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A Study of Physico-Chemical Properties and Heavy Metals in Contaminated Soils of Municipal Waste Dumpsites at Dholpur, India

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Abstract: The study assesses the qualities of contaminated soils of three municipal waste dumpsites in Dholpur, Rajasthan. The pH of the dumpsite soils ranged from 6.12±0.36 to 7.85±0.31 which is tending towards neutral or alkaline pH. Water holding capacity and moisture content at dumpsites were in good amounts (28.33±1.23 to 46.48±1.09 and 32.43±1.69 to 50.74±1.22 % respectively). Organic matter was higher (1.70±0.49 to 2.65±0.28%) at dumpsites as compared to their adjoining areas. Clay texture class played a significant role in differentiating normal soils of adjoining area than dumpsite soils. Total metal concentrations of Cr, Cu, Fe, Ni, Pb and Zn were also analyzed and elevated levels of heavy metals were obtained at dumpsites (34.56±1.05 to 110.75±2.59 mg/kg). Metal contamination at dumpsite was in the order of Pb>Cu>Cr>Ni>Zn>Cd imparting highest contamination to Recco Area dumpsite while Housing board dumpsite was least contaminated. Cr and Cd were not detectable from all adjoining areas while Pb, Zn, Fe, Ni and Cu were present in least amounts (7.12±0.20 to 36.84±4.12 mg/kg). Physico-chemical properties and heavy metal concentrations at each dumpsite were also correlated with each other and many significant correlations were observed. This work will prove valuable in providing baseline information for further soil quality monitoring studies in study area.

Keywords: Heavy metals, Soil contamination, Environmental monitoring, MSW management

1. Introduction

Unorganized, indiscriminate and unscientific dumping of municipal wastes is very common disposal method in many Indian cities which cause adverse impacts to the environment (Mahar et al., 2007). Nearly all human activities generate waste, and the way in which this is handled, stored, collected and disposed of, can pose risks to the environment and to public health (Zhu et al., 2008). Several fluxes of waste and cover materials from different sources end up at these dumpsites and due to the heterogeneity and complexity of wastes, these dumpsites contain a variety of contaminants which can pollute the soil of the area (Sukop et al., 1979). The physico-chemical properties of the degraded soils at these sites are one of the important factor playing roles in vegetation development (Gairola and Soni, 2010). For instance, soil structure and acidity affects the absorption and accumulation of mineral elements by plants (Tresow, 1970) and thus play a very important role in vegetation establishment and development at such sites. Different Sources such as electronic goods, used batteries, etc., when dumped with municipal solid wastes raise the heavy metals in dumpsites and dumping devoid of the separation of hazardous waste can further elevate noxious environmental effects.The occurrence of various heavy metals such as Mn, As, Cr, Cd, Ni, Zn, Co, Cu, and Fe in MSW dumpsites was reported by many workers (Amusan et al., 2005; Esakku et al., 2003; Hoffmann et al., 1991; Ogundiran and Osibanjo, 2008; Smith, 2009). Since these contaminants affect the environmental qualities in and around such open dumpsites, monitoring of soil qualities especially heavy metal content in dumpsite becomes necessary which can facilitate to recommend suitable remedial measures (Biswas et al., 2010). The present study was undertaken to compare the influences of municipal waste dumping on selected soil physico-chemical properties and heavy metal levels. A significant importance of this work will be in providing baseline information for further soil quality monitoring studies and to understand their potential uses in making various soil amendments in future studies.

2. Materials and method

2.1 Study area- The present study was performed in and around three municipal waste dumpsites in Dholpur city (25045' N and 81084' E) of Rajasthan, India. The per capita waste generation in the city is 0.43 kg/capita/day and is projected to be increased at

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the level of 0.66 kg in 2021 (AMC, 2009). The three study sites are Recco Area, Near Muchkund and Rajakhera Road waste dumping sites located in and out of the city respectively. These dumpsites contain mixture of both organic and inorganic waste materials, such as food wastes, papers, cardboards, metals, tins, glass, ceramics, battery wastes, textile rags, plastics, sewage night-soils and other miscellaneous materials such as bricks, ash, fine dust, rubber and wood wastes etc. (Sharholy et al., 2007).

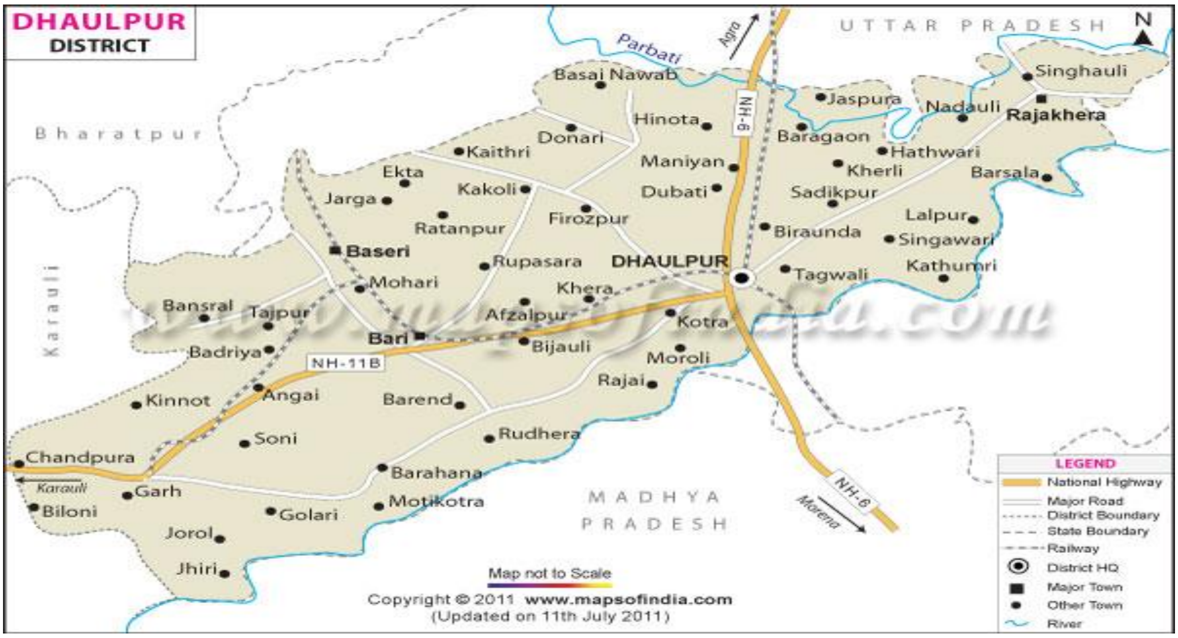


Figure 1. Map of study area

2.2 Soil sampling- Sampling was done from May 2011 to June 2012 at the interval of every four months. Soils were sampled along different directions and from centre of dumpsites from 10-20 cm depth at each site. Grab soil samples were mixed to form composite samples in triplicates in each direction and at the centre of dumpsites and in every season. A total of 45 samples for each site were analyzed. Same procedure was followed for soil sample collection at adjoining areas of these dumpsites. After bulky inorganic objects such as cloth, plastic, glass, rubber, and metal had been sorted out manually, the samples were air dried and ground to pass through a 2-mm sieve. The soil samples were kept in polythene packets for further analysis.

2.3 Physico-chemical analysis Physico-chemical properties such as pH, conductivity, soil texture, moisture content, water holding capacity (WHC), bulk density, organic matter, cation exchange capacity (CEC) were analyzed. The pH and electrical conductivity were measured in a soil suspension (1:10 w/v dilution) by digital pH meter (labotronics-LT-1) and conductivity meter (Systronics-304), respectively. Bulk density was calculated following Blake and Hartge (1986). Moisture content and water holding capacity was computed following Saxena (1989). Organic matter was examined by Potassium dichromate titration method (Saxena, 1989). Cation exchange capacity (CEC) of soil was determined as per the procedure outlined by Jackson (1974). The texture of the soil was determined by using hydrometer test (Hamdeh, 2004). Same procedures were followed for the analysis of background soil samples for each site.

2.4 Heavy metal analysis- Total metal concentrations of heavy metals such as Cr, Cu, Fe, Ni, Pb and Zn were analyzed. For heavy metal analysis one gram sample of soils were digested separately in the presence of HNO3 following the procedures of Ogundiran and Osibanjo (2008). Atomic Absorption Spectrophotometer (AAS, ECIL-4141) was used to analyze total metal concentrations of digested soil samples. Procedural blanks and internal standards were also used where appropriate. For comparison of the results, soils of adjoining areas of all three sites also studied which were unaffected by dumping of waste materials. Microsoft Office Excel-2007 and Origin 8.1 software packages were used for statistical analysis of the data. Pearson's product moment correlation r was used to express the relationship between different quantitative variables.

3. Result and discussion Soil quality can be monitored by a set of measurable attributes termed indicators. These indicators can be broadly grouped as physical and chemical indicators and one can assess overall soil quality by measuring changes in these indicators (Dalal and Moloney 2000; Sahrawat and Narteh 2002). In the present study various physico-chemical properties of the degraded soils of the dumpsites were evaluated and these values were compared with the background values of the soil of their adjoining areas.

3.1 Physico-chemical properties of the soil The selected physico-chemical properties which can be used as the indicator of the soil are presented in table 1. The pH of the dumpsites ranged from 6.12± 0.36 to 7.85± 0.31 which is tending towards neutral or alkaline, while the pH in adjoining area soils was slightly acidic (Table 1). The pH has been shown to change to a more neutral pH in acidic soils (Fowles 2007). Electrical conductivity at dumpsite 1 was lowest (0.87±0.43 dSm-1) while it was highest at site 2 (1.60±0.43 dSm-1). This indicates that at site 2 movement of charge particles are more than other two sites which is a good indicator for the growth of plants. The electrical conductivity at adjoining areas was higher than dumpsites (Table 1). Water holding capacity and moisture content at site 2 was highest among others (50.77±1.32% and 48.58±1.19%, respectively). This can be attributed to the presence of high amount of sewage sludge dumped by nearby sewage treatment plant which holds good amount of water during rainy season. These two properties of the soil were higher as compared to other dumpsite soils possible due to the presence of more clay texture in the soil.

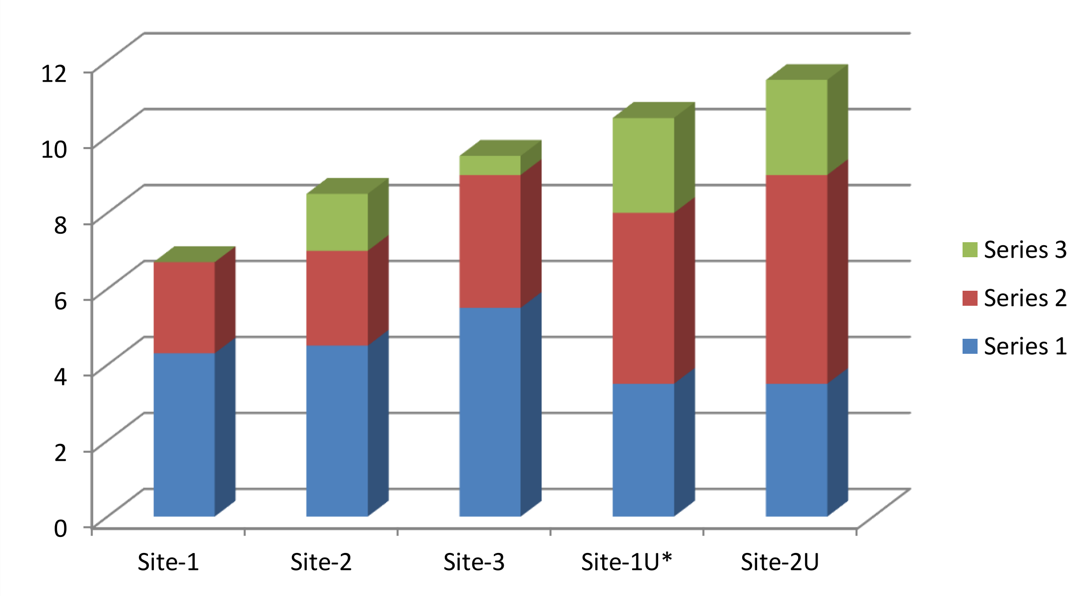
Table 1: Selected Physico-chemical properties of the dumpsite soils and their background levels

Soil properties	Site 1	Site 2	Site 3	Site 1U*	Site 2U	Site 3U
pH	6.32±0.16	6.39±0.59	7.16±0.31	5.40±0.34	5.80±0.12	5.37±0.35
Electrical Conductivity (dSm-1)	0.87±0.43	1.60±0.43	1.30±0.26	1.24±0.40	2.31±0.20	2.06±0.43
Moisture content (%)	35.53±1.79	50.77±1.32	44.18±1.63	51.4±1.97	57.38±1.80	54.01±1.67
Water holding capacity (%)	31.23±1.23	48.58±1.19	39.38±1.30	53.06±0.80	60.56±1.35	50.91±1.25
Bulk density (g cm-3)	3.11±0.40	1.47±0.48	2.18±0.51	2.02±0.53	0.60±0.13	1.06±0.42
Organic matter (%)	1.50±0.39	2.45±0.48	2.22±0.59	0.79±0.32	1.85±0.45	0.74±0.32
Cation exchange capacity (c mol kg−1)	3.12±0.70	6.12±0.86	5.48±0.78	4.32±0.60	10.83±0.55	9.08±0.39

The bulk density was highest at site 1 (3.11±0.40 g cm-3) while it was lowest (1.47±0.48 g cm-3) at site 2. The bulk density was quite variable at adjoining areas with the lowest being at site 2U (0.60±0.13 g cm-3). High bulk density at dumpsites can reduce the root length and limits the root penetration in dump soil (Rai et.al, 2010). It is very important to note that the organic matter was quite high at the dumpsites (1.50±0.39-2.45±0.48%) as compared to their adjoining areas where it ranged from 0.74±0.32-1.95±0.45%. This is mainly because of the presences of many organic waste residues which add more organic matter after their decay. Apart from this accumulation and subsequent decomposition of plant residues also result in building organic matter (Gairola and Soni, 2010). The cation exchange capacity at the dumpsite was quite low as compared to their adjoining areas. At the dumpsites it was lowest at site 1 (3.12±0.70 c mol kg−1) while was highest at dumpsite 2 (6.02±0.86 c mol kg−1). The adjoining areas of all these sites had fairly high values of CEC as compared to dumpsites and it ranged from 4.62±0.60 to 10.83±0.55 c mol kg−1. The increase in the CEC and organic matter results in plants taking up nutrients more easily and the changes in CEC and pH improve soil conditions for crop growth (Aydinalp and Marinova, 2003).

As the texture of the soil plays a very important role in plant species establishment and development and also influences physical parameters of the soil, the soil texture class was evaluated for all the study sites and their adjoining areas. The results are represented in figure 2. The soils of the dumpsite had very low clay content (0.63±0.42-6.42±0.92%) and maximum sand content (44.59±1.42-53.78±1.46%). Maximum Sand texture of the soil was at site 3 while silt was highest at site 2 (Figure 2). Site 2 had maximum clay content (6.42±0.92%) as compared to other two sites. On the other hand at the adjoining areas clay texture counted maximum part in soils (20.21±0.85-29.44±1.32%) while sand content was lowest ranging from 18.81±1.1621.06±1.19%. As all these adjoining areas are mostly used as agricultural purposes the presence of clay-soil is understandable.

These properties at the dumpsites are quite variable than undumped areas mostly be



(Graph between Mean Value and Study Site)

Figure-2 Soli texture class at dumpsite soli and their adjoining area.

cause of the heterogeneous composition of waste materials at these sites.

3.2 Heavy metal concentrations The total metal concentrations of selected heavy metals have been given in table 2. Site 1 was highly contaminated with all heavy metals tested. This site had highest Pb contamination (108.85±3.99 mg/kg) followed by fe, Ni, Cu, Cr, cd and Zn. All these concentrations were quite higher than their background values at adjoining areas while Cr and Cd were not detectable at its adjoining area (Table 2). At site 2, Cr and Cd concentrations were not detectable while other heavy metal concentrations were in the order of Fe>Cu>Pb>Ni>Zn. The adjoining area of this site was not much contaminated and only a little concentration of Fe, Zn and Pb were detected. These observations clearly indicate that the level of heavy metal contamination is higher at dumpsites which may pose some serious concerns to their surrounding environment and organisms. All these concentrations are quite higher than their background values which can be used for monitoring of heavy metal concentrations for such site.

Table 2: Total metal concentrations (mg/kg) of selected heavy metals at study sites

Heavy metals	Site 1	Site 2	Site 3	Site 1U*	Site 2U	Site 3U
Cr	42.86±3.35	ND**	ND	ND	ND	ND
Cu	70.63±1.62	90.70±1.84	ND	14.96±1.96	ND	ND
Fe	102.46±4.51	85.85±1.08	50.20±2.10	27.94±4.22	14.42±1.22	ND
Ni	82.12±2.04	87.54±1.57	53.35±2.16	26.16±2.40	ND	ND
Pb	95.15±3.99	86.80±1.63	71.47±3.34	17.65±2.71	8.14±1.23	7.32±0.30
Zn	32.46±1.07	54.98±1.29	108.00±3.26	21.8±1.13	20.74±0.83	18.21±0.83
Cd	25.50±0.89	ND	ND	ND	ND	ND

U*- Adjoining undumped areas of site 1, 2 and 3 representing soil background levels. ND- Not detectable. Data represents mean ± SEM of three replicates.**

4. Conclusion- This study indicates the level of contamination at the municipal waste dumpsites and explores the relationship between ranges of quantitative variables. All the studied dumpsites are contaminated with heavy metals with the maximum being at Recco Area dumpsite (Site 1). Thus the open dumping of waste should be discouraged and a proper monitoring and remediation plan is needed to reduce the chances of ground water pollution by leaching of these contaminants.

Some physical properties and good amount of organic matter in dumpsite soils indicate that these soils have the potential to be used in compost after various experimental treatments. Further in-situ and in-vitro bioaccumulation studies can also be performed by using the information in this study. The study is useful in providing indicators of contamination at such open dumpsites and thus will be helpful in making any remediation plan for these contaminated soils. Artificial reclamation with mature soil is recommended for these sites.

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