Impact of Municipal Solid Waste Dumping on the Geotechnical Properties of Soil and Ground Water in Ariyamangalam, Trichy, India

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ABSTRACT

Management and disposal of municipal solid waste (MSW) is one of the major environmental problems in Indian cities. The current practices of the uncontrolled dumping of waste on the outskirts of towns/cities have created a serious environmental and public health problem. The annual rate of growth of urban population in India is 4% and rate of generation of solid waste increases exponentially with growth rate. Typical landfill of MSW may occupy an area of several acres. Unscientific dumping pollutes the environment to a greater extent and hence it is difficult to find the balance between economic growth and environmental protection. The dumping of municipal solid waste causes changes in the geotechnical properties of the soil and the quality of ground water. The focus of the present study is to carry out a comprehensive laboratory study on soil and water collected from in and around MSW dumping yard in Ariyamangalam, Tiruchirapalli and to investigate the changes in the index properties, compaction characteristics, hydraulic conductivity and shear strength properties of the soil. The results show that dumping has increased the the cohesion and compressibility of the soil, making it more plastic. Co-efficient of volume change, compression index and consolidation co-efficient show a similar trend. Diffusion of organic content into the soil causes the increase in its compressibility. The increase in compressibility is also evident from the increase in liquid limit. This can be attributed to reaction of leachate with the soil. The groundwater is also severely polluted in the vicinity of the dumping yard. This observation of change in geotechnical properties may be useful to carryout land development and water quality assessment activities in order to meet the land requirement in urban areas like Trichy and improving the quality of suburban environment in the vicinity of the dump yard sites.

KEYWORDS: Municipal Solid Waste; Dry Density; Optimum Moisture Content; Shear Strength; Compressibility
INTRODUCTION

Urbanization is rapid in a fast developing nation like India with the exponential rate of increase in magnitude and density of urban population. This unprecedented rise in urban population, results in high generation of solid waste. Collection and disposal of municipal solid waste are one of the key service concerns faced by civic bodies in these rapidly urbanizing cities of India. The quantum of municipal solid waste generated is enormous and keeps increasing every year. Metro cities in India generate about 30,000 tonnes of waste per day and Class I cities about 50,000 tonnes per day. A concise database containing the estimates on the generation and collection of solid waste is seldom maintained. Studies carried out by NEERI indicate that the per capita generation rate increases with the size of the city and varies between 0.3 to 0.6 kg/capita/day. The estimated annual increase in per capita waste quantity is approximately 1.33 % per year. The per capita generation of solid waste for Indian cities is calculated based on the quantity transported per trip and number of trips made per day. The generated municipal solid waste includes residential, commercial, industrial and hospital waste. They constitute both biodegradable and non-biodegradable material like food waste, industrial and commercial plastic, timber, steel, rags and textiles, paper, rubber, leather, etc.

Expanding city lines put enormous pressure on availability of land. In line with this, land utilized for dumping the municipal solid waste is a major concern. The two issues related to the dumping of municipal solid waste are the availability of land for dumping and reclaiming the dumpsite for future development. Limited availability of land encourages the uncontrolled dumping of waste, on the outskirts of the city causing a serious environmental and public health hazard. The quantity of solid waste generated, the scarce availability of land and the pollution caused to the soil and groundwater makes the management of municipal solid waste a major challenge in a dense urban environment. Municipal bodies spend a considerable expenditure on solid waste management in India. In spite of such high budget allocation, level of service provided is often inadequate, bordering on poor. Municipal solid wastes are collected and dumped on soil, with or without liners. Control of contamination in soil and ground water, thereby to a large extent depends on the geotechnical properties of the soil profile in the site where the municipal solid waste is dumped. Many authors have worked on the characterization of municipal solid waste and the groundwater table pollution problems associated with it. But very limited research is done on geotechnical aspects of this problem. This study presents the geotechnical characterization of soil on a dumpsite in Ariyamangalam, Trichy. The groundwater quality is also assessed in the dumpsite and also its vicinity. The study aims to create a (i) comprehensive geotechnical database of the soil, which includes its index and engineering properties (ii) physical and chemical properties of water collected from within and around the dumping yard.

The geotechnical database includes grain size characterization, classification, hydraulic conductivity, compaction and compressibility characteristics and shear strength properties of the soil samples from the site and a control sample at a distance of 1 km from the dump yard. The water database consists of physical and chemical properties of groundwater like odor, color, turbidity, sulphates, alkalinity, dissolved oxygen, hardness, pH, bio-chemical oxygen demand, chemical oxygen demand and total dissolved solids. These properties are used to assess the potential of the dump in contamination of the soil and groundwater.

STUDY AREA

Ariyamangalam earlier situated at the outskirts of the Corporation of Trichy, owing to growth and expansion is now integrated into the city. It is 10 km in the east direction from Trichy. This dumpsite caters to needs of the entire city and its suburbs. It has an area of 47 hectares (Figure 1).
It is being used for more than 20 years and the dumping rate at present is nearly 400 MT/day. There is no treatment done to the municipal waste and the entire quantity of the municipal solid waste have been dumped at this disposal site.

![Location Map](image)

**Figure 1:** Ariyamangalam Municipal Solid Waste Dump Yard

On an average 50 number of trucks collect the waste from various collection points and dump them on the site. There is no liners or segregation of solid waste at present. The municipal solid waste is directly dumped in the soil. The average height of dump is 13 feet. Table 1 gives the details of the dumpsite. This area is surrounded by schools, residences, rice mill and commercial complexes. At present, unit 2 is being dumped and units 1, 3, 4, 5 and 6 are dumped to a maximum height of 20 feet. There is a proposal for segregation of waste in the near future. Figure 2 shows the solid waste dumped at the site.

![MSW dump](image)

**Figure 2:** MSW dump in Ariyamangalam Dump Site
Table 1: Details of Municipal Solid Waste Dump Site, Ariyamangalam

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Description</th>
<th>Ariyamangalam Dump Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Total Area (Acres)</td>
<td>47</td>
</tr>
<tr>
<td>2</td>
<td>Area Filled (Acres)</td>
<td>42</td>
</tr>
<tr>
<td>3</td>
<td>Maximum Height Of Garbage (Feet)</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>Average Height Of Garbage (Feet)</td>
<td>13</td>
</tr>
<tr>
<td>5</td>
<td>Current Rate Of Dumping (Mt/Day)</td>
<td>400</td>
</tr>
<tr>
<td>6</td>
<td>Quantity Of Garbage Dumped Till 2011</td>
<td>12,00,000</td>
</tr>
<tr>
<td>7</td>
<td>Depth Of Groundwater Table (Feet)</td>
<td>19</td>
</tr>
</tbody>
</table>

Composition of Municipal Solid Waste at the Dumpsite, Ariyamangalam

The generated municipal solid waste includes residential, commercial, industrial, institutions (schools, marriage halls, hotels and restaurants, etc.) and hospital wastes. Major part of the solid waste dumped at the site (nearly 57 %) consists of organic waste like kitchen waste from residences, marriage halls hotels, vegetables, fruits and flowers from markets. Others include recyclable waste like plastic, wood, paper, hospital waste like syringes, tissues, soiled cotton and toxic waste like pesticides, chemicals, bulbs, spray cans, etc. Toxic wastes constitute nearly 23 % of the total dumped waste. Figure 3 shows the breakup of the physical composition of the waste dumped at Ariyamangalam. The biodegradable fraction is high as in any Indian MSW. The high biodegradable fraction combined with the tropical climate warrants frequent collection and removal of refuse from the collection points.
Organic waste: kitchen waste, vegetables, flowers, leaves, fruits.
Toxic waste: old medicines, paints, chemicals, bulbs, spray cans, fertilizer and pesticide containers, batteries, shoe polish.
Recyclable waste: paper, glass, metals, plastics.
Soiled waste: hospital waste such as cloth soiled with blood, bottles, syringes, needles, etc.

**Figure 3:** Composition of MSW dumped at Ariyamangalam Site

The ash and fine earth content of Indian MSW is high due to inclusion of street sweepings; drain silt, construction and demolition debris. This proportion also decreases with increase in population and improvement in infrastructure like better roads.

Dumping of municipal solid waste alters the geotechnical properties of the soil in the dumpsite and the quality of the groundwater. A study of these properties is vital for the management of the dump yard and also during the reclamation of the site. Lavanda and Clark (1990) as effective stress increases due to increasing burial depth, the change in void ratio and compression of waste components may lead to an increase in unit weight. Their study was to measure the hydraulic conductivity of waste as a function of unit weight. Nanda et al. (2011) investigated the effect of leachate on the soil below the landfill with respect to pH, Optimum Moisture Content, Maximum Dry Density and Unconfined Compressive Strength properties. MSW wastes were characterized, then soil samples were tested for the various properties. To determine the contamination of soil at various depths and at various points, disturbed samples were obtained at different depths both within and outside the site. They concluded that the change in the Geotechnical properties of the soil differs with the increase in depth since the effect of leachate, number of years of dumping of MSW, height of MSW dumped and the type of materials dumped is the main reasons. Musa Alhassan (2012) studied the effects of municipal solid waste on the geotechnical properties of soils. Soil samples taken from three trial pits at depths of 0.5, 1.0 and 1.5 m, were used for the investigation. Two of the trial pits were located around the studied dump site to serve as control points or uncontaminated soil, while the third trial pit was located within the dump site to serve as contaminated soil. Soil samples collected were subjected to specific gravity, natural moisture content, particle size analysis, consistency, compaction, permeability, triaxial and consolidation tests. The results of the investigation show that Municipal Solid Waste (MSW) lowers the specific gravity, increases the natural moisture content, increases the fine particle content, lowers the maximum dry density with higher optimum moisture content, lowers both the cohesion and the angle of internal friction, increases the coefficient of
permeability, coefficient of consolidation and coefficient of volume compressibility of the soil. These effects reduced with depth. Anita Agrawal et al. (2011) in their study characterized leachate and groundwater samples are tested. The study area was taken for MSW dumps of Raipur town. It is finalized that the groundwater below the MSW dump site is highly contaminated due to leachate when compared to the groundwater samples taken from around the site.

MATERIALS AND METHODS

Experiments are conducted to study the index and engineering behavior of the soil and contaminate in the groundwater in and around the municipal solid waste dump yard. Seven soil samples and four water samples are collected from different locations for the study.

Sampling

Soil

Soil samples are collected at a depth of 1 m below ground surface from six different locations inside the Ariyamangalam dumping yard and are designated as Sample 1, Sample 2, Sample 3, Sample 4, Sample 5 and Sample 6 by excavating the ground surface. The decomposed soil - solid waste which was dumped more than 15 years ago were collected from locations 1, 3, 4, 5, and 6. Sample 2 is obtained from the area that is dumped at present. Control sample at 1 km from the dumping yard is collected in the same manner.

Water

The water samples were collected from the open well behind the solid waste dump. This site is used to dump municipal solid waste for more than 15 years and hence it is highly polluted making it unsuitable for domestic purposes. Groundwater samples 1, 2 and 3 are collected from open wells having water level at about 19 feet from ground level and groundwater sample 4 is from a bore well whose depth is about 120 feet below ground level. Three control samples have been collected from outside the dump site, at 0.5 km, 1 km and 2 km from the dump site.

METHODOLOGY

Soil

Various laboratory tests were performed as per Indian Standard Specifications to determine the index and engineering properties of the soil.

Index Properties

i. A specific gravity test was conducted using specific gravity bottle as per IS: 2720-1980 for the municipal solid waste used in this study. Specific gravity values reported are an average of six tests.

ii. Grain size distribution analysis was performed by dry sieve analysis (IS: 2720 Part 4 - 1985)

iii. Liquid limit of the soil sample was determined by the Casagrande apparatus as per IS: 2720 Part 5 - 1985. The soil sample is sieved through 425 micron IS sieve and tested. Plastic limit of the soil was conducted by standard method (IS: 2720 Part 5-1985). The plastic limit values reported is an average of three determinations.
iv. Organic content in the soil is found using Loss on Ignition method at 105° C and 360° C.

Compressibility Characteristics

Compaction test was carried out for the sample with various percentages of water to obtain the optimum moisture content by standard method as per IS: 2720 Part 7 -1992. The compressibility testing was carried out using consolidometer (IS: 2720 Part 15 – 1992) to determine the compressibility characteristics of the collected samples. Various consolidation parameters viz. Coefficient of compressibility, coefficient of volume compressibility, coefficient of consolidation, compression index, coefficient of settlement and swelling index were determined.

Shear Strength Parameters

Direct shear test was conducted to determine the shear strength parameters of the collected samples. Tests were performed in accordance with IS: 2720 Part 13 - 1986.

Water

Various Physical and chemical properties of the water were tested. Physical properties include smell, odor, color and turbidity. The chemical properties include pH, sulphates, alkalinity, dissolved oxygen, hardness, total solids, biochemical oxygen demand and chemical oxygen demand.

RESULTS AND DISCUSSION

The results of the experiments carried out on the soil and water samples collected from in and around the municipal solid waste dumping yard at Ariyamangalam is presented and discussed.

Index Properties

The samples obtained from the dump yard were dark brown gray in color with a pungent odor. To characterize the samples collected from the MSW dumping yard and the control sample, index properties like specific gravity test, grain size distribution and consistency limit tests were conducted. The results are presented in the following sections.

Organic Content

The organic content values of the soil samples 1, 2 and 3 collected from the site ranges from 40.88% to 60.17% and that for the control sample collected at a distance of 1km is 23.84%. This infers that the soil below the dump site has high organic content due to the seepage of leachate when compared to the control sample.

Specific Gravity

MSW has high organic content and there is a possibility of MSW containing soluble salts. Waste materials with grain size larger than 4.75 mm were removed prior to testing. The specific gravity of the dump site samples ranged from 1.84 to 2.38 and that for the check sample was 2.65. The specific gravity of soil in the dump site is relatively low and greatly discrete because of higher organic content when compared to the control sample.
Grain Size Distribution

The grain size distribution analysis was performed by dry sieving. The samples from the MSW dump site contain gravel size fraction of 1% to 15.8%, coarse sand fraction ranging from 21.4% to 35%, sand ranging from 14% to 19.6%, fine sand ranging from 31.6% to 50.8% and fine contents ranging from 3.6% to 8.4%. The control sample contains gravel size fraction 3%, coarse sand fraction 34.4%, medium sand fraction 19.4%, fine sand fraction 38% and fine contents 5.2%. The figure 4 shows the grain size distribution curve for the samples.

Figure 4: Grain Size Distribution

Consistency Limits

The liquid limit of the dump site samples 1 to 6 varies from 20% to 30% and all the samples exhibited non-plastic behavior. The liquid limit value of the control sample is 15% showing less compressibility than that of the samples obtained from the dump yard. The plasticity index also shows a similar trend – the control sample is low plastic while the samples collected from the dump yard fall in the moderate plastic category. This shows that dumping has increased the plasticity of soils.

Soil Classification

As per IS soil classification system samples from 1 to 6 collected from the dump yard and the control sample are classified as silty sand (SM). The samples contain less than 12 % fines which are non-plastic in nature. Dumping has increased the plasticity of the silt. Table 2 shows the index properties and classification of the samples collected from the dump site and the control sample.

Table 2: Index Properties of Soil Samples (continues on the next page)

<table>
<thead>
<tr>
<th>Tests</th>
<th>Control Sample</th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Sample 3</th>
<th>Sample 4</th>
<th>Sample 5</th>
<th>Sample 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPECIFIC GRAVITY</td>
<td>2.22</td>
<td>2.09</td>
<td>2.19</td>
<td>2.38</td>
<td>1.84</td>
<td>2.24</td>
<td>2.13</td>
</tr>
<tr>
<td>GRAVEL (%)</td>
<td>3</td>
<td>15.8</td>
<td>15.2</td>
<td>1</td>
<td>2</td>
<td>6.4</td>
<td>11</td>
</tr>
<tr>
<td>COARSE SAND (%)</td>
<td>34.4</td>
<td>32.2</td>
<td>35</td>
<td>21.4</td>
<td>33.6</td>
<td>27</td>
<td>35</td>
</tr>
</tbody>
</table>

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### Compaction Characteristics

The soil sample collected from MSW dumping yard and the control sample is compacted using standard proctor compaction test. The maximum dry density of the MSW dump site samples tested varies from 17.5 kN/m³ to 19.5 kN/m³ and optimum moisture content varies from 14.28 % to 16.66 % whereas the maximum dry density of the control sample is 19.8 kN/m³ and the optimum moisture content for the same is 13.95 %. Figure 5 shows the compaction characteristics of the various samples collected. It is observed that the samples collected from the dump site have maximum dry density at higher optimum moisture content, the compaction curves thereby shift towards the right. This indicates the soil structure changes from flocculated to dispersed and soil has increased permeability, lower shear strength at higher strain.

![Compaction Characteristics of Soil Samples](image)

**Figure 5:** Compaction Characteristics of Soil Samples
Strength Characteristics

In assessing the stability of the landfills, assessment of the strength parameters is essential. Hence it was planned to assess the strength characteristics of soil samples collected from the MSW dumping yard and the control sample by conducting the direct shear test in the laboratory. Direct shear tests were conducted to determine the shear strength parameters i.e. cohesion and the angle of internal friction of Ariyamangalam MSW solid waste soil sample and the control sample taken at a distance of 1 km from the dump site. It is observed that the cohesion of samples 1 to 6 ranges between 25 kN/m² to 75 kN/m² and that for the control sample is 15 kN/m². The angle of internal friction of the samples taken from within the site ranges from 11°18′ to 30°27′ and that for the control sample is 38°27′.

The angle of internal friction of the soil sample collected from the Ariyamangalam dumping yard is lower than that of the control sample obtained outside the MSW dump site. Further the cohesion of the samples studied in the present work is also higher than that of the control sample. The study indicates that the shearing strength parameters are significantly modified as an effect of dumping. There is an increase in cohesion and decrease in angle of internal friction, indicating the increase in plasticity of the soil samples collected in the dump yard. Table 3 shows the strength characteristics of the soil samples from the dump site and the control sample.

### Table 3: Effect of Dumping on Shear Strength Parameters of Soil

<table>
<thead>
<tr>
<th>Direct Shear Test</th>
<th>Control Sample</th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Sample 3</th>
<th>Sample 4</th>
<th>Sample 5</th>
<th>Sample 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cohesion (c) (kN/m²)</td>
<td>15</td>
<td>75</td>
<td>50</td>
<td>70</td>
<td>70</td>
<td>60</td>
<td>25</td>
</tr>
<tr>
<td>Angle of Internal Friction (φ)</td>
<td>38°27′</td>
<td>11°18′</td>
<td>26°33′</td>
<td>23°11′</td>
<td>22°14′</td>
<td>25°27′</td>
<td>30°27′</td>
</tr>
</tbody>
</table>

Permeability

Soil samples were compacted at their respective maximum dry density and optimum moisture content in permeability mold. Thus prepared samples are allowed for saturation. Then the coefficient of permeability of the samples was obtained and reported in the table 4. The results suggested that the coefficient of permeability ranged from $2.11 \times 10^{-5}$ cm/sec to $3.15 \times 10^{-5}$ cm/sec and that for the control sample is $4.44 \times 10^{-4}$ cm/s. There is a marked decrease in the permeability of the soil samples, which is consistent with the results of the compaction test. For fine sands, silts, mixtures comprising sands, silt and clays the coefficient of permeability usually ranges from $10^{-3}$ to $10^{-7}$ cm/sec. The permeability value of samples used in the present study is comparable with this reported value. Table 4 shows the permeability values of the samples collected.
### Table 4: Coefficient of Permeability

<table>
<thead>
<tr>
<th>Description</th>
<th>Control Sample</th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Sample 3</th>
<th>Sample 4</th>
<th>Sample 5</th>
<th>Sample 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficient of Permeability (cm/sec)</td>
<td>4.44×10⁻⁴</td>
<td>3.02×10⁻⁵</td>
<td>2.28×10⁻⁵</td>
<td>2.72×10⁻⁵</td>
<td>2.3×10⁻⁵</td>
<td>2.11×10⁻⁵</td>
<td>3.15×10⁻⁵</td>
</tr>
</tbody>
</table>

### Consolidation Characteristics

It is a common practice to evaluate the compressibility of soil by employing the theory of one dimensional consolidation. Under increase of load in a layer of soil, under an existing effective stress, the settlement is calculated using the equation derived from Terzaghi’s theory of one dimensional consolidation. Hence, consolidation test was carried out on samples collected from the MSW dumping yard.

The soil samples have been compacted at its maximum dry unit weight and optimum moisture content in consolidation ring and then consolidation test was conducted. Figure 6 plots the e-log p curve for samples 1, 2, 3, and control sample. The shape of the compression curve is similar to that for normally consolidated soils. The compression index is calculated from the slope of loading curve and swelling index is calculated from unloading curve. The compression index and swelling index values of the samples are given in Table 5.

![Figure 6: e – log p curve](image-url)
Table 5: Consolidation Characteristics

<table>
<thead>
<tr>
<th>Description</th>
<th>Control Sample</th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Sample 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficient of compressibility $a_v$</td>
<td>$1.1 \times 10^{-3}$</td>
<td>$1.6 \times 10^{-3}$</td>
<td>$3.5 \times 10^{-3}$</td>
<td>$4.5 \times 10^{-3}$</td>
</tr>
<tr>
<td>Coefficient of volume compressibility $m_v$</td>
<td>$0.521 \times 10^{-3}$</td>
<td>$0.727 \times 10^{-3}$</td>
<td>$1.429 \times 10^{-3}$</td>
<td>$1.91 \times 10^{-3}$</td>
</tr>
<tr>
<td>Compression Index $C_c$</td>
<td>0.298</td>
<td>0.432</td>
<td>0.951</td>
<td>1.22</td>
</tr>
<tr>
<td>Coefficient of consolidation $C_v$</td>
<td>$8.687 \times 10^{-2}$</td>
<td>$4.238 \times 10^{-3}$</td>
<td>$1.629 \times 10^{-3}$</td>
<td>$1.450 \times 10^{-3}$</td>
</tr>
<tr>
<td>Consolidation Settlement $S_c$</td>
<td>0.782</td>
<td>1.091</td>
<td>2.143</td>
<td>2.865</td>
</tr>
<tr>
<td>Swelling Index $C_s$</td>
<td>5.916</td>
<td>5.678</td>
<td>6.93</td>
<td>6.934</td>
</tr>
</tbody>
</table>

The compression index value of samples 1 to 3 ranges from 0.43 to 1.22 and that of the control sample is 0.298. Swell index for the samples from the dump site ranges from 5.67 to 6.93 and that for the control sample is 5.91. There is an increase in the compressibility of the soil samples due to dumping as observed from table 5. Co-efficient of consolidation decreased by 97.19% and the settlement increased by 61.5%. The swell index has also increased by 9.18%. There is a steep increase in the compression index also.

Water Quality Analysis

To assess the quality of water, tests for physical and chemical properties were conducted and results are discussed. The physical properties of the water collected from the dump site have a moderate fishy odor and that of the control samples at 1 km and 2 km is nil. The odor of the control sample of 0.5 km from the dump site has a mild fishy odor. The color of the ground water is light yellow for sample 1 (collected from the dump yard) and the samples 2, 3 and 4 are colorless. Control samples taken at 0.5 km, 1 km and 2 km, the water was colorless.

Various tests for the chemical properties and their results shown in table 6 infer that the groundwater below the dump site is not potable up to 2km. Sulphates, alkalinity, hardness, COD and BOD do not fall within the desirable limits up to 0.5 km from the dumping yard and as the distance increases the sulphates and alkalinity falls within the desirable limits but hardness, COD and BOD values are high up to 2 km from the dumping yard making the water unsuitable for drinking purposes. This indicates that the pollution due to the MSW dump extends upto 2 km from the dump site. Table 6 shows the results of the water analysis. There are no traces of heavy metals in the water.

The results of the water analysis show that the water the pollution caused by contamination due to dumping is very high within a radius of 0.5 km from the dumping yard. The water sample taken at 0.5 km from the dump site is not potable as the values of chemical properties do not fall within the desirable limits according to ICMR standards for potable water. This is significant as the dumping yard is surrounded with low income communities in its immediate vicinity. Parameters like hardness, COD and BOD continue to show undesirable limits even up to 2 km from the site.
Table 6: Results of Water Analysis for Samples Collected

<table>
<thead>
<tr>
<th>TESTS</th>
<th>CONTROL SAMPLE 1</th>
<th>CONTROL SAMPLE 2</th>
<th>SAMPLE 1</th>
<th>SAMPLE 2</th>
<th>SAMPLE 3</th>
<th>SAMPLE 4</th>
<th>LIMITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphates (mg/l)</td>
<td>198.343</td>
<td>179.619</td>
<td>1011.67</td>
<td>917.85</td>
<td>825.4</td>
<td>799.95</td>
<td>desirable limit 150 to 400 (mg/l)</td>
</tr>
<tr>
<td>Alkalinity - bicarbonate alkalinity</td>
<td>86</td>
<td>78</td>
<td>135</td>
<td>110</td>
<td>45</td>
<td>50</td>
<td>desirable limit up to 100 (mg/l)</td>
</tr>
<tr>
<td>Dissolved Oxygen (mg/l)</td>
<td>4.3</td>
<td>5.2</td>
<td>5.8</td>
<td>5</td>
<td>1.3</td>
<td>4.8</td>
<td>desirable limit 4 to 6 (mg/l)</td>
</tr>
<tr>
<td>Hardness (mg/l)</td>
<td>341</td>
<td>467</td>
<td>290</td>
<td>280</td>
<td>255</td>
<td>285</td>
<td>desirable limit 300 to 600 (mg/l)</td>
</tr>
<tr>
<td>pH</td>
<td>7</td>
<td>7.6</td>
<td>6.18</td>
<td>6.29</td>
<td>6.24</td>
<td>6.28</td>
<td>desirable limit 6.5 to 8.5</td>
</tr>
<tr>
<td>Turbidity (JTU)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>desirable limit 0 to 5 JTU</td>
</tr>
<tr>
<td>BOD</td>
<td>2.1</td>
<td>2</td>
<td>39</td>
<td>27</td>
<td>42.7</td>
<td>18.8</td>
<td></td>
</tr>
<tr>
<td>COD</td>
<td>4</td>
<td>3.7</td>
<td>23</td>
<td>64</td>
<td>61</td>
<td>58</td>
<td></td>
</tr>
<tr>
<td>Total Dissolved Solids</td>
<td>427</td>
<td>459</td>
<td>391</td>
<td>399</td>
<td>405</td>
<td>389</td>
<td>desirable limit up to 500 mg/l</td>
</tr>
</tbody>
</table>

CONCLUSION

Experiments were conducted to characterize their index properties, compaction characteristics, strength characteristics and permeability characteristics of soil. The following conclusion has been arrived based on the experimental work on municipal solid waste collected from the Ariyamangalam dumping yard, Trichy.

- The specific gravity of the samples is slightly lower than that of the control sample showing the presence of organic content in the soil.
- As per IS classification system, the samples are classified as sandy silt (SM). But it is observed that dumping has increased the plasticity in the soils.
- Dumping has caused the compaction curves to shift towards the right (i.e) maximum dry density increased with the increase in optimum moisture content. This is consistent with the increase in plasticity of the samples.
- The permeability value of the samples shows that the samples have organic silts of low plasticity.
- The compressibility of the samples shows a significant increase with an increase in swell index and consolidation settlement.
The behavior of the samples studied can be attributed to the effect of leachate on soil from the municipal solid waste.

- Contamination of ground water is severe up to 0.5 km from the dumping yard.
- Hardness, COD and BOD fall out of desirable limits up to 2 km. Organic content in the water is very high up to 2 km.

REFERENCES


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