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Full Length Research Paper

Assessment of Physico-chemical Properties of Soil in the Dumping Sites of Himachal Pradesh, India

Rakesh Kumar Singh* & Smriti Thakur**

Scientist-E, G.B. Pant National Institute of Himalayan Environment and Sustainable Development, Himachal Regional Centre, Mohal, Kullu - 175126, Himachal Pradesh, India.

***Junior Project Fellow, G.B. Pant National Institute of Himalayan Environment and Sustainable Development, Himachal Regional Centre, Mohal, Kullu - 175126, Himachal Pradesh, India.*

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Corresponding Author:
Rakesh Kumar Singh.

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ABSTRACT

Management of solid waste is one of the biggest issues of the present time for the hilly states. Lack of large open spaces in hilly terrains and indiscriminate dumping of municipal solid waste (MSW) in dumping sites are the two major reasons for its management. The leachate from the unsegregated MSW percolates down into the soil and changes its physico chemical properties. The present study aims to evaluate the impacts on physico chemical properties of soil of municipal solid waste dumping sites of seven towns namely Manali, Kullu, Mandi, Bilaspur, Hamirpur, Kangra and Chamba of Himachal Pradesh. Two soil samples from each dumping site and one soil sample from control site of each dumping site were collected. The chemical analysis of these soil samples have been carried out. The results showed that for different soil parameters, the dumping sites have higher values as compared to control sites. A negative significant relationship at mean significance at the 0.05 level has been found between organic carbon and available phosphorus (R^2= -0.83) for dumping site and a positive significant relationship is seen between organic carbon and available phosphorus (R^2= 0.80; $p< 0.05$) for control sites. Difference in results for dump and control sites confirmed the effect of municipal solid waste on soil properties.

Introduction

With a drastically increasing population of humans, there is also an increase in the usage of goods and other resources, therefore, producing more waste. Management of solid waste in a scientific manner is the biggest problem mainly in developing countries. The waste from the households is creating a situation of havoc as there is no source of segregation. The mixed waste from households is the biggest stone in the path to managing solid waste scientifically. Both biodegradable and non-biodegradable waste when mixed is difficult to segregate. Processes related to waste management such as recycling, compost making etc becomes very difficult, so this waste is sent to the open dumping sites. Such dumping of untreated solid waste causes the formation of the heap of waste.

The solid waste dumped in the dumping sites causes the contamination of the soil, causing a change in the physicochemical properties of the soil. Humic acid (HA) like some exogenous substances in municipal wastes can react with soil components (in the humic acid the hydrophilic groups can interact with the polyvalent cations present on the surface of soil particles) to cause changes in soil physical properties (Piccolo and Mbagwu, 1997). Soils that have been waste-amended are reported to have high organic matter content (Anikwe, 2000). Although it is generally argued that the levels of heavy metals and other particulate matter in municipal wastes are low, long term dumping of untreated municipal wastes and increasing toxicity of urban refuse due to rapid industrialization make use of municipal wastes potentially hazardous (Anikwe and Nwobodo, 2002). The main reason which serves for vegetation changes is chemical properties of soil (Neave et al., 1994).

The pollutants from solid waste provide as an external force affecting the physico-chemical characteristics of soil which ultimately contributes towards the poor production of vegetation (Papageorgiou, 2006). In the first place, the pollutants hinder the normal metabolism of plants which is a form of invisible injury and owing to which the visible injury appears as a consequence (Ahmed et al., 1986). Since the quality of soil is an important element of sustainable agriculture as it plays an important role in shaping the solid waste disposal methods (Uma et al., 2016). By studying the effect of solid waste on the soil properties of dumping sites, health of soil can be determined and better management and disposal techniques can be suggested on the basis of these studies.

Globally several studies have been conducted on the effect of MSW on soil of dumping sites, but very less data is available for India, particularly for the Indian Himalayan regions. As Indian Himalayan region is an ecologically sensitive zone with a difficult hilly terrain making waste management and its disposal a biggest challenge for this region. Therefore, there is an immediate need to study the effect of solid waste on physico-chemical properties of soil and on environment. This study will pave a way for scientific waste management practices and for policy making especially for the hilly regions. The study aims to investigate the impact of municipal solid waste on the physico-chemical characteristics of the soil in the different study sites selected for the study which mainly comprised of dumping sites of different district headquarters of Himachal Pradesh.

Material and Methods

Study area

The present study was carried out in the seven urban towns of Himachal Pradesh, which is a Himalayan state in India. It is located between 30^{O} 22'40''N - 33^{O}12'40''N Latitude to 75^{O}45'55''E -79^{O}04'20''E Longitude with an altitudinal range of 350m to 6975m amsl (Geographical features of Himachal Pradesh 2019). Himachal Pradesh covers a total geographical area of 55,673sq.km. (Geographical features of Himachal Pradesh 2019). Climatic conditions of Himachal Pradesh vary from semi tropical to semi arctic type. The average rainfall is 152cm, which is received by the state throughout the year. The season in the state can be divided into three main categories i.e. winter (October to February), summer (March to June) and rainy (July to September). Due to altitudinal variation temperature varies from 40^{o}C in summers to -20^{o}C in winters in different parts of the state (Geographical features of Himachal Pradesh 2019). In some high altitudinal area heavy snowfall is experienced during winter seasons while the summers are hot in some parts of the state.

On the bases of development and physio chemical properties, soil can be divided into nine groups in Himachal Pradesh i.e. alluvial soils, brown hill soil, brown earth, brown forests soils, grey wooded or podzolic soils, grey brown podzolic soils, planosolic soils, humus and iron podzols alpine, humus mountain speletal soils (Geographical features of Himachal Pradesh 2019). The forests vegetation according to Champion and Seth classification is divided into eight categories i.e Tropical Dry Deciduous Forests, Subtropical Pine Forests, Subtropical Dry Evergreen Forests, Himalayan Moist Temperate Forest, Himalayan Dry Temperate Forest, Sub-Alpine Forest, Moist Alpine Scrub, Dry Alpine Scrub (Champion & Seth, 1968).

Description of the dump site

All the dumping sites selected were located in hilly terrain. Dumping site except for Kangra which is located near water source such as river, lake or streamlets. From the secondary data collected from different Municipal Councils for the year 2018, it was known that on an average 13.1 metric ton of amalgamate solid waste is dumped each day in the dumping sites selected for the study. The chief components of this non segregated municipal solid waste comprise of biodegradable kitchens waste, plastic wrappers, polythene, aluminum foils, papers, cardboard, plastic bottles, clothes, tins, metal container, glass, dust, electronic items and other miscellaneous items which are dumped in these sites on daily basis. This heap of trash is stocked in these dumping sites, where secondary segregation of waste is done by the employees employed through outsourcing. The major share of mixed waste which is unable to segregate is either landfill or kept piled in open as such.

Experimental design and data collection

On the bases of reconnaissance survey, literature review and availability of secondary data seven sites in six districts of Himachal Pradesh were selected for the study purpose. The selected sites showed altitudinal variation. The seven locations sampled were Manali-Rangri (Kullu), Kullu-Pirdi, Mandi-Saat Meel, Bilaspur-Kharian, Hamirpur-Dagneri, Kangra-Mission Road and Chamba-Kuran. At each dump sites, 4 samples of soil were collected from the dumping site and 3 samples were collected from the control sites which were 100 meters away from dump area (Nwaogu et al., 2017). The soil samples were collected by digging small pits. Same procedure was repeated for the collection of soil samples from the control sites. Total 49 samples were collected i.e. 28 for dump sites and 21 for the control sites.

Soil sampling and chemical analysis

Total seven sites, four at dumping site and three at control site were identified for the collection of soil samples. Before collecting soil samples the above lying waste was removed, then after digging small pits up to 20 cm with the help of spade and khurpa, composite samples were made by mixing soil from different layers of soil profiles. This same procedure was repeated for all the control sites also. The samples were air dried and all the visible pebbles, both organic and inorganic debris, root residues etc were removed from these soil samples. After drying the soil samples these were ground and then sieved through 2mm sieve and stored in labeled polythene bags before analysis. The different standard procedures were followed for the chemical analysis of soil in the laboratory. Organic carbon was determined through Walkley–Black's rapid titration procedure (Janitzky, 1986) (Nelson and Sommers, 1982). The electrical conductivity (E.C.) and pH of the soil were determined through using a glass electrode attached to a multi-parameter system (Eutech, PC 700) in a suspension of soil to water in a ratio of 1:5)(w/v). Available Nitrogen in the soil was measured by Kjeldahl method through the Gerhardt Automatic Analyser (KES 12L, KEL PLUS, and India) (Subbiah and Asija, 1956). Available Phosphorous in the soil was determined through Olsen's (1954). Available Potassium was determined through digestion of samples using a flame photometer (MJ 272, Rescholar, India).

Data and statistical analysis

Box plots were used to represent relationship between physico-chemical properties of soils at both control and waste disposal sites. For statistical analysis "The R Project for Statistical Computing 3.5.2" tool was used. To generate correlation matrix "Performance Analytics" package was used while for one way ANOVA and Tukey HSD test Stats Package was used (Nwaogu et al., 2017). One-way ANOVA was used for analyzing Soil data; it was followed by a post hoc Comparison-Tukey HSD test (Nwaogu et al., 2017). These tests were applied to assess the effect of dumped waste on the physico chemical properties of the soil in the dumping sites.

Results and discussion

Comparative assessment of physico-chemical variables at control and waste dumping sites

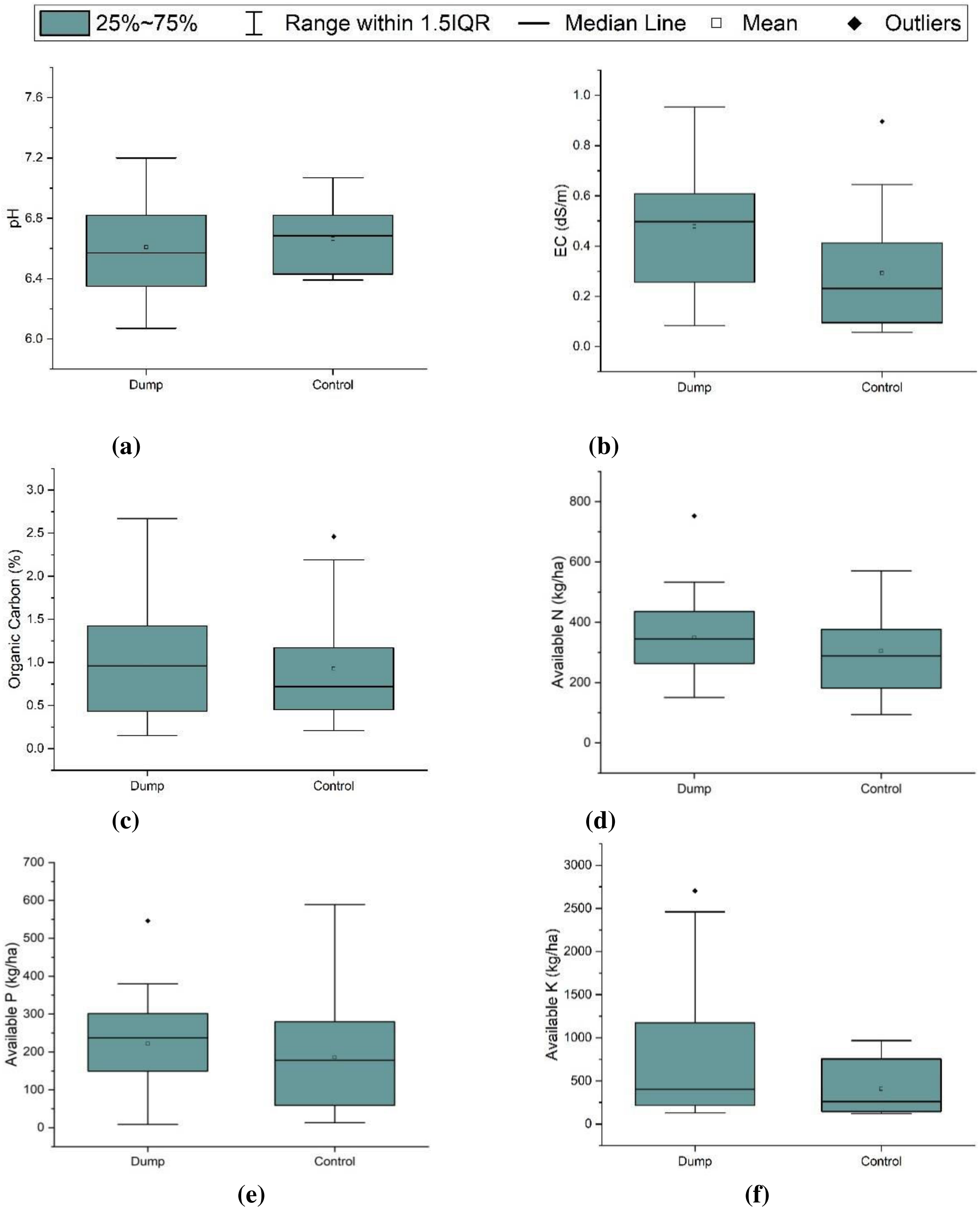

Fig.1. Physico-chemical properties of soil at control and waste dumping sites.

The Physico-chemical parameters of dump and control sites were compared using Box Plots and shown in figure.1. The inter quartile range (IQR) of pH of dump sites was wider than that of control sites. The mean pH of dump site (6.61) was slightly acidic than that of pH of control sites (6.66) figure 1(a), this may be because of the end product that is formed as a byproduct on decaying of organic matter in dumping sites (Pillai et al., 2014 and Ali et al., 2014). In figure.1(b), for electric conductivity, the IQR was wider and higher as compared to Control site with one outlier value in control site. The mean EC of dump site (0.48 dS/m) was higher than the control site (0.29 dS/m). The increased EC for dump sites was possibly due to increase in dissolved salts of magnesium and sodium due to function of leachate as during diffusion they could effectively exchange some of the cations present in soil (Pillai et al., 2014). In figure.1(c), for the Organic carbon of control site the IQR was narrow and lower than dump site. The mean of O.C. of dump site has a higher value (1.03%) as compared to control site (0.93%) due to higher quantity of organic or biodegradable waste in MSW (Anikwe 2000). In figure.1(d), for the total nitrogen, the IQR was higher for dump site with one outlier. The mean of available nitrogen is 348.99kg/ha for dump site which is higher than that of control site which is 304.64kg/ha. In figure.1 (e), the available phosphorous, the IQR for control site is wider and lower than that of dump site. The mean of dump site is 221.57kg/ha while that of control site is lower that is 185.48kg/ha. The presence of higher level of available potassium in dumping sites (745.35 kg/ha) as compared to the control site (406.25kg/ha) (figure.1f), the result was different from the findings of Islamabad (Ali et al 2014) for potassium, this may be due to different in sources of waste.

Pearson's Correlation for different physico-chemical parameters

In the figure 2 & 3, correlation matrix is representing person correlation between different physico chemical parameters along with scatter plot. For the figure.2, at the dumping site, significant correlation was found between pH and electrical conductivity of the dump soil (-0.83) at p 0.05 level.

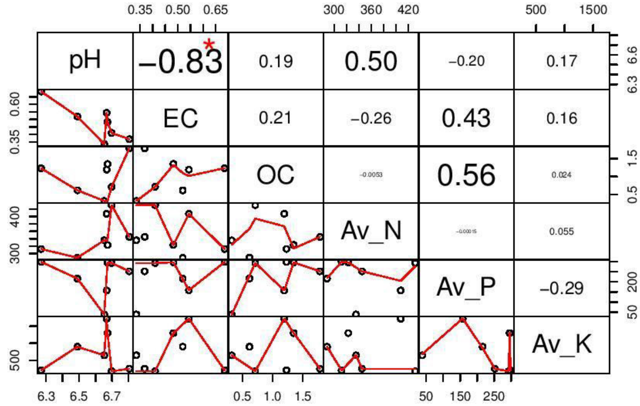

Fig.2. For dumping sites * means significance at 0.05 level.

For the control sites from the scatter plot, it was estimated that at P=0.05, positive significant correlation was found at 0. 79 between organic carbon and available phosphorous (figure.3), in the same figure.3, negative significant correlation of available phosphorous with available potassium (-0.72) was shown. Other than these, for both dump and control site, no significant correlation was found between any of the physico chemical parameters of the soil.

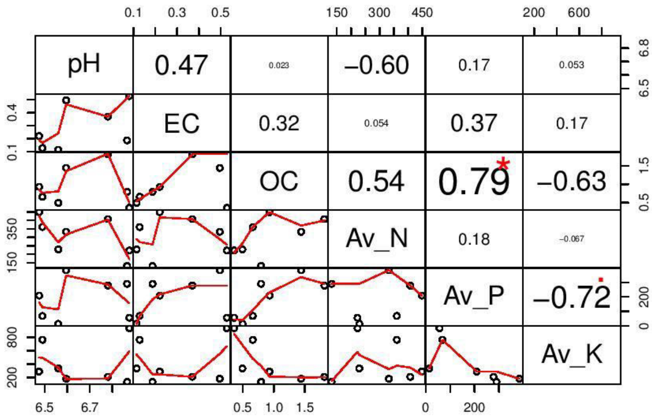

Fig .3. For control sites *means significance at 0.05 level.

ANOVA analysis for the difference between dumps and control sites

The result for difference in the mean concentration of physico-chemical parameters in soil between the dump sites and control sites is represented in Table-1. Significant difference was illustrated between dump and control sites for available potassium (p=0.04) and electric conductivity (p=0.02) of dump and control sites at a significance level 0.05 as shown in table. For the rest of parameters pH, OC, total N, available phosphorous no significance difference was illustrated.

Table-1: The concentrations of different soil parameters (mean ± standard error) in dump and control sites. *F*-ratio is the F-statistics; p-value represents corresponding probability value from one-way ANOVA. Level of significance is 0.05 for difference estimation.

Soil parameters	Location		One Way ANOVA	
	Dump	Control	*F*-ratio	*p*-value
pH	6.61±0.06	6.66±0.06	0.33	0.56
EC (dS/m)	0.48±0.05	0.29±0.07	5.36	0.02
OC (%)	1.03±0.14	0.93±0.18	0.19	0.66
Av_N (kg/ha)	348.99±26.21	304.64±38.31	0.93	0.34
Av_P (kg/ha)	221.57±22.97	185.48±42.33	0.90	0.35
Av_K (kg/ha)	745.35±138.83	406.25±82.05	3.52	0.04

One way ANOVA for difference between selected locations

The soil data for different dump and control sites was analyzed using one way ANOVA followed by Turkey's post hoc test to estimate the Significance differences (p<0.05) between different sites in relation to soil parameter which is shown by different letters (a>b>c>d>e>f>g) in the row. Significant difference was observed for the soil of different dump sites for the organic carbon (0.04), available phosphorus (<0.01) and available potassium (<0.01) at a significance level of p<0.05. Significant difference for organic carbon is seen highest for Chamba, Hamirpur, Mandi and Manali followed by Bilaspur and Kangra and least significant difference at P<0.05 was noted for Kullu dump site (Chamba=Hamirpur=Mandi=Manali>Bilaspur=Kangra>Kullu) (Table-2). The most probable reason for this, is the difference in composition of waste, as high content of organic or biodegradable waste was produced in the towns with high organic carbon content. For the available phosphorus significant difference trend in decreasing order is as follows; Bilaspur=Chamba=Hamirpur=Kangra=Manali=Mandi>Kullu. The highest significant difference for the available potassium is noted for Mandi followed by Bilaspur, Hamirpur, Kullu trailed by Chamba and least significant difference for the Kangra and Manali sites (Mandi>Bilaspur=Hamirpur=Kullu>Chamba>Kangra=Manali) (Table-2). The significant difference in available potassium and phosphorus is due to difference in waste composition for different sites. Significant difference at P<0.05 level for control site was only observed for available Potassium (0.04) in which the highest significant difference was estimated for Kullu and Mandi followed by Bilaspur, Chamba. Hamirpur, Kangra and Manali (Kullu= Mandi > ilaspur=Chamba=Hamirpur=Kangra= Manali) Table-2. The possible reason for this might be different land use of control sites such as open fallow land, nearness to roads, rivers, forests and agricultural lands.

Table-2: One way ANOVA for difference between selected locations

The concentration of soil physio-chemical parameters (mean ± standard error) for dump sites and control sites. F-ratio is the F-statistics for the test of a particular analysis; p-value represents corresponding probability value from one-way ANOVA. Significance differences (p<0.05) between different sites in relation to soil parameter was estimated using Tukey's post hoc test and shown by different letters (a>b>c>d>e>f>g) in the row.

Soil parameters		Location							One Way ANOVA	
		Bilaspur	Chamba	Hamirpur	Kangra	Kullu	Manali	Mandi	*F*-ratio	*p*-value
Dump Soil	pH	6.5±0.3	6.8±0.3	6.7±0.3	6.7±0.2	6.7±0.4	6.3±0.1	6.7±0.4	1.25	0.32
	EC (dS/m)	0.5±0.5	0.4±0.2	0.5±0.2	0.4±0.2	0.3±0.2	0.7±0.2	0.5±0.1	0.95	0.48
	OC (%)	0.6±0.2b	1.8±1a	1.4±0.8a	0.7±0.5b	0.3±0.1c	1.2±0.8a	1.2±0.2a	2.54	0.04
	Av_N (kg/ha)	288.5±97.3	345±210.3	323±120.2	431.2±252.4	335.6±92.4	312±57.8	407.7±88.8	0.50	0.80
	Av_P (kg/ha)	216±72.6a	251.9±41.3a	295.8±209.1a	292.8±9.0a	38.6±24.8b	298.4±35.3a	157.4±83.4a	3.96	<0.01
	Av_K (kg/ha)	897.8±612.3b	250.3±80.6c	1301.2±650.9b	175.6±50.2c	644.2±240.7b	204±19.1c	1723.5±1052.6a	12.94	<0.01
Control Soil	pH	6.5±0.1	6.9±0.3	6.5±0.2	6.8±0.1	6.9±0.1	6.6±0.3	6.5±0.1	1.87	0.22
	EC (dS/m)	0.2±0.2	0.2±0.1	0.1±0.1	0.4±0.1	0.5±0.2	0.5±0.6	0.1±0.1	0.95	0.52
	OC (%)	0.9±0.1	0.8±0.8	0.5±0.1	1.8±0.9	0.4±0.1	1.4±1.1	0.7±0.1	1.43	0.32
	Av_N (kg/ha)	448.4±102	131.7±53.2	228.9±66.5	407.7±230.6	222.7±110.9	332.4±168.5	360.6±22.2	1.62	0.27
	Av_P (kg/ha)	208.9±44.8	290±14.3	13.5±0.6	277.7±25.4	56±9.5	384±289.9	68.2±12.8	3.38	0.07
	Av_K (kg/ha)	288.7±92.1b	133.8±15.7b	334.7±143.7b	209.3±112.6b	934.8±46.2a	181±67.1b	761.5±9a	3.97	0.04

Conclusion

In hilly state such as Himachal Pradesh, there is a need of detailed study on the effects of solid waste on soil health of the dumping sites. Dumping of municipal solid waste can pose a great risk to soil and its surrounding environment in the dumping sites. Since soil is a very important natural resource for the growth of vegetation therefore there is a need to conserve it. In the long run unscientific and continuous dumping of municipal solid waste in the dumping sites will lead to degradation of soil quality. From the evaluation of soil samples from the different dumping sites in Himachal Pradesh showed different trends for different physico chemical parameters. The concentrations of different physico chemical parameters were higher for dumping sites as compared to control sites. So, from these results, it can be concluded that the physico chemical parameters were higher for dumping site which may be caused by unscientific dumping of municipal solid waste. The leachate which percolate into soil, can lead in change in its physical and chemical properties. This can further lead to decreased potential of soil as an important natural resource to sustain life, be it flora or fauna. It is recommended to study the presence of heavy metals in soil to know further effects of municipal solid waste dumping sites. Long time monitoring is required to be done of the soil of dumping sites to validate results.

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