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A Case study approach on Municipal Solid Waste generation and its impact on the soil environment in Dharapuram Municipality, Tamilnadu, India

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Abstract: The increasing level of municipal solid waste is a serious problem in the urban and rural areas. A high rate of growth of population and increasing per-capita income have resulted in the generation of enormous municipal solid waste and it posing a serious threat to entire environmental quality and human health. However, due to the limited resources and precise regulatory guidelines, the treatment and disposal of solid wastes in an effective and appropriate manner is grossly inadequate. In this paper, Dharapuram Municipality was selected and conducted a case study about the solid waste generation and its adverse impacts on the soil environment in and around the dump yard. The physico – chemical characteristics of solid waste and soil samples were analyzed based on standard procedure. It was observed that the present management systems of municipal solid waste are inadequate and irregular. However, municipalities and other organizations are making efforts for managing the waste generated in Dharapuram Municipality. The present paper summarizes the current situation of the solid waste generation and the soil quality of Dharapuram Municipality, Tamilnadu, India.
Keywords: Solid Waste, Soil, Parameters, Heavy Metals, Municipality, Population.

Introduction

In the developing countries, the ever increasing human population and the associated anthropogenic activities have accelerated the phenomenon of urbanization in the past decade. Out of total increase of 181.4 million people during the last decade i.e. 2001-2011, 90.4 million increases are in rural areas while 91.0 million is in urban areas[1]. With the rising population and the associated unsustainable practices, there has been an enormous increase in the quantum as well as the diversity of the solid waste being generated. “Municipal Solid Waste” (MSW) includes the commercial and residential waste generated in municipal or notified areas in either solid or semi-solid form excluding industrial hazardous waste; e-waste and including treated bio-medical waste. Solid waste generation is a natural phenomenon and amount of waste produced is directly proportional to the population growth. Therefore, Municipal Solid Waste Management (MSWM) is one of the major neglected parts in handling the waste and it becomes the environmental problems of Indian megacities. Meager collection and inadequate transportation causes the accumulation of MSW at every nook and corner. The management of MSW is going through a critical phase, due to the unavailability of suitable facilities to treat and dispose of the larger amounts of MSW generated daily in metropolitan cities[2]. Indian cities now generate eight times more MSW than they did in 1947 because of increasing urbanization and changing life styles [3]. The rate of increase of MSW generated per capita is estimated at 1 to 1.33% annually [4]. MSW generation rates in small towns are lower than those of metro cities, and the per capita generation rate of MSW in India ranges from 0.2 to 0.5 kg/ day. The projections made for waste generation have been done on the basis of the waste generated per person per day as of 2001 and the census projections for 2011-20 given by the census of India website [5] and NEERI [6] shows that the generation of municipal solid waste will increasing in nature due to the population and socio economic growth in all states of India.

Due to the disposal of waste in open place and open burning, there is lot of problems to the environment. Municipal landfill sites produce leachate that contains concentrated toxic chemicals[7]. Leachate production is a result of rainfall and of surface water or groundwater entry into the landfill site. Some of the hundreds of toxic substances found in landfill leachate are: lead, cadmium, chromium, mercury, toluene, dioxins, organophosphates, and PCBs. It contains mixtures of many chemicals having a potential risk to human health through penetrating into the ground water. Also it changes the soil property and texture. Due to the disposal of solid waste in the soil having without precautions causes serious problem to the soil color, texture, properties, soil microorganism etc. Due to migration of leachate, soils have been contaminated with heavy metals such as lead, copper, zinc, iron, manganese, chromium, and cadmium and these heavy metals in solid wastes lead to serious problems because they cannot be biodegraded [8]. Repeated application of MSW has been shown to increase the trace elements and heavy metals in soils and converting the soil to alkaline condition.

Experimental

MSW Characterization

In the present study, fresh commercial and residential waste samples were collected two days per week and totally 8 to 10 samples for a month in Dharapuram Municipality dump site while at the time of disposing waste from trucks into dump yard. The sampling was started from month of January and continues up to December of the year 2013. The samples collected from all the locations were subjected to segregation and further segregated samples were weighing separately. The dried and pulverized biodegradable portion of MSW was used for physico - chemical analysis. For the characterization of MSW, samples were thoroughly mixed for 30 minutes in the ratio of 1:10 with distilled water using mechanical shaker. The respective filtration subjected for analyzing of various physico – chemical parameters with reference to the APHA procedure [9].

Soil Sampling and Analysis

Soil samples were collected at selected locations in the study area to assess the existing soil conditions in and around the dump yard for the months of May and December 2013. This will establish the baseline characteristics and will facilitate in the identification of the incremental concentrations from the proposed activities at a later stage. In the present study, the soil samples were collected from four locations (S1 to S5) with the distance of 200 m from the Dharapuram open dump site boundary. Soil samples were collected in four directions such as North, East, West, South and one sample had been taken from the dumpsite itself. Soil samples were collected at surface (0 – 15cm) and subsurface (16-30cm). A total number of 10 samples were collected, properly labeled and brought to the laboratory for analysis. All soil samples were air dried to a constant weight, sieved to <2 mm through a stainless steel sieve and homogenized preserved in clean plastic containers for subsequent use [10]. The details of the sampling locations are given Table 1. The collected soil samples were subjected to NEPM procedure for the determination of various parameters[11]. For general analysis, the sieved soil samples were mixed with distilled water in the ratio 1:20 and kept for overnight at mechanical shaker. The filtered samples were used to analysis the parameters such as pH, EC, Chloride, Total Alkalinity, and Total Hardness based on the procedure described in APHA procedure. For the determination of total metal content, boiling aqua regia (3:1 hydrochloric/nitric acid) was used to extract the metals from the samples. The strong and concentrated acid mixture is capable of extracting inorganic metals. One gram of soil was mixed with 18 ml of concentrated HCl and 6 ml of concentrated HNO_3 and moistened with a little deionised water. The mixture was gently boiled in a hot plate until about 5–10 ml of extract remains in the flask and allowed to cool for about 15 min. Then, 18 ml of concentrated HCl and 6 ml of concentrated HNO_3 were added and boiling was repeated till about 5–10 ml of extract remains in the flask. After cooling, the extract was filtered through Whatman No. 42 filter paper and was made up to 50 ml with distilled water [12].

Table 1 Sampling Location

S.No.	Direction	Type
S1	North	0 – 15 cm
S2		16 – 30 cm
S3	East	0 – 15 cm
S4		16 – 30 cm
S5	West	0 – 15 cm
S6		16 – 30 cm
S7	South	0 – 15 cm
S8		16 – 30 cm
S9	Dump site	0 – 15 cm
S10		16 – 30 cm

Results and Discussion

Quantification of Solid waste

The solid waste sample was quantified for all the months in the year 2013 on regular interval period to know about the exact production of the waste generation in the Dharapuram town. The monthly average of the municipal solid waste was given in the Table 2. The major sources of generation of solid waste are: Domestic, Commercial areas and vegetable markets, Hotels and restaurants, Street Sweeping, Health care facilities except Bio medical waste, Slaughter house, & Construction activities, Horticultural waste, Worship places etc., The quantification results of the Dharapuram Municipality showed that the average generation of the solid waste per day is 33.22 MT/day for the year 2013. There was no more greater deviation in the generation of solid waste between the months of the year 2013. Also the per capita generation of solid waste for was 0.5875 kg/day/capita. Again the per capita generation values clearly indicated the uniform generation of the solid waste throughout the year. There was a small deviation in the generation of the solid waste; but it may be due to the socio economic factors and various environmental factors.

Table 2 Quantification of solid waste for 2013

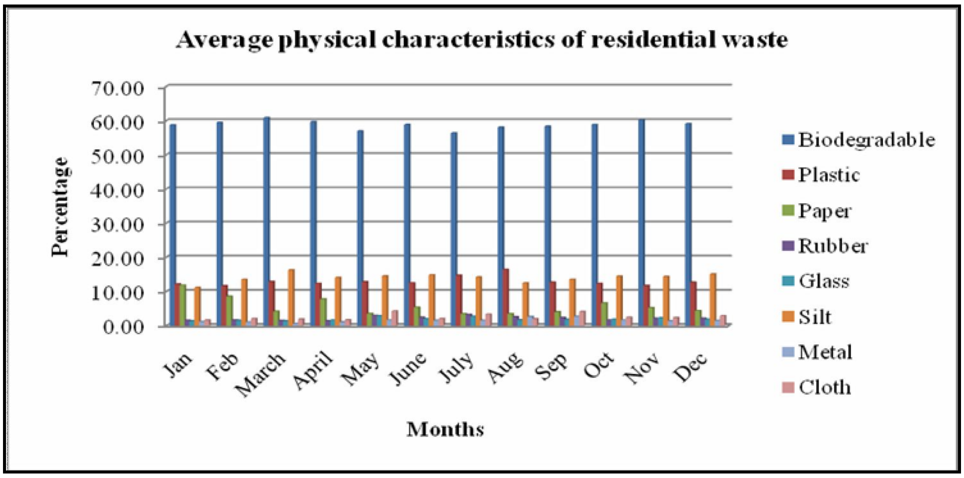
Month	Waste Generated (MT)
January	32.32
February	34.49
March	33.63
April	36.16
May	30.86
June	31.53
July	32.07
August	32.19
September	33.51
October	32.84
November	33.6
December	35.51
Average	**33.22**
Per capita Genaration	0.5875 kg/day/capita

Characterization of MSW

No previous study has thoroughly explicated a waste composition analysis for Dharapuram Municipality;Samples of refuse from the disposal facility were collected and analyzed for physical and chemical characteristics. The average of the physical characteristics of the MSW of residential waste and commercial waste collected during 2013 was shown in Figure 1 and Figure 2.

From the results it was clearly observed that the major portion of the waste from all the categories like commercial and residential was biodegradable waste for all the months. Next to that silt, plastic and cloth were followed. The results were compared with solid waste composition reported by other researchers. The another researcher[13] reported that the MSW composition from Perungudi dumping site (Chennai City, Tamil Nadu) contained about 60–70 % combustible materials such as textile, leaves, plastics, food waste, etc., with an average of 65 %. The non-combustible fraction such as metals and glass was about 30–40 % with an average of 35 %. The same results were observed by various research works at various places by various authors. The solid waste composition in most Asian countries is highly biodegradable, mainly composed of an organic fraction with high moisture content [14]. Also, other author revealed that the biodegradable waste was high when compared to non-biodegradable waste in MSW composition at Chennai city [15].

Figure 1 Average physical characteristics of residential waste



The relative percentage of organic waste is generally increasing with the decreasing socio-economic status; so rural households generate more organic waste than urban households. For example, in south India the extensive use of banana leaves and stems in various functions results in a large organic content in the MSW. Also, it has been noticed that the percentage of recyclables is very low, because of rag pickers who segregate and collect the materials at generation sources, collection points and disposal sites [3]. The change in lifestyles has caused considerable change in the composition of MSW generated in India too. The physico-chemical characteristics of residential and commercial waste were shown in the Table 3 and 4 respectively. The bulk density increased when the particle size decreased, significantly higher bulk density suggests that these MSW fractions have less pore space and are more quantity may dumped in the dump site.

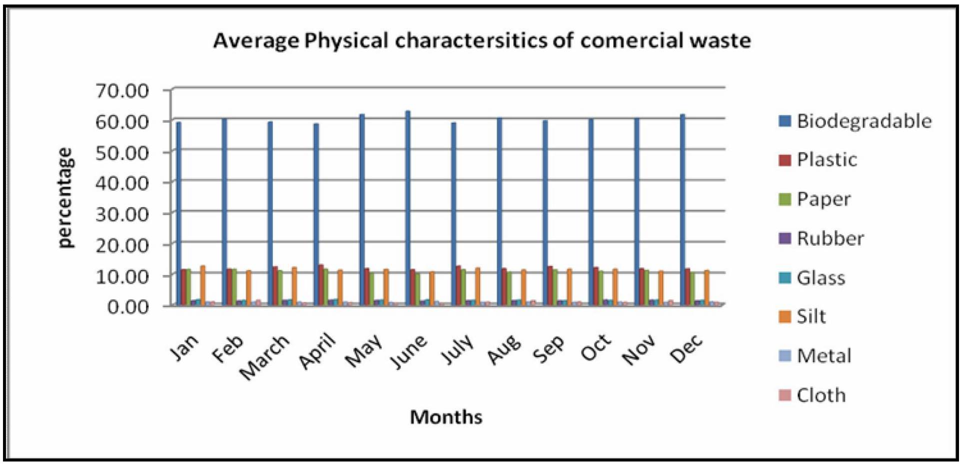


Figure 2 Average physical characteristics of commercial waste

Normally the pH of the MSW was not much deviated from the neutral value for the all months. The moisture content in the samples may vary due to the seasonal changes, winter; southwest, northeast monsoon and occasional rainfall may increase the moisture content in the MSW. Also it causes the inconveniences for the municipality workers while at the time of collection and also it will allow the insects to breed and cause some serious health problems. The presence of Total Organic Carbon in the MSW highlights the amount of organic carbon in the whole organic matter. Current results conclude that the organic carbon in the MSW was in reasonable range and it will support the increase of carbon content while in composting process. The presence of remaining parameters such as Calcium, Sodium, Potassium, Sulphate and phosphate are in less percentage and it will not pose any serious hazards to the soil environment.

Soil Quality Analysis

The quality of the soil in and around the Dharapuram dump yard was studied in detail to assess the different physico-chemical parameters for May and December months of year 2013. The soil samples at different depths were collected and analyzed. The results of the physico-chemical parameters of the soil at May and December months were given in Table 6 and 7 respectively.

Table 4: Physico-Chemical Characteristics of Residential Waste

Composition	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec
Bulk Density (kg/m^3)	182	182	182	184	184	184	181	184	181	183	183	182
Moisture (%)	20.94	22.87	19.97	22.15	22.62	21.84	22.27	22.09	22.26	22.09	21.51	20.21
pH	7.86	7.64	7.67	7.47	7.81	7.54	7.61	7.48	7.64	7.50	7.81	7.77
Loss on Ignition (%)	16.05	16.94	17.75	18.70	18.24	18.25	18.54	18.32	17.29	17.53	17.10	18.15
Ash Content (%)	8.03	8.98	8.45	8.94	9.54	10.02	8.91	9.46	9.06	8.93	8.99	9.35
Total Organic Carbon(TOC) (%)	18.37	18.89	18.94	18.01	18.09	17.68	19.19	18.45	18.71	19.05	18.04	19.58
Calcium(Ca) (%)	0.86	0.82	0.81	0.76	0.96	0.84	0.84	0.99	0.90	0.87	0.92	1.00
Sodium(Na) (%)	1.49	2.07	1.64	1.68	1.72	1.80	2.02	1.84	1.91	1.79	1.71	1.76
Potassium(K) (%)	1.62	2.13	1.75	2.31	2.28	1.81	2.05	1.97	1.84	1.96	1.91	1.52
Sulphate(SO4) (%)	1.73	2.24	1.78	1.80	2.44	1.87	2.15	2.01	1.88	1.94	1.88	2.03
Phosphate(PO4) (%)	0.70	1.45	0.84	1.43	1.50	1.74	1.86	1.64	1.00	1.32	1.42	1.65
Total Nitrogen (TN) (%)	0.69	0.87	0.69	1.71	0.98	0.76	0.99	0.87	0.79	1.10	0.81	0.78

Table 5: Physico-Chemical Characteristics of Commercial waste

Characteristics	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec
Bulk Density (kg/m3)	185	179	171	173	183	178	182	184	182	180	182.53	180.54
Moisture (%)	22.01	20.70	20.41	18.86	22.32	20.95	22.78	20.33	24.78	21.69	23.16	23.23
pH	7.24	7.42	7.57	7.49	7.51	7.38	7.65	7.61	7.88	7.60	7.59	7.56
Loss on Ignition (%)	18.27	17.08	18.16	17.23	20.03	17.85	20.13	17.48	21.02	18.75	20.82	17.99
Ash Content (%)	8.41	7.20	8.66	6.96	9.67	7.96	9.75	8.43	9.67	8.83	9.20	7.77
Total Organic Carbon (TOC) (%)	16.32	16.53	14.73	16.56	17.85	16.45	17.90	17.31	18.19	16.19	18.22	19.11
Calcium(Ca) (%)	1.00	0.98	0.74	0.71	0.85	0.88	1.07	1.38	1.01	0.99	0.88	1.16
Sodium(Na) (%)	1.83	1.58	1.77	1.56	2.35	1.94	2.73	1.65	1.65	2.13	2.58	1.98
Potassium(K) (%)	1.31	1.67	1.60	1.52	1.33	1.62	1.46	1.55	1.53	1.74	1.49	1.67
Sulphate(SO4) (%)	2.09	1.69	1.47	0.91	2.31	1.69	1.63	1.64	1.90	1.58	2.60	2.15
Phosphate(PO4) (%)	1.34	1.47	1.43	1.51	2.01	1.42	1.87	1.01	1.89	1.74	1.78	1.18
Total Nitrogen (TN) (%)	0.72	0.63	0.68	0.66	0.95	0.77	0.88	0.75	0.81	0.69	1.07	1.08

The values of moisture content shows that the surface soil has high moisture content, and also the moisture content was higher at December month than May. The organic content present in the soil sample was ranged between 4.5 to 6.35 % and 4.98 to 6.89 % at surface for May and December months. The percentage of the organic content at sub surface level was ranged between 2.98 to 4.73 % at May month and 3.78 to 5.83 % at December Month. The pH values obtained from the studies confirmed the alkaline nature of the soil. From the above studies it was observed that the sample collected at north direction shows the higher EC for both the seasons. The cations and anions decrease in the middle and bottom soil layers and hence the conductivity decreases with increase in depth from the ground level. The concentration of the chloride at surface of the soil was between the range of 192 to 672 mg/kg and 124 to 543 mg/kg at subsurface for May month. But the chloride content was increased at December month; the values were ranged between 273 to 763 mg/kg at surface of the soil and 453 to 1763 mg/kg at subsurface level of the soil. After the north east monsoon, there was more chance for the production of leachate with more dissolved ions and percolated in to soil. Then the high concentration of the total alkalinity was observed at surface and sub surface for both seasons. It was clearly shows that the concentration of total alkalinity was higher at December month. The total hardness present in the soil sample was high at both top surface and 1m below the ground level for both May and December months. The values were shown in the Tables 6 and 7 respectively.

Contamination of heavy metals in the environment is of major concern because of their toxicity and threat to human life and the environment [16]. Many investigators have conducted researches on heavy metal contamination in soils resulting from various anthropogenic sources such as industrial and municipal wastes [17, 18,19,20,21]. In this study, the concentrations of heavy metal present in the collected soil sample for May and December months were reported in Table 6 and 7 respectively. The iron concentration of soil was high for both the seasons and it was ranged between 546 to 1029 mg/kg for the both surface and sub surface level. It was observed that the concentration was increased while increase in depth. The high concentration of Fe was observed in the leachate sample and it may the reason of high concentration of Fe in soil sample. Due to this factor, the soil sample was highly brownish in color.

Table 6 Soil Quality Analysis at May month

Location	Soil Sample Details	Moisture Content (%)	Organic content (%)	pH	Electrical Conductivity (µmho/cm)	Chloride (mg/kg)	Total Alkalinity (mg/kg)	Total hardness (mg/kg)	Iron (mg/kg)	Cd (mg/kg)	Cu (mg/kg)	Mn (mg/kg)	Pb (mg/kg)	Cr (mg/kg)	Zn (mg/kg)
North	**S1 (0 - 15 cm)**	3.37	4.5	7.63	689	672	1435	1267	815	2.12	12.35	56.4	4.5	4.12	12
	S2 (16 - 30 cm)	2.17	3.25	7.65	354	983	1654	1782	893	1.02	2.73	34.5	2.1	1.31	2.3
East	**S1 (0 - 15 cm)**	4.67	4.65	6.98	298	192	1293	1293	673	1.72	2.1	67.4	5.9	3.2	6
	S2 (16 - 30 cm)	3.65	2.98	7.35	243	567	1398	1672	873	2.53	1.23	24.3	1.2	1.1	6.2
West	**S1 (0 - 15 cm)**	7.89	6.64	7.8	562	193	900	983	893	3.67	2.15	89	3.2	2.1	5
	S2 (16 - 30 cm)	3.64	4.73	7.03	283	567	1243	1209	982	0.05	1.56	79	1.02	1.01	1.2
South	**S1 (0 - 15 cm)**	4.64	5.73	7.34	196	263	673	1190	546	1.28	8.34	82.3	1.5	1.3	2.3
	S2 (16 - 30 cm)	2.09	4.2	7.24	124	1199	1299	1892	782	0.73	2.83	78.9	1.2	0.56	0.7
Dump yard	**S1 (0 - 15 cm)**	8.98	6.35	6.93	287	263	678	1289	892	3.89	23.54	72	3.89	2.3	11.2
	S2 (16 - 30 cm)	3.75	4.65	7.08	543	986	1529	1900	1029	1.98	9.43	93	1.23	0.8	12.3

Table 7 Soil Quality Analysis at December month

Location	Soil Sample Details	Moisture Content(%)	Organic content(%)	pH	EC (µmho/cm)	Chloride (mg/kg)	Total alkalinity (mg/kg)	Total hardness (mg/kg)	Iron (mg/kg)	Cd (mg/kg)	Cu (mg/kg)	Mn (mg/kg)	Pb (mg/kg)	Cr (mg/kg)	Zn (mg/kg)
North	**S1 (0 - 15 cm)**	4.47	5.6	6.75	673	763	1263	1562	834	2.87	15.87	62.8	4.8	5.23	13
	S2 (16 - 30 cm)	2.34	3.78	7.65	456	873	1267	1723	872	1.25	1.25	62.7	5.3	3.4	2.45
East	**S1 (0 - 15 cm)**	5.63	4.98	7.82	546	283	1342	1562	653	9.63	1.54	72.8	6.4	4.2	4
	S2 (16 - 30 cm)	3.21	5.63	7.45	456	453	1234	1562	764	1.76	0.2	54.8	4.3	2.1	3.4
West	**S1 (0 - 15 cm)**	6.73	6.73	7.89	534	273	1342	783	873	6.78	1.86	78.2	4.7	1.3	6
	S2 (16 - 30 cm)	3.74	5.53	7.34	534	653	1726	1263	783	1.89	0.3	62.6	1.6	1.1	1.3
South	**S1 (0 - 15 cm)**	6.72	6.73	8.03	198	345	782	1289	564	9.87	13.87	62.6	23.7	1.4	3.1
	S2 (16 - 30 cm)	4.87	5.83	7.83	153	1298	1263	1782	873	1.76	1.98	63.1	34.9	0.8	0.6
Dump yard	**S1 (0 - 15 cm)**	9.73	6.89	7.89	453	423	1234	1342	673	3.98	22.89	87.8	23.7	2.1	12.6
	S2 (16 - 30 cm)	4.56	4.5	7.56	874	1763	1532	1983	1421	2.92	8.54	86.2	22.1	0.78	12.3

Cadmium content was decreased with increasing depth of soil profile; the adsorption was more at the surface than at the lower layers because of higher content of organic matter at the surface. Cadmium content was retained by adsorption in mineral interface and interaction with organic matter. The adsorption of metals by organic matter was more at the surface due to higher content of organic carbon. The copper concentration was not observed for all the samples, some of the samples were shown below the detectable limit level. It is well known that copper is a rather immobile element in soils, and the greatest amounts of adsorbed copper have always found for Fe and Mn oxides [22]. The manganese concentration of the soil sample was obtained between the range of 34.5 to 89 mg/kg for May month and 54.8 to 87.8 mg/kg for December month. The less concentration of Pb was observed in all soil samples at both May and December month. Lead has highly chalcophilic properties. Thus, its primary form in its natural state is galena (PbS), and the natural lead content of soil is inherited from parent rocks [22, 23].

Conclusion

The quantification of the MSW during 2013 was shown the major composition of the waste was biodegradable waste. The composition of the commercial and residential wastes was 58.83% and 61.68% respectively. The physico-chemical characteristics of the commercial and residential waste were concluded that the waste comprises of high bulk density, moisture content and total organic carbon. The remaining parameters in the waste were present in considerable quantity. Soil samples collected from the various depths confirmed the soil quality of in and around the dump yard. It shows that pH of soil confirms the alkaline nature and the concentration of total alkalinity, total hardness, chloride of the soil sample were higher than the standard limit. Iron concentration was higher than the other heavy metals. The high concentration of Fe in the leachate sample may increase the concentration of Fe in soil sample. Due to this factor, the soil sample was highly brownish in color. The research concludes that the disposal of MSW without having proper treatment should be regulated to attain the sustainable development of the environment.

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