International Journal of Geology, Earth & Environmental Sciences ISSN: 2277-2081
Online International Journal Available at http://www.cibtech.org/jgee.htm
2022 Vol. 12, pp. 204-212/Pankaj and Prama
Research Article (Open Access)

IMPACT OF MUNICIPAL SOLID WASTE DUMPING ON SOIL QUALITY

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ABSTRACT
The problem of waste disposal is huge. With the increasing population each year, the amount of waste generated is also increasing at a great rate. In-spite of several efforts the disposal and management of the municipal solid waste is becoming a big problem in the world especially among the developing and underdeveloped nations. Improper handling, lack of segregation and unplanned dumping of solid waste is causing a lot of nuisances in the environment. The current paper discusses about the effects of dumping municipal solid waste in one of the dumping grounds of Jaipur city in Rajasthan. The presence of municipal solid waste dumpsite caused lot of changes in the physicochemical properties of the soil.

***Keywords**: Municipal Solid Waste, Dumpsite, Dumping Grounds, Soil Quality, Landfill*

INTRODUCTION

The changing life style and easy availability of products has made life easier. Introduction of sophisticated machinery and mechanization of all production processes has increased the quantity and availability of a variety of goods in the market in the last decade. This has serious implications on the environment, mostly associated with the generation of large amount of waste and its handling and management. This problem is easily tackled in the developed nations due to less population, availability of funds and technology. But in the developing nations the management and handling of the municipal solid waste is not very efficient. This has serious impacts on the environment. Thus, due to large population and lack of proper waste management system in most of the developing nations, municipal solid waste is dumped on open grounds without any segregation. Disposal of household hazardous waste that includes batteries, paint residues, paint cans, ash, plastic products, discarded medicines and electronic wastes considerably adds to the heavy metal content in MSW dumping sites (Ahsan *et al*., 2013; Esakku *et al*., 2008).

Soil is usually the most polluted part of the ecosystem around dumpsites. Seepage of water through the waste causes leaching of undesirable components that pollutes soil it as it is the medium of transporting and distributing chemical elements (Magaji, 2012). The disproportionate input of unsorted municipal solid wastes leads to changes in physical and chemical characteristics of the soil. Soil pollutants deteriorate the quality, texture and mineral content of the soil, and disturb the biological balance of the organisms in it and have lethal impact on the plant growth and development (Maheshwari *et al*., 2010). Few exogenous substances like humic acid found in municipal wastes can react with soil components (the hydrophilic groups in the humic acids may interact with the polyvalent cations present on the soil particle surface) thus changing the soil physical properties (Piccolo and Mbagwu, 1997). The polluted soil affects human health through direct human contact or inhalation of the polluted airborne dust and the consumption of the garden vegetables grown on abandoned dumpsites or around active dumpsites (Anekwe and Nwobodo, 2002).

The current research work involves the study of physico-chemical characteristics of soil around a municipal solid waste dumping site situated in Jaipur, Rajasthan and its comparison with control soil.

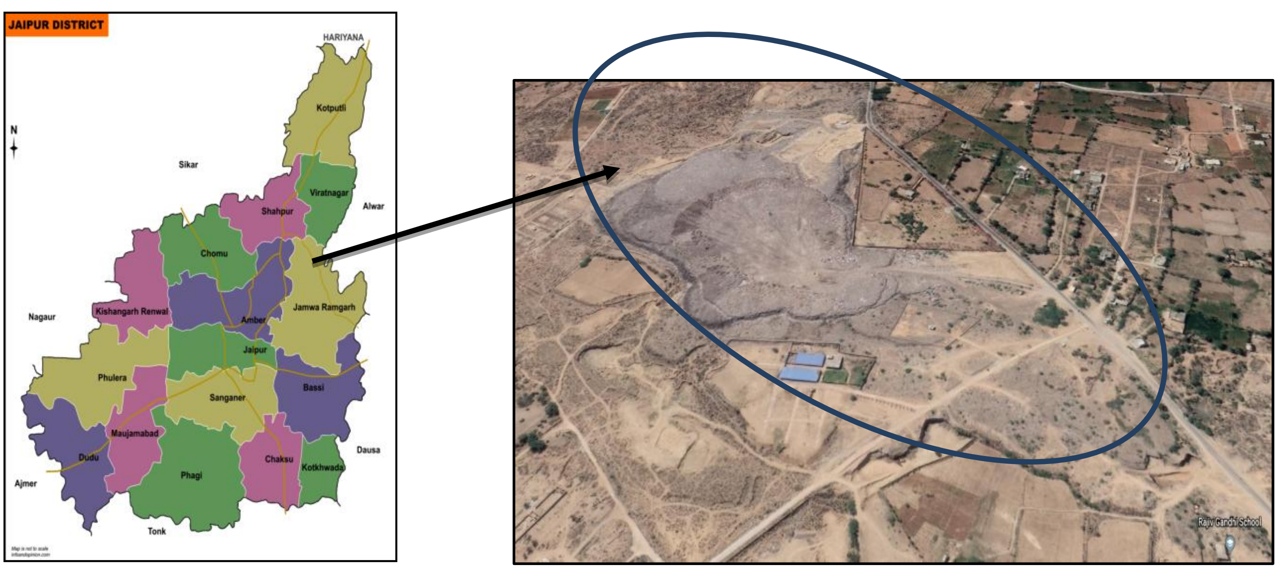
STUDY AREA

The state of Rajasthan is situated between 23º3' and 30º12' N latitude and 69º30' and 78º17' E longitude. It spreads over an area of 132,140 square miles (342,239 square kilometers). Jaipur city is capital of Rajasthan state and is popularly known as the "Pink City". It is situated in the eastern part of Rajasthan. The area of Jaipur district is 11,117.8 sq. km. Jaipur district has 47.6 % rural, 52.4 % urban population, and the total population is 66,26,178 with an average population density of 470 people per sq. km. (Census of India, 2011).

The district has a dry climate with a hot season. Normally, cold season starts from December and lasts till February after that hot season follows which continues up to mid-June. During the mid-June to mid-September period, it is visited by the southwest monsoon, remaining period till winter is post monsoon season. The summers in Jaipur are very hot while winters are extremely cold. The maximum temperature ranges between 40°C to 47°C in May. Heat waves are common for a few days in the season, when day temperature rises 4 to 6°C above the normal temperature. During winters, minimum temperatures remain around 4 – 9°C. Mist and fog are also common during the morning hours after the passage of western disturbances.

Jaipur receives over 650 millimeters (26 in.) of rainfall annually but most rains occur in the monsoon months between June and September. Monsoon usually sets around 25th June, and last up to middle of September. Rainfall decreases sharply in October and November.

Municipal solid waste of Jaipur is dumped in three major dumping grounds situated at Sewapura, Langariyawas and Mathuradaspura. The dumping site at Mathuradaspura village is an open dumping ground (Figure 1). It lies in the north-east part of the Jaipur, in Jamwa Ramgarh Tahsil. The area of the village is about 365 hectares (Census of India, 2011). A total of 176 bigha has been allotted for the waste disposal. This is one of the oldest dumping sites. Almost 400-410 TPD of garbage is dumped here. The field surveys indicate that the municipal solid waste without segregation is dumped on the land without any covering. Alluvial and wind-blown sand is found in Mathuradaspura, Gwardih and Langariyawas. The aquifer present is of young alluvium type in the vicinity of the study area surrounded by older alluvium and Quartzite type of aquifer. The Jamwa Ramgarh comes under the area where the groundwater is over exploited.



(A) (B)

Figure 1: A. Map of Jaipur city. B. Satellite view of Mathuradaspura municipal solid waste dumpsite.

MATERIALS AND MATHODS

Soil Sampling

To investigate the pollution of soil by municipal waste dumps the present study considered the dump site as point source of pollution (Liu *et al*., 2007). The soil samples were collected randomly from 12 sites at different depths. Grab sampling technique was utilized to collect the soil samples. For locating the sampling points in the study area, the active dumpsite was considered as the center point and an area with radius 2.5 km was taken into consideration for soil sample collection. Uniform distance between the sampling sites could not be maintained due to following reasons: construction activities, hard rocky soil layers, inaccessibility (due to private ownership, stray animals, undulating surface, excessive amount of solid waste etc.). Samples were collected according to 'depth-waning principle', that implies that the pollutant concentration reduces with depth (Liu *et al*., 2007). At the point of sample collection, the surface was cleared off the dried leaves, plastic, or other waste material. A core cutter was used to collect undisturbed sample. The soil samples were collected in clean, labeled zip-lock polythene bags, and were tightly sealed. The soil samples were brought to the laboratory, were dried in oven at 30 degrees centigrade for a period of 24 hours in pre- cleaned, dried and weighed petri-plates. The characteristics studied are listed in table 1.

Table 1: List of physicochemical parameters studied

S.No.	Parameter	Unit	Method used
1.	Bulk Density	g/cm^3	-
2.	Water Holding Capacity	%	-
3.	Moisture content	%	Drying in hot air oven
4.	pH	-	Digital pH meter (Labman, LMPH-10)
5.	Electrical Conductivity	milliS/cm	Digital conductivity meter (Labman, LMCM-20)
6.	Organic Carbon and Matter	%	Walkley–Black Method (1934
7.	Chloride	mg/kg	Mohr's method
8.	Available Nitrogen	kg/ha	Macro Kjeldhal method

RESULTS AND DISCUSSION

Physicochemical properties of soil

Several studies have proved that pollutant concentration may decrease when municipal waste leachates migrate through soil layers due to physical, chemical and biological processes (Wang *et al*., 2004; Liu *et al*., 2003; Tchobanoglous *et al*., 1993).

***Water holding capacity (WHC, %)*:** Water holding capacity ranged between 27.422% and 48.33% in the upper soil layer. Maximum WHC was observed in site 5 (Table 2). Akinbile (2012), Tripathi and Misra (2012), Jadoun and Singh (2014), Saritha *et al.,* (2014) also reported high water holding capacity in the sites close to the municipal solid waste. WHC was found to be more in the sites close to the dumpsite this may be due to the organic matter fraction and soil texture. High water holding capacity also reflects the ability of the dumpsite soil to hold leachate for a longer time. The elevated organic matter in the soil around the dumpsite affects the soil texture and increases the pore spaces in the soil thus increasing the water holding capacity of the soil around the dumpsite.

***Bulk Density (g/cm^3)*:** The bulk density of the soil ranged between 1.211 g/cm^3 and 1.693 g/cm^3 in the surface layer and between 1.204 g/cm^3 and 1.705 g/cm^3 in the lower layer. Municipal solid waste increases organic and inorganic fraction in the soil causing an increase in soil matrix thus reducing the soil bulk density as compared to uncontaminated soil (Akintola *et al.,* 2021). Raised bulk density of the soil around the dumpsites can reduce the root length of the plants and also reduce root penetration in dump soil that may lead to less availability of nutrients (Tripathi and Misra, 2012). High value of bulk density in the lower horizon may be due to the relatively more compaction as compared to the upper layers (Viji and Prasanna 2011; Anikwe and Nwobodo 2002). In the current study bulk density was quiet variable with the distance which may be due to anthropogenic activities around the dumpsite (Table 2).

Moisture content (%): The moisture percent in most of the sites increased with the depth. Maximum moisture percent was observed in site 5 i.e., 5.438% and lowest in site 9 i.e., 0.388% in surface layers. The moisture content of soil around the dumpsite was higher than that of uncontaminated site (1.069%) especially in sites that had high organic carbon. This is in accordance with the observations of Akinbile (2012) and Moura *et al.,* (2009). The moisture content around the dumpsite may be due to the increased activity of microbes and high organic matter (Zhang *et al.,* 2007). The increase in moisture content with the depth was also reported by Ihedioha *et al.,* (2016).

Table 2. Physical properties of the soil samples around the dumpsite *(Mean±SD)*

Site	Distance	Depth (cm)	Water holding capacity (%)	Bulk density (g/cm^3)	Moisture (%)
1.	300.18 mt	0-15	43.28±0.258	1.242±0.124	2.709±0.251
		15-30	44.15±0.366	1.251±0.221	2.166±0.173
2.	487.60 mt	0-15	40.199±0.325	1.261±0.025	1.877±0.750
		15-30	38.27±0.141	1.272±0.058	1.984±0.768
3.	624.10 mt	0-15	34.420±0.122	1.449±0.091	2.433±0.688
		15-30	31.551±0.163	1.452±0.025	1.647±0.506
4.	678.44 mt	0-15	47.088±0.180	1.693±0.215	1.384±0.059
		15-30	39.536±0.143	1.705±0.213	1.479±0.164
5.	708.08 mt	0-15	48.33±0.118	1.219±0.025	5.793±0.835
		15-30	43.716±0.209	1.223±0.031	5.825±0.554
6.	760.71 mt	0-15	41.377±0.157	1.211±0.036	0.813±0.009
		15-30	41.984±0.174	1.204±0.028	1.507±0.086
7.	824.07 mt	0-15	34.621±0.234	1.215±0.088	1.221±0.340
		15-30	32.155±0.315	1.221±0.045	1.437±0.055
8.	1.14 km	0-15	36.400±0.662	1.328±0.145	0.887±0.162
		15-30	27.801±0.128	1.333±0.037	0.921±0.068
9.	1.24 km	0-15	39.314±0.146	1.537±0.052	0.388±0.151
		15-30	40.152±0.169	1.548±0.017	0.653±0.133
10.	1.50 km	0-15	42.219±0.133	1.437±0.054	0.809±0.044
		15-30	44.374±0.106	1.422±0.028	0.991±0.025
11.	1.47 km	0-15	27.422±0.185	1.425±0.032	0.947±0.044
		15-30	21.49±0.195	1.429±0.095	0.985±0.036
12.	2.5 km	0-15	40.125±0.163	1.395±0.061	1.178±0.056
		15-30	37.856±0.157	1.398±0.079	1.468±0.069

pH**:** The pH ranged between 7.796 and 8.868 in the upper layer while in the second layer it ranged between 7.713 and 8.762. The pH decreased down the profile in all the sites and was high as compared to control. According to Goswami and Sarma (2008) the soil pH may reduce with depth due to the leaching action of waste, nature of soil, mechanical composition etc. The pH of the soil samples in the current study showed alkaline nature. The alkaline pH represents the biological stabilization of the organic components (Maiti *et al*., 2016) and methanogenic stage of the waste and is usually reported in mature landfills. The dumpsite at Mathuradaspura is in operation since last 25 years which suggests stabilized condition. The pH in all the sites was higher than the pH of uncontaminated soil. Akintola *et al.*, (2021), Ali *et al*., (2014), Kanmani and Gandhimathi, (2013), Azeez *et al*., (2011), Goswami and Sarma (2008) and Elaigwu *et al*., (2007) also reported high pH value of the soil collected in the vicinity of municipal solid waste dumpsite. pH is very crucial in terms of the mobility of metals, their bioavailability. Metal availability is fairly low when the pH is around 6.5–7 (Chimuka *et al*., 2005). Alkaline soil conditions result in immobilization of soil heavy metals especially in arid and semi-arid conditions thus favoring plant growth (Ali *et al*., 2014). The high pH value of the soil may be attributed to the quality of leachate leaching from the dump site (Elaigwu *et al*., 2007). The presence of carbonates, bicarbonates, sodium, potassium and other alkaline materials contribute to the alkalinity of the soil and the most optimal range of the pH of the compost for crop yield has been reported to be in the range 5.5-8.5 (Goswami and Sarma, 2008). Another reason for high pH may be mineralization of carbon and the subsequent production of OH- ions by ligand exchange along with the introduction of basic cations, such as K^+, Ca^{2+}, and Mg^{2+} (Mkhabela and Warman, 2005).

Electrical conductivity (EC, milliS/cm)**:** Electrical conductivity ranged between 0.271 mS/cm to 1.056 mS/cm in the surface layer while in the lower layer it ranged between 0.236 mS/cm and 1.002 mS/cm. The EC value decreased with depth in all the sites (Table 3). Similar result was obtained by Mekonnem *et al*., (2020). EC values in all sites was higher than the EC of uncontaminated soil. EC of the soil solution is linked to the dissolved solutes of soil and is often used as a measurement of soil salt quantity (Brady and Weil, 1996). Thus, high EC value of soil indicate excess amount of soluble salts or ionic impurities present in the waste that are leached during waste decomposition. According to, Goswami and Sarma (2008) EC value lower than 0.5 milliS/cm is safe for plant growth but higher values may be toxic to plants, affecting their water absorbing capacity. Zhang *et al*., (2007) reported a decline in soil EC values over time, possibly because of nutrient uptake by crops and leaching. In the current study, high value was found in areas around the older dumpsite where active dumping was not taking place. Kanmani and Gandhimathi (2013), Goswami and Sarma (2008) also reported high EC values in the MSW compost amended soil.

Organic matter (OM, %)**:** Organic matter ranged from 0.491% to 2.229% in the upper soil layer while in the lower layer it ranged between 0.391 to 1.221 % (Table 3). Maximum organic matter was found in the site 5 which was situated adjacent to the old dumpsite. The high level of organic matter present in the upper horizon of the dump sites may be attributed to the high organic fraction in municipal solid wastes (Kiba *et al*., 2012). High organic matter was also reported by Gupta 2019, Kanmani and Gandhimathi (2013), Akinbile (2012), Chukwujindu *et al*., (2010), Goswami and Sarma (2008) in soil around the dumpsite. According to Kiba *et al*., (2011) the main source of carbon in soils around dumpsites include decaying organic waste and SUW (solid urban waste), thus SUW applications increases soil nutrient and heavy metal contents and also improves the soil structure. Organic matter favors the pooling of essential and non-essential mineral elements for plant growth and development, hence increased organic matter content may lead to increased soil productivity (Anikwae and Nwobodo, 2002). The soil organic matter content declined with increasing depth of the dump site soils, as also reported by Vijayalakshmi *et al*, (2020), Anikwae and Nwobodo (2002). The organic matter content found in the subsoil has an important role in adsorption reaction in the soil thus preventing pollutants from reaching ground water sources (Alloway and Aryes, 1997). Some sites showed relatively high organic matter, contributing to an increase in pH as also reported by Ali *et al*., (2014). This is due to release of exchangeable cations during mineralization of organic matter (Anikwe and Nwobodo, 2002).

Chloride content (mg/kg)**:** The chloride content in the soil was highest in site 5. It ranged between 58.22 mg/Kg and 463.63 mg/kg in the surface layer while in the subsequent layer it ranged from 38.34 mg/kg to 454 mg/kg. Chloride content in all sites was very high as compared to the control, may be due to their proximity to the dumpsite. Similarly, Kanmani and Gandhimathi (2013) also reported high chloride content in soil around a dumpsite situated in Tiruchirappalli, Tamil Nadu (India). Chloride content reduced with the soil depth indicating accumulation of salts in the surface layers. Elevated soil salinity is related to high soil pH and under such conditions the availability of certain plant nutrients is reduced that might lead to severe disturbance in the nutrient balance of the plants. High salinity also leads to water stress in plants. Soil salinity disrupts the plant–microbe interaction, which is an important ecological factor in plant growth especially in degraded ecosystems (Paul and Nair, 2008). Under such stressful conditions, they become more

Table 3. Chemical properties of soil samples collected from the dumpsite (Mean ±SD)

Site	Distance (mt/km)	Depth (cm)	pH	EC (milliS/cm)	Organic Matter (%)	Chloride (mg/kg)	Ava. Nitrogen (kg/ha)
1.	300.18 mt	Surface 15-30	7.796±0.015 7.713±0.020	0.569±0.011 0.532±0.020	1.905±0.248 1.008±0.088	329.91±2.95 285.65±4.72	266.158±1.163 223.475±1.393
2.	487.60 mt	Surface 15-30	8.463±0.025 8.266±0.179	0.408±0.005 0.376±0.005	1.535±0.069 0.806±0.088	193.12±10.531 156.2±1.230	156.98±0.630 140.80±1.312
3.	624.10 mt	Surface 15-30	8.547±0.002 8.520±0.010	0.608±0.020 0.612±0.128	1.065±0.103 0.930±0.108	352.63±10.84 349.5±5.422	189.135±6.305 136.600±3.640
4.	678.44 mt	Surface 15-30	8.34±0.015 8.21±0.005	0.380±0.015 0.328±0.012	1.613±0.088 0.908±0.089	285.890±4.564 311.217±5.423	150.88±0.727 108.20±4.815
5.	708.08 mt	Surface 15-30	8.760±0.020 8.573±0.042	1.056±0.001 1.002±0.003	2.229±0.205 1.221±0.069	463.63±1.878 454.40±0.710	243.70±9.63 153.40±3.63
6.	760.71 mt	Surface 15-30	8.868±0.031 8.762±0.020	0.426±0.280 0.385±0.014	1.065±0.151 1.030±0.069	300.57±4.099 273.35±3.550	239.99±6.940 154.40±3.150
7.	824.07 mt	Surface 15-30	8.650±0.070 8.642±0.021	0.578±0.156 0.531±0.017	0.986±0.019 0.723±0.018	198.204±3.580 134.577±4.125	255.366±1.950 217.281±1.281
8.	1.14 km	Surface 15-30	8.119±0.050 8.045±0.129	0.522±0.025 0.514±0.036	1.275±0.066 1.072±0.058	244.626±3.001 184.007±2.156	210.340±2.446 196.485±2.378
9.	1.24 km	Surface 15-30	8.265±0.005 8.261±0.029	0.680±0.010 0.420±0.012	1.345±0.146 0.863±0.136	298.20±0.710 272.16±4.099	201.744±6.304 136.590±3.639
10.	1.47 km	Surface 15-30	7.992±0.044 7.856±0.052	0.271±0.014 0.236±0.024	0.491±0.022 0.391±0.140	58.22±5.940 38.34±0.710	141.85±3.150 127.98±1.668
11.	1.5 km	Surface 15-30	8.324±0.220 8.311±0.047	0.426±0.150 0.415±0.250	1.188±0.142 1.055±0.122	256.114±0.124 221.315±0.488	157.45±1.256 116.47±1.340
12.	2.5 km	Surface 15-30	7.801±0.110 8.143±0.240	0.418±0.042 0.386±0.015	1.232±0.033 1.126±0.051	238.264±0.941 210.007±0.998	165.28±1.726 113.08±2.443
Control Soil			7.241±0.070	0.244±0.020	0.524±0.048	42.126±0.941	130.79±0.739

susceptible to diseases caused by pathogenic fungi. When uptake of chloride rises to a toxic level, it is easily converted to toxic compounds (like hypochlorites), before it can be detoxified with the nitrate reductase (Berges *et al*., 1995).

***Available Nitrogen (kg/ha)*:** The available nitrogen varied between 141.85 kg/ha to 266.158 kg/ha in the surface layer while in the second layer it varied between 108.20 to 223.475 kg/ha. The available nitrogen content was highest in site 1 (Table 3). The value of available nitrogen was higher in all sites as compared to the uncontaminated soil. The available nitrogen is the mineralizable fraction of nitrogen that is available to the plants. With the mineralization of organic matter, nitrogen is also released into the soil (Hernandez *et al*., 2002). The availability of nitrogen in the initial years of application of compost or landfill soil is less but with time the availability increases. The available nitrogen content was found to be high in the current study, similar results were obtained by Gupta (2019) as well as Goswami and Sarma (2008) which may be due to presence of stabilized waste. The nitrogen content decreased with increase in soil depth in the current study, similar observations were made by Anikwae and Nwobodo (2002). The quantities of available nitrogen and carbon from MSW are closely linked to the maturity of compost, mineral fertilizers, soil characteristics and environmental factors (Crecchio *et al*., 2001). Excess nitrogen supplied to plants may cause changes in the shoot/root ratio and reduce mycorrhizal induction in soil leading to nutrient imbalance.

CONCLUSION

The current study revealed that the municipal solid waste has greatly affected the soil properties around the dumpsite. On comparing the values with the uncontaminated site, it was found that the sites around dumpsite have higher values of pH, conductivity, moisture content, organic matter, salinity and available nitrogen. the soil pH was towards alkaline range indicating stabilized condition of waste. In the present study the active dumpsite was not accessible so the sample collection was done from the old dumpsite region. The prevailing conditions indicate that if the waste segregation is done in an effective manner in the initial stages of municipal waste collection, then the organic fraction from the waste can be utilizes to prepare compost. To obtain good quality of compost proper segregation of polyethylene products, metals, and other hazardous waste needs to be done. Numerous authors have confirmed that some inorganic contaminants, such as anions, continue leaching for decades.

Old landfills and dumpsites result in unnecessary occupancy of land and excessive nutrient load in soil leading to environmental pollution, hence landfill mining may be a viable method for recycling the accumulated nutrients and remediating the occupied land but only if the metal pollution is low. Unmanaged dumpsite may lead to pollution of water resources, soil, air and affects the flora and fauna to varied extent. Prolonged dumping of unsegregated waste may lead to leaching of excessive minerals and metals in the soil and ultimately to ground water causing disturbances in the ecosystem balance and structure.

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