SOIL SUITABILITY FOR SOLID WASTE DUMPING: IMPLICATION FOR GROUNDWATER PROTECTION

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ABSTRACT

Anthropogenic activities in Urban cities of developing countries has resulted soil pollution and groundwater contamination. Therefore the objective of this paper is test suitability of soil for solid waste dumping based on Physio-chemical parameters and textural analysis of soil around periphery of Davanagere Urban city.The city experiences semi-arid climate with a moderate rainfall located in Central Karnataka, India. Textural analysis indicated that soil is silt loam with moderate high permeability (10^{-3} to 10^{-4} cm/sec).The collected soil sample terminate slightly less in Liquid Limit and more in Plastic Limit (Liquid Limit>50% and Plastic Limit<30%). Soil suitability index was computed based on ratings allotted for each soil parameter and site suitable for solid waste dumping is determined. The study indicates that the soil has neutral pH and moderately high permeabilityand hence groundwater protection works to be taken up for sites selected based on soil suitability index.

KEYWORDS

Solid waste dumping, Soil parameters, Soil texture, Soil Suitability Index

1. INTRODUCTION

Solid Waste Management (SWM) is a major challenge all over the globe especially in urban cities [1]and open dumping is the common practice for final disposal of Municipal Solid Waste (MSW) inIndia. In developing countries, the majority of inhabitants in most towns of India often use unsafe solid waste disposal practices, such as open dumping, burning and burying [2]. Erratic dumping of these wastes has posed complex environmental problems like soil and groundwater contamination. Several environmental pollution and soil degradation problems were found as a consequence of poor planning of landfills that includes the three stages namely collection, disposal and material recovery [3].

Urban sprawls in cities have posed a difficult task for collecting waste from neighbourhood in India and Latin American cities [3]. The major factors affecting are industrialization resulting in increase in projected population growth and rapid technology development and the direct impact of these being on water supply and sewage planning, electricity, transportation /and solid waste disposal [2]. Solid waste management in further aggravated owing to overgrowth rate from 0.9 to 1.5% than the predicted population in urban cities of India.

Moreover, optimized siting decisions have gained considerable importance under smart city development schemes, in order to ensure minimum damage to the various environmental subcomponents as well as reduce the stigma associated with the residents living in its vicinity, thereby enhancing the overall sustainability associated with the life cycle of a landfill.

The disposal of solid waste on site necessitates knowledge on the soil characteristics, vegetation[4]. Soil is an interface for precipitation incident, surface runoff and infiltration. Soil acts as a media to interflow of water/leachate into ground water[5;6]. If soil have high porous, interflow is more and ground water contamination is more and also leachate will spread in subsurface of soil strata will effect on surrounding agriculture land/soil [7;8]. The soil quality is poor, land will not use as agricultural land rather than favour for solid waste disposal site. So that soil play an important role while selecting the site for disposal of solid waste. Soil is one of the important natural resource, contains different type of nutrients, minerals, metals etc[9;10]. Those are influence to plant growth and crop production. Formation of 0.01m of soil layer takes 100-400years.The Physio-chemical parameters of soil are very important for soil management, plant growth and site suitability [9]. It is an important part of biosphere where the living organism are survival. Heavy metal contamination in the soil and further leaching has degraded the soil and ground water quality [10]. The soil has capacity to percolate liquid, in that some part of liquid will reaches to ground water. If liquid contains strong contaminants will cause ground water contamination. Deep percolation of Leachate in larger quantities will result in unsuitable aquifer resources for irrigation, commercial and residential purpose [11]. Therefore, the objective of present work is soil suitability for solid waste dumping in order to protect ground water contamination.

2. STUDY AREA

Davanagere, the sixth largest city and the Manchester of Karnataka state, is located at the centre of the Karnataka as shown in fig 4. The latitude of davanagere is 14.28^0 and longitude is 75.59^0 and 602.5m above sea level. It has the population of 4.35 lakh and covers an area of 77 sq.km as per 2001census (Table 1) and is identified for smart city development under the Ministry of Housing and Urban affair, Government of India. The generation of solid waste is 0.244kg/day as shown in table 1 & 138TPD from 41wards of Davanagere Municipal Corporation.

Table 1: Population and solid waste Statistics in Davanagere city, Karnataka, India

City	population 2001	Per-capita waste generation (kg/day) 2001	Increased population 2011	Per-capita waste generation (kg/day)2011	Percentage increases in population
Davanagere	364523	0.214	480441	0.244	1.19

Source: Population census and KPCB by state Karnataka 2001-2011.

Climate: The Urban Davanagere a semiarid climate. It is influenced by local steppe climate. The average temperature of Davanagere is 25.7^0 C, high temperature in Davanagere is 36^0 C and low temperature is 16^0 C. The humidity of Davanagere is 65%.

Rainfall: The average annual Rainfall of Davanagere is 765.4mm (per year).

Water resources: The south and western parts of the Davanagere district are irrigated by Bhadra reservoir and 2^{nd}largest irrigation tank called Shanti Sagar which is major source of water.

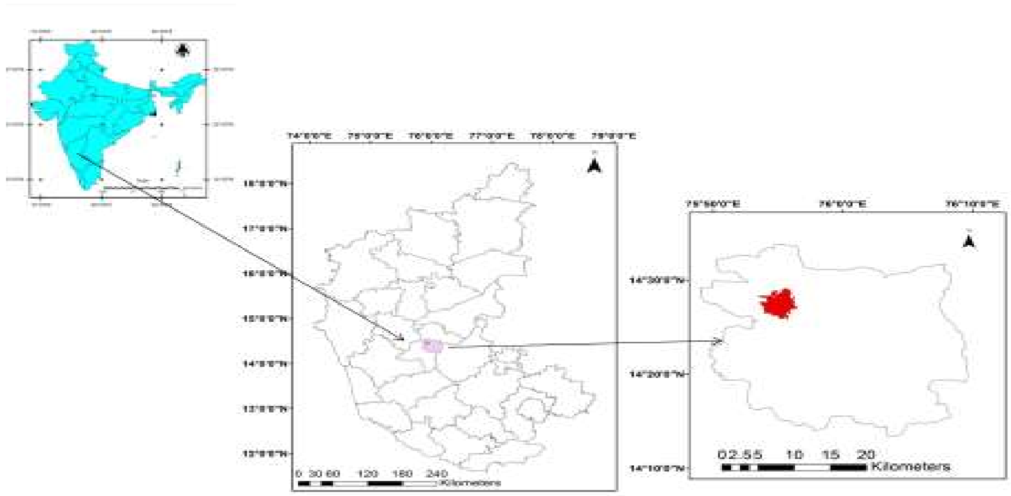

Figure 1: Map showing the Study area of Davanagere, Karnataka, India

2.1 SOIL SAMPLING

The solid waste dumps at periphery of the city for suitability of solid waste disposal, soil analysis is carried out by collecting the soil sample around Davanagere city and location of collected soil sample as shown in fig(2).

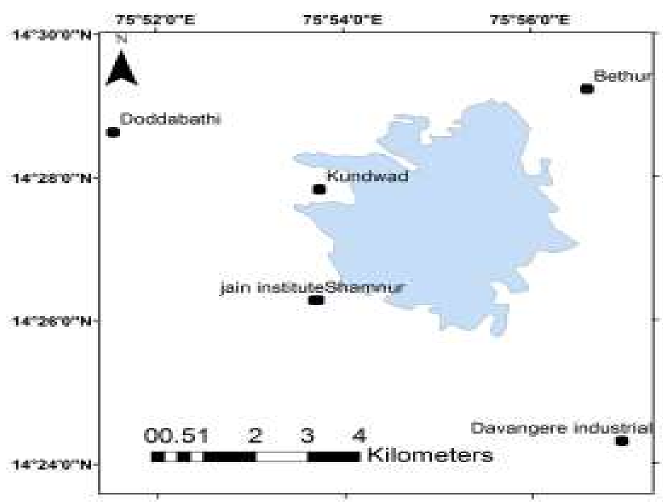

Figure 2: The location of soil sample collected around Davanagere, Karnataka, India.

The collection of soil sample is done by standard method. Core cutter method of soil sample collection is used. A core cutter consist of a steel cutter, 10cm diameter, 13cm height, 2.5cm high dolly is driven in the cleaned surface with the help of rammer, till 1cm of dolly protrudes above the surface. The core cutter containing the soil, is dug out from ground. The dolly is removed and the excess soil is trimmed off. Then taken that soil into laboratory for conducting the test. Six soil samples were collected from different places and test were Conducted on soil. The textural analysis on soil is carried out and physiochemical parameters of soil are moisture content, pH, Organic Matter, Electrical Conductivity Potassium, Nitrogen, Permeability, Phosphorus and Field Density were computed for soil suitability.

3. MATERIALS AND METHODOLOGY:

The process flow chart of soil analysis is as shown in Fig 1.The primary step is to select the location of soil sample based on soil texture and land use. The collection soil sample around periphery of Davanagere city. The samples are collected in polythene bags and made tight cover without air passing into the bags. After collection of soil sample, soil parameters are assigned.

By using standard methods, the experiment are conducted on collected soil sample. Analysis of soil is carried out for the study of various soil parameters like Moisture content, pH, Organic matter, Electrical Conductivity, potassium, Nitrogen, Permeability and Field density. The methods used to know the quality of collected samples are as follow: For Moisture content of collected soil sample is by oven dry method, pH is done by Potentiometric method, Organic matter by Walkley and Black method, Electrical conductivity by Electrical conductivity method, Potassium by Flame photometer method, Phosphorous by Bray's method, Nitrogen by Alkaline Potassium permanganate method, Permeability by Variable head method, Field density by core cutter method.

Based on physiochemical soil parameters, we got quality of soil. The Quality Rank Rating (QRR) are given to each parameter based on land use activity like agriculture and those values decide whether soil is suitable for dumping solid waste. QRR six is defined as area unsuitable for agriculture and suitable for a landfill site. QRR one is defined as unsuitable area of land fill site. The cumulative factor of QRR gives SSI (Soil Suitability Index) values by using formulae (1) and that will decide which soil is suitable for solid waste disposal.

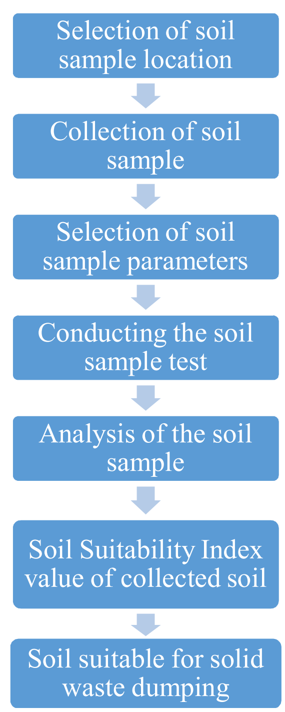

Figure 1. Soil suitability analysis for solid waste dumping

4. RESULT AND DISCUSSION

4.1 SOIL CHARACTERISTICS

Soil characteristics is a basic input for identification of solid waste dumping site. Soil acts as a media to interflow of water/leachate into ground water. If the soil have high porous the interflow is more and ground water contamination is more and also the leachate will spread; that affects the soil quality. Experimental results obtained on the characteristics of soil presented in Table 2 and 3. Each of these soil conditions has distinct characteristics that can be observed in the field.

4.2 SOIL TEXTURAL CHARACTERISTICS

The textural characteristics of soil sample collected around Davanagere is presented in table 2. Soil quality based on unsuitability for agricultural purposes and that site is considered as solid waste disposal site. From the study it was observed that the soil quality varied in different locations.

Table 2. Soil textural characteristics of the soil sample collected near Davanagere, Karnataka

Sl no	Place	Lat	Long	LL	PL	%Sand	%Silt	%Clay	Soil classification
1	Bethur	14.487	75.943	50.56	46.94	17	74	9	SL
2	Shamnur	14..438	75.895	48.88	43.23	12	77	11	SL
3	Davanagere industrial area	14.405	75.949	31.21	28.03	10	77	13	SL
4	Dodd Bathi	14.777	75.859	40.03	38.20	16	74	10	SL
5	Kundvad	14.463	75.896	29.19	26.79	18.5	76	5.6	SL
6	Near Jain institute of technology	14.438	75.895	38.66	36.29	12	78	10	SL

***Note**:SL- Silty loam*

The grain size of the particles are encountered by hydrometer test. Hydrometer analysis is based on stock's law which defines the rate of free fall of a sphere through a liquid. It is a sedimentation analysis method. By plotting diameter of the particles and percentage of fine on a logarithematic scale and obtain particle size distribution curve of collected soil sample around periphery ofDavanagere city as shown in fig 3. Obtain a result of percentage of silt, clay, and sand. The soil classification of variety of soil is based on Particle size distribution is known as textural classification[12]. The purpose of soil classification is to arrange various types of soil into group based on engineering point of view or agricultural or characteristics of soil. The soil classification is based on grain size-IS 1948-1970, soil particles below 0.002mm are considered as clay size, between 0.002-0.075 are silt size and above 0.075mm are considered as sand particles.By plotting percentage of silt, sand and clay in USDA soil textural triangle, obtained type of soil.

The textural analysis of soil indicates, if soils have larger portion of sand content indicating that leachate can percolate deeper and has a high risk for ground water contamination[13]. The uncontaminated soil is relatively uniform and contaminated soil has more fines than the uncontaminated soil. The high percentage of fine content for contaminated soil quality is from emanating the decomposed MSW above the soil. During bacterial degradation or decomposition of municipal solid waste large amount of fines are produced.

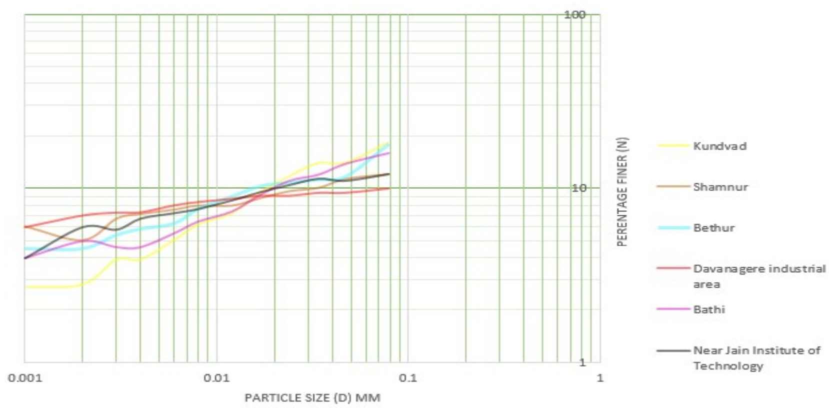

Figure. 3 Particle size distribution curve of collected soil around, Davanagere, Karnataka

The Davanagere area covers Silt loam type of soil with different sand, silt, clay content in soil as shown in tab 2. The soil of bethur, kundvad, davanagere industrial area, near Jain institute of technology, Dodd Bathi, Shamnur area covers silt loam type of soil and is suitable for landfill. Silt loam is a type of soil containing large amount of silt with small amount of clay and sand. It is composed of 2/3 $^{rd.}$ of silt, with remaining are split up as sand and clay.Itis a sub division of loam soil. The plant growing in a Silty loam soil need great amount of water compared to sandy soil. It is easily identified, plant does not grow well in Silty loam. The bamboo, grass, ferns, berry bushes are grown in Silty loam soil [14]. In this soil, silt is more dominated where the soil is deposited by erosion with large quantity of loose soil. The liquid limit is ranged between 29.19 to 50.56% and plastic limit from and plastic limit is ranged from 26.79 to 46.94%. The limitation of liquid limit is greater than 50% and plastic limit is less than 30%. The liquid limit decreases with increasing leachate concentration [14]. This may be due to the presence of salts in the leachate. It has been noticed that presence of calcium ion can decrease the liquid limit of soil. The plastic limit of the soil sample showed an increasing trend upon addition of leachate. The variation in plastic limit may be due to the effect of increasing concentration of contaminants in the soil [14].

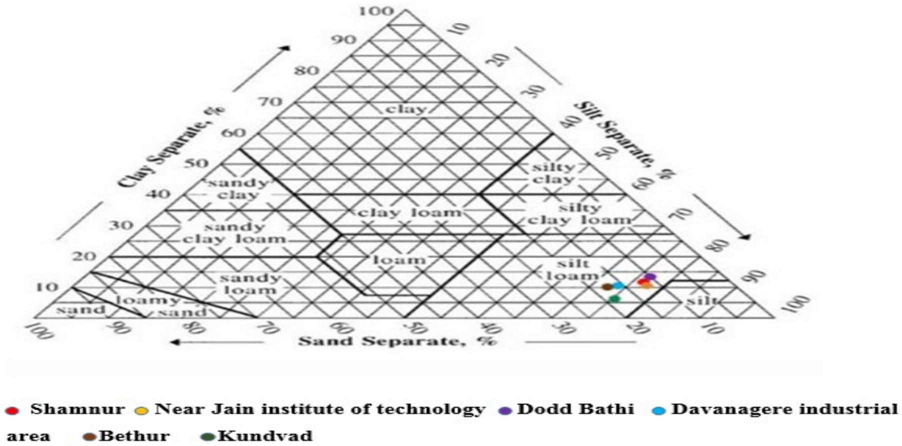

Figure 4. Soil texture classification of collected soil sample, Davanagere, Karnataka.

4.3 PHYSIOCHEMICAL PARAMETERS

The soil characterization was carried out for parameters like moisture content, pH, Organic Matter, Electrical Conductivity, Potassium, Phosphorous, Field density, Nitrogen content, Potassium and Permeability of soil. The Physio-chemical study of territory is very significant because both physical and chemical properties which bear upon soil productivity. The Physio-chemical parameter are shown in table 3.

Table 3. Physiochemical parameters of the soil samples collected near Davanagere, Karnataka, India

Sl no	Place	MC %	pH	OM %	EC dS/m	K Kg/ha	P Kg/ac	FD Gms/cm³	N Kg/ac	k Cm/sec
1	Bethur	16.34	6.34	0.72	0.56	183.68	11.27	1.81	64.51	0.00028
2	Shamnur	13.21	6.26	0.765	0.59	79.92	22.98	1.75	68.54	0.00049
3	Davanagere industrial area	7.71	6.14	0.36	0.44	93.2	10.39	1.93	32.25	0.00041
4	Dodd Bathi	19.3	7.04	0.12	1.86	78.48	36.69	1.99	10.75	0.00059
5	Kundvad	9.24	6.58	0.18	0.3	96.36	6.19	2.1	16.12	0.00474
6	Near Jain institute of technology	15.13	6.39	0.36	3	244.64	31.92	1.50	77.95	0.00094

Note: MC-Moisture content, OM-organic matter, EC- Electrical conductivity, K- Potassium, FD Field density, N- Nitrogen, k- Permeability, P- Phosphorus.

4.3.1 MOISTURE CONTENT (MC)

Moisture content of soil is the percentage of water content present in the soil. It is ratio of mass of free water in collected soil to the mass of dry soil sample [15;16]. It is varies from 7.71 to 19.30% for the samples collected (Table.3). The moisture content of soil should be less than 20%. If not, increase in the gas production and leachate formation takes place. Due to increase in leachate formation ground water contamination is also more [17;18]. All the collected soil sample shows moisture content is within the limit. Davanagere industrial area shows maximum QRR value of 6 which is unsuitable for crop production and suitable for solid waste disposals.

4.3.2 PH

pH decides the amount of hydrogen present in the soil sample and ranges from 0-14. Low pH indicates sour of soil [19;20]. High pH is salty soil. The pH of collected soil samples ranges from 6.14-7.04 (Table 3).The soil pH should be within the limits of 6-8.5. Leachate is acidic in nature and will reduce the soil pH [21]. Therefore soil pH less than 8.5 are suitable for solid waste dumping.

4.3.3 ORGANIC MATTER (OM)

Organic matter of the soil includes animal and plant waste with rate of decomposition [22;23]. It is ranged between 0.12-0.76percent.Its limitation is less than 0.5 %. Davanagere industrial area shows less organic matter in the soil and microbial activity is also less due to less water holding capacity [24;25]so that soil is unsuitable for crop production and suitable for solid waste disposal.

4.3.4 ELECTRICAL CONDUCTIVITY (EC)

Amount of soluble salts in a sample is expressed in terms of electrical conductivity (EC) and measured by conductivity meter [21]. The conductivity cell is coated by platinum black. Represented by ds/m at 25^0. The EC of the collected soil ranges from 0.30-1.86ds/m (Table3). the limitation of EC is 1-2dS/m. High salt content in the soil leads to exosmosises and plasmolysis leads to inhibition of water, that condition of soil is unfavourable for crop grow[26]. Kundvad shows high concentration of salts leads to stop the flow of fluid into the soil strata.

4.3.5 POTASSIUM (K)

Potassium is the main source of nutrients to plant growth. This is from runoff of agricultural field. The potassium is ranged between 78.48-244.64kg/ha. The limitation of K is less than 120kg/ha. Soil has less K not supply nutrient to grow plant and the water holding capacity of the soil become less [25;27]. Leaching of leachate is less and less cause of ground water contamination.

4.3.6 PHOSPHORUS (P)

Phosphorus acts as co-limiting factor of eco-system productivity [23]. It is ranges from 6.19 to 36.69kg/ha (Table 3). It is limited to less than 9 kg/ha. Kundvad shows 6.19kg/ha of P present in the soil is unfavourable for crop grow and suitable for solid waste dumping, because excess phosphorous will runoff, interflow and cause ground water and surface water pollution[27].

4.3.7 NITROGEN (N)

Nitrogen is one of the macro nutrient of the soil [28]. The available nitrogen is depends on varying degree of soil microbial decomposition. It is ranged from 10.75-77.95kg/ac (Table3). The limitation of N is 110-220kg/ac. The N content of soil sample is below the limitation is due to less N fixation in the soil and less microbial decomposition taken in soil. So that all collected soil sample are not suitable for crop production and suitable for solid waste dumping.

4.3.8 FIELD DENSITY (FD)

Field density is carried by core cutter method. This shows the natural compacted condition of soil[29]. It is represented in terms of grams/cc. It is ranged between 1.503-2.10gm/cc. The limitation of field dry density is 1.6-1.8gm/cc. The soil of Shamnur shows 1.75gm/cc which indicates medium compacted condition of soil. Field density defines the soil carrying capacity of solid waste. If soil is within limit that will not allow to pass the leachate into the soil media and prevent ground water contamination.

4.3.9 PERMEABILITY (K)

Permeability of soil is the ability of soil to permit water to flow through its pores [29;30]. It is one of the important properties of Geo-Technical Engineers[31]. The permeability of soil is ranged from 0.00028-0.00474cm/sec (Table 3). Bethur has less permeable capacity is 0.00028cm/sec which means it contain more clay in the soil. The limitation of soil permeability of silt loam is 10^{-3} to 10^{-4} cm/sec. The less permeability of soil will decrease the flow of water into the soil strata and decrease the ground water contamination.

4.4 SOIL SUITABILITY INDEX

A range of soil parameters has been identified to estimate soil quality. For calculation of SSI (soil suitability index) Soil pH, Potassium (K), Nitrogen (N), Phosphorus (P), Electrical Conductivity (EC), Organic matter (OM), Permeability of soil (k) are accounted by taking a maximum quality rank rating value of each parameter is 6 which is unsuitable for crop production and that land is utilized for solid waste disposal site and minimum quality rank rate of each parameter is 1 which is unsuitable for landfill site.

The SSI is calculated using the equation (1). The values of SSI are illustrated in Table 4.
SSI = ∑ Individual soil rank rate value…. (1)

Table 4. Soil Suitability Index value of collected soil sample for landfill around Davanagere city, Karnataka, India:

Sl. no	Place	MC	pH	OM	EC	K	P	N	FD	K	SSI	Remark
1	**Bethur**	2	3	2	3	2	4	6	3	3	28	-
2	**Shamnur**	4	2	1	2	5	3	6	2	2	27	-
3	**Davanagere industrial area**	6	1	3	5	4	5	6	4	1	**35**	**Suitable (3)**
4	**Dodd Bathi**	1	6	5	1	6	1	6	5	5	**36**	**Suitable (2)**
5	**Kundvad**	5	5	4	6	3	6	6	6	6	**47**	**Suitable (1)**
6	**Near Jain Institute of Technology**	3	4	3	4	1	2	6	1	4	28	-

Note: MC-Moisture content, OM-organic matter, EC- Electrical conductivity, K- Potassium, FD-Field density, N- Nitrogen, k- Permeability, P- Phosphorus.

The SSI for each of selected site is shown in table 4, priority 1 is assigned for the maximum value of SSI. Kundvad area is the first priority based on maximum SSI (47) and indicates this site is more suitable for solid waste landfill. The Dodd Bathi and Davanagere industrial sitehaving next priority (2) and (3) shows SSI value 36 and 35respectivelywhich indicates an areas are also suitable for landfill.

5. IMPLICATION ON GROUND WATER QUALITY

Soil suitability is significant in terms of Groundwater contamination owing leachate percolation especially in sandy to loamy soils.The leachatefrom landfill contains high concentration of toxic chemicals along with that, the high concentration of verity of conventional and non-conventional pollutants are exist. Pollutants in leachate modifies soil properties and alters the behaviour of soil. Leachate lowers the soil pH and leads to disintegrations of silt/sand particles reducing the density and increasing the hydraulic conductivity of the soil. Increase in plastic limit, and liquid limit results in further degradation of soil.Sites at Kundvad, Davanagere industrial area, Dodd Bathi are suggested to be further protected with heavy liners with either natural or synthetic liners. The liners have ability to maintain integrity and impermeable over the life of landfill. The clay liners are used in a design and construction of waste landfill.

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