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Influence of prolonged disposal of municipal solid waste on soil productivity factors

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Abstract
The prolonged disposal of municipal waste influences the soil productivity factors. Therefore, the present study was carried out at dumping site near Chandi bridge Hardwar (Uttarakhand) to determine the effect of physico-chemical parameters of the solid waste on soil productivity factors of soil at different sites- Site-A: It was near to slump area. Site -B (500 meter far from site-A: It was used for dumping and partially submerged with water and had a swampy condition, Site-C (500 meter far from site-B): It was near to Chandi devi ropeway and contained fresh as well as partially decomposed waste. Site- D and Site-E (500 meter far from site-C): It was used for dumping and had putrefied odour due to decomposition of fresh waste. The control site- X (Bilkeshwar mountain region): 10 Km far from experimental sites in N-W direction of Chandi bridge municipal waste dumping area at Hardwar (Uttarakhand), India during the year 2006-2009 at present these sites have been closed for dumping of waste. The soil productivity factors viz. available nitrogen (0.32 ppm), organic matter (0.89%) were found maximum at site-A, temperature (24.61^{0}C) at site-C and electrical conductivity (1.05 dSM^{-1}) available phosphorus (33.16ppm), available potash (260.17ppm) at site-E of dumping area in comparison to the soil of control site-X (Bilkeshwar mountain range). At control site, bulk density (1.37 g/cc) and pH (7.65) were maximum while the bulk density (1.08 ± 0.22) g/cc at site-D and pH (7.02) at site-E were observed minimum. The results were statistically analyzed to indicate that the dumping of municipal waste influenced the pH and bulk density of soil and increased the acidity and porosity of soil through which pollutants leach to ground water. But higher amount of organic matter, N, P, K makes it fit for the raw material that may be used in fertilizing industries by using appropriate technologies. The study would be helpful for utilization of municipal wastes in compost formation and to indicate the influence of municipal waste on soil quality of the dumping sites of other places.

Keywords: Municipal solid waste, Productivity, Physico-chemical parameter, Soil, Soil fertility

INTRODUCTION

With the increase of human population, non-degradable and toxic substances are being indiscriminately disposed and their needs are also touching to the zenith for luxurious life. Therefore, Municipal Solid Waste Management is one of the major environmental problems for Indian cities. When rainfall occurs, rain comes in contact with solid waste and forms leachate which finds its way to percolate into aquifers and soil strata that may contain a large amount of organic content, heavy metals and inorganic salts (Aziz *et al*., 2010; Aziz and Maulood, 2015; Mojiri *et al*., 2016). Long term disposal of biowaste and municipal waste affects the phisico-chemical properties of soil (Anikwe and Nowobodo, 2002; Yuksel *et al.,* 2004 and Montemurro *et al.,* 2005) and contains heavy metals (Lisk, 1988; Zhang *et al*., 2002; Pasquini and Alexander, 2004), while Modak and Nangare (2011) have done quantitative and qualitative assessment of Municipal Solid Waste at Nagpur City. Nanda *et al.* (2011) and Musa (2012) suggested to construct properly engineered waste disposal landfills to improve public health and prevent surface water, ground water, air and soil from pollution. Sruti *et al*. (2014) studied soil pollution near MSW site at Thrissur, Kerala. Gupta and Chopra (2018) evaluated the ground water quality near solid waste dumping site at Chandi bridge, Hardwar. The present study was aimed to investigate the interaction between various soil fertility factors and municipal solid waste that were being disposed at municipal dumping site near Chandi bridge Hardwar (Uttarakhand) and to provide the data to fertilizer industries for the possible use of municipal wastes of other places.

MATERIALS AND METHODS

Study area: Hardwar (latitude 29^{o}26' N and longitude 77^{o}30' E.) is a holy place located in Uttrakhand, India and is a chief revenue center for trade and commerce at Uttrakhand. Its average altitude is from the sea level is 250 Mt. The annual rainfall is 2315.4 mm and summer temperature ranges between min 16^{0} C to max 41^{0} C while in winter the temperature ranges between min. 40 ^{0}C to max. 18 ^{0}C. The total population of Hardwar was 14, 44, 213. Normally at that time, Hardwar received on average around 2000 visitors (tourists plus pilgrims) and produced approx. 22.66 MT/day solid waste. Although Rana *et al.* (2017) estimated that Indian MSW generation in 2011 was 127,486 tonnes per day (TPD) while total collected MSW was 89,334 TPD and TERI (2015) reported recycled MSW was 15,881 TPD. The number of tourist and visitors used to be more than 2 crores on specific days like Mhakumbha mahotsava at Hardwar. The waste generated from the central Hardwar that was always packed with the tourist, was dumped near Neel Parvat, Chandi bridge municipal dumping area during the year 2006-2009 which has now been closed as per government initiative under Swachh Bharat mission. The area of Experimental sites covered approx.20000 mt^2.

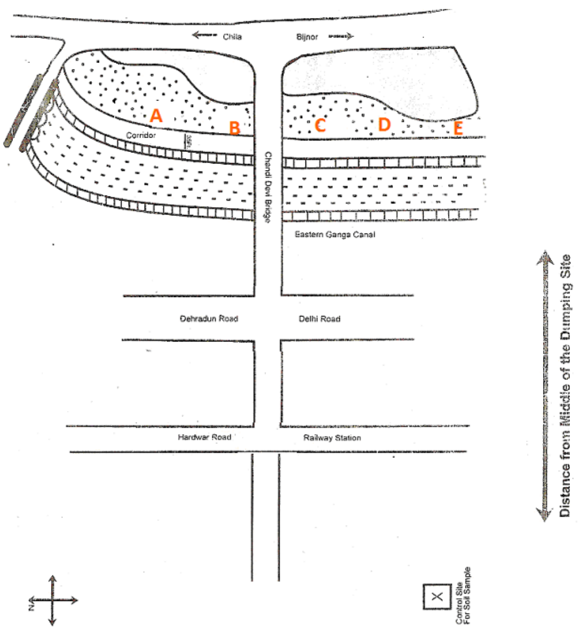

Fig. 1. *Study area showing different sampling sites near Neel Parrvat Chandi Bridge, Hardwar during the year 2006-2009.*

Sampling sites: During the study period of 2006-09, urban waste samples (n=36) were collected by random sampling from a depth of 9 inches from various experimental sites (Site-A, B, C, D, E, X). Site-A It was near to slump area and was prohibited from dumping and contained decomposed waste. Site-B (500 meter far from site-A): It was partially submerged with water and had a swampy condition, Site-C (500 meter far from site-B): It was close to Chandi Ropeway where irregular dumping went on and contained fresh as well as partially decomposed waste. Site- D and Site-E (500 meter far from site-C): These were open for dumping and had putrefied odour due to decomposition of fresh waste. The control site- X (Bilkeshwar mountain region) 6 Km far from experimental sites in N-W direction of the dumping area near Chandi bridge along with Eastern Ganga canal (Fig-1). Each soil sample (100 gm) was taken from different locations of sites whose mean values are tabulated in table-1. The soil sample was passed through a 2 mm mesh size iron sieve. The surface material was removed by the help of scrubber.

Sample analysis: Soil Samples (100 gm) from different sites of the dumping area and the control site were brought to the laboratory in polythene bags. These samples were air dried and ground. Many analysis were carried out to determine the parameters that help to evaluate soil quality. The analysis of physico-chemical parameters viz. temperature, bulk density, pH, electrical conductivity, available nitrogen, phosphorus, potash and organic matter were determined following the standard methods (cited in Trivedi and Goel, 1984 and Hesse, 1994). Nitrogen was determined by Kjeldal method, organic matter following Walkley and Black method (cited in Trivedi and Goel, 1984).

Statistical analysis: The mean ± S.D. values, percentage change, analysis of variance (ANOVA) one way statistical test and Correlation coefficient (r) of physico-chemical parameters in soil of different experimental and control sites were determined with the help of EXEL (Microsoft Office), SPSS and Sigma plot.

RESULTS AND DISCUSSION

The mean values ± standard deviation (S.D) of physico-chemical properties (viz. temperature, bulk density, pH, electrical conductivity, available nitrogen, available phosphorus, available potash, organic matter) of different dumping sites of municipal waste dumping area of Neel Parvat, Chandi bridge are given in Table 1 The classification of waste on the basis of its characterization is shown in Table 2. ANOVA one-way in and correlation among various physico-chemical parameters are shown in Table 3 and Table 4 respectively. Various physico-chemical original values in form of dots and lines representing the best fitted curve of

Table 1. Mean of physico-chmeical parameters of municipal solid waste dumping area during 2006-09 (Annual mean ± SD, % increase given in parenthesis).

Parame-ters	Site-X (Control)	Site-A	Site-B	Site-C	Site-D	Site-E
Temp, °C	21.45 ± 1.77	23.49 ± 1.80 (+ 9.54%)	22.31 ± 1.90 (+4.00%)	24.61 ± 2.19 (+14.74 %)	23.14 ± 1.71 (+7.86 %)	23.17 ± 2.02 (+8.00 %)
BD, g/cc	1.37 ± 0.10	1.21 ± 0.17 (-11.80 %)	1.28 ± 0.14 (-6.93 %)	1.09 ± 0.22 (-20.64 %)	1.08 ± 0.22 (-21.14 %)	1.14 ± 0.17 (-16.69 %)
pH	7.65 ± 0.35	7.39 ± 0.12 (- 3.36 %)	7.55 ± 0.22 (- 1.25 %)	7.29 ± 0.10 (-4.69 %)	7.06 ± 0.27 (-7.64 %)	7.02 ± 0.29 (-8.19 %)
EC,dSM^{-1}	0.24 ± 0.05	0.33 ± 0.06 (+40.68 %)	0.45 ± 0.08 (+90.24 %)	0.68 ± 0.20 (+186.70 %)	0.98 ± 0.23 (+310.67 %)	1.05 ± 0.23 (+340.37 %)
N, %	0.05 ± 0.03	0.32 ± 0.19 (+531.10 %)	0.28 ± 0.20 (+455.16 %)	0.24 ± 0.17 (+363.83 %)	0.24 ± 0.17 (+379.87 %)	0.25 ± 0.17 (+389.69 %)
P, ppm	12.67 ± 6.39	31.83 ± 20.35 (+151.26 %)	14.35 ± 7.00 (+13.27 %)	17.78 ± 8.45 (+40.39 %)	14.87 ± 7.01 (+17.36 %)	33.16 ± 20.68 (+161.84 %)
K, ppm	48.44 ± 6.51	73.98 ± 14.82 (+52.72 %)	98.63 ± 21.80 (+103.61 %)	133.39 ± 48.73 (+175.38 %)	177.21± 84.24 (+265.84%)	260.17 ± 173.79 (+437.11 %)
O.M %	0.48 ± 0.38	0.89 ± 0.76 (+86.50 %)	0.79 ± 0.67 (+65.39 %)	0.65 ± 0.51 (+35.69 %)	0.82 ± 0.70 (+70.40%)	0.85 ± 0.73 (+76.56 %)

Table 2. Mean values of characterization of all the waste components during 2006-09.

Total Waste/ Tons	O.M/ Tons	Paper/ Tons	Textile Products / Tons	Plastic/ Tons	Glass / Tons	Metals / Tons	Miscell / Tons
20.05 ± 65.76	11.12 ± 3.77 (+55.46 %)	0.47 ± 2.22 (+2.37 %)	3.01 ± 1.31 (+15.01 %)	1.90 ± 0.83 (+9.48 %)	0.24 ± 0.87 (+1.21 %)	0.25 ± 0.09 (+0.12 %)	3.28 ± 7.37 (+16.36 %)

Table 3. ANOVA one way of physico-chemical parameters and characterization of soil during 2006-09.

Parameters	Temp	BD	pH	EC	N	P	K	O.M	Characterization
F critical	2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.12
F calculated	3.81	5.12	13.19	51.44	3.84	5.84	10.67	0.70*	79.13

Significant variation (P<0.05) and insignificant variation (P>0.05)*

Table 4. Correlation coefficient (r) among various physico-chemical parameters of soil during 2006-09.

Parameters	Temp	BD	pH	EC	N	P	K	O.M
TEMP	+ 1							
BD	-0.847	+ 1						
pH	-0.564	+ 0.869	+ 1					
EC	+ 0.433	-0.804	-0.947	+ 1				
N	+ 0.599	-0.548	-0.417	+ 0.299	+ 1			
P	+ 0.381	-0.275	-0.465	+ 0.258	+0.522	+ 1		
K	+ 0.369	-0.687	-0.908	+ 0.958	+ 0.304	+ 0.438	+ 1	
ORG MATTER	+ 0.393	-0.501	-0.567	+ 0.437	+ 0.9139	+ 0.645	+ 0.469	+ 1

original values are indicated in Fig. 2a by using MATLAB.

The characterization of dumping waste revealed that the total waste material received from different dumping areas of Haridwar city was 20.05 ± 6.57 Tonnes (T). Among all kinds of waste and its components, the organic matter, paper, textile product, plastic, glass, metal and miscellaneous waste were 11.12 ± 3.77 T, 0.47 ± 2.22 T, 3.01 ± 1.31 T, 1.90 ± 0.83 T, 0.24 ± 0.87 T, 0.25 ± 0.09 T and 3.38 ± 7.37 T respectively. The literature study reports similar dumping waste material as in present work that had higher organic fraction of waste in Jalandhar (33%), Varanasi (31%), Bhopal (40%), Kolkata (50%), Chandigarh, Mohali, and Panchkula (22%,59%) having greater moisture content (Sethi *et al*.,2013; Rana *et al*., 2018). The present study revealed that among various components, percentage of organic matter (55.45 %) was maximum and metal object (0.12 %) was minimum. This may be due to availability of metal objects in municipal waste which is more precious than other components of waste, therefore it was collected more curiously by local rag picker of city. They sold it in easy available market for trading: hence the metallic percentage was quite low.

Soil temperature is one of the deciding factors in the process of litter decomposition. The growth of plants is unaffected due to warming of the soil around their roots by the interior heat of the earth (Miller and Turk 2002). In present study, it was observed that the temperature was found minimum 22.31 ± 1.90 ^{0}C (+ 4.00 %) at site-B and maximum 24.61 ± 2.19 ^{0}C (+ 14.74 %) at site-C. The minimum temperature at experimental site-B may be because of its more stabilized waste where microbial population was low. The increase of the temperature at site-C appeared to be due to high metabolic activity of microbes at the initial stage of compost development. The municipal waste made a covering layer upon the soil, which helps to retain the moisture and provide low oxygen condition for microbes that is responsible of putrefied odour near the municipal waste dumping sites. Chan *et al*. (1997) have observed the quite higher temperature (33.9 ^{0}C) in landfill site at Junk Bay in Hong Kong in comparison to the temperature observed in present study at dumping site of Hardwar. The higher temperature at Junk Bay may be due to cover landfill that was covered by soil that had been laid there for about 3 years.

The electrical conductivity was minimum (0.33 ± 0.06 dSM$^{-1,}$ + 40.68 %) at site-A, where municipal waste has been stabilized and it was maximum (1.05 ± 0.23 dSM$^{-1,}$ + 340.37 %) at site-E. The conductivity ranged in between 0.33 ± 0.06 dSM^{-1}to 1.05 ± 0.23 dSM^{-1}. This may be due to arrival of more fresh waste at site-E which in turned may have released various acidic salts present in municipal waste and increased the EC of soil. Hence, it may be said that higher amount of municipal waste enhanced the salt concentration in soil which may have detrimental effect on soil productivity. Caravaca *et al*. (2003) have also observed increase in EC due to composted residue at different sites of the soil at Murcia (S-E Spain). Useh *et al.* (2015) revealed that the distribution of charged particles was higher in the dumpsite than its corresponding control sites at Kubwa, Abuja, Nigeria, supported the growth of certain plants and bacteria due to complex biochemical reactions.

In case of available nitrogen, site-A had the maximum available nitrogen (0.32 ± 0.19 %, + 531.10 %) due to presence of stabilized waste (compost) while site-C and site-D had minimum available nitrogen (0.24 ± 0.17, + 363.83 %). This may be due to that site-A had more amount of degradable waste material (Humus) as waste was converted in to humus and the nitrogen level might have increased. Therefore, decomposed municipal waste had a positive influence on soil productivity by increasing available nitrogen to the soil. The application of composts obtained from waste increased the available nitrogen content in soil is in close proximity noticed by Kowed *et al*. (1982), Schoossing (1983), and Giusquiani *et al.* (1988). Rapid uptake of nitrogen in available form of (NO_3^- and NH_4^+) by the plants takes place only when all wastes get decomposed by microbes and during decomposition of fresh waste maximum nitrates may percolate up to ground water.

In present study, the available phosphorus was minimum (14.35 ± 7.00 ppm, +13.27 %) at site-B and maximum was (33.16 ± 20.68 ppm, +161.84 %) at site-E. This may be due to the difference in pH of site-E and site-B as also studied by Ozores and Obreza *et al*., (1999) at S-W Florida and also may be due to that the waste contains large proportion of organic material which acts as the source of phosphorus during decomposition of waste and get associated with iron. Thus, it can be said that slightly basic pH increases the available P and affects the soil productivity positively.

The available potash was found minimum (73.98 ± 14.82 ppm, + 52.72 %)) at site-A and maximum (260.17 ± 173.79 ppm, (+ 437.11 %)) at site-E. This may be due to more amount of urban waste containing ash that comes due to burning of waste containing higher amount of organic matter because burning is a common disposal practice for litter in Hardwar. As the amount of waste increased, the potassium content might have also increased and because of its cationic behavior might have helped to accumulate K on the upper layer of soil. The higher K content in the soil has also been reported by Martinez (2003) at Spain, Rao and Shantaram (1996) at Amberpet landfill site, Hyderabad and Chan *et al.* (1997) at Junk bay landfill site, Hongkong. Therefore, it may be quoted as a remark that the municipal wastes have a positive effect on soil quality by increasing the K content of the soil.

In case of organic matter, the minimum value (0.65 ± 0.51 %, + 35.69 %) was found at site-C and the maximum value (0.89 ± 0.76 %, + 86.50 %) at site-A. Gairola (2010) indicated that accumulation and eventual decomposition of plant residues triggers a build-up of organic matter. Higher amount of organic matter makes the soil porous and airy, thus decreasing the bulk density of soil which on turn affects the plant productivity positively. The presence of higher organic matter at dumping site can reduce the bulk density and increase total porosity and hydraulic conductivity in heavy clay soils as also observed by Anikwe (2002) on the soil property of Nigeria. In present study, the bulk density was found minimum 1.08 ± 0.22 g/cc, (-21.14 %) at site-D and the maximum 1.28 ± 0.14 g/cc, (-6.93 %) at site-B and ranged in between 1.08 ± 0.22 g/cc to 1.28 ± 0.14 g/cc during present study. The minimum increase -21.14 % at site-D and maximum percentage decrease in B.D was observed -6.93 % at site-B in comparison to the soil of control site-X. This may be due to that site-D received more fresh municipal waste and organic matter formation took time here that is why this site showed lesser percentage decrease. It was found during the winter season microbial population decreased that might have reduced the organic matter formation and increased the bulk density of municipal solid waste soil at Chandi bridge, Hardwar. Therefore, influence of municipal waste increased the amount of organic matter, which is essential for soil productivity and decreased the BD, which may help in plant growth while the pH was found minimum 7.02 ± 0.29 at site-E and maximum 7.55 ± 0.22 at site-B and ranged between 7.02 ± 0.29 to 7.55 ± 0.22 at ex-

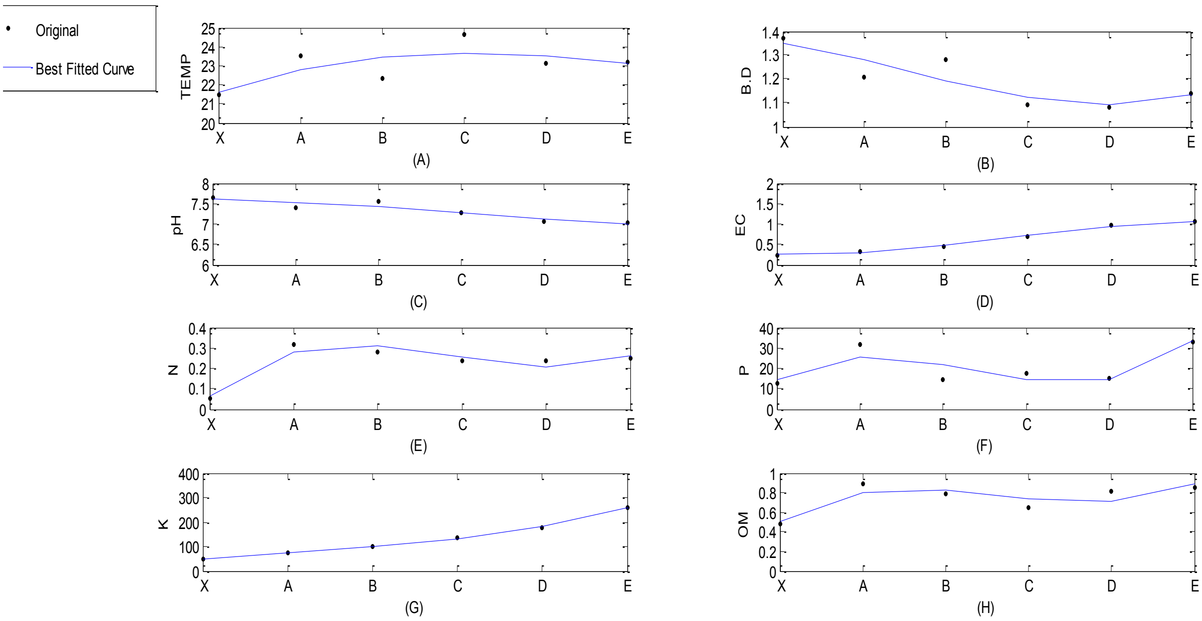

Fig. 2. *Showing best fitted curve of original data using MATLAB for various physico-chemical parameters of different sites of Chandighat dumping sites denoted as sites-A, B, C, D and E which are 500meter apart from each other and site-x as the control site (Bilwkeshwar mountain).*

perimental sites. Therefore, the minimum percentage decrease in pH was -8.19 % at site-E and maximum percentage decrease was -1.25 % at site-B in comparison with control site-X. The monthly observation of pH in present study indicated that only site-D and site-E had acidic property of soil in summer which clearly revealed that all the organic material of municipal waste tended to degrade rapidly in summer season. It was observed that the soil pH ranged from 6.0 to 8.0 due to fresh municipal waste, which was in the initial stage of stabilization. Similar findings have been given by Kowaed *et al*. (1982) and Bulent Topcuoglu (2015) in agriculture soil at greenhouse of Antalya, Turkey. In present study lower values of pH have been reported at site-D and site-E of the t dumping area which received more fresh waste and decreased value of pH. Hence it may be stated that the pH should be maintained properly before using municipal waste for agro purpose.

The correlation coefficient (r) study revealed that if the temperature is maintained, the parameters BD and pH affected negatively to E.C, N, P, K and organic material that helped to increase the productivity factors of soil. The maximum correlation of temperature was observed with nitrogen (r= +0.599) and minimum (r= +0.369) with potassium. It showed that temperature helps to break the organic material and dissociate the nitrogenous substance and increases the nitrogen content in soil that increases the productivity of soil. It was also revealed that the temperature influenced the pH negatively (r= -0.564) which showed that higher temperature decreased the pH and made soil acidic which is a negative indicator of productivity because acidic municipal soil increases the leaching of heavy metal which may contaminate the ground water. The correlation coefficient (r) of EC was negatively correlated with the Bulk Density (r= -0.804) and pH (-0.947). The minimum correlation of electrical conductivity was with available nitrogen (r= + 0.299) and the maximum (r= +0.958) with potassium at the experimental sites The correlation of EC with pH further proves that a low pH marks the influence on the concentration of dissolved salts and thereby increasing the conductivity as pH decreased, while in the case of BD it was further observed that presence of higher BD of mountain soil of control site-X was due to higher clay content and thereby showing low EC. In case of the available nitrogen, it was negatively correlated with the pH (r= -0.417) and B.D (r= -0.549) while available nitrogen was positively correlated with E.C (r= +0.299) and temperature (r= +0.599) at the experimental sites. The maximum positive correlation was observed with organic matter (r= +0.913) and minimum with E.C (r= +0.299). This relation further revealed that slightly acidic range of pH increased the formation of organic matter and during this process EC of soil increased due to liberation of ionic salts. Hence it may be said that the disposal of waste increases available nitrogen in soil due to decomposition but at later stage the associated forms of nitrogen leach out because of increase in acidity and the soil becomes poorer in nitrogen which is retained back in the soil as pH increases after completing the stage of decomposition. The phosphorus is negatively correlated with the pH (r= -0.465) and BD (r= -0.275) while it was positively correlated with temperature (r= +0.381), EC (r= +0.258) and N (r= +0.522) and showing maximum positive correlation with available nitrogen (r= + 0.522) and minimum negative correlation with bulk density (r= -0.275) at all the experimental sites. It indicates that as pH decreased, the leaching of cementing agent from soil increased that in turn increased the exchangeable cations which may reduce the BD. It also showed that as much as nitrogen content increased, the phosphorus content also increased due to liberation of PO_4 ions from dead material by microbial action.

The potash is positively correlated with the E.C (r= +0.958), temperature (r= +0.369), N (r= +0.304) and phosphorus (r= +0.438) while potash was negatively correlated with BD (r= -0.687) and pH (r= -0.908) at the experimental sites. It showed that as much as potash concentration increased the conductivity of soil also increased due to liberation of ions into soil which helped to increase the productivity by reducing the bulk density of soil. The organic matter was negatively correlated with bulk density (-0.501) and pH (-0.567) while it was positively correlated with temperature (+0.393), EC (+0.437), N (+ 0.913), P (+ 0.645), K (+ 0.469) at the experimental sites. It may be due to degradation of organic matter which produces carbon dioxide gas as an end product. This gas becomes dissolved in the soil water and forms carbonic acid having mineral dissolving capacity several times greater than the pure water which may increase the conductivity of the soil, therefore, reducing the density of soil.

Further, the analysis on correlation of these parameters indicated that bulk density was negatively correlated with the organic matter (r= -0.501) at the experimental sites. The minimum negative correlation (r=-0.804) was noticed with EC while the maximum positive correlation (r= +0.869) was recorded with pH. It indicated that the soil should have lower density so that water could move from it and make the soil porous and airy that restricts the anaerobes development. The correlation coefficient (r) among different parameters with the pH showed that pH is positively correlated with the BD (r= +0.869) and negatively (r= -0.564) with temperature at the experimental sites. The minimum negative significant correlation was observed with EC (r= -0.947) and maximum with nitrogen (r=-0.417). The correlation revealed that increase in temperature decreased the pH due to inverse relation as observed at site-E.

Conclusion

The present study concluded that overall municipal solid waste at dumping sites increased the temperature, electrical conductivity, nitrogen, phosphorus, potash, organic matter while it decreased the bulk density and pH of soil at all dumping sites of the area. The ANOVA one way revealed that various physico-chemical parameters viz. (temperature, bulk density, electrical conductivity, pH, nitrogen, phosphorus, potash and characterization values) the difference between F calculated and critical value were too large, hence these parameters and characterization differed significantly ($P<0.05$) but in case of organic matter of soil of municipal waste dumping sites, the values were insignificant ($P>0.05$). Further, the correlation study revealed that the organic matter, available nitrogen, P, K, electrical conductivity status were negatively correlated with bulk density and pH value of soil that itself showed negative correlation with temperature value of soil of all the experimental dumping sites. Thus, the municipal solid waste influenced the pH, bulk density of soil and increased the acidity and porosity of soil through which pollutants may have leached to ground water. But higher amount of organic matter, NPK makes it fit for the raw material that may be used in fertilizing industries by using appropriate technologies so that the waste can become a boon for fertilizing industries as well as for farmers which may use such waste as fertilizers and protect the environment from unhygienic conditions.

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