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ANALYSIS OF PHYSICO CHEMICAL CHARACTERISTICS OF SOIL AND SQI AROUND MUNICIPAL SOLIDWASTE DUMPYARD IN VELLALORE-COIMBATORE-TAMILNADU, INDIA

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ABSTRACT

One of the most serious threats faced today by mankind is the pollution of our environment which includes soil pollution. Soil is an essential component for the survival of organisms. Due to rapid increase in population and industrialization there is an increase in solid waste generation and it is disposed by dumping on land. Proper municipal solid waste management is not practiced in Coimbatore, though several initiatives are taken by the corporation. Coimbatore Corporation collecting the municipal solid waste from 100 wards and dumping at Velllore dumpyard, which is 14 kms from the city. Many town panchayats and village panchayats in Coimbatore collects the solid waste from their wards and dump the min nearby open areas. Three municipal solid waste disposal sites were selected based on quantity of solid waste dumping in that location and close to the irrigation land. This paper deals with the study of polluted soil due to solid waste dumping in and around Coimbatore. A detailed investigation was made respect to area of solid waste dump, sampling of soil, characteristics of soil required for irrigation. The soil characteristics such as pH ,EC, MC, OM, Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+} were estimated and related parameters such as SQI, SAR, CEC and ESP were also calculated. The characteristics study of soil samples from the above locations showed that the solid waste dump at these sites had changed the soil characteristics, which was within acceptable limits at certain places only.

Key words: Solid waste, Open dumping, Soil characteristics, SQI, SAR, CEC, ESP.

INTRODUCTION

Soil is one of the important natural resource which provides the main mineral elements for plant growth and crop production. Formation of 1 cm top soil layer requires 100-400 years (Deshmukh 2012). Soil pollution arises due to the leaching of solid waste

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from landfills. Developed countries are investing huge amount of money for the control of all types of pollution. India is a developing country and due to many reasons like lack of financial resources and trained man power, environment pollution is not properly addressed. Municipal Solid Waste management is a complex issue due to changing life style of people and rapid urbanisation (Kadapa et al. 2008) In India, MSW produced at an average rate of 300-600gm/capita and it is disposed on land without taking any specific precaution. There are many open dumps causing soil pollution which makes soil unfit for irrigation purposes and reduces crop yield. Soil quality is considered as a key element of sustainable agriculture and hence soil quality plays an important role in deciding the solidwaste disposal methods. The aim of this study is to investigate the implications of soil properties due to solidwaste dumping in Vellalore Dumpyard. The health impacts due to solid wastes includes exposure of workers, rag pickers and children in nearby schools to toxic and infectious materials. The water supply is contaminated due to waste dumping and leakage from landfill sites. It also increases the risks of injury and infection. The insects and flies from the solid waste dumps rests on the food materials in the nearby localities and consumption of those food materials causes serious health impacts such as nausea, food poisoning and diarrhoea.

EXPERIMENTAL

Materials and methods

Description of study area

Coimbatore district is situated in the Western side of Tamil Nadu holding many advantages of its own. It is often referred to as the "Manchester of South India" and also "the Pump City" due to its textile and motor industries. Also it is a favourite place for many visitors due to its enchanting climate. Coimbatore was elevated as a municipal corporation in 1981. In and around Coimbatore Corporation, irrigation is the main source of living for the people. The solidwaste generated from 100 wards in Coimbatore Corporation is dumped at Vellalore dumpyard located at a distance of 14 km from the city. Here though the landfilling and composting methods of solid waste disposal is practiced, it is not properly organized by the agents. Huge portion of solid waste is dumped in this site which is close to the irrigation land. During rains, the surface water percolating through the garbage dissolves harmful chemicals that are carried away from dumpsites to the surface or sub-surface and reaches the nearby land or groundwater respectively. This causes soil pollution and groundwater pollution. The open dumping of solidwaste at the outskirts of corporation which poses a serious threat to the surrounding localities as well.

The domestic wastes were brought to the Vellalore dump yard by lorries and tractors. The quantity of waste dumping daily is about 800 tonnes/day. The various processing units of Vellalore dump yard are closure, composting yard, lagoons, landfill & segregation area. The total area of the dumpyard is 643 acres and it consists of closure (48 acres), landfill (48acres), compost yard (24 acres) and four lagoons(40 acres), which consists of 4 ponds (each pond of 10 acres) constructed with drainage pipe to collect the drainage water from the locality nearby the dump yard.

Sampling and methodology

Soil samples collection, preservation and analysis were done as per standard methods. The soil samples were collected from January to June in two years (2012 & 2013), which includes summer and winter season of Coimbatore. The top soil was cleaned and samples were collected from digging up to 0.5 m depth. Soil samples were collected in fresh polythene bags and transported to Environmental Engineering laboratory of Sri Ramakrishna Institute of Technology in Coimbatore for physico-chemical analysis. The samples were naturally dried by spreading it on a tray and crumbled mechanically. The sample was sieved using 2 mm sieve.

Eight soil samples in and around vellalore dumpyard were collected. The soil physico-chemical characteristics such as pH EC, MC, OM, Ca^{2+}, Mg^{2+}, Na^+, and K^+ were calculated. Soil related parameters such as SQI, SAR, CEC and ESP were also calculated to identify the suitability for irrigation. Following characteristics of the soil sample were analysed based on standard methods which are given in Table 1.

Table 1: The methods adopted for physico chemical analysis of soil

S. No.	Soil characteristics	Symbol	Units	Test methods
1	pH	pH		pH Analyser
2	Electrical conductivity	EC	µmohs/cm	EC Analyser
3	Moisture content	MC	%	Oven dry method
4	Organic matter	OM	%	Titration method
5	Calcium	Ca^{2+}	mg/L	EDTA (0.05 N) titration
6	Magnesium	Mg^{2+}	mg/L	EDTA (0.05N) titration
7	Sodium	Na^+	mg/L	Flame photometer
8	Potassium	K^+	mg/L	Flame photometer

RESULTS AND DISCUSSION

Accumulation of salts can result in three soil conditions such as saline, saline-sodic and sodic soils. Each of these soil conditions has distinct characteristics that can be observed in the field, which are useful for diagnosing the problem. Completely the white soil are saline, soil with a brownish-black crust are sodic, and grey-coloured soils are generally saline-sodic. The following physical observations/symptoms may be helpful in diagnosing salt-related soil with good structure (non-sodic soil), soil with poor and dense structure (sodic soil). The major sources of salt problems can be traced as irrigation water, cultural practices (mainly fertilization), salt water intrusion and leaching of pollutants from solid waste dumps. Hence, it is necessary to study the soil characteristics in terms of pH, EC, MC, OM, Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+} and the soil salinity hazards parameters such as Sodium Absorption Ratio (SAR), Cation Exchange Capacity (CEC) and Exchangeable Sodium Percentage (ESP).

The soil quality parameter in and around vellalore dumpyard is presented in the Table 2 Soil quality based on suitability for irrigation purposes is presented in the Table 3. From the study it was observed that the soil quality varied in different locations.

Table 2: Statistics of soil chemistry of Vellalore Dumpyard

Para-meters	Units	Year -2012				Year -2013			
		Max	Min	Mean	Median	Max	Min	Mean	Median
pH	-	9.20	8.04	8.63	8.61	9.09	8.01	8.53	8.51
EC	mS/cm	1.01	1.0	1.01	1.01	1.06	1.0	1.01	1.0
MC	%	7.14	6.00	6.55	6.77	7.128	6	6.51	6.76
OM	%	3.13	2.00	2.60	2.63	3.11	1.89	2.52	2.56
Ca^{+2}	mg/l	85.00	6.00	33.00	37.00	80	5	29.5	31
Mg^{+2} l	mg/l	100.24	60.96	79.79	89.94	99.24	58.96	76.28	85.94
Na^{+}	mg/l	59.00	5.00	22.00	33.50	50	6	19.12	28.5
K	mg/l	16.00	6.00	9.27	11.84	12	5	8.08	9.75
SAR	-	8.03	0.75	3.18	4.59	6.84	0.92	2.84	3.96
CEC	meq/l	7.01	3.5	5.05	5.98	10.01	5.08	7.187	6.72
ESP	%	29.15	5.24	13.36	17.09	45.93	9.54	25.31	16.79

Table 3: Soil quality based on suitability for irrigation purposes – Vellalore Dumpyard

Para-meters	Range	Class	Vellalore Dumpyard			
			No of samples		Percentage of samples	
			2012	2013	2012	2013
pH	< 6	Acidic soil	0	0	0	0
	6.0 to 8.5	Normal	4	4	50	50
	> 8.5	Alkali soil	4	4	50	50
ECm S/cm	< 1	Normal soil				
	1-2	Critical for germination	8	8	100	100
	2-3	Critical for growth of salt sensitive crops	0	0	0	0
	>3	Severely injurious to crops	0	0	0	0
SAR%	<13	Saline, normal soil	8	8	100	100
	>13	Saline-sodic	0	0	0	0
CEC meq/100 g	2-7	Sandy loam sand	1	0	12.50	0
	7-15	Sandy loam	7	8	87.5	100
	15-30	loam or silt	0	0	0	0
	30-40	Clay loam	0	0	0	0
	>40	Clay or peat	0	0	0	0
ESP%	< 15	Saline, normal	0	6	0	75
	>15	Sodic	8	2	100	25

pH

The pH values of soil sample around vellalore dumpyard varied from 8.04-9.20with a mean value of 8.63 during 2012 and during 2013 itvaried from 8.01-9.09 with a mean value of 8.53. It is observed that pH values of 50% soil samples around dumpsite were less than 8.5 which are normal soil and 50% of samples were greater than 8.5 which is alkali soil during 2012& 2013 respectively as presented in Table 2&3. The high values are possibly due to the presence of soluble sodium along with HCO^-_3ions, which precipitates calcium and magnesium carbonates during evaporation (Deshmukh 2012).

Electrical conductivity

Around Vellalore dumpyard it varied from 1.01mS/cm- 1.0mS/cm with mean value of 1.01 mS/cm during 2012 and the mean value of 1.0 mS/cm during 2013.It is observed that 100% of soil samples around dumpsite were under the category of critical for germination during 2012 and 2013 respectively as presented in Table 2&3.

Moisture content

The moisture content less than 20% will not increase gas production and cannot support microbial degradation, which is responsible for landfill gas production (Oyedele et al. 2008). Around Vellalore disposal site moisture content ranged from 6% to7.14% with a mean value of 6.55% during 2012 and it varied from 6% to 7.12% with a mean value of 6.5% during 2013, respectively as presented in Table 2 & 3.

Organic matter

Organic Matter is also an important parameter of soil and it is mainly from bio degradable materials in the solid waste. Organic matter of soil samples ranged from 2% to 3.13% with the mean value of 2.63% during 2012 and varied from 1.89% to 3.11% with a mean value of 2.52% during 2013, respectively around vellalore disposal site respectively as presented in Table 2 & 3. The organic matter content in waste soil in three locations is less than normal soil (ie 7.35%) attributing to the poor vegetation and high rate of organic matter decomposition under high temperature which leads to extremely high oxidizing condition (Kameriya et al. (1995), Saritha et al. 2014).

Calcium

Calcium occurs naturally as limestone, gypsum and apatite. It is an essential macro element andare non-toxic except at very high doses. Around vellalore disposal site, the presence of calcium varied from 6.0 mg/L to 85 mg/L witha mean value of 33 mg/L during 2012 and it varied from 5 mg/L to 80 mg/L with a mean value of 29.5 during 2013 respectively as presented in Table 2&3.

Magnesium

If Mg levels are low and lime is required, dolomitic lime (rich in Mg) will be recommended. Magnesium level greater than 300 mg/L are considered toxic (Dale Cown Agri-Food lab). Magnesium is present in ionic form Mg^{2+} adhered to the soil colloidal complex. Acidic soils contain relatively low levels of magnesium, neutral soils and soils with high pH contain more exchangeable magnesium (Sculte 2004). Around vellalore disposal site, presence of magnesium varied from 60.96 mg/L to 100.24 mg/L with a mean value of 79.79 mg/L during 2012 and it varied from58.94 mg/L to 99.4 mg/L with a mean value of 76.28 mg/L during 2013respectively as presented in Table 2 & 3. The magnesium level varied from 10.7 mg/L to 79.79 mg/L, which is below the toxic level. So pollution due to magnesium is not significant.

Potassium

Potassium is considered the second important macro element for soil and crop productivity. Hence excess of potassium is not harmful (Utpal et al. 2008). Around Vellalore disposal site presence of potassium varied from 6 mg/L-16 mg/L with the mean value of 9.27 mg/L during 2012 and it varied from 5 mg/L to 12 mg/L with the mean value of 8.08 mg/L during 2013 respectively as presented in Table 2 & 3. There is no limiting value for potassium in soil as it is a nutrient for the plants and has no adverse effects on soil properties (Izhar Ahamed et al. 2014)

Sodium

The sodium hazard is usually expressed as SAR (Oosterbaan et al. 1992). It is reported that sodium directly affects the availability of crop water and causes adverse physico-chemical changes in the soil, particularly to soil structure. It has the ability to disperse soil thus leading to decreased permeability, lowered shear strength and increased compressibility (Jaboobi et al. 2014). At high temperatures sodium salts decomposes when the solidwaste degrades, the heat is generated may attribute to the loss of sodium at dumpsite (Eddy et al. 2006). Around vellalore dumpyard presence of sodium was ranged from 5.00 mg/L -59.0 mg/L with the mean value of 22.00 mg/L during 2012 and it varied from 6 mg/L -50 mg/L with the mean value of 6 mg/L during 2013, respectively as presented in Table 2 & 3.

Soil quality based on suitability for irrigation purposes

Soil salinity is a characteristics of soils relating to their content of water soluble salts (Charman & Murphy 2000). Accumulation of salts can result in three soil conditions saline, saline-sodic and sodic soils. Each of these soil conditions has distinct characteristics that can be observed in the field, which are useful for diagnosing the problem. The following items need to be observed for soil salinity hazards such as Sodium absorption ratio (SAR), Electrical conductivity (EC) Cation Exchange Capacity (CEC) and Exchangeable sodium percentage (ESP)

Sodium adsorption ratio (SAR)

The sodium absorption ratio (SAR) is used to estimate exchangeable sodium percentage (ESP) of soil. The SAR is used in the soil studies because of its good co-relation with ESP besides its easy estimation and calculation than ESP. However, it is also found that estimation of ESP from SAR values may be more accurate than ESP analysis. SAR indicates the equilibrium relation between soluble and exchangeable cations. The SAR values below 13 categorize into normal soils whereas above 13 are indicating salt affected soils. This is to say that SAR above 13 implies that exchangeable sodium has greatest effect on plant growth by dispersing the soil (Deshmukh 2012). Excess sodium in sodic soils cause's soil particles to repel each other, preventing the formation of soil aggregates has greatest effect on plant growth by dispersing the soil.

The Sodium Adsorption Ratioin the sample is calculated from the formula.

$$(SAR) = Na^{+}/(Ca^{2+} + Mg^{2+}/2)^{1/2} \ldots\ldots \text{ (Ragunath., 1987)}$$

Around vellalore disposal site SAR was ranged from 0.75% to 8.03% with the mean value of 3.18% during 2012 and it varied from 6.84% to 92% with the mean value of 2.84% during 2013 as given in Table 2 & 5. It is observed that 100% of the soil samples falls in Saline, Normal soil. It can be used for sodium sensitive crops.

Cation Exchange Capacity (CEC)

Cation exchange capacity (CEC) denotes the ability of soil to hold nutrient cations in readily available forms. CEC influences the pH, salt content of soil solution composition and physical properties of soils. It classifiessoils as the presence of smectite (montmorillonite) clay if the CEC value are high and kaolinite as the predominant clay minerals in soils if the CEC is low.

$$\text{Cation exchange capacity (CEC)} = Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}$$

Around Vellalore disposal site it ranged from 3.5 meq/100 g- 7.01 meq/100 g with the mean value of 5.05 meq/100 g during 2012 indicating sandy loam sand and sandy loam respectively and 12.5% of samples within 2-7 and 87.5% were between 7-15 range during 2012 indicating sandy loam sand and sandy loam respectively and it varied from 5.08 meq/100 g- 10.01 meq/100 g with the mean value of 7.187 meq/100 g, and 100% of soil samples ranged from 7-15 during 2013respectively as presented in Table 2 & 3.

Exchangeable sodium percentage (ESP)

ESP is a very important chemical property that defines the physical character of salt affected soils. Excess exchangeable Na is harmful to plants as it tries to develop unwanted physical andchemical change in the soils. In strong alkaline soils, Ca and Mg carbonates precipitates under semi arid conditions. When soils show low ESP < 15 the water uptake capacity is improved implying that strong relation between soil and water (US Salinity book no 60 1954). It is also used to indicate soil instability if the soil ESP value is > 6% and it is susceptible to structural instability problems. Characteristics of Saline, Sodic and Saline-Sodic soils are given in Table 4. ESP can also be calculated as:

$$ESP\ \% = [\text{Exchangeable sodium/Soil cation exchange capacity}] \times 100$$

$$ESP = Na^{+} + /(Ca^{2+} + Mg^{2+} + Na^{+} + K^{+)} *100$$

Table 4: Characteristics of saline, sodic and saline-sodic soils (USDA hand book No. 60)

S. No.	Range	Class
1	<6%	Non sodic
2	6-10	Sodic
3	10-15	Moderately sodic
4	15-25	Strongly sodic
5	25	Very strongly sodic

Around Vellalore disposal site it ranged from 5.24% to 29.15% with the mean value 13.36% during 2012 and 100% of soil was above 15 during 2012 and 9.54% to 45.93% with the mean value of 25.31% during 2013, and 75% of soil samples above 15 and only 25% of samples were less than 15 during 2013. It indicates 100% of soil samples were sodic during 2012 and75% of soil samples were saline and normal remaining 25% were sodic during 2013.

Soil quality index

Contaminated sites are of great concern for their potential impact on public and ecosystem health has been an area of great concern for a long time in and around Coimbatore. Soil quality is defined as the soil's capacity to function within natural or managed ecosystem boundaries and to sustain plant productivity while reducing soil degradation (Doran et al 1994). As soil quality is a complex functional concept and cannot be measured directly in the field or laboratory (Stocking, 2003) but can only be inferred from soil characteristics (Diack and Stoot, 2001), a range of soil parameters or indicators has been identified to estimate soil quality. For calculation of SQI Soil pH, Calcium, Magnesium, Potassium and ESP are accounted by taking a maximum value of 12. The SQI is calculated using the equation 1 & 2. The values of SQI are illustrated in Table 5.

$$SQI = \sum \text{Individual soil property index value} \quad \ldots(1)$$

$$SQI\ \% = (\text{Total SQI/Maximum value of SQI measured})*100 \quad \ldots(2)$$

Table 5: Summary of soil quality index of Vellalore

Sample ID	2010	2011	2012	2013	Mean
A_1	0.00	8.33	0.00	8.33	4.17
A_2	8.33	16.67	8.33	16.67	12.50
A_3	0.00	8.33	8.33	16.67	8.33
A_4	8.33	16.67	8.33	16.67	12.50
A_5	8.33	8.33	0.00	8.33	6.25
A_6	0.00	8.33	0.00	8.33	4.17
A_7	8.33	16.67	8.33	16.67	12.50
A_8	0.00	8.33	0.00	8.33	4.17

Table 6: Status of soil quality based of SQI

SQI	Class	Vellalore
		Percentage of samples
90-100	Very low	0
70-90	Low	0
50-70	Medium	0
30-50	High	0
0-30	Very High	100

The status of soil quality in the study areas were compared with the SQI range by taking the mean values of WQI calculated during 2010, 2011, 2012 and 2013 respectively and presented in Table 6. The SQI analysis show that all the sample locations come under very high category in all the study areas. It was observed that the selected parameters have possible deficiencies on soil. Crop yield is invariably related to soil fertility status and thus SQI in the study area shows the deficit in soil nutrients as well as pH value at higher order (Zornoza et al 2007).

CONCLUSION

Soil quality indicators implies the contamination by open dump sites and is useful in deciding some remediation for these contaminated soil. From the results, it is concluded that soil quality in and around Coimbatore region most of the soil samples are within the limits except in some places. Therefore proper solid waste management practice should be implemented to minimize the adverse impact on the soil further in situ bioaccumulation studies can also be performed to avoid soil contamination due to open dumping of solidwaste.

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