28.4	25.24	14.09	18.84	20.74
Water content W = (Ww/Wd) × 100	11.16	13.09	15.55	17.33	18.82
Dry density of compacted soil d = γt/l + w	16.19	16.69	16.85	15.90	14.93
Dry density of saturation line d = G*γw/l + (WG/S) KN/m^3	16.45	15.93	15.31	14.91	14.80

Advantages and Limitations

Soundings can be used to determine the depth and thickness of subsurface layers, depth to the water table, and bedrock. Profiling can be used to detect and locate contaminant plumes, resistivity values can be used to estimate geological formations (2). Like all geophysical methods resistivity data are ambiguous, meaning that many different "models" can produce the same data. To narrow down the number of possible models, other geological information is needed (borehole and /or monitoring well data). Electrical resistivity is slow because electrodes must be driven into the ground between measurements. Arrays cannot be oriented parallel to buried electrical power lines, utilities and fences since the current injected into the ground will flow more easily through the metal feature. Data are influenced by near surface conductive layers. The current will always travel most easily along highly conductive layers. If the surface is highly conductive it may not be possible to collect data below the top layer (2).

Details of the Site

The site is located about 6 km west of Chikmagalur town. The site is bounded by Indavara village towards southeast, Hukunda village towards south and Narganahalli towards north. It lies near the road which connects Chikmagalur town and Joladalu. The site is connected by a cart track to the main road.

Topography. The site for waste disposal is located on an undulating topography with steep slope towards south and southwest. There is no major drain in the area and it comprises of only first order drainage system, topographically, northern part of the area is about 50 meters higher than the southern part (3).

Climate. The area is situated in Malnad tract. The climate during summer months from March to May is hot. The period from June to October forms the rainy season. The winter (December—February) season is considerably cold. The area enjoys the pleasant climate. The mean temperature during summer season is 25—35 C and mean daily minimum at 19 C. At the end of September, there is slight increase in daily temperature. Later, the weather becomes progressively cooler. January is generally the coldest month with the mean daily maximum at 10—32 C and mean daily minimum at 14.3 C with mean temperature of 14.3 C. Relative humidity is generally high in the southwest monsoon, and the post-monsoon seasons. February and March are driest months of the year when the relative humidity in the after-noon is less than 35%. The winds are in general light with some increase in force during the late monsoon and early monsoon seasons (3).

Rainfall. Chikmagalur town receives an average of 923 mm rainfall annually, with about 65 normal rainy days. About 82% of the annual rainfall occurs during summer monsoon season. Pre-monsoon contributes about 22% and north-east monsoon contribute about 26% of the annual normal rainfall. In all the three seasons the co-efficient of variation is more than 30%. Monthly rainfall pattern indicates that July is the month with highest rainfall (130.82 mm) and June (110 mm) ranking next to it. The months between April to November gets more than 50 mm of rainfall (3)

Geology of the Study Area

The Bababudem schist forms the main lithological unit in the study area, which are represented by

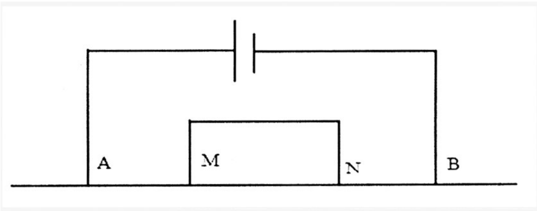

Figure 1. Schlumberger resistivity array.

phyllites and meta-volcanic. A few exposures of these rocks are seen near the western and eastern part of the study area. These rocks show almost east-west trend and dips southerly. They are fine grained and schistose in nature. These rocks are intruded by amphibolites dyke and are well exposed at the north-western part of the study area (3).

Groundwater Occurrence in the Study Area

Groundwater in the area occurs under water table condition. The weathered and jointed schist's forms the main aquifer. The major recharge to groundwater takes place from the atmospheric precipitation. As the area covers under forest land, there were no Ground water structures in and around the study area. However a hydro-geological and topographical study indicates that the depth to water tables in the area range between 20 to 50 meters below ground level (3).

Hydro-Geomorphology of the Study Area

The major geomorphic unit in the area is Pedi plain and dotted with pediment, developed on schistose rock. The depth of weathering is significantly moderate. The ground water potential in these units is found to be moderate. Ground water flow path is towards north to south (3).

Table 8. Permeability test by falling head method.

	Initial head (H_1) cm	Final head (H_2) cm	Time (sec)	Average time (sec)
1	10	30	258	
2	10	30	270	278
3	10	30	308	

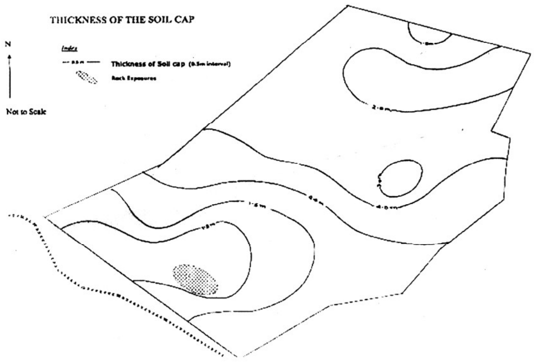

Figure 2. Map of thickness of the soil cap.

Geophysical Investigation

To assess the thickness of the soil cap, weathered zone and depth to bed rock, geophysical investigation has been carried out. The surface geophysical method adopted in the survey in electric resistivity method (2).

The resistivity values are abtained by different surface exploration methods. The one which is used in the present investigation is called vertical electrical soundings (VES) or depth probing. The value would be the true resistivity, provided that the ground is homogenous (2).

The standard Schlumberger configuration as shown in Figure 1 below has been adopted for carrying out the survey and the digital resistivity meter (model—DDR II) used is the one fabricated by IGIS, Hyderabad (2).

Resistivity Survey

The total number of 23 vertical electrical survey (VES) was carried out up to a depth of 50m to get the geo-electrical section of the area (Tables 2 to 9). According to experimental data soil is rich in clay content and hence percolation of leachate is prevented (4).

According to the study conducted the soil type is clayey and impervious in nature. Hence this soil can be used for the disposal of solid waste (5).

The soil type is clayey and impervious in nature, because according to experimental data it has high moisture content (6).

Table 9. Sub-surface geological sections as interpreted from resistivity data.

VES No.	Thickness of soil cap in meters	Thickness of weathered zone in meters	Depth to bed rock in meters	Nature of bed rock
V_1	1.25	15.3	16.55	Hard and massive
V_2	1.60	12.8	14.40	,,
V_3	2.11	10.3	12.41	Moderately fractured
V_4	1.05	08.4	09.54	,,
V_5	1.80	15.3	16.10	,,
V_6	2.49	12,1	14.59	,,
V_7	1.51	10.3	11.81	Hard and massive
V_8	1.60	08.4	10.00	,,
V_9	1.55	07.2	08.75	,,
V_{10}	1.59	15.5	17.09	,,
V_{11}	0.80	16.3	17.10	,,
V_{12}	1.46	08.1	09.56	,,
V_{13}	0.78	07.2	07.98	,,
V_{14}	1.00	21.3	22.30	,,
V_{15}	1.01	25.2	26.21	Moderately fractured
V_{16}	2.57	22.1	24.67	Hard and massive
V_{17}	2.36	15.3	17.66	Moderately fractured
V_{18}	1.99	20.3	22.23	,,
V_{19}	2.03	12.2	14.23	,,
V_{20}	1.92	15.4	17.32	Highly fractured
V_{21}	1.75	10.2	11.95	Moderately fractured
V_{22}	2.34	15.3	17.64	Moderately fractured
V_{23}	2.32	18.3	20.62	Hard and massive

From the test conducted on plastic limit, it was observed that the soil is clayey in nature and hence it can contain more moisture content and good water holding capacity (6).

The sample of soil was analyzed for dry density and a value of 17 KN/m^3 was obtained as compared to the 16KN/m^3 dry density of normal soil. It was observed from experimental study that when maximum dry density increased, it resulted in increased strength of soil and also increased water holding capacity of soil. Hence it can be concluded that water holding capacity of soil is good (7).

According to the experimental data the soil is highly impervious in nature. Hence it does not allow water to percolate through it. This type of soil can be used for the disposal of solid waste (8).

Interpretation of Ves Data

From the interpreted data it is found that the area under investigation represent a typical three layered sections with top soil cover followed by weathered rock and a compacted bed rock (Tables 2—9). By interpreting the vertical electrical sounding data following maps have been generated viz. thickness of the soil cap, thickness of the weathered zone, and depth to bed rock.

The thickness of the soil cap varies from less than 0.78 to 2.57m. The maximum thickness of 2.57m soil is noticed in western part of the study area and minimum of a 0.78m of soil thickness is noticed in the western part. In south-western portion of the area the thickness of the soil is in the range of 0.8 to 2.5 m (Fig. 2).

The thickness of weathered zone range between 7.2 to 25.2m. The maximum thickness of 25.2m of weathered zone is found towards western part of the area and the minimum thickness of 7.2m is observed at the northern portion of the study area. The major part of the study area comprises less than 10m of weathered zone. The depth to bed rock is in the range of 25 to 2m. The depth to bed rock is high as 25m at the north western part of the area and almost compact rock are exposed at the central part of the area.

The nature of the resistivity curves indicates highly fractured bed rock at VES Nos. 20, moderately fractured bed rock at VES Nos. 3,4,5,6,15,17,18,19, 21 and 22 and compact bed rock at VES Nos. 1,2,7 to 14 and 23 (2).

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