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Assessment of Soil Fertility Around Municipal Solid Waste Disposal Site Near Sangamner City, Maharashtra, India

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Abstract

The disposals of municipal solid waste (MSW) in open dumps are a widespread activity around the vicinity of urban area. When rainwater interacts with dumping yards, generate a leachate and percolates through the soil strata and after particular time they pollute the groundwater and soil in the vicinity. In view of this, assessment of soil fertility around MSW disposal site near sangamner city, Maharashtra was carried out. Soil samples (n=16) close to dumping yard and away from considerable distance (controlled samples) were collected and analyzed for parameters like pH, EC, organic carbon, available NPK and boron by using standard methods. The pH, EC, organic carbon, available NPK and boron of soil samples were found to be higher near the dumping site as compared to control samples. The pH of samples was found to be alkaline ranges from 8.1 to 8.8 while EC increases from 0.2 to 8.3 dS/m which is toxic to plants and crops in the nearby area. The percentage organic carbon lies between 0.8 and 12.2. The available NPK was varying from low to medium and boron ranges from 0.5 to 9.7 ppm in the study area. The minimum dispersion was found in pH (0.23) and higher in N (71.61) from standard deviation (SD) value. It was observed that, since the waste was disposed, a number of contaminants readily penetrate and deteriorate the soil in the area. Thus, the disposal of waste should be discouraged and waste management and treatment should be put in place for protection of soil fertility around dumping site near the Sangamner city.

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Introduction

The increasing urbanization and industrialization with changing consumer habits and standards of living have been contributed to the augmentation in MSW[1]. The threat of environmental pollution from MSW has been haunting the human being world since early times and is still increasing due to excessive growth in developing countries. MSW is normally termed as

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"garbage" or "trash" is an expected consequence of human activity[2]. Rapid urbanization and population explosion in India has led to the migration of people from villages to cities which generate thousands of tones MSW daily[3]. Urban MSW is usually generated from human settlements, hospitals, small industries and commercial activities. Similarly, the economic development leads to enormous amounts of solid waste generated by the dwellers of the urban areas[4].

The major cause of the pollution in the urban society is the solid wastes which are the organic and inorganic wastes generated by fast increasing production, consumption and other human activities. It is usually unwanted and which are not useful to the first user[5]. In India, the magnitude of MSW is estimated to augment significantly in the future as the country struggles to attain an industrialized nation status by the year 2020[6, 7]. The huge amount of MSW generated has posed a serious threat to eco-friendly environment and around three lakh tones of solid waste generated daily. The mode of disposal of solid waste in India is dumping on land as a cheaper method of waste disposal. A variety of studies revealed that about 90 % of MSW is disposed of unscientifically in open dumps and landfills, creating problems in public health and the environment[8]. The unplanned disposal of MSW at dump site without covering is considered as a dangerous practice in incorporating waste management.

The disposal of solid waste requires large area and proper drainage of the land disposal of MSW. It causes an impact on groundwater contamination and quality of soil[9]. MSW compress counter different material dust, food waste, packing in the form of paper, plastic, metal, glass discards, clothing, etc. which may exert impact on soil properties. An MSW dumping at open dumps demonstrate a major source of metals released into the environment[10, 11]. The soil and groundwater is polluted due to the leachate formed in association with rainfall that penetrates through the trash and normally results in the migration of leachate into the soil and groundwater strata[12]. The soil is contaminated due to infiltration of leachate in association with chemicals and heavy metals i.e. lead, copper, zinc, iron, manganese, chromium, and cadmium. These heavy metals lead to severe problems since they cannot be biodegraded[13].

The contamination of soil by heavy metals and chemical constituents from waste disposal sites is a risky problem in municipal regions[14]. In addition to this, when screening for pollutants in soil at contaminated sites, the results are often necessary directly, since analysis of the contaminated soil is essential prior to resolve of remediation methods[15]. Research works related to such aspects have been carried out by several researchers[2, 4, 11, 15-19]. Similarly, Deshmukh (2012, 2015) evaluated the soil fertility status of Sangamner area[20,43] and Deshmukh and Aher (2016) assessed the impact of MSW on groundwater quality near the Sangamner city using GIS approach[9]. However, special attentions on soil fertility study around the MSW dumping yard have not yet attempted. The major part of the Sangamner area, particularly around the MSW dumping yard is suffering the problems of alkalinsation, salinization, water logging, etc. due to huge amount of MSW from Sangamner city area along with over irrigation and excess use of chemical fertilizers. Based on soil boron narrow concentration range between plant deficiency and toxicity symptoms and also the human health problems in Sangamner area, an attempt has been made to assess the soil fertility along with boron concentration around MSW disposal.

Sharholy et al. (2008) stated that, new assessment must be carried out on the generation and characterization of MSW in India. A large number of samples have to be collected and analyzed to attain statistical reliable results since the MSW is heterogeneous. In view of this, in the present study assessment of soil fertility around MSW disposal site near Sangamner city was carried out. Accordingly, the analyses of soil fertility parameters such as pH, EC, organic carbon available NPK and boron (B) were determined by analyzing 16 soil samples with close and away (controlled samples) from dumping site. It was found that the range of soil parameters was increased significantly around the dumping yard and decreased with increasing the distance from the site. Therefore, there is an urgent need to create public awareness on the soil issue, its pollution sources, prevention of soil quality and improve the fertility status. Enormous programs with the participation of the citizens can help to minimize the MSW generation as well as identification of suitable dump site. It will be supportive to conserve the soil fertility around the present dumping yard in the study area.

The Study Area

The selected study area around MSW dumping yard is located in the southern direction of the Sangamner city at 1.7 km in Ahmednagar district of Maharashtra, India (Figure 1 and 2). This area and its surrounded region are a part of Deccan trap, where basaltic lava flows erupted in the Cretaceo-Eocene age. Moreover, extensive colluvio-alluvial deposition (locally up to 20 m thick) observed around the Pravara River, which is a prime source of soil in the present area. This area is consisted with late quaternary Pravara formations that overlie the basalts along the Pravara River and its tributaries[21-23]. The Sangamner city consisted with 65,804 populations (Census, 2011) with 16.32 km^2 area. There are various activities within the 27 wards of the city which are contributing to solid waste generation like construction of building, agricultural market, slaughterhouse, institutional activities, hotels and restaurants. The Sangamner city is generating about 34 tones of MSW per day, which is increasing upto 41- 45 tones at the time of festivals and other celebrations[9]. Generated MSW from Sangamner city has been dumped in dumping yard without any segregation, treatment and disposal. It is observed that, the soil fertility around the dump yard area is facing severe hazard from waste materials. Dump site is not sufficient to collect the enormous quantity of waste (Figure 2). Thus, this dump site is the serious concern about decreasing groundwater quality and soil fertility in the present study area.

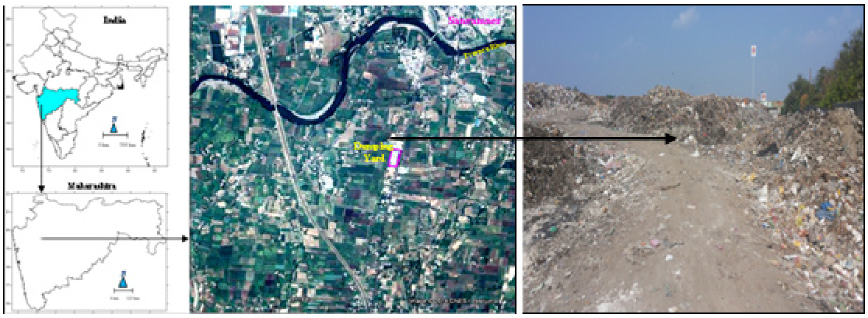

Fig. 1: Location map of MSW dumping site and allied area near Sangamner city

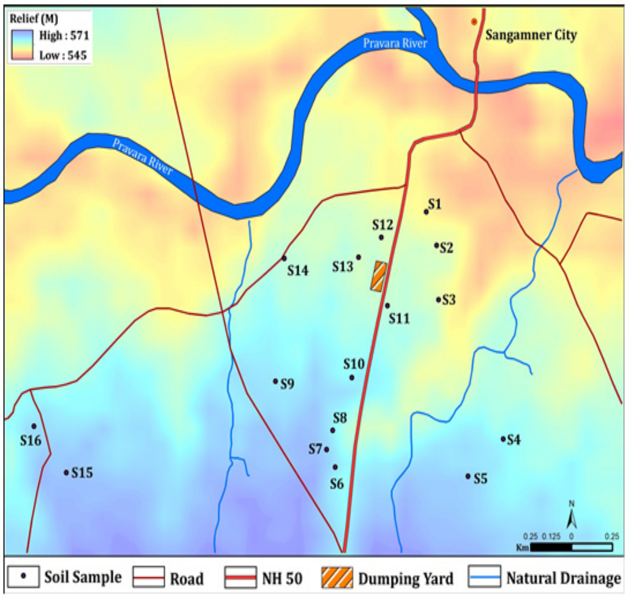

Fig. 2: Map of the MSW dumping site along with soil samples

Materials and Methods

Selected 16 surface soil samples (0-20 cm) were collected in cloth bags as per the standard procedures[24, 25]. Out of 16, four samples (S4, S5, S15 and S16) were collected away from the MSW dumping yard at considerable distances, as the controlled samples and remaining are in the vicinity of the dumping yard (Figure 2). Quartering technique was used for preparation of collecting soil samples. The samples were dried in the air and passed through 2 mm sieve and stored in cloth bags. The soil pH and EC were determined from the saturation extract (l: 5 soil water ratio) of soils[24, 26]. Organic carbon was estimated by Walkley and Black method[27, 28]. Moreover, the available N (Alkaline permanganate method), P (Olsen's method) and K (Flame photometer method) were estimated by standard procedures[28, 29]. The B was determined by azomethine H method[29]. Results obtained from the analysis of the soil samples were presented in Table 1.

The descriptive statistical analysis of soil fertility parameters through standard deviation (ó) was carried out in a quantitative manner to study the variations in the study area. SD is a measure which is used to quantify the amount of variation or dispersion of a set of (soil fertility) data values. A low SD means the data points tend to be close to the mean of the set, while a high SD means the data points are spread out over a wider range of values. Furthermore, selected parameters were classified in low, moderate and high deviated group from the study area, according to the calculated SD value (Table 2).

Table 1: Soil fertility parameters around MSW dumping site

Sample	pH	EC (dS/m)	Organic Carbon (%)	N (kg/ha)	P (kg/ha)	K (kg/ha)	Boron (ppm)
S1	8.3	4.7	3.9	235	39	215	6.9
S2	8.4	4.5	4.9	232	46	235	5.3
S3	8.3	5.3	6.2	201	56	229	4.2
S4	8.1	0.2	1	90	16.1	81	0.6
S5	8.1	0.25	1.1	88	15.3	75	0.5
S6	8.3	0.3	1.8	115	29	98	1
S7	8.5	1.8	2.1	135	37	114	2
S8	8.6	2	3	166	30	119	2.3
S9	8.7	2.1	4	186	36	183	2.8
S10	8.4	2.29	3.2	170	40	134	3
S11	8.8	7.5	12.2	282	78	254	9.7
S12	8.7	8.3	10.6	272	63	250	9.6
S13	8.6	7.9	11	280	67	260	9.7
S14	8.6	2.8	1.16	249	48	239	8.3
S15	8.1	0.4	0.8	101	25	116	1.1
S16	8.2	0.5	0.95	92	20	78	0.89
Maximum	8.8	8.3	12.2	282	78	260	9.7
Minimum	8.1	0.2	0.8	88	15.3	75	0.5
Mean	8.4	3.2	4.2	180.9	40.3	167.5	4.2
SD	0.23	2.85	3.83	71.61	18.46	71.49	3.50

Table 2: Variation in soil parameters range from actual mean in the study area

S. No.	SD Range	Standard Deviation	Parameter
1	0-25	Low deviation	pH, EC, OC and B
2	25-50	Moderate deviation	P
3	50-75	High deviation	N and K

Results and Discussions

Soil pH

Soil pH is considered as a key variable in soils which controls various chemical processes that take place. The pH of natural soil is normally lies between 7 and 8.5 and its variation is might be possible due to biological activity, temperature, disposal of municipal waste, etc[16]. Soil pH directly affects the life and growth of plants as it affects the availability of all nutrients in the soil[19]. The pH value depends upon the experimental temperature and sample to water ratio. In the present study, pH ranges from 8.1 to 8.8 reflecting the alkaline nature of the soils. It is interesting to observe a narrow range of variation in pH in the study area. This can be attributed to the high buffering capacity of the soils and absence of carbonate in the saturation extract[30]. The highest pH 8.8 was recorded at S11, which is close to MSW while the lowest pH 8.1 was recorded at S4, S5 and S15 which are the controlled soil samples away from MSW. Similarly, the higher values of pH are also recorded at S8, S10, S12, S13 and S14 samples which are near the vicinity of dumping yard (Table 1). Different factors like leaching action of waste, soil nature and mechanical composition may be responsible for increasing pH of soil samples[31]. The calculated SD value of the pH (0.23) was not effectively deviated from the actual mean (8.4). It means that, the variation within pH (8.1 to 8.8) was low in the study area (Table 2).

Electrical Conductivity

Electrical Conductivity (EC) of soil depends upon the dilution of soil suspension. The hazardous caused due to the waste is most often encountered because of the high total salt and sodium content level, large amount of ionic substance and soluble salt increases the value of EC in the MSW treated soil[31]. The EC of soil samples ranges from 0.2 to 8.3 dS/m in the study area. The highest EC was recorded for the soil samples collected close to dumping yard i.e. S11, S12, S13 as compared to the samples away from MSW (S4, S5, S15 and S16). The increase in EC is due to the increase in the amount of dissolved salts in the soil due to infiltration of leachate[32]. Normally, plants suffer water strain in humid soil conditions when EC is higher. When EC is maximum, salt are accumulating in the plant tissues which causes toxicity. When EC is higher due to boron or aluminum even at low concentration, it will show increasing trend. High value of EC can be toxic to plants and may prevent them from obtaining water from the soil[31]. The calculated SD value of the EC (2.85) was also slightly deviated from the actual mean (3.2). It means that, there is low variation (02 to 8.3) within EC in the area (Table 2).

Organic Carbon

Organic matter occurs in soil where domestic waste is dumped. The soil in which organic content is high causes serious trouble to mankind and to vegetation[33]. Main source of organic matter in biodegradable solid waste is food scraps, lawn waste, cow dung waste, fallen leaves, etc. In the study area, the organic carbon content in soil samples was observed from 0.8 to 12.2 %. The percentage of higher organic carbon may be due to biodegradable solid wastes in MSW. The soil samples S1, S2, S3, S11, S12 and S13 show a high percentage of organic carbon, whereas S4, S5, S15, S16 showed low percentage of organic carbon in the soil samples (Table 1). As like of pH and EC, the calculated SD value of the OC (3.83) was also low deviated from the actual mean (4.2). It means that, there was low variation within OC (08 to 12.2) in the study area (Table 2).

Available Nitrogen

The amount of nitrate may increase in soil as a result of higher use of nitrogen fertilizer[34]. The maximum level of nitrogen fertilizer is used for plants grown in soils. It consists of carcinogenic substances like as nitrosamines, especially plants such as lettuce and spinach leaves are eaten. There is dangerous increase of NO_3 and NO_2[35]. In the present study, the available nitrogen varies from 88 to 282 kg/ha. It shows soils from the area have low to medium nitrogen status as per the critical limits for soil test value used in India[36]. The calculated SD value of N (71.61) was highly deviated from the actual mean

(180.9). Thus, high variations within N were observed (88 to 282 kg/ha) as compared to other parameters in the area (Table 2). From the Table 3 it is observed that 3 (18.75 %) samples lie in the medium range while the remaining 13 (81.25 %) samples show low nitrogen status. The medium range of nitrogen was observed around the MSW dumping site for the soil samples which have higher values as compared to the controlled sample values. Previous literature[20] has shown the low status of available nitrogen in the same area. Thus, the medium status of nitrogen in the present area is caused as an effect of an MSW dumping site.

Table 3: Classification of soil fertility parameters for soil test values used in India

Parameter (Kg/ha)	Low (kg/ha)	Soil sample	Medium (kg/ha)	Soil sample	High (kg/ha)	Soil sample
Available N	< 250	S1 to S10 and S14 to S16 = 13 (81.25 %)	250-500	S11, S12, S13 =03 (18.75 %)	> 500	-
Available P	< 10	-	21-30	S4, S5, S8, S15, S16 =05 (31.25 %)	> 30	S1 to S3, S6, S7, S9 to S14 =11 (68.75 %)
Available K	< 150	S4 to S8, S10, S15, S16 =08 (50 %)	151-200	S9=01 (6.25 %)	> 200	S1 to S3, S11 to S14 =07 (43.75 %)

Available Phosphorous

Phosphate ion enters the soil solution either as a result of mineralization of organophosphates or the use of fertilizers. The plants take available P typically in the form of H_2PO_4 from the soil solution. Chemisorptions of P occur due to the interaction of phosphate ions with the atoms like Al, Fe or Ca depending upon soil pH[37]. In addition to this, the amount of phosphorous may increase in soil as a result of the transport of leachate from the MSW dumping yard. In the present study, the phosphorous content ranges from 15.3 to 78 kg/ha. The calculated SD value of the P (18.46) was moderately deviated from the actual mean (40.3). The phosphorus showed moderate variation in the study area (Table 2). The concentration of P was higher in the 11 (68.75 %) samples around the dumping yard (Figure 2 and Table 3). The controlled soil samples S4, S5, S8, S15 and S16 consisted with the medium concentration of P. The previous literature[38, 39] available in the same area reported that available P is in the low status. However, it is observed that, the majority of the soil samples have shown high levels of P due to MSW dumping yard in the study area.

Available Potassium

Potassium is considered the second important macro element for soil and crop productivity. Hence, excess of potassium is not harmful[31]. Potassium content in the soil is due to degradation of solid waste and it is one of the essential elements for healthy growth[40]. Nitrogen and water cannot be utilized effectively if potassium is scarce in the soil. Around disposal site, the calculated SD value of the K (71.49) was highly deviated from the actual mean (167.5). It indicates there was also high variation within K (75 to 260) in the present area (Table 2). 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[41]. However, the potassium from the anthropogenic sources can contaminate the soil and groundwater. The highest concentration of K is greater than 200 kg/ha was found at samples S1 to S3, S11 to S14 which are located close to MSW (Table 1). The remaining samples (S4 to S8, S10, S15 and S16) showed the low concentration of K which is less than 150 kg/ha (Table 1 and Table 3).

Boron

Higher B availability in surface soils as compared to subsurface soils is related to increased soil organic matter[42, 43]. Boron contamination is a serious environmental problem affecting both ecosystems and human ecology. There are many causes of boron accumulation in the surface soil and/or deep ground, including irrigation, a dry local climate, fertilizer, industrial wastewater, MSW and mining[44]. Boron is more likely to be deficient in soils than to cause toxicity. B toxicity can occur in semi-arid and arid regions due to excess B in groundwater added from MSW leaching which degraded soil quality and fertility. Hence, leaching may be an important management tool to prevent phytotoxicity and soil quality caused by high-boron content generated from MSW. The boron content in the soil samples from the area varies from 0.5 to 9.7 ppm (Table 1). The calculated SD value of the B (3.50) showed low deviation from the actual mean (4.2). Therefore, the variation within B (0.5 to 9.7 ppm) is also low like that of pH, EC and OC in the study area (Table 2).

The affected soils by MSW (S1, S2, and S11 to S14) showed the high content of B which are located around the MSW dumping yard. The permissible limits of boron concentration relative to boron tolerance of crop plants have been classified by Richards (1968)[45]. According to Richards, the safe limit for sensitive plants for boron concentrations in the soil is 0.7 ppm while marginal limit ranges from 0.7 to 1.5 ppm and unsafe is greater than 1.5 ppm. Considering these limits, soils from the study area are categorized (Table 4). It is observed that B concentration in soil is safe for 02 (12.5 %) samples, marginal for 03 (18.75 %) samples and unsafe for 11 (68.75 %) samples in the area. The B concentrations were recorded < 0.7 ppm, as a safe limit in the controlled soil samples which are away from MSW. This indicates that 68 % samples and 18.75 % samples have crossed the unsafe and marginal limit, respectively, of boron and showed toxic concentrations of B (Table 4).

Table 4: Classification of soils based on boron concentrations from the area

Class	Boron concentration (ppm)	Locations and No. of Samples
Safe	< 0.7	S4, S5 =02 (12.5 %)
Marginal	0.7 to 1.5	S6, S15, S16 =03 (18.75 %)
Unsafe	> 1.5	S1 to S3, S7 to S14 = 11 (68.75%)

Conclusions

In the present study, pH found to be alkaline and EC ranged from 0.2 to 8.3 ds/m. The high EC in the samples close to dump yard may be due to the presence of large amounts of ionic substances and soluble salts released from MSW dump as compared to the controlled soil samples. Moreover, comparatively high OC with an average mean 4.2 was found around dump site is responsible for an increase in pH and EC also. It may be due to discharge of exchangeable cations during mineralization of organic matter. The results of the study revealed that, the range of NPK is higher in the soil samples around dumping yard than that of controlled samples. B availability in soil samples ranges from 0.5 to 9.7 ppm and also higher around dumping yard. From the study area 68.75 % soil samples showed the unsafe limit of B caused boron toxicity which is the effect of MSW on the of soil. In general, it was found that, the range of parameters was increased significantly around the MSW and decreased with increasing the distance from the dumping yard. According to SD, the higher dispersion was observed in N (71.61) while low in pH (0.23). It revealed that, the high variation in the N is due to impact of MSW and its solubility and mobility.

The MSW disposals at dumping site have been affecting the soil fertility. Since the waste was disposed directly onto surface of soil, a number of contaminants including heavy metals readily penetrate and eventually they contaminate the soil and affect the surrounded crops and vegetation of the area. The present study gives an insight into the probable impact of MSW on soil fertility in comparison to the controlled soil samples. Thus the soil status of the area shows diversity in soil fertility which suffering due to open dumping of waste and local irrigation practices. As a result, the land around the MSW dumping yard is mostly utilized in brick industry and some allied non-agricultural purposes. The current disposal method of MSW must be immediately abandoned and dump site should be rehabilitated and closed. The suitable new sites should be chosen under predefined conditions and far from any environmental interest areas like agriculture, river, and cities. Efforts can be made for classification, processing and recycling of MSW materials prior to distribution of major waste in the dump site. There is an urgent need to create public awareness on the soil issue, pollution sources, causes and prevention of soil quality and improve fertility in the study area.

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