IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 1 Issue 7, September 2014.
www.ijiset.com
ISSN 2348 – 7968

Quality Assessment of Soil at municipal solid waste dumpsite and possibilities of reclamation of land

Izhar Ahmed[1], Dr.TVD.Prasad Rao[2], Mushtaq Hussain[3]
[1]Research Scholar, Dept. of Chemistry, Osmania University, Hyderabad, India
[2]Associate Professor, Dept. of Chemistry, P.G College, Osmania University, Hyderabad, India
[3]Lecturer, Shinas College of Tech, Sultanate of Oman

Abstract

Municipal solid waste is disposed by dumping on land in most Indian cities. Dumping of municipal solid waste alters the physico-chemical properties of the soil. The present investigation aims to study the effect of dumping on the physico-chemical properties of the soil. The moisture content of MSW dumpsite soil in the present study is less than 20%, which will not increase the gas production. The high ash content reveals the low calorific value of the MSW soil. Except EC, SAR, chloride, nitrate and lead, all other soil parameters including metals are within the permissible limits as per USEPA-2011 & 2012 for land use as agriculture, residential, park and industrial use.

Key words: Municipal Solid Waste (MSW), United States environmental protection act (USEPA)

Introduction

The management of solid waste is an area of universal concern for both the developed and developing world. An important reason for exercising care in the dumps relates to land use. Current demand for land use has increased the pressure for urban regeneration and re-development of former derelict. Land property adjacent to MSW sites are increasingly being used for industrial, commercial and residential purposes. Waste soil consists of waste material such as concrete debris, decayed wood, plastics and others. The heterogeneous content of waste soil makes the properties difficult to categorize and analyze. The generation of waste by various human activities and the way in which the waste is disposed off can pose a risk to public health. Several waste materials from different sources end up at the dumpsites and due to the heterogeneity and complexity of wastes, these dumpsites contain a variety of contaminants which pollute the soil.

The heavy metals contamination may be induced in the soil when municipal solid wastes from different sources, such as electronic goods, painting waste, used batteries, etc. are dumped at dumpsite.

This, work conducted would help in the settlement estimation and design of foundation for future development in order to understand the chemical behavior of waste soil after closure of dumping area.

Study area

The autonagar dumpsite is spread over an area of about 47 acres and used to receive an average 800 metric ton of garbage per day. About 8.7 lakh m^3 MSW has been dumped at this dumpsite, which weighs ~4.35 lakh-tons. The Autonagar dumpsite is in existence for more than 20 years. It has been closed in the year 2005.

Methodology

Composite sampling method is used to collect the MSW soil samples. The soil samples were collected from different points taking into consideration the height of the different layers within the MSW dumpsite. Approximately 1Kg of soil sample was collected from sampling points in Air tight Polythene bags of high quality to prevent the changes in moisture content and volatile contents.

The physical properties of dumpsite soil such as moisture, volatile content, fixed solids and ash was determined using hot air oven and muffle furnace. The chemical properties of soil samples collected from the MSW dumpsite, like concentration of major ions was studied using standard methods and instruments [1]. Heavy metals were analyzed by using ICPMS in National geophysical research institute, Hyderabad, India. The major cations and anions along with the metals in composite soil samples from the autonagar MSW dumpsite is analysed and their values are compared with the available standard limits as per USEPA-2011 & 2012 (Environmental Protection Act),which states the use of soil for various purposes like agriculture, residential, industrial or commercial use.

The possible chemical reactions of the present MSW dumpsite soil are also discussed to know the possible adverse effects on the ground water due to the dumpsite. Various chemical characterization were carried out in order to ascertain the various problems of MSW soil and to know whether the soil can leach the pollutants into the ground water.

Results and Discussions

Physical Composition of Soil

The physical composition of solid wastes is given in **table-1**. The physical composition of the composite samples of the dumpsite soil was analyzed for Pre and Post monsoon seasons of the year 2008.

Moisture Content:

The moisture content ranges from 7.33 to 12.82% with a mean value of 10.27 % in the pre monsoon season and ranges from 10.67 to 19.29% with a mean value of 14.31% in post monsoon season. In most of the municipal solid waste soil samples, the moisture content is found to vary from 15 to 40 %, with the change of season of the year, the humidity and weather conditions (particularly rain). The presence of moisture (unsaturated conditions) in a landfill increases gas production because it encourages bacterial decomposition. Moisture may also promote chemical reactions that produce gases [2].

Table-1 Physical Analysis of MSW Soil (pre and post monsoon 2008)

	SS1		SS2		SS3		SS4		SS5	
	PRE	***POST***	***PRE***	***POST***	***PRE***	***POST***	***PRE***	***POST***	***PRE***	***POST***
% MOISTURE	8.8	10.67	12.2	15.4	7.33	10.83	12.82	15.36	10.27	19.29
% VOLATILE SOLIDS at 550^{o}C	4.712	6.63	4.83	7.6	4.2	6.13	3.23	6.45	8.12	9.21
% FIXED SOLIDS	95.28	93.36	95	92.32	96.67	93.86	94	93.55	91.64	90.78
% VOLATILE SOLIDS at 815^{o}C	9.08	10.17	10.04	11.76	8.52	9.47	9.8	9.72	11.6	14.46
% ASH	90.9	89.82	89.43	88.24	92.23	90.52	91.3	90.28	87.4	85.54

The rate of gas production is directly proportional to the percentage of water content of refuse [3].

The moisture content present in the samples collected from MSW dumpsite for both the seasons is less than 20%, which will not increase the gas production. If the moisture content is less than 20 % it is not sufficient to support the biological activity of bacteria which is responsible for landfill gas production [4].

Volatile solids and Fixed Solids

The organic content of the soil is oxidized into volatile oxidation products, whereas inorganic content gives solid oxidation products on heating the soil sample. The total solids are composed of two components, volatile and fixed solids. The volatile solids are organic compounds of animal or plant origin. The fixed solids consist of sand, gravel and salts.

The volatile content of soil samples from Autonagar MSW dumpsite ranges from 3.23 to 8.12% with a mean value of 5.018% in the pre monsoon season and 6.13 to 9.21% with a mean value of 7.208% in post monsoon season.

The fixed solids (sand, gravel and salts) range from 91.64 to 96.67% with a mean value of 94.518% in the pre monsoon season and 90.78 to 93.86% with a mean value of 92.774% in post monsoon season. Volatile organic compounds (VOCs) are the most common and the most mobile subsurface contaminants of the waste at sites. VOCs are toxic and carcinogenic. Soil VOCs are a potential source of ground water contamination. Soil VOCs may also be associated with ingestion, which can occur when children play in contaminated soil or when the compounds of VOC`s are absorbed into the edible portion of agricultural plants.Volatile solids (VS) content, determined by ignition at 550^oC, is often used as a measure of the bio-degradability of the organic fraction of MSW. Accurate measurement of soil volatile organic compound (VOC) concentrations is crucial as soils that are contaminated with VOCs are potential reservoirs of long-term ground water contamination.

Volatile solids at 815^{o}C and Ash

Volatile solids at 815^{o}C range from 8.52 to 11.6% with a mean value of 9.8% in the pre monsoon and 9.47 to 14.46 % with a mean value of 11.11% in post monsoon seasons. At 815^{o}C the volatile matter and the salts are burnt. The volatile matter volatilizes and the salts become ash. Accordingly ash may be defined as the non-combustible matter of the soil. Therefore ash content contains the burnt up salts, sand and gravel from fixed solids. The volatile solid at 815^{o}C is due to the decomposition of carbonates as well as of partial evaporation of alkaline metals and chlorine at high temperature.

The ash content ranges from 87.4 to 92.23 % with a mean value of 90.25% in the pre monsoon season and 85.54 to 90.52 % with a mean value of 88.88 % in post monsoon season.

The residue consists of oxides of salts containing anions such as phosphates, chlorides, sulfates, and other halides and cations such as sodium, potassium, calcium, magnesium, iron, and manganese. During the process of converting organic salts into ash at 815^{o}C the carbon containing portion is decomposed.

The calorific value of Indian solid waste varies between 800 to 1000 kcal/kg (on dry inert free basis), while the density varies between 300-500 kg/m^3. The calorific value of MSW autonagar is low, since high the percentage of ash less will be the calorific value. In majority of Indian cities, the volatile or decomposable matter content is found to vary from 10-30 % [5].

Chemical Properties of MSW Soil

The chemical characteristics of MSW soil is presented in **table-3**.

pH

Table-2 Classification of Soil based on pH

Denomination	**pH range**
Extreme acid	3.5–4.4
Very strong acid	4.5–5.0
Strong acid	5.1–5.5
Moderate acid	5.6–6.0
Slight acid	6.1–6.5
Neutral	6.6–7.3
Slightly alkaline	7.4–7.8

IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 1 Issue 7, September 2014.
www.ijiset.com
ISSN 2348 – 7968

Moderately alkaline	7.9–8.4
Strongly alkaline	8.5–9.0
Very strongly alkaline	> 9.0

The pH of the soil samples are found to be in the range of 6.66 to 7.9, indicating neutral to moderately alkaline nature of the soil (when compared to the United States Department of Agriculture Natural Resources Conservation Service, formerly Soil Conservation Service classifies soil pH ranges as given in **table-2)**. The pH of the soil is a measure of the acidity or basicity of the soils. Soil pH is considered as a major variable in soils as it controls many chemical processes that take place. It plays an important role in leaching of heavy and trace metals to the ground water.

When pH is considered the present MSW soil is fit for Residential, Parks, Industrial and Commercial use as per EPA-2012 Standard limit (pH: 6 – 8)

Electrical Conductivity (EC)

The electrical conductivity of the autonagar MSW soil ranges from 1010 to 12400 µ.Sm/cm, which is above the permissible limit of 700 µ.Sm/cm for land use as Agricultural / Residential purposes and 1400 micro.Sm/cm for its use as industrial purpose. Based on the EC values of the soil, it is concluded that dumpsite area is not suitable for agricultural, residential and industrial purposes. Electrical conductivity depends upon total number of anions and cations. The high EC values in the study area i.e. autonagar MSW dumpsite, may be due to high concentration of cations and anions, because more the concentration of ions, more will be the EC.

EC also depends upon major salts present in soil solution, which adversely affects the soil properties. Sodicity occurs in soil where sodium content is low. Alkalinity gives rise to formation of calcium carbonate and subsequent calcium lock up. Salinity occurs when the salts of Na, Ca and Mg with chloride, bicarbonate and sulphate accumulates in the soil. Soil electrical conductivity is an indirect measurement that correlates with several soils physical and chemical properties. The electrical conductivity of soils varies depending on the amount of moisture held by soil particles. Sands have a low conductivity, silts have a medium conductivity and clays have a high conductivity. Consequently, EC correlates strongly to soil particle size and texture.

BOD and COD

The BOD varied from 24 to 223 mg/Kg with a mean value of 126.8 mg/Kg. Biochemical oxygen demand (BOD) is a measure of the amount of oxygen that bacteria will consume for decomposing biodegradable organic matter under aerobic conditions. COD values ranges from 379 to 4174 mg/Kg with an average of 2118 mg/Kg.COD value is always higher than the BOD values, as COD includes both biodegradable and non-biodegradable substances. Therefore BOD and COD indicate the organic load of the soil samples. BOD and COD values give an idea about the organic carbon content of the soil sample.

SODIUM

The sodium in the soil samples ranges from 1052.5 to 1779.6 mg/Kg with a mean value of 1378.56 mg/Kg. Clay and organic matter are covered in negative electrical charges called exchange site

Table-3 chemical Characterization of MSW Soil in mg/Kg

	SS1	SS2	SS3	SS4	SS5
PH	6.66	6.73	7.7	7.9	6.54
EC	12400	7600	2900	1803	1010
Ca	551.1	359	200	750	500
Mg	115.8	72	98.2	579.5	105

Na	1779.6	1090.7	1250	1052.5	1720.5
K	1185.5	784	125	150	300
HCO3	881	973	1274	1086	890
Cl	3753.8	2265.8	1772.5	531.75	443.125
F	2.6	2.8	1.7	2.3	1.9
NO3	1263.1	908.6	643.82	500.6	623.54
SO4	552.9	386.8	318.75	298.81	327.79
COD	1945	2529	4174	379	1563
BOD	135	159	223	24	93
SAR	5.68	4.34	5.71	2.20	5.8
ESP	6.57	4.85	6.62	1.86	6.7

Cations are attracted to and hold onto the negative exchange sites. Soils with poor structure tend to have many more sodium cations attached to the clay. This causes the clay particles to disperse when wet land sets like hard surface, when dry. The sodium hazard of soil is usually expressed as the sodium adsorption ratio (SAR) [6].

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

To estimate the Sodium levels in soil, Exchangeable Sodium Percentage (ESP) is also used.

$$ESP = \frac{100\,(-0.0126 + 0.01475\ SAR)}{1 + (-0.0126 + 0.01475 SAR)}\ \%$$

The SAR of autonagar MSW Dumpsite soil ranges from 2.20 to 5.8 with an average value of 4.74. The ESP value ranged from 1.86 to 6.7 with an average value of 5.32. It is found that the MSW dumpsite soil has normal physical conditions and it may be classified as saline when the

SAR, ESP, EC and pH values of MSW Dumpsite soil are compared with the standard values in **table-4**.

The EPA has set a limiting SAR value of 1(one) for land use as agriculture and 2.4 for land use as residential/industrial purposes. When the SAR values of the MSW dumpsite are compared with the EPA standards it is found that the soil cannot be used for agricultural, residential and industrial purposes.

Table - 4 General classifications for sodium hazard of soil based on SAR values.

Classification	**Sodium adsorption ratio (SAR)²**	**Exchangeable Sodium Percentage (ESP)**	**Electrical conductivity** (EC)	**Soil pH**	**Soil physical condition**
Sodic	≥13	≥15	<4000	>8.5	Poor
Saline-Sodic	≥13	≥15	>4000	<8.5	Varies
Slightly Saline	<13	<15	2000 - 4000	<8.5	Normal
Saline	<13	<15	>4000	<8.5	Normal
High pH	<13	<15	<4000	>7.8	Varies

Toxicity arising from the sodium ion itself is rare, due to the fact that problems with soil structure usually arise well before sodium can build to toxic levels. Sodium salts are critically important because, as noted above, they have the potential to impair soil structure. High soluble salts usually occur in soils with a persistent drainage problem or when soluble salts are present at high levels in irrigation water [7]. But the adverse effect of the normal and saline soil present in the MSW dumpsite is that, it will allow the leachate to percolate easily and consequently it may pollute the ground water around it.

Potassium

The potassium in MSW soil ranges from 125 to 1118.5 mg/Kg with a mean value of 295.51 mg/Kg. 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. But the potassium from the anthropogenic sources can contaminate the ground water.

Potassium is leached by weathering. Although it is soluble in water, little is lost from undisturbed soils because it is released from dead plants and animal excretions, it is quickly and strongly bounds to clay particles and it is retained ready to be re-adsorbed by the roots of other plants [8].

Calcium

The calcium ranges from 200 to 750 mg/Kg with a mean value of 436 mg/Kg. There is no limiting value for calcium in soil.

Calcium plays an important role in determining soil physical and chemical characteristics, i.e. structure and pH. Calcium ions cause soil colloids (clay platelets) to bond or aggregate together, forming crumbs or peds. Exchangeable calcium levels and soil acidity are usually closely related. Calcium is available in the pH range 7.0 to 8.5. Under low pH or acidic soil conditions, exchangeable calcium levels in the soil are usually low and the solubility of manganese and aluminium increase and may become toxic [9].

Magnesium

Magnesium ranges from 72 to 579.5 mg/Kg with a mean value of 270.7 mg/Kg. The soils containing greater than 300 mg/Kg of magnesium are considered toxic [10].

Except the composite sample SS4, all other samples are having magnesium concentration below this toxic level. According to EPA, soil containing 32500 mg/Kg of magnesium is considered uncontaminated.

In high magnesium soils the magnesium ions on the clay surfaces having a 50% greater hydrated radius than calcium which leads to absorb more water. This will tend to weaken the forces that hold soil particles together resulting in less aggregate stability and greater dispersion of soil particles reducing infiltration rates and hydraulic conductivity (drainage).

Magnesium is present in relatively soluble forms and is found in ionic form (Mg^{2+}) adhered to the soil colloidal complex. Acid soils especially sands; often contain relatively low levels of magnesium. Neutral soils or those with high pH usually contain more exchangeable magnesium [11].

Chloride

The chloride ranges from 443.12 to 3753.8 mg/Kg with a mean value of 1753.4 mg/Kg. All the samples are within the permissible limit of 4000 mg/Kg as per EPA-2012 regulation for uncontaminated soil.

Virtually, the chlorine in soil occurs as the soluble chloride ion. Chloride is not strongly associated with either soil minerals or organic matter and therefore exists primarily in a dissolved form in the soil solution. Chloride salts accumulate in saline soil [11].The present MSW soil is slightly saline and has not reached to toxic levels. Chloride concentrations below 70 ppm are safe for most plants. However, higher levels of chloride may be toxic to plants and contribute to the total soluble salt concentration. If the present MSW dumpsite is used for residential purposes and the ground water is used as drinking water, the EPA has set a standard limit of 1000 mg/Kg for chloride. The EPA has also set a chloride standard limit of 1400 mg/Kg for agricultural soils. Based upon these two limiting value for chloride the Autonagar MSW dumpsite cannot be used either for residential or agricultural purposes as the average chloride value for the present MSW dumpsite is 1753 mg/Kg.

Fluoride

The fluoride in the MSW soil ranges from 1.7 to 2.8 mg/Kg with a mean value of 2.26 mg/Kg. The fluoride concentration of all the samples in the Present MSW soil is well below the EPA limit of 80 mg/Kg for the soil use as agricultural purpose. It indicates that autonagar dumpsite is suitable for agricultural use as far as fluoride is considered.

Fluoride of soil is mainly bound in complexes. Fluoride in alkaline soils at pH 6.5 and above is almost completely fixed in soils as calcium fluoride, if sufficient calcium carbonate is available [12].

The possible sources of fluoride in the MSW soil may be the molecular fluorine used for plasma etching in manufacturing semiconductors and flat panel display production. Fluorine is indirectly used in the production of low friction plastics such as Teflon, Freon and in the production of uranium. Fluorochloro hydrocarbons are used extensively in air conditioning and in refrigeration. When fluorine ends up in soils, it will become strongly attached to soil particles. There is no possibility of fluoride to leach to the ground water around the Autonagar dumpsite since its very low content in soil and its soil chemistry.

Sulphate

The sulphate ranges from 298.81 to 552.9 mg/Kg with a mean value of 377.01 mg/Kg. The sulphate content in the present MSW soil is found to be well below the EPA standard limit of 3000 mg/Kg. A limiting value of 5000 mg/Kg of sulphate may harm the Portland cements used for constructions. In high rainfall SO_4^{2-} is readily leached [13]. Sulphate is a naturally occurring substance that contains sulphur and oxygen. It is present in various mineral salts that are found in soil. Decaying plant and animal matter may release sulphate into water. The extent of sulphate in the present scenario of Autonagar is of least concern and the possibility of contamination of ground water with sulphate around the dumpsite is negligible.

Carbonates and Bicarbonates

The bicarbonate content ranges from 881 to 1274 mg/Kg with a mean value of 1020.8mg/L. Carbonate has not been detected in the soil samples of dumpsite. Carbonates and bicarbonates are related to the soil alkalinity. Alkali or alkaline soils are clay soils with high pH (> 8.5) are having a poor soil structure and a low infiltration capacity. The causes of soil alkalinity are natural or they can be man-made. The natural cause is the presence of soil minerals producing sodium carbonate (Na_2CO_3) and sodium bicarbonate ($NaHCO_3$) upon weathering [14]. Bicarbonates are ions that attracts calcium ions forming a $Ca(HCO_3)_2$ molecule. Large amounts of bicarbonate ions in water will precipitate calcium. When the high bicarbonate water reaches the soil, the calcium can be removed from the soil particle. Sodium can then take the calcium's place at a rate of two sodium ions to each calcium ion. In this way a calcium-dominant soil can become a sodium dominant soil by the use of high bicarbonate [15].

Nitrate

The nitrate ranges from 500.6 to 1263 mg/Kg with a mean value of 787.9 mg/Kg. All the samples of the dumpsite soil exceeds the standard limit of 200 mg/Kg (for uncontaminated soil) as per EPA-2012 indicates that the soil is highly contaminated with nitrate. Due to very high solubility of nitrate in soil and because soils are largely unable to retain anions, nitrates can enter the groundwater. Nitrate remaining in the soil can leach during rains and contaminate surface and ground waters. The autonagar MSW dumpsite is highly contaminated by nitrate hence there is high possibility of nitrate to enter the ground water in and around the dumpsite.

METALS IN MSW SOIL

The occurrence of various heavy metals such as Mn, As, Cr, Cd, Ni, Zn, Co, Cu, and Fe in MSW dumpsites is reported by many researchers [16].

Since these contaminants affect the environmental qualities in and around such open dumpsites, monitoring of soil qualities especially heavy metal content in dumpsite becomes necessary which can facilitate to recommend suitable remedial measures.

Table-5 Concentration of metals in MSW soil in mg/Kg

METALS	SS1	SS2	SS3	SS4	SS5
Iron	1422.1	5180	3842.7	5439	437
Nickel	7.63	12.35	10.54	8.43	7.82
Lead	129.99	193	123	135.66	34.89
Cobalt	10.94	5.5	9.42	10.27	4.71
Copper	32.96	29.53	113.53	53.86	33.19
Zinc	46.73	236.7	187.22	29.88	41.32
Arsenic	1.449	1.578	0.093	0.482	1.22
chromium	18.49	25.64	10.31	23.22	18.35
Manganese	66.76	370.54	54.33	12.89	73.64
Cadmium	0.574	0.4	0.27	2.1	0.43

Iron

Iron in the soil samples ranges from 437 to 5439 mg/Kg with a mean value of 3264.14s mg/Kg. The iron concentration in all the soil samples from MSW dumpsite is found to be within the EPA-2012 permissible limits of 15000 mg/Kg for uncontaminated soil. Most of the iron in soil is found in silicate minerals or iron oxides or hydroxides. Iron in soil exists in ferrous (Fe^{2+}) and ferric (Fe^{3+}) forms. Soil pH and the aeration status of the soil determine which of the two ions predominates. Ferric iron compounds have low solubility in soil solution and conditions that favor the formation of these compounds decrease iron availability. The concentration of iron in the soil solution decreases sharply as the soil pH increases. Poor soil aeration, or reduced oxygen level is caused by flooding or compaction. It can affect iron availability depending on soil conditions [17].

The high BOD and COD of the Autonagar MSW soil indicates the high concentration of Organic matter of the soil which improves iron availability. But the pH of the autonagar MSW dumpsite soil is neutral to moderately alkaline which indicates that the availability of iron is low. High values of soil pH reduce Iron availability while acid soils increase iron availability [18].

Nickel

Nickel in the soil samples ranges from 7.63 to 12.35 mg/Kg with a mean value of 9.35 mg/Kg. The Nickel value of autonagar MSW dumpsite soil is found to be within the permissible limits of 37 mg/Kg for land use as agricultural or Residential or Park and 82 mg/Kg for land use as industrial land, as per EPA-2011 standards. The nickel in soil is as low as 0.2 ppm or as high as 450 ppm in some clay and loamy soils. The soil chemistry of nickel is based on the divalent cation (Ni^{2+}) with nickel ferrite the most probable solid phase that can be precipitated in soil. Nickel may be increasingly bound to organic matter and a part of which forms easily soluble chelates in surface and sludge amended soils [19]. The average soil pH of the present MSW soil is 7.1 and has very less effect on nickel mobility. Soil pH is the most important factor for controlling nickel solubility, sorption and mobility with the clay, iron, and manganese. The soil organic matter content is of secondary importance [20]. The larger part of all nickel compounds that are released to the environment will adsorb to sediment or soil particles and as a result become immobile. Ground water contamination around the dumpsite due to nickel is remote as the autonagar MSW dumpsite soil is not acidic.

Lead

The Lead in the soil samples ranges from 123 to 193 mg/Kg with a mean value of 123.30 mg/Kg. All the soil samples except SS5 are above the permissible limit of 45 mg/Kg of lead for the soil use as agricultural purpose and also above the permissible limit of 120 mg/Kg of lead for land utilisation as parkland or residential use as per EPA-2012 Standard. Lead can pose a threat to the environment if it moves through the soil and contaminates ground water. Many factors influence the mobility and bioavailability of lead such as pH, soil texture (especially clay content) and organic matter content. Since dissolved lead in soils is commonly in the form of Pb^{2+}. The adsorption on cation exchange sites of clays or organic matter can decrease the mobility and availability of lead in the short term. Lead chlorides, lead acetates and lead nitrates are readily soluble in the soil environment and will be leached from the soil. Even in composted municipal solid waste, the solubility of lead decreases as the material age becomes more [21]. Hence there is possibility that lead would be leached out of the MSW dumpsite soil and contaminate the groundwater.

Cobalt

The Cobalt in the soil samples ranges from 5.5 to 10.94 mg/Kg with a mean value of 8.16 mg/Kg. The cobalt concentration in all samples of the MSW soil is within the permissible limit of 19 mg/Kg and 21 mg/Kg as per EPA-2011 for land use as agricultural/Residential purpose and Industrial purpose respectively. Natural cobalt can stay for years in soil. The soil contains some amount of cobalt. The more acidic the soil, greater is the potential for cobalt toxicity at any concentration. Soils with high cobalt concentrations usually also have high arsenic and nickel concentrations and these elements are generally more toxic to plants and humans than cobalt.

Copper

Copper in the soil samples ranges from 29.53 to 113.53 mg/Kg with a mean value of 52.61 mg/Kg. Except the soil sample SS3, all the other samples have copper concentration within the permissible limit of 62 mg/Kg for agricultural land use and 92 mg/Kg for industrial/residential land use as per EPA-2012 standards. Higher copper levels were usually found in dusts from more urbanised and industrialised centers [22]. Copper is strongly adsorbed to soil particles and therefore has very less mobility relative to other trace metals. As a result of this less mobility, copper tends to accumulate in soil. Soil types have finite holding capacities for copper ions and leaching can occur when the copper levels exceed the capacity. Soil factors that influence the availability of copper in soils are pH, cation exchange capacity, organic matter content, presence of oxides of iron, oxides of manganese, oxides of aluminum and redox potential. The water content of soil influences the copper holding capacity through biotic and abiotic oxidation-Reduction reactions [23], [24].

Zinc

The Zinc in the soil samples ranges from 29.88 to 236.7 mg/Kg with a mean value of 108.37 mg/Kg. The zinc concentration in the present MSW soil is found to be within the permissible limit of 290 mg/Kg for land use as agriculture and residential purpose as per EPA-2012. Zinc may be adsorbed to clay minerals and may also form stable compounds with soil organic matter, hydroxides, and carbonates. Soil pH has been identified as one of the main factors affecting zinc mobility and sorption in soil. Zinc becomes more soluble as pH decreases [25]. Based on the chemical reactions of zinc with the soil material and high concentrations of zinc (near to permissible limits in composite sample SS2) in the Dumpsite, there is every possibility that zinc may leach out and contaminate the ground water around the autonagar MSW dumpsite.

Arsenic

The Arsenic in the soil samples ranges from 0.09 to 1.57 mg/Kg with a mean value of 0.96 mg/Kg. The arsenic concentration in the present MSW soil is found to be within the permissible limit of 11 mg/Kg for land use as agriculture and 18 mg/Kg for residential/industrial purpose as per USEPA-2012. Arsenic is rarely found in its elemental form and most commonly occurs as sulphides and as complexes with iron, nickel, copper and cobalt. Arsenic forms a variety of inorganic and organic compounds in soils and is present mainly as inorganic species, either As (V) or As (III) [26]. Under oxic soil conditions (pH 5-8), Arsenic is commonly present in +5 oxidation state. Among the Arsenic species found in the soil environment, compounds of As(V) and As(III) are the most important inorganic arsenic species because their compounds are highly soluble in water and may change valence states depending on the pH and redox conditions [26]. The minerals such as FeAsO and other forms of Fe(III) are reduced to the soluble Fe(II) and gets sorbed in soil. As(II) is released into soil solution [27].

Chromium

The Chromium in the soil samples ranges from 10.31 to 25.64 mg/Kg with a mean value of 19.20 mg/Kg. The chromium concentration in the present MSW soil is found to be within the permissible limit of 67 mg/Kg for land use as agriculture and 70 mg/Kg for residential purpose as per USEPA-2012. Cr (III) is relatively stable in most of the soils, although oxidation of Cr (III) to Cr (VI) can occur under specific environmental conditions. The factors influencing the rate of chromium oxidation are soil pH, availability of manganese oxides, presence of low molecular weight organic compounds and soil water activity. Adsorption increases with decreasing pH as a result of protonation of the surface hydroxyl sites. The presence of SO_4^{2-} and dissolved inorganic carbon depresses the adsorption of Cr (VI) [28]. At pH > 8.5, Cr (VI) is completely mobile and can readily leach out of the soil and into the ground water system. In the present study it can be predicted that the Chromium may leach to ground water due to the soil conditions at autonagar MSW dumpsite.

Manganese

The manganese in the soil samples ranges from 12.89 to 370.54 mg/Kg with a mean value of 115.63 mg/Kg. The manganese concentration in the present MSW soil is found to be within the permissible limit of 500 mg/Kg for non-polluted soil as per USEPA Standards. The concentration of manganese in the soil samples of autonagar MSW dumpsite is within the limits of 3000 mg/Kg for land use as parkland and 1500mg/Kg for residential purpose as per EPA-2012. The availability of manganese is influenced by soil pH, Organic matter content and moisture and soil aeration. Manganese availability increases as soil pH decreases. Manganese toxicity is common in acid soils below pH 5.5. Soils having high organic matter and near to neutral pH are deficient in manganese. Under prolonged waterlogged conditions, soluble manganese leaches out of the soil [29].

Cadmium

The Cadmium in the soil samples ranges from 0.4 to 2.1mg/Kg with a mean value of 0.756mg/Kg. The cadmium concentration in the present MSW soil is found to be within the permissible limit of 1 mg/Kg, except the sample SS4 for land use as agriculture, 1.2 mg/Kg for residential purpose and 1.9 mg/Kg for commercial purpose as per EPA-2012. A variety of factors influence the mobility of cadmium in soils with pH and soil type, including particle size, metal oxides, hydroxides and organic matter. The movement of cadmium within the soil matrix is likely to occur under acidic conditions. The presence of high concentrations of dissolved organic matter in soil leachates enhances the cadmium mobility and there by causes a risk to ground water quality. The degree of mobilization is dependent on soil type, aeration and moisture content.

Conclusions

The moisture content present in the soil samples collected from MSW dumpsite for both the seasons is less than 20% which will not increase the gas production. The high content of ash with a mean value of 90.25% in the pre monsoon season and 88.88 % in post monsoon season reveals that the calorific value will be low.

The physico-chemical analyses of MSW dumpsite soil revealed that except EC, SAR, chloride, nitrate and lead, all other parameters including metals are within the permissible limits as per EPA-2011 & 2012 for land use as agriculture, residential, park and industrial use.

Heavy metals escape from a landfill; they are likely to do so primarily in the aqueous form, via landfill leachate or runoff. Another important characteristic is the pH level; lower pH values (acidic conditions) will tend to increase the solubilities of metals. A model developed by Bozkurt et al. also addressed long-term conditions. Their model results indicated that the binding capacity of humic substances should be sufficient to bind all Cd, Cr, Pb, Zn, and Hg present in a landfill, Their model also predicted that the binding capacity of hydrous ferric oxides, formed by oxidation reactions in the post-methane forming phases of MSW dumpsite, would be sufficient to bind three times as much of the metals that are susceptible to such binding. In addition, the model predicted that the alkalinity of typical wastes is high enough to buffer increasing concentrations of acids generated in the latter stages of a landfill's cycle, so that higher mobilization rates of heavy metals would not be expected for many thousands of years. It is found that heavy metals in most cases appear to be strongly attenuated in MSW dumpsite soil, and that natural attenuation processes provide significant remediation, limiting the effects of dumpsite on groundwater to an area usually not exceeding 1000 m from the landfill [30]. The non-biodegradable organic matter and the attenuated metals of the MSW soil can be removed by mining and chemical-biological processes to alter the form of metal contaminants in order to decrease their toxicity and/or mobility.

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