Effect of Solid Waste on Heavy Metal Composition of Soil and Water at Nathiagali-Abbottabad

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Summary: This experiment concluded that the waste material produced tangible impacts on soil and water system of Nathiagali. The dumping of waste resulted in a marked increase in the concentration of metals in soils and the measured metals varied in the order of Mn > Fe > Zn > Cu > Pb > Ni > Cu. The metal species were found higher on the site of waste accumulation and decreased with the increasing distance from the dumping site. The dumping place had the highest soil EC as compared to the nearby soils. The pH trend was found apparently inconsistent. Water samples exhibited higher content of heavy metals. This could be attributed to the leachates percolated from the solid and liquid wastes. Metal concentrations were found in excess to the WHO water quality standards. Therefore, an effective awareness, recycling and land filling techniques for the solid waste management in the study area is urgently needed.

Introduction

Waste is anything, which is no longer of use to the disposer. It can also be defined as any unavoidable material resulting from an activity, which has no immediate economic demand and which must be disposed off. Nearly every member of the population generates wastes of one kind or another. There are local variations in waste generation and the proportions of constituents change over weekly and seasonal cycles. Storage and collection of waste are some of the more visible signs of successful or unsuccessful solid waste management systems [1-3]. If successful, the result is clean surroundings and good public sanitation; if unsuccessful, litter and poor public sanitation are everywhere. Solid waste has been a serious environmental problem for many cities in developing countries [4, 5]. If waste is not discarded properly on land, in addition to affecting plant and animal health, trace elements contained in solid waste may be leached from the soil and enter either ground or surface water and dangerously contaminate it. Soil pollution is important because several soil pollutants tend to get into the groundwater, surface water and air [6].

Among the multitude of environmental problem existing in Pakistan, solid wastes have become one of the most prominent in the recent years, not only because of the increase in the amount, but chiefly because of the lack of an efficient management system and monitoring associated impacts on ecosystem. It was estimated that the solid waste generated every day is about 0.5 million tons, half of which is produced by 70% of the population living in rural areas [7]. The rate of waste generation per person is 0.3 to 0.6 kg per day, while the rate of waste generation per house is about 1.9 to 4.3 kg per day and the waste generation growth rate is 2.4% per year [8].

This study focuses on the impacts of waste on heavy metal composition of soil and water at Nathiagali- a mountain resort town of Abbottabad known for its scenic beauty, hiking tracks and pleasant weather. The drastic increase in the tourists in the area has put some adverse impacts on its panoramic landscape. The pollution left behind by the tourists and improper disposal of solid waste by the local hotels and restaurants are some of the bi-attributes of the tourism threatening the fragile ecosystem of the area. Lack of awareness on part of the visitors, local communities and line agencies regarding solid waste management is one of the most important factors contributing to the degradation of environment. The reports on waters and soils as affected by open dumping of wastes are available, but there are still information gaps. At Nathiagali, such investigations have not been made previously. Thus, the study was aimed to assess the impact of solid and liquid waste on heavy metal concentrations in soil and water and to compare their values to the WHO recommendations for water quality.

Results and Discussion

Soil Analysis

Soil is the medium that supports plant growth and modulates water, nutrients and pollutants

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transport in the terrestrial environment. Logically, the connotations of soil quality should include environmental sustainability [9, 10]. It is important to study the impact of waste on soils. Laboratory analysis showed that waste material appeared to regulate the form of heavy metal in soil system. The application of organic and inorganic waste resulted in a marked increase in the concentration of metals. The measured metal contents in the soils varied in the order: Mn > Fe > Zn > Cu > Pb > Ni > Cd (Table-1). It has been reported that soils Mn is higher than other micronutrients except Fe [11]. Some of the sources for Mn in the soils are fertilizers, sewage, sludges and non-ferrous smelters. Critical Mn concentration in the soils is 1500 to 3000 mg kg^{-1} as reported by Kabata-Pendias and Pandias [12]. The average concentrations of these elements in the soil solution near the dumping site increased significantly with the waste application. The experiment showed that the samples near the dumping site were found more contaminated by heavily metals. The higher magnitude of these metals could be related to the enhanced metal holding capacity of soil for these elements due to the addition of waste. He and Singh [13] reported an increased soil cation exchange capacity (CEC) under organic amendments. Soil samples of the polluted site contained higher concentration (mg kg^{-1}) of Pb *i.e.* 2.7 as compared to least polluted site (50 m away from the dumping site (0.72) and unpolluted place (0.53). The total contents of Zn and Cu in the surface soil were 8.2 and 0.8 mg kg^{-1} soil, far less than the toxic level of 300 mg kg^{-1} for Zn [14] and 150 mg kg^{-1} for Cu [15]. The concentration trend of Cu in the soils was found lowest as compared to the other elements. The soil concentration of Fe was inversely related with the distance of the dumping site (Table-2). Waste applied soil has 3.2 mg kg^{-1} Cd concentration whereas a negligible Cd concentration was found in the soils without waste (Table-1). Critical level of Cd in soil was reported between 3 to 5 mg kg^{-1} by Kabata-Pendias and Pandias [12]. Accumulation of Cd in soil was reported by Yarlagadda *et al.* [15] and Kachenko and Balwant [16] when irrigated with waste effluents. Although the concentration of Pb observed in soil sample was low as compared to Mn, Zn or Fe. The concentration trend for all the metals with respect to the distance from the dumping place remained identical. The concentration of Pb detected was within permissible limit of WHO, *i.e.* 13 mg kg^{-1} as also reported by Kachenko and Balwant [16] and Ihsanullah *et al.* [17]. Increased quantity of Pb was reported in soil by Miller *et al.* [18].

Table-1: Changes in heavy metals (mg kg^{-1}) in soil as affected by waste.

Soil Sample	Mn	Fe	Zn	Cu	Cd	Ni	Pb	EC	pH
Non-polluted soil	3.22	4.15	2.17	0.38	0.16	0.27	0.53	0.58	5.40
0	50.51	41.28	8.17	0.94	3.21	1.21	2.70	1.53	5.49
5	49.20	39.32	7.20	0.93	2.11	1.10	2.24	1.40	5.45
10	41.32	31.23	7.34	0.85	2.15	1.15	1.15	1.20	5.71
20	39.54	24.68	6.40	0.86	1.86	0.80	1.02	0.94	5.17
30	35.34	21.85	5.23	0.72	1.85	0.72	0.92	0.95	5.90
40	24.85	19.42	5.48	0.75	1.72	0.63	0.98	0.83	5.78
50	11.53	10.2	4.48	0.71	1.45	0.68	0.72	0.73	5.22
WHO Std (1996)	1.0	50	1.50	0.5			13.0		

Note: The figures in the 1st column (*i.e.* 0, 5, 10, 20, 30, 40 and 50) show the distance (meter) of soils sampled away from the dumping site at Nathiagali

Table-2: Changes in water parameters as affected by waste disposal.

Water sample	TDS mg L^{-1}	EC dS m^{-1}	pH	Total coliforms per 100 mL
Tap-water	86	0.18	6.18	12
Site 1	290	0.92	6.11	> 300
Site 2	462	0.87	6.66	> 300
Site 3	438	0.88	6.65	> 190
Site 4	436	0.87	6.63	> 175
Site 5	440	0.88	6.36	> 80
Site 6	439	0.87	6.28	> 87
Site 7	442	8.72	6.16	> 28

The metal species in the soils studied may reflect the variability of metal composition in the solid or liquid waste thrown at the site. Han *et al.* [19] reported that organic wastes carry variable forms of toxic elements (heavy metals). Khan [20] conducted a study on the impact of industrial effluents on environment and found heavy metals such as Ni, Zn, Fe, Cu, Pb, Cr and Mn in the soil above the permissible limits. It has been critically noticed in this experiment that the soil concentrations for all metals was found above the permissible limit of WHO (see Table-3).

Table-3: WHO standards for quality of drinking water.

Property	WHO standard
Drinking water (E. coli)	Must not be detectable in 100 mL sample
TDS (mg L^{-1})	< 1000
Cd (mg L^{-1})	0.003
Cu (mg L^{-1})	2.0
Pb (mg L^{-1})	0.01
Mn (mg L^{-1})	0.5
Ni (mg L^{-1})	0.02
Zn (mg L^{-1})	3.0
pH	6.5-8.5

The pH and EC of the soils are indicators of the background chemical matrices of the soils and they may be, over the long run, affected by the water quality, organic and inorganic inputs etc. The EC (1:5) of the soil was higher in the samples collected from the dumping site. The dumping place exhibited highest EC value (i.e., 1.53 dS m^{-1}) whereas the soil without any waste exhibited lowest value of EC (0.58 dS m^{-1}). The pH trend was found inconsistent among the sampling sites near or far from the pile of waste.

However, the pH was enhanced in waste polluted soil as compared to the clean place.

Water Analysis

For an effective management of water resources, a continuous and systematic monitoring of relevant parameters is required to prevent further contamination and the sustainable management of water resources. Total concentration of dissolved solids in water is a general indication of its suitability for any particular purpose or use. During the experiment the TDS were found as 94 mg L^{-1} in tap water at Nathiagali whereas waters from the site of the waste disposal gave TDS range of 290 to 462 mg L^{-1} (Table-2). The enhanced TDS could indicate the presence of salts due to waste. Water that contains less than 500 mg L^{-1} of dissolved solid is generally satisfactory for the domestic use and other industrial purposes. Water that contains more than 1000 mg L^{-1} of dissolved solids usually contains minerals that give it a distinctive taste or make it unsuitable for human consumption.

Total coliforms recorded in tap water were 12 per 100 mL whereas the waters collected at various sites near the dumping sites were dangerously polluted with bacteria. The number of coliforms decreased up to 120 at farther location of water sampling (Table-2). According to WHO guidelines, the *E coli* and *faecal coliform* bacteria must not be detectable in any 100 mL sample of all water intended for drinking. Coliform bacteria are small rod like gram negative organisms that are capable of fermenting sugars (lactose) with the production of acids and gas in abundance. It has been assumed that water can not be polluted without their presence. Therefore, their presence is considered as an indication of fecal pollution of water. The coliform has gained a widespread acceptance among water analyses as best measure of fecal contamination. Bacteriological contamination of drinking water has been reported to be one of the most serious problems throughout the country in rural as well as urban areas [21-23].

The pH values of water samples were found slightly less than 6.5 and more than 6 whereas the WHO standards for raw waters lie in the pH range of 6.5 to 8.5. Water samples near dumping site produced relatively higher EC value (0.92 dS m^{-1}) as compared to the tap water collected from an hotel where the EC value was recorded as 0.18 dS m^{-1} (Table-2). The higher EC values indicate the greater amount of salts in the water due to pollution. Rhoades *et al.* [24] classified waters on the basis of salinity and reported the EC value of drinking water as less than 0.7 dS m^{-1}.

Manganese concentrations of various sites at Nathiagali were shown in Table-4. The Mn level of water was above WHO's recommendation ranging from 15.2 to 8.5. However, the Mn in tap water was found within WHO limit (Table-3). Iron content was found 0.82 mg L^{-1} in tap water whereas the spring water collected at various places gave Fe level up to 1.30 mg L^{-1}. The values were above the range of WHO. Zinc concentration of tap water and other samples was found within acceptable level (Table-4). Water samples showed the lowest amount of Cu as compared to other elements. Tap water had Cu value of 0.02 mg L^{-1}. The changes among various sites (far and near) under the influence of waste were found not different for Cu level. Higher concentration of Cd in water samples was recorded. Cadmium value of 0.01 mg L^{-1} is considered appropriate. Water of Nathiagali showed tangibly higher concentrations of heavy metals. These metals could apparently be attributed to the leachates percolated from solid and liquid wastes into springs and soils system.

Table-4: Changes in heavy metals (mg L^{-1}) in water as affected by waste.

Water Sample	Mn	Fe	Zn	Cu	Cd	Ni	Pb	ECdS m^{-1}	pH
Tap water	**0.06**	**0.82**	**0.03**	**0.02**	**0.01**	**0.003**	**0.001**	**0.18**	**6.18**
Site 1	**15.2**	**1.20**	**2.52**	**0.14**	**0.08**	**0.12**	**0.14**	**0.92**	**6.11**
Site 2	**10.5**	**1.31**	**2.13**	**0.15**	**0.08**	**0.08**	**0.11**	**0.87**	**6.66**
Site 3	**11.3**	**1.11**	**2.34**	**0.14**	**0.05**	**0.07**	**0.12**	**0.88**	**6.65**
Site 4	**12.3**	**1,20**	**1.94**	**0.12**	**0.06**	**0.08**	**0.14**	**0.87**	**6.63**
Site 5	**10.3**	**1.12**	**1.84**	**0.11**	**0.06**	**0.08**	**0.21**	**0.88**	**6.36**
Site 6	**9.4**	**1.34**	**1.81**	**0.14**	**0.07**	**0.07**	**0.13**	**0.87**	**6.28**
Site 7	**8.5**	**1.01**	**1.42**	**0.11**	**0.06**	**0.06**	**0.11**	**8.72**	**6.16**

Experimental

This research was aimed to ascertain the impacts of waste material on soil and water system at Nathiagali where the solid and liquid waste is being disposed off down inside the forest of Ayubia National Park from hotels, shops and houses etc at various places. For this purpose, water samples were taken on 26th Oct, 2009 in cleaned and rinsed plastic bottles at various points that were randomly selected in the vicinity of the dumping sites. Bottles were also washed with the respective water sample at the time of sampling and completely filled up with water, so as to avoid any air or bubble inside the bottle. Water samples were filtered and saved in the refrigerator for the desired analysis of some chemical characteristics. These characteristics included pH, electrical conductivity (EC), amount of dissolved solids, calcium hardness, total hardness, turbidity, total coliform bacteria and some heavy metals: copper (Cu), zinc (Zn), manganese (Mn), iron (Fe), lead

(Pb), nickel (Ni) and cadmium (Cd). Water pH was measured immediately after sampling with a pH meter (model: 7020). The pH meter was calibrated with a buffer solution having pH 4 and 7. The EC was measured with EC meter (model: AGB 1000). The unit of conductivity for all samples was converted to dS m^{-1}. Total dissolved solids (TDS) were measured using an empty china dish that was weighed and a known sample volume was dried in a pre-weighed china dish in an oven. The change in the weight of dish was the TDS of the sample.

Total coliform bacteria were determined by colony forming units (CFUs) using membrane filtration method. Membrane filtration was carried out by filtering 100 mL of water through a membrane filtration assembly. Bacteria were retained on the membrane which was placed on the Petri dish containing nutrient agar. Petri plates were then incubated after a recovery period of one hour, at 37 ^{o}C for total coliform bacteria for 24 h. The existing bacteria grew into visible colonies and counted manually depending on the type of sample. Petri dishes, medium and forceps were autoclaved. After each sample, the filtration unit was sterilized using 70% methanol.

Heavy metals analysis were carried out by taking 50 mL of water sample in a graduated cylinder and filtered via 0.22μM filter paper. The filtrate was analyzed for various heavy metals by atomic absorption spectrophotometer (AAS).

Soil Analysis

Soil samples were randomly collected in plastic bags at a distance of 0, 5, 10, 20, 30, 40 and 50 meters from the waste dumping site up to the depth of 30 cm using an auger. The samples were properly marked at the time of sampling. The samples were air dried, crushed and sieved via 2 mm sieve. The pH and electrical conductivity (EC) of the soil samples were measured in 1: 5 sample: water suspension after shaking it over for 1 h by a mechanical shaker. A weighed sample of soil was digested separately with 25 mL concentrated HCl by gradual heating it over a hot water bath for 1 h. After drying 20% HNO_3 was added to the sample and it was heated again for 1h. The solution was diluted to 100 mL with deionized water and passed through a 0.22μM filter. Samples were analyzed for heavy metals (Cu, Zn, Mn, Fe, Pb, Ni, Cd) by AAS. Three samples were collected from each sampling spot of soil and water. The data were statistically analyzed and means were calculated for each measured parameter.

Conclusion

It could be concluded that the metal forms in the soils were materially changed by waste application. The amounts of metals increased significantly with the addition or haphazard disposal of waste in soils. The analyzed species of heavy metals in the soils could reflect the variability of metal composition in the solid or liquid waste. EC and pH of the soils and water samples significantly enhanced with waste. The parameters measured in water samples were compared to WHO water quality standards. Most of these parameters tested found in excess of the WHO recommendations. This situation could be apparently related to the poor management of solid waste system at Nathiagali. Appropriate measures should be undertaken for a rational disposal of domestic waste to mitigate contamination. The study may help to make environmental awareness among the people and would protect natural resources (water, soils and biodiversity) in the area.

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