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Research Article

Assessment of Soil Contamination near Unlined Municipal Solid Waste Landfill

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Abstract

The disposal of municipal solid waste into the landfills has been recognized as the major source of soil, surface water and groundwater contamination. Municipal solid waste disposal site for the city of Ludhiana, in Punjab, India, has become an overflowing landfill because of the indiscriminate dumping of solid waste at the site. The leachate produced by landfilling site contains a large amount of high concentration of organic and inorganic constituents beyond permissible limits. This study was therefore undertaken with the objective of assessing the possible impact of leachate percolation on soil quality in the vicinity of an unlined landfilling site. The effect of distance of soil source from the dumping yard, contamination level of soil and effect of seasonal variation on soil quality was also studied. It has been found that soil of the studied area contains high concentration of contaminants and with the passage of time values of various parameters increased, reason being with time the solid waste material degraded and the waste constituents percolated down along with rainwater. This is clearly evident from the results that Jamalpur landfilling site at Ludhiana is greatly affecting the soil quality of its surroundings through careless handling of solid waste and leachate. There is a great need of soil and groundwater quality monitoring within the studied area and the concerned authorities must take certain remedial measures not only to control the existing soil pollution at the moment but also to prevent further contamination in future. Therefore, we must improve our current waste management practices and construct properly engineered sanitary landfill sites to curtail soil and groundwater pollution.

Keywords: *Leachate, Landfilling, Municipal solid waste, Soil and groundwater pollution.*

1. Introduction

Municipal solid waste (MSW) disposal is a global concern, most especially in developing countries across the world, as poverty, population growth and high urbanization rates combine with ineffectual and under-funded governments to prevent efficient management of wastes (Cointreau, 1982). Landfills are the primary means of MSW disposal in many countries worldwide because they offer dumping high quantities of MSW at economical costs in comparison to other disposal methods such as incineration. Most of the landfills in developing countries including India are not designed with proper leachate collection mechanism. Leachate produced form landfilling sites is heterogeneous and exhibits huge temporal and seasonal variations. Landfill leachate produced form MSW landfill sites is generally heavily contaminated and consist of complex wastewater that is very difficult to deal with (Palaniandy *et al*., 2009; Foul *et al*., 2009, Daud *et al*., 2009; Mohajeri *et al*., 2010). The generation of leachate is a result of percolation of precipitation through open landfill or through cap of the completed site (Aziz *et al*., 2007). Leachate is characterized by high concentration of organic matter, ammonia nitrogen, heavy metals and chlorinated organic and inorganic salts (Renou *et al*., 2008). The characteristics of leachate are highly variable depending on the waste composition, amount of precipitation, site hydrology, waste compaction, cover design, sampling procedures, and interaction of leachate with the environment, landfill design and operation (Reinhart and Grosh, 1998; Kulikowska and Klimiuk, 2008). The management of leachate is among the most important factors to be considered in planning, designing, operation and long-term management of an MSW landfill (Halim *et al*., 2010). Leachate causes the pollution of the soil, surface water and groundwater. Precipitation that infiltrates through the municipal solid waste leach the constituents from the decomposed waste mass and while moving down causes contamination of subsurface soil. The soil which is an important component of landfill site is a media where polluted materials are deposited. Because of continuous transportation to other media (air, ground and surface water) from this media by evaporation, erosion and infiltration, this component is a natural source which is needed to carefully monitor (Banar *et al*., 2009). The amount of leachate produced by the landfill increases by increasing the amount of precipitation falling on the landfill surface. When leachate penetrates through the soil layers, it contaminates the ambient environment. Constituents move within the soil matrix, mainly due to

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the concentration gradient (Rattan and Shukla, 2004). The degree of contamination in the aquifers depends on the transport rate of contaminants and depository conditions at the site as the contaminants permeate through the soil media (Vasanthi *et al*., 2008). Therefore, understanding the leachate transportation within the soil depends on understanding the structures of the soil. Soil is expected to minimize the amount of contaminants percolate to the groundwater. It can attenuate the landfill leachate by adsorption, biodegradation, ion exchange reactions, precipitation, and filtration (Smith *et al*., 1999). It has been showed that the top soil has considerable effects on the elements that may pass through to the aquifer. In waste disposal areas, the upper soil strata usually contains greater amount of organic matter than in lower strata (Al-Soufi, 1994). Many modelings have been done worldwide to evaluate the transport of various contaminants through the soil profile (Gupta and Gurdeep, 2007; Jeffery and Sajostrom, 2010). The organic substances were initially adsorbed by soil and released when soil became saturated. Not all the constituents were removed from the MSW leachate when passed through the soil strata (Tuffaha, 2006). The variations in soil porosity, hydraulic conductivity, particle size, surface area, and permeability will lead to variation in contact time with the leachate. Therefore, variations in the outlet leachate characteristics exist. 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). A number of incidents have been reported where MSW leachate contaminated the surrounding soil and polluted the underlying groundwater aquifer or nearby surface water bodies. The MSW exert specific environment and health impacts including spread of epidemics and therefore, required to be properly managed and disposed. Nanda (2011) investigated the effect of leachate on the soil below the landfill with respect to pH, Moisture Content, Maximum Dry Density and Unconfined Compressive Strength properties. To determine the contamination of soil at various depths and at various points, samples were obtained at different depths both within and outside the site. They concluded that the change in the geotechnical properties of the soil differs with the increase in depth since the effect of lechate, number of years of dumping of MSW, height of MSW dumped and the type of materials dumped is the main reasons. Musa Alhassan (2012) studied the effects of MSW on the geotechnical properties of soils. Soil samples taken from three trial pits at depths of 0.5, 1.0 and 1.5 m, were used for the investigation. Two of the trial pits were located around the studied dump site to serve as control points or uncontaminated soil, while the third trial pit was located within the dump site to serve as contaminated soil. Soil samples collected were subjected to specific gravity, natural moisture content, particle size analysis, consistency, compaction, permeability, triaxial and consolidation tests. The results of the investigation show that MSW lowers the specific gravity, increases the natural moisture content, increases the fine particle content, lowers the maximum dry density with higher optimum moisture content, lowers both the cohesion and the angle of internal friction, increases the coefficient of permeability, coefficient of consolidation and coefficient of volume compressibility of the soil. These effects reduced with depth.

In the present study, the impact of leachate percolation around a MSW landfill site on soil quality was investigated. The effect of distance of soil source from the dumping yard, contamination level of soil and effect of seasonal variation on soil quality was also studied. This study was therefore undertaken with the objective of assessing the possible impact of leachate percolation on soil quality in the vicinity of an unlined MSW landfill site of Ludhiana City, Punjab, India.

2. Materials and methods

2.1 Study location

Ludhiana is the largest city in Punjab, both in terms of area and population. It lies between latitude $30^0$55' N and longitude $75^0$54' E. The Municipal Corporation limit of city is spread over an area of 141sq.km. The population of the city within the Municipal Corporation area is estimated at 34,87,882 in 2011 (Ludhiana District Census Report, 2011). The climate of Ludhiana is semi arid with maximum mean temperature reaching upto 42.8^0C and minimum mean temperature is as below as 11.8^0C. Total rainfall during the year is 600-700 cm; 70% of total rainfall occurs from July to September. The altitude varies from 230 m to 273 m from mean sea level. Leachate sample for the present study was collected from Jamalpur landfilling site of Ludhiana city. Details of landfilling site are shown in Table 1 (Vision 2021, Ludhiana City Development Plan, 2001). Fig.1 shows municipal solid waste heaps at Jamalpur landfilling site. No cover of any description is placed over the spread waste to inhabit the ingress of surface water or to minimize litter blow and odours or to reduce the presence of vermin and insects. Rag pickers regularly set fire to waste to separate non-combustible materials for recovery. Since, there are no specific arrangements to prevent flow of water into and out of landfill site, the diffusion of contaminants released during degradation of landfill wastes, may proceed uninhibited. No proper compaction is done to compress the waste into the site.

Table 1 Details of at Jamalpur landfilling site

Land area (acres)	Average depth (in ft.)	Future life (years)
25	8 to 10	25

2.2 Leachate sampling

To determine the quality of leachate, integrated samples was collected from different landfill locations. Leachate sample was collected from landfilling site on Tajpur Road at Jamalpur Village having 25 acres of low lying land area. This site is non-engineered low lying open dump. It has neither any bottom liner nor any leachate collection and treatment system. Therefore, all the leachate generated finds its paths into the surrounding environment. The landfilling site is not equipped with any leachate collectors. Leachate samples were collected from the base of solid waste heaps where the leachate was drained out by gravity. Leachate samples were collected in January end, 2012. Various physico-chemical characteristics like *viz* pH, Total Solids (TS) Suspended Solids (TSS), Total Dissolved Solids (TDS), Turbidity, Hardness, Biological Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Chloride (Cl^-), Nitrate (NO_3^-), Total Phosphorus (TP), Sulphate (SO_4^{2-}) and heavy metals like Iron (Fe), Lead (Pb), Chromium (Cr), Cadmium (Cd), Copper (Cu), Zinc (Zn), Nickel (Ni) and Arsenic (As) were analyzed to determine pollution potential of leachate discharge from MSW landfilling site to estimate its pollution potential.

Fig. 1 Municipal solid waste heaps at Jamalpur landfill site *(January, 2012)*

2.3 Soil sampling

Soil samples were collected at a depth of 1 m below ground surface from six different locations. Soil samples were collected from landfilling site and of surrounding area nearby to landfilling site at different distance S-1 (5m ±1), S-2 (15m±1), S-3 (20m ±1), S-4 (35m±1), S-5 (40m±1) and S-6 (50m±1) from the landfill location within an area of 50 meters from the periphery of landfill site to determine pollution potential of leachate discharge from solid waste landfilling site on soil of the adjoining area. Water extracts were prepared based on modified standard test method for shake extraction of soil with water (ASTM, 2006). The water extracts were analyzed for the parameters such as pH, Organic carbon, Nitrate (NO_3^-), Total Phosphorus (TP), Sulphate (SO_4^{2-}). Soil sampling was carried out in January 2012 during winter season. Again after a time period of six months (i.e. July 2012) during rainy season when a rise in water table was expected; soil samples were collected from the same locations to determine the effect of leachate discharge from solid waste landfilling site on soil of the adjoining area with time.

2.4 Analytical Work

Analytical methods were according to “Standard methods for examination of water and wastewater” specified by American Public Health Association (APHA, 2005). The pH was measured by electronic pH meter (4500-H^+.B of Standard Methods). Total Solids (TS) was determined by properly shaken unfiltered sample and estimated by gravimetric method (2540.B of Standard Methods). Total Dissolved Solids (TDS) was determined by filtered sample through Whatman filter paper-44 and estimated by gravimetry (2540.C: Standard Methods). Turbidity was measured by Nephelometer by using optical properties of light (2130.B of Standard Methods). Chemical Oxygen Demand (COD) was determined by refluxion of sample followed by titration with Ferrous Ammonium Sulphate (FAS) was adopted (5220.C: Standard Methods). Biological Oxygen Demand (BOD_5)-Winkler’s method was used for estimating initial and final DO in the sample and BOD_5 was determined (5210-B of Standard methods). Argentometric volumetric titration method in the presence of Potassium chromate provides reliable results of chloride (4500-Cl^-.B of Standard Methods). Nitrate was analyzed by HACH Portable Spectrophotometer (DR 2800) by Cadmium Reduction Method (8039) adapted from Standard Methods at a wavelength of 450 nm. Total Phosphorus was analyzed by HACH Portable Spectrophotometer (DR2800) by Molybdovanadate Method (10127) with Acid Persulfate digestion adapted from Standard Methods at a wavelength of 420 nm. Sulphate was analyzed by HACH Portable Spectrophotometer (DR 2800) by SulfaVer 4 Method (8051) adapted from Standard Methods at a wavelength of 520 nm. Heavy metals like Iron, Lead, Chromium, Cadmium, Copper, Zinc, Nickel and Arsenic were determined using ELICO double beam SL 210 UV-VIS Spectrophotometer. Specific gravity of soil was determined by using pycnometer (ASTM D854: 10 Standard Test Methods). Walkey and Black volumetric titration method was used to determine the Organic carbon content in soil.

3. Results and Discussions

3.1 Leachate Quality

Leachate sample of MSW landfilling site was analyzed for various physico-chemical characteristics to estimate its pollution potential. It has been found that leachate sample contains high concentration of organic and inorganic constituents beyond permissible limits. While, heavy metals concentration was in trace amount as the waste is domestic in nature.

The results of leachate analyzed for various physico-chemical characteristics and also standards for the discharge of treated leachate on Inland surface water, Public sewers and Land disposal were shown in Table 2.

3.2 Soil Quality

Collected soil samples nearby to MSW landfilling site was analyzed for various parameters to determine the impact of leachate percolation on soil quality in the vicinity of an unlined MSW landfilling site.

Table 2 Physico-chemical characteristics of the leachate

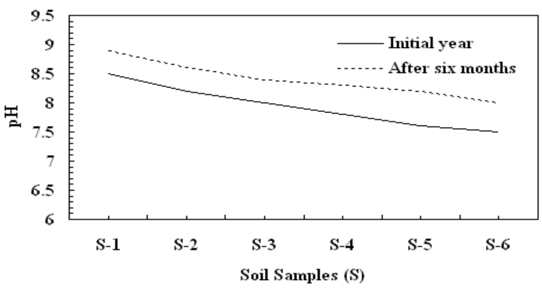
Parameters*	Jamalpur landfilling site	Standards (Mode of Disposal)**		
		Inland surface water	Public sewers	Land disposal
Appearance	Brownish	-	-	-
Odour	Sewage smell	-	-	-
pH	9.8	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0
TS	7695	-	-	-
SS	1132	100	600	200
TDS	6563	2100	2100	2100
Turbidity (NTU)	79	5	10	10
Hardness	638	300	-	-
BOD_5	495	30	350	100
COD	2535	250	-	-
BOD_5/COD	0.19	-	-	-
Chloride	1836	1000	1000	600
Nitrate	18.6	-	-	-
Total Phosphorus	83.5	-	-	-
Sulphate	65.1	-	-	-

* All values in mg/l except for pH and turbidity.
** Municipal Solid Wastes (Management and Handling) Rules, 2000

It has been found that soil of the studied area contains high concentration of contaminants and with the passage of time values of various parameters increased, reason being with time the solid waste material gets degraded and the waste constituents percolates down along with rainwater thus polluting soil and groundwater nearby to municipal solid waste dumping site. The result of soil samples analyzed for studied parameters of the soil samples were shown as under:

3.2.1 pH

The pH values of the soil samples were alkaline in nature and showed an increasing trend in pH values with time. pH values of the soil samples initially were 8.5, 8.2, 8.0, 7.8, 7.6 and 7.5 after a time period of six months were 8.9, 8.6, 8.5, 8.3, 8.2 and 8.0.

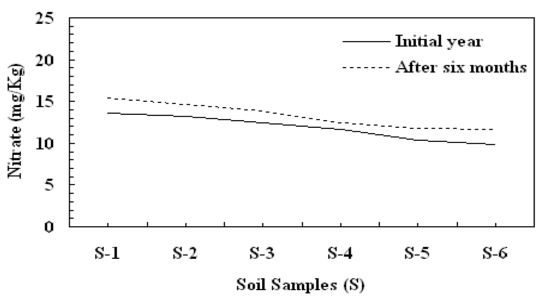


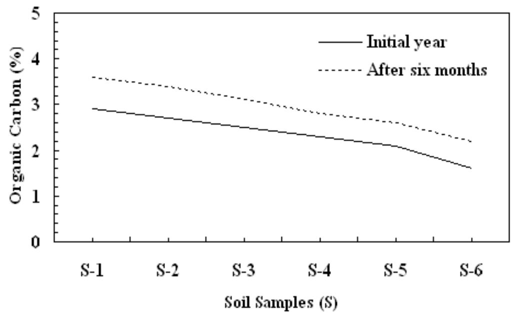
3.2.2 Organic Carbon (%)

Organic Carbon value of the soil samples initially were 2.9%, 2.7%, 2.5%, 2.3%, 2.1% and 1.6% and the organic carbon values of the soil samples after a time period of six months were 3.6%, 3.4%, 3.1%, 2.8%, 2.6% and 2.2%. The organic content value of the soil samples near the landfilling site was more due to the seepage of leachate when compared with sample collected from farther area. The organic content values of the soil samples increased with the passage of time, reason being with time the solid waste material gets degraded and the waste constituents percolate down along with rainwater.

3.2.3 Nitrate

Nitrate value of the soil samples initially were 13.6 mg/kg, 13.2 mg/kg, 12.5 mg/kg, 11.7 mg/kg, 10.3 mg/kg and 9.8 mg/kg and the nitrate values of the soil samples after a time period of six months were 15.4 mg/kg, 14.6mg/kg, 13.8 mg/kg, 12.4 mg/kg, 11.8 mg/kg and 11.6 mg/kg.

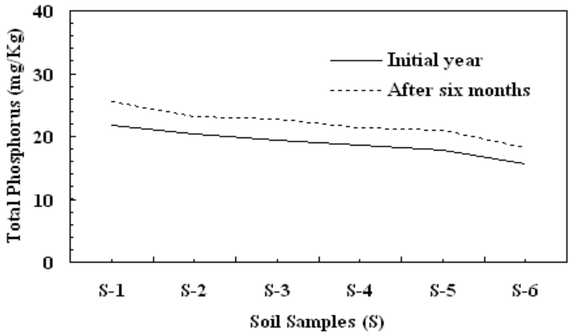




3.2.4 Total Phosphorus

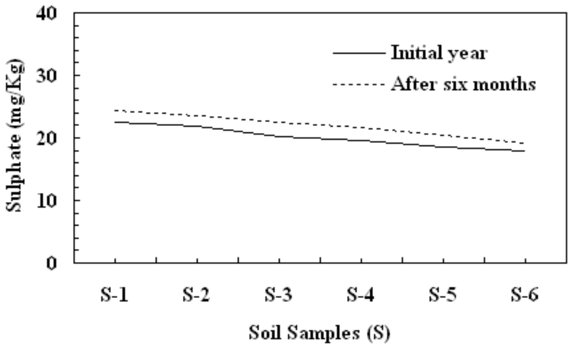
Total phosphorus value of the soil samples initially were 21.7 mg/kg, 20.3 mg/kg, 19.4 mg/kg, 18.6 mg/kg, 17.8

mg/kg and 15.6 mg/kg and the total phosphorus values of the soil samples after a time period of six months were 25.6 mg/kg, 23.2 mg/kg, 22.8 mg/kg, 21.3 mg/kg, 20.9 mg/kg and 18.3 mg/kg.



3.2.5 Sulphate

Sulphate value of the soil samples initially were 22.6 mg/kg, 21.8 mg/kg, 20.3 mg/kg, 19.6 mg/kg, 18.5 mg/kg and 17.9 mg/kg and the sulphate values of the soil samples after a time period of six months were 24.3 mg/kg, 23.6 mg/kg, 22.4 mg/kg, 21.7 mg/kg, 20.5 mg/kg and 19.2 mg/kg.



4. Conclusions

Municipal landfills pose serious threat to their surrounding environment and a great source of pollution especially soil and groundwater pollution. The present study was carried out to assess the soil quality near an unlined MSW landfill site. The major findings are as under:

- It has been found that leachate sample contains high concentration of organic and inorganic constituents beyond permissible limits. While, heavy metals concentration was in trace amount as the waste is domestic in nature.
- The soil samples of the studied area contains high concentration of contaminants and with the passage of time values of various parameters increased, reason being with time the solid waste material gets degraded and the waste constituents percolate down along with rainwater thus polluting soil and groundwater.
- The uncontrolled accumulation of leachate over time at the landfill base represents a significant threat to the soil and groundwater quality. This is clearly evident from the results that Jamalpur landfilling site at Ludhiana is greatly affecting the soil quality of its surroundings through careless handling of solid waste and leachate. There is a great need of soil monitoring within the study area and the concerned authorities must take certain remedial measures not only to control the existing soil pollution at the moment but also to prevent further contamination in future.

4.1 Remedial Measures

The leachate generated from the landfill site is affecting the soil quality in the adjacent areas through percolation in the subsoil and with the passage of time the concentration of parameters were found to be increased. Therefore, some remedial measures are required to prevent further contamination.

- Public enlightenment on waste sorting, adoption of clean technology.
- It is strongly suggested that the concerned authorities should take serious steps for the control of soil pollution and for the safety of local environment and public health as well through improved techniques of solid waste management, leachate collection and soil and ground water monitoring on regular basis.
- Use of engineered landfills to prevent further contamination is recommended. Engineered landfills must be constructed to include containment systems and structures designed to protect the environment. These measures include impermeable liner and drainage system at the base of the landfill, gas pipes, rain water collection control and monitoring boreholes.

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