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Effect of Landfill Leachate on the Stream water Quality

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ABSTRACT: The influence of leachate from open solid waste dumping near Salhad stream (Abbottabad, Pakistan) was investigated to quantify the variations of water quality during August 2007 to April 2008. Samples were collected from five different sites located along the Salhad stream. Two sites were located before the mixing of solid waste leachate with the surface water. One sampling site was of leachate and other two sampling sites were affected with solid waste leachate. Samples were analyzed for various physical and chemical parameters like pH, water temperature, electrical conductivity (EC), total dissolved solids (TDS), Biological oxygen demand (BOD), chemical oxygen demand (COD) and dissolved oxygen (DO). Microbiological analysis was done by using Membrane filter technique. The results of various parameters determined strongly suggested that landfill leachate had severe deleterious impact on the water quality of Salhad stream. The parameters exceeding the allowable limits of WHO, EC and National Environmental Quality Standards included pH, TDS, BOD, COD, total bacterial counts and total coliform counts. Heavy metals like Pb, Cd and Cu were released from the leachate into the Salhad stream which might affect the sustainability of the aquatic life. Integrated, multi-sector approaches are required to deal with the contamination problem and sustainable management of the Salhad stream water.

Key words: Fecal coliform, Heavy metals, BOD, COD, Water quality standards

INTRODUCTION

For centuries human have been disposing off waste products by burning, discharging in streams, storing them on ground, or putting them into landfills. In addition to contaminated surface runoff, human induced influences on surface water quality reflect direct waste discharge into a stream. Most commonly, the surface and ground water quality is affected by waste disposed and land use. One of the major sources of contamination is the storage of waste materials in excavations. Water soluble substances that are disrupted, spilled, spread or stored on the land surface eventually may infiltrate. The extent of enteric diseases in different areas depends upon the extent to which certain water is exposed to contamination. The incidence of typhoid fever, bacillary dysentery, infectious hepatitis and other enteric infections in many third world countries including Pakistan may transmit through water. Cholera is still a wide spread water borne disease in some developing countries (KRAMP, 1997).

One of the biggest challenges of 21st century is safe water-supplies and environmental sanitation which are vital for protecting the environment, improving health and alleviating poverty. According to the World Water Assessment Programme issued by United Nations, the average availability of water per person is expected to drop by one-third over next 20 years and so one-third of humanity (about 2.7 billion) will be under the shadow of acute water scarcity by 2025. The access to "closer and cleaner drinking water" is still a distant dream for about one-sixth of humanity on this planet (Harvey *et al*., 2002; Smedley and Kinniburgh, 2002). It is predicted that this increasing scarcity, and competition over water resources in the first quarter of the 21st century, will dramatically change the way we value and use water (Mroczek, 2005).

During the past two decades, investigators have taken a serious look over the environmental impacts of open dumps. As rain water infiltrates through trash in dump, it accumulates an ample assortment of chemical and biological substances. The resulting fluid or leachate may be highly mineralized and as it infiltrates some of the substances it contains may not be removed or degraded. The proper collection,

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transportation and disposal or dumping of municipal solid waste in Abbottabad city of Pakistan has not been carried out Domestic solid waste in a sufficient and keeping in view of the size of the city, therefore the environmental and sanitary conditions have become more serious year by year. Salhad dumping area is about 100 canals and its capacity to store solid waste is about 183 metric ton/day and the site is in use since 1984. The leachate and odor of waste is disturbing the people and polluting the adjacent stream known as Salhad stream.

The specific objectives of the present study were to analyzed seasonal variation in the water quality of Salhad stream before and after the discharge of leachate from landfill situated at the bank of Salhad stream.

MATERIALS & METHODS

The study area was Salhad stream, located in the Southern part of Abbottabad. Various sampling sites have been shown in Fig.1. Salhad stream is characterized by all four seasons winter from October to March, spring from April to May, summer from May to August, fall from November to December and rainfall monsoon from July to August. This Salhad stream supplies water to local community and then discharges into the river "Dorr". The water of river Dorr is largely used by the local farmers for irrigation, bathing and drinking purpose. The physicochemical analysis of Salhad stream water was done from July 2007 to April 2008. Sampling was done according to the recommended procedure; about 1.5 liter of water was collected in a clean plastic can for physicochemical analysis. The bottles used were first washed with detergent then with hot water and finally rinsed with distilled water. On reaching the laboratory the samples were filtered through Whattman filter paper. All the samples were stored at 4°C in refrigerator.

Membrane filter technique (MFT) was used for bacterial analysis. The MFT offers the advantage of isolating discrete colonies of bacteria (APHA, 2005). The U.S. EPA stated that the MF Technique is preferred for water testing because it permits analysis of larger quantity of water samples in a short time. For the total bacterial count, nutrient agar media and for total coliform Eosin methylene blue (EMB) agars were used. After samples collection, necessary dilutions were made. All the procedures were carried out under sterilized conditions. The plates were incubated at 37°C for 48 h. After the incubation period, the colonies were counted using colonies counter. Total number of colony forming units (CFU/10 ml) was calculated by multiplying it with the dilution factor.

For Biochemical oxygen demand analysis BOD 5 days test (BOD5) was used and chemical oxygen demand (COD) were analyzed by dichromate reduction method (APHA, 2005). The physical parameters, like electrical conductivity, total dissolved solids and NaCl concentration were determined by using Conductivity meter/TDS meter, and Microprocessor HI 9835. Dissolved oxygen was determined by using dissolved oxygen meter (Microprocessor Auto Cal HI 9145).

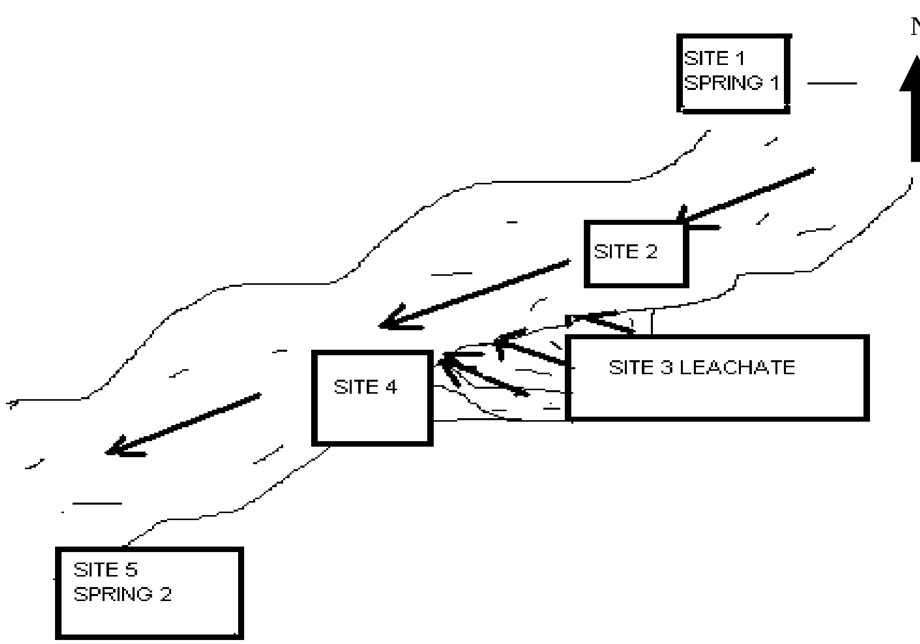

Fig. 1. Sketch of sampling sites of the study area

Temperature and pH were measured by using HANNA sensor checker. All these parameters were measured under the field conditions and then in the laboratory for comparative analysis.

All the heavy metals were analyzed through atomic absorption spectrometer (A Analyst 700, Perkin Elmer).The instrument was calibrated with appropriate set of calibration standards in each case, prepared by using available 1 mg/ml AAS standard solutions. The leachate sample was first filtered through whattman filter paper then to 10 ml of sample 2 ml sulfuric acid, 2 ml phosphoric acid, 2 ml perhydrochloric acid, 1ml of hydrogen peroxide were added and heated for 10-30 minutes. Later, 10 ml of nitric acid, 20ml of conc. Hydrochloric acid and 6ml of perhydrochloric acid were added and heated for more than 30 minutes for proper digestion and to release all gasses, then sample was cooled for analysis.

RESULTS & DISCUSSIONS

The details of sampling results obtained are given in Figs. 2-8 and Tables 1-2. The pH at various sampling sites varied from 5.9 to 9.1 during different months. The lowest value (5.9) was recorded at site 1 which may be related to factors like low DO concentration and fungus growth at the site. (Somashekar and Ramaswamy, 1984) have shown that the alkaline water harbor more plants than acidic waters. Alkaline pH was observed in the leachate sample (site 3) throughout the sampling duration (Fig. 2). Higher pH values were observed in the month of April due to mineralization of carbonates, bicarbonates and hydroxides. These chemical species might have contributed towards higher alkalinity at site 3.

The surface water temperature of stream varied considerably during different months. It is evident from Fig.3 that the temperature variations reflected the prevailing climatic conditions of the region to which Salhad stream is exposed. The minimum water temperature was 9.1°C in the month of December, while the maximum temperature was recorded 42°C in July at site 3 (leachate sample) due to intense solar radiation, clear atmosphere and low leachate discharge and due to large amount of chemicals present in leachate.

Liu *et al* (2005) described aquatic temperature regimes of various parts of the Lena watershed and documented significant stream temperature changes induced by reservoir regulation and natural variations. They suggested that the latitudinal differences in climatic variables such as air temperature might be the major control on stream temperature regime.

Fig. 4. shows that the minimum value of TDS was recorded in the month of September after heavy rainfall due to dilution and flushing of organic and inorganic waste. While the maximum value was recorded in the month of December due to dry season having no rainfall so the minerals accumulated and remained in the stagnant water in dissolved form. The TDS concentration mainly depends upon geogenic influences for example geology of the basin or on anthropogenic influences for example solid waste dumping. In all samples average TDS value was found within WHO permissible limit of 500 ppm except leachate that contained different minerals and chemicals at higher concentration (Fig. 4).

According to EU directive 98/83 (1998), the standard value of conductivity is 2500 u S/ cm at 20°C. Our results showed that the leachate site 3 values for conductivity were very high (Fig.5). The conductivity values for all samples except Site 3 were within the maximum permissible limit for drinking purpose. The conductivity of leachate sample was higher than the recommended standard value. The highest conductivity value in the month of December indicated that it might be due to dry weather where the cations, anions and the total solids accumulated at these sites. The conductivity of samples for September month showed comparatively low value due to dilution of these ions after heavy rainfall season. The higher conductivity values of leachate sample were almost equal in July, December and February, while lowest in the month of September and April due to dilution of samples after heavy rainfall. The importance of electrical conductivity is its measure of salinity, which greatly affects the taste. Consequent to increase in NaCl concentration, an increase in ionic strength of leachate sample may also be expected resulting in TDS and conductivity values higher than the permissible limits (Langenegger, 1990).

Fig. 6 shows that low dissolved oxygen values were detected in the month of July which may be due to high temperature which releases oxygen from the stream water. While the low values were observed in December, also indicating the effect of climate on the concentration of dissolved oxygen in water. Moreover, the respiring plant and other microorganisms might have utilized the available DO. Site 3 of leachate sample showed the presence of very low level of DO as it was characterized by high temperature and various chemical pollutants which can limit the concentration of oxygen. If water is too warm, there may not be enough oxygen in it.

The standard value of BOD is 80 mg/L for inland waters (NEQS, 2000). All samples showed the BOD values beyond the permissible limits which implied that stream water contained high bacterial load needing more oxygen to degrade the organic matter (Fig. 7).

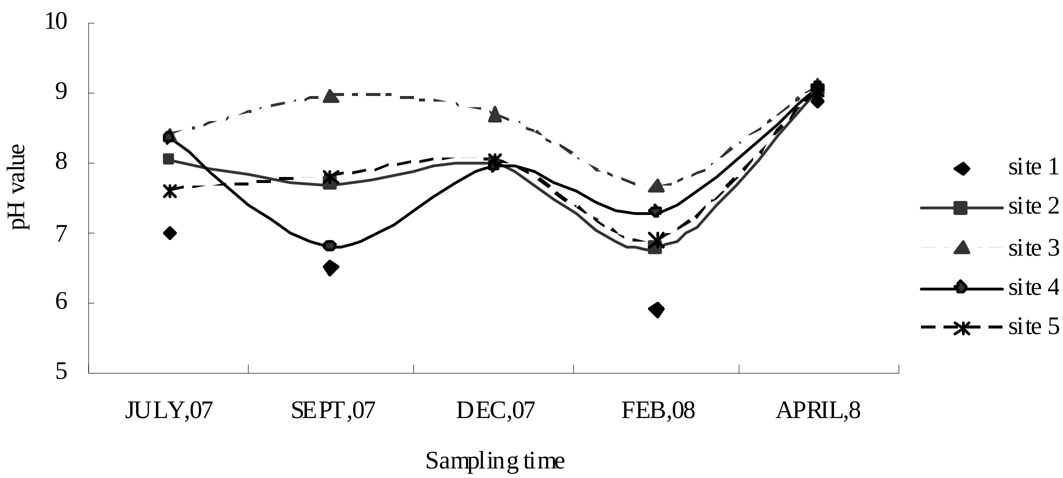

Fig. 2. Seasonal variations in pH at various sampling sites of Salhad stream

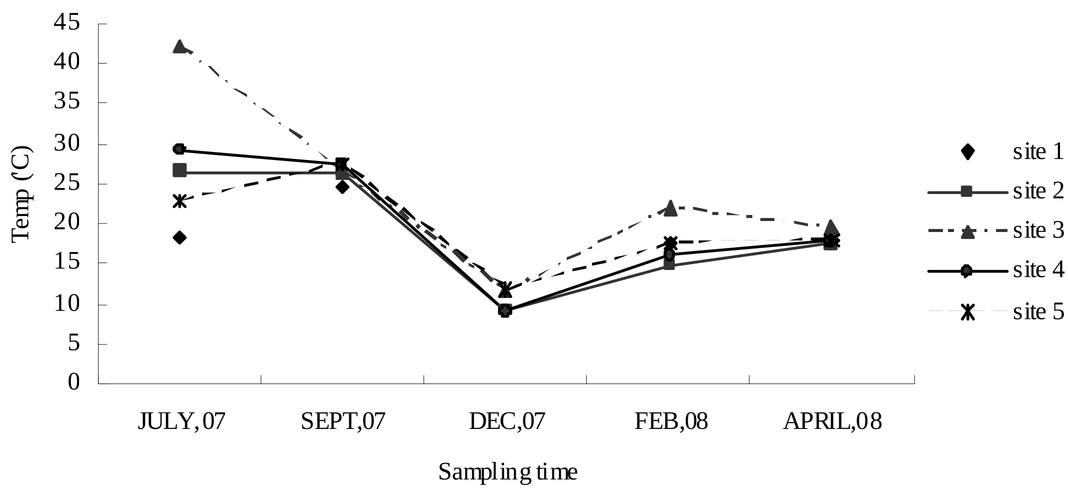

Fig. 3. Seasonal variations in temperature at various sampling sites of Salhad stream

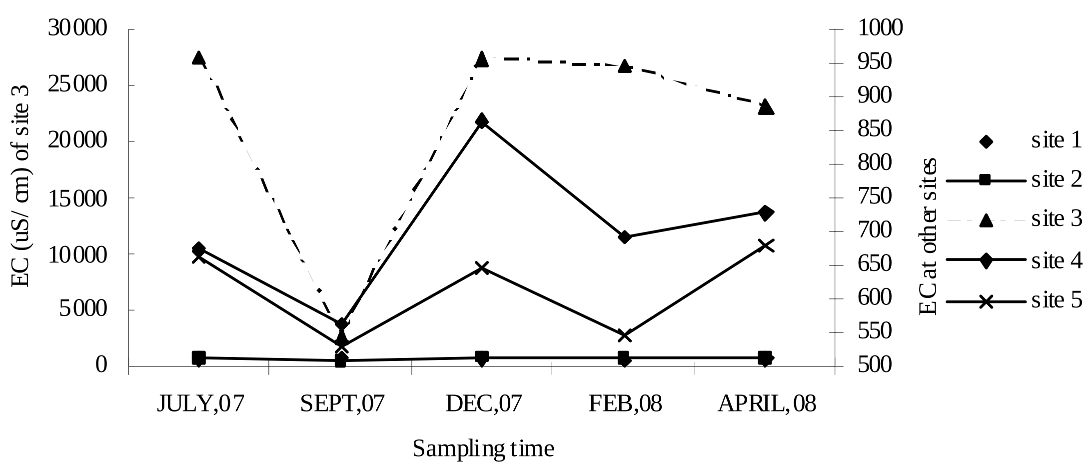

Fig. 4. Seasonal variations of conductivity at various sampling sites of Salhad stream

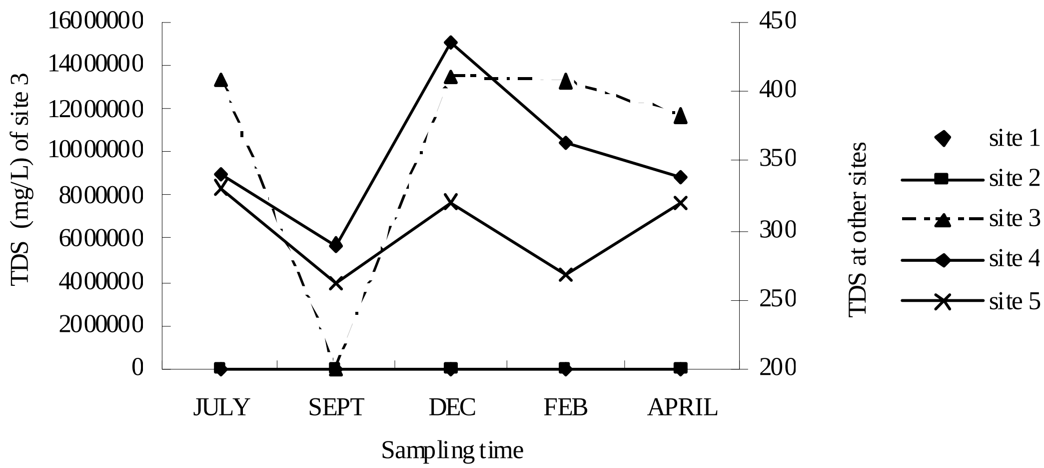

Fig. 5. Seasonal variations in TDS at various sampling sites of Salhad stream

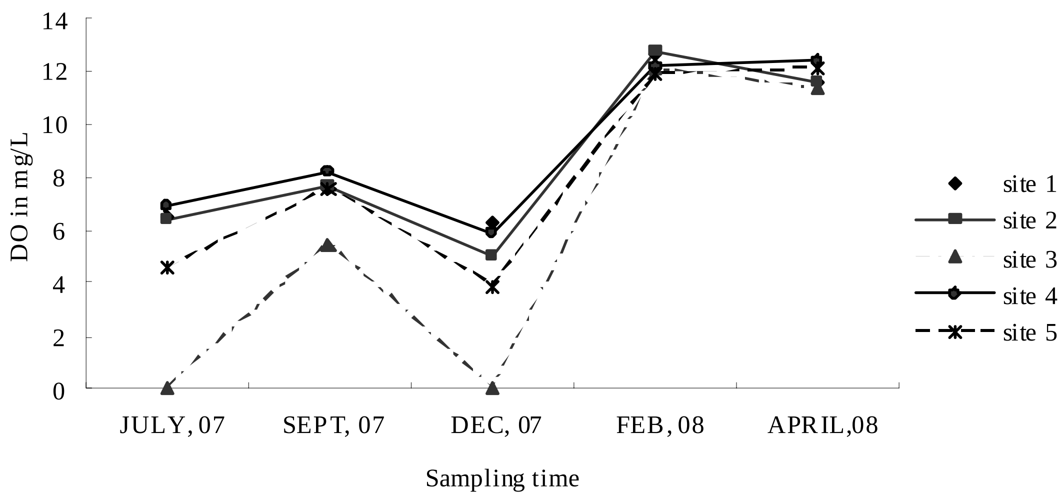

Fig. 6. Seasonal variations in DO at various sampling sites of Salhad stream

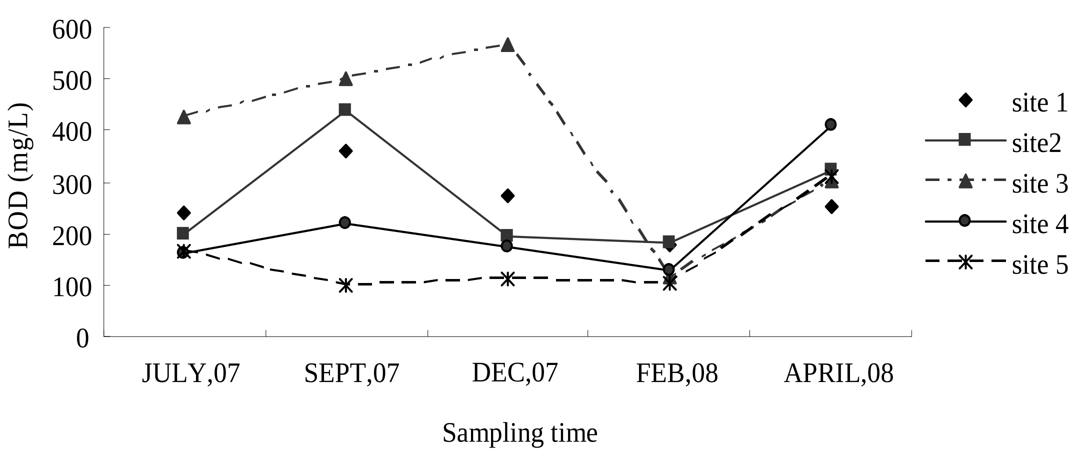

Fig. 7. Seasonal variations in BOD at various sampling sites of Salhad stream

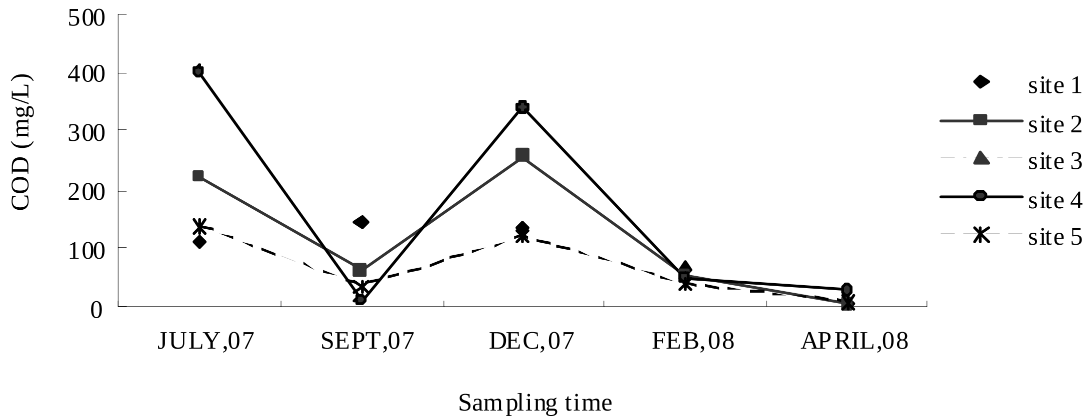

Fig . 8. Seasonal variations in COD at various sampling sites of Salhad stream

Seasonal variations in BOD values appears to be a function of changes in the degree of dilution, quantity of organic matter and the activities of microorganisms carrying out decomposition of carbonaceous and nitrogenous matter. The minimum values were observed in the month of February due to cold weather and low biological activities as most of the microorganisms involved in decomposition of organic matter cannot survive at that temperature. The highest BOD value was caused by the decomposition of algal cells and sewage disposal having high quantity of organic waste (Behera *et al,* 2004). BOD values are found to be more in June and August due to high microbial activity. They also found an increase in BOD values from April to August due to decrease in temperature.

According to EU guidelines the COD value in drinking water is 5 mg/L. Fig. 8 shows the results of COD values of sampling sites detected during the study period. It was observed that COD values were higher than the permissible limits in all samples which mean that the stream water was highly polluted with the chemicals which might have resulted either from agricultural runoff from agricultural land around the stream or it may be originated from the solid waste leachate. Ni et al (2007), suggested that the modified chemical oxygen demand (COD) monitoring may provide better indication of the pollution level of water bodies. The correlation between the sediment organic carbon and COD was investigated using sediments sampled in the middle Yellow River, China. The modified COD in turbid water and supernatant water could be 40 and 10 % less than the monitored COD values, respectively.

The results of microbial counts from various samples collected have been shown in Tables 1 and 2. The microbial counts were taken on the logarithmic scale to accommodate all smaller or larger values or to show the logarithmic increase in bacterial count. The highest bacterial load was observed in the month of September due to optimum temperature, which increases the biological activity, and subsequent to rainfall, which mixed the leachate into stream significantly. Site 3 of leachate sample showed lesser bacterial counts than the site 2 (before mixing with leachate) in the months of July and September 07 because the rain water mixes the solid waste of Abbottabad cantonment area with the main stream of Salhad and may be the pH and the presence of other undesirable chemicals in the leachate was highly unfavorable for the growth of bacteria. According to WHO guidelines and NEQS (2000) of drinking water should have coliform bacterial count of 0/100 ml and 10/100 ml, respectively.

Bacterial communities represent sensitive yet informative indicators of the presence of toxic substances in the environment (Monavari and Guieysse, 2006). The presence of coliform in water is an important indicator of contamination by human fecal matter or from animal excreta which are potential public health problem due to the presence of pathogenic bacteria and viruses. Anwar et al (2001) determined the bacteriological quality of drinking water in Lahore using H2S strip test and chlorination status of these water samples was also assessed. The results showed that the maximum contamination was observed during summer months (June-August), followed by autumn months (September –November) and spring months (March-May) of the year. The lowest figures were detected during winter months (December-February). From Table 2 it is clear that the highest total coliform numbers were speculated that land use could also contribute to fecal coliform. Runoff from agricultural lands bordering the stream would add to fecal coliform because of livestock and manure applications, if the

Table 1. Seasonal variations of total coliform load (CFU/ml) at various sites

Time	Site 1	Site 2	Site 3	Site 4	Site 5
July 2007	$9.30x10^3$	$1.03 x10^5$	$1.98 x10^4$	9.3	$5.40 x10^3$
Sep. 2007	$7.20 x10^3$	$9.80 x10^4$	$1.72 x10^4$	8	$6.80 x10^3$
Dec. 2007	11.2	52	$1.63 x10^4$	$2.68 x10^4$	$2.02 x10^4$
Feb. 2008	4.6	12.7	$3.40 x10^4$	$1.80 x10^3$	10.2
April 2008	8.5	13.8	39.2	43.6	15.6

Table 2. Seasonal variations of fecal coli form counts (CFU / ml)

Time	Site 1	Site 2	Site 3	Site 4	Site 5
July 2007	7.1	$1.80 x10^4$	$2.10 x10^3$	$1.40 x10^4$	1.5
Sep. 2007	7.1	$5.00 x10^3$	$1.20 x10^4$	$4.00 x10^3$	1.8
Dec. 2007	1.4	$1.55 x10^4$	$8.10 x10^3$	$1.29 x10^4$	3.3
Feb. 2008	2.9	$2.00 x10^4$	$2.20 x10^4$	$1.14 x10^3$	1.3
April 2008	2.1	$1.38 x10^4$	$1.74 x10^4$	$8.20 x10^2$	3.1

cattle have direct access to stream, feces may be deposited directly into a stream.

The variations of heavy metals in Salhad stream have been shown in Figs. 9 A-D. Fig. 9A shows that Cu contamination did not exceed the NEQS and WHO (2004) standard guidelines (2 mg/L), thus Cu might not pose any significant health problems. Fig 9B showed that Cd concentration was higher than the permissible limits at site 1, which implied that the contamination might have occurred due to pesticides and fertilizers used in the adjacent field areas. WHO (2004) standard value of Cd is 0.003 mg/L, According to Fig. 9B; high Cd content in the leachate was due to the solid waste composition that contained batteries and paints. The high Cd concentration in drinking water causes damage to kidneys. Cadmium (Cd) is one of the most toxic heavy metals in the arable soil for crop growth and yield formation (Sanita di and Gabrielli, 1999). It originates mainly from anthropogenic activities such as industrial processes, mining activities and application of Cd containing sewage sludge and phosphate fertilizers (Sandalio *et al*. 2001). Plants may absorb cadmium from irrigation water through irrigation of polluted waters. Once in the plants, Cd may become a part of food chain and cause harmful effects on human health.

WHO (2004) standard value of Ni is 0.02 mg/L. Fig 9C showed that Ni concentration was high in most of the samples and its peak values were detected in the leachate in the month of February 08. Like other metals the concentration of Ni was also high in the month of December due to dry cold weather. Ni concentration at sites 1 and 5 were within the permissible standards except in the month of December where negligible rise in the values was observed. Thus Salhad stream was not contaminated with the Ni. WHO standard value of Pb is 0.01 mg/L. Fig. 9 D showed that most of the samples contained higher Pb values than the permissible limits. The site 1 of Salhad stream had the high Pb concentration in the month of December. The lowest concentrations of Pb were observed in the month of September after heavy rainfall flushing and dilution of metal may have occurred. Leachate contained higher Pb concentration in all other months which was a potential threat for the aquifer sustainability. It appeared that the sources of Pb were batteries or the erosion of Pb containing deposits in the landfill. Aquatic microorganisms can bioaccumulate Pb that can disrupt the normal biochemical pathways taking place in the aquatic ecosystems.

The results suggested that water quality of Salhad stream was badly affected by the discharge of leachate from Salhad landfill. The parameters exceeding the allowable limits of WHO, EC and National Environmental Quality Standards included pH, TDS, BOD, COD, total bacterial counts and total coliform counts (Table 3). Thus the water of Salhad stream has been polluted physically, chemically and biologically through discharge of landfill leachate. Such unchecked discharge of landfill leachate may pose serious threat to communities utilizing the waters of Salhad stream for drinking, irrigation and other purposes. Water that has been used by people and is disposed into a receiving water body with altered physical and/or chemical parameters is defined as wastewater. If the water has been contaminated with soluble or insoluble organic or inorganic material, a combination of mechanical, chemical, and/or biological purification procedures may be required to protect the environment from periodic or permanent pollution or damage. For this reason, legislation in industrialized and in many developing countries has reinforced environmental laws that regulate the maximum allowed residual concentrations of carbon, nitrogen, and phosphorous compounds in purified wastewater, before it is

Variations of metal concentration at various sampling sites

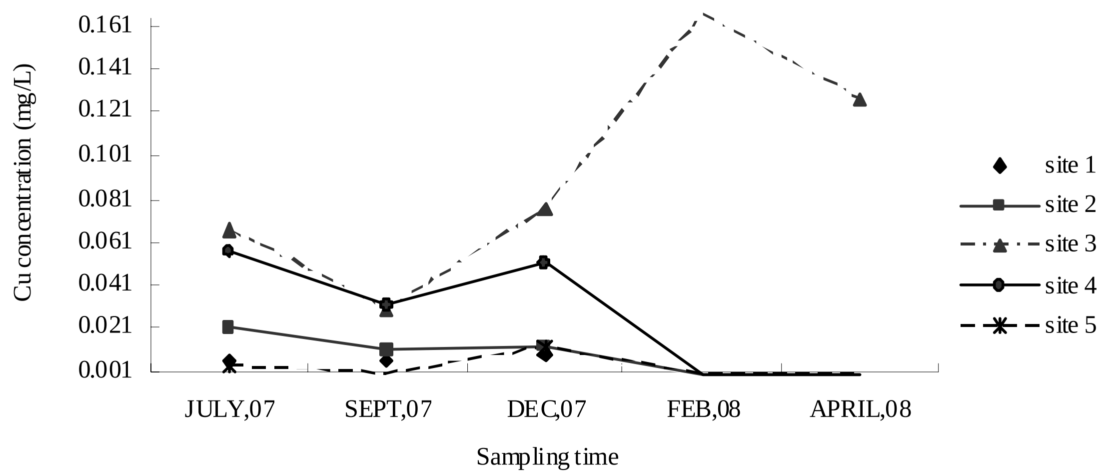

Fig. 9 A. Seasonal variations in Cu concentration in different month

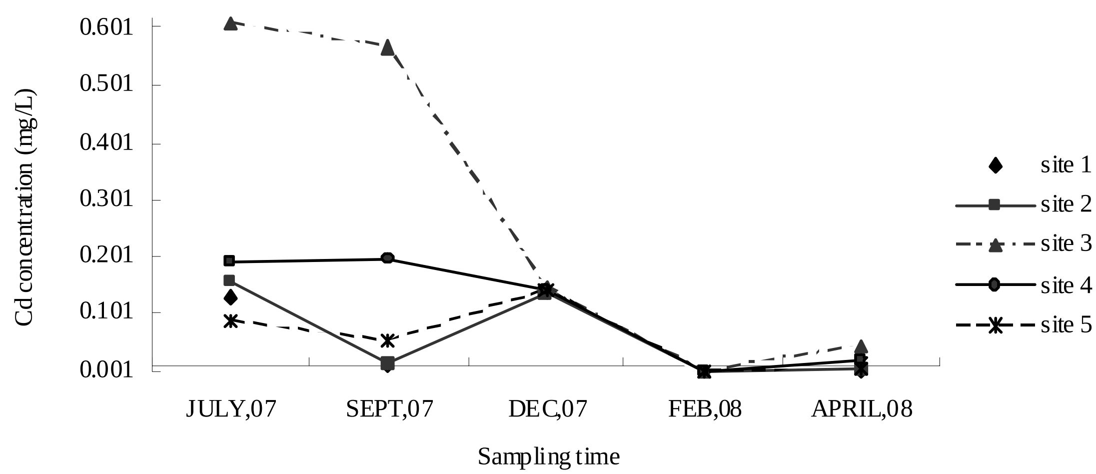

Fig. 9 B. Seasonal variations in Cd concentration in different month

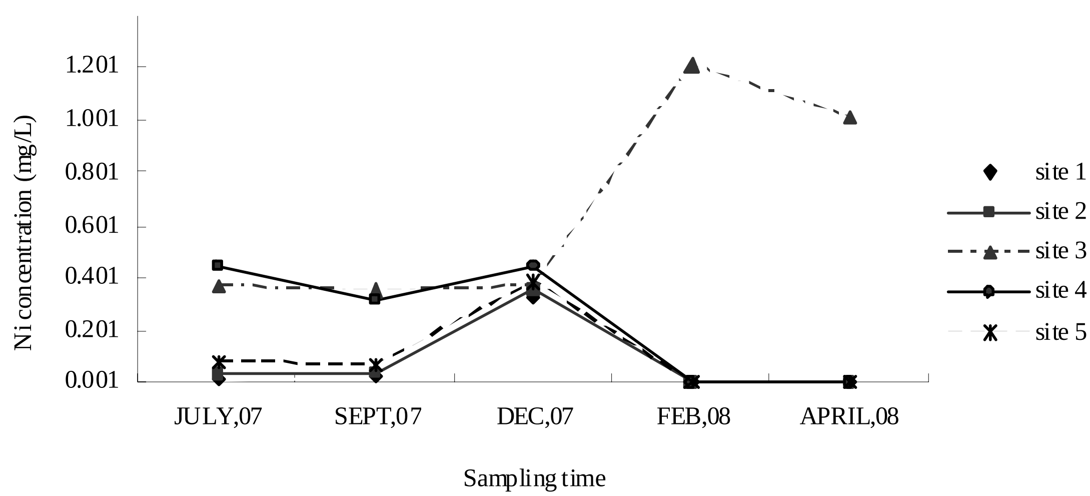

Fig. 9 C. Seasonal variations in Ni concentration in different month

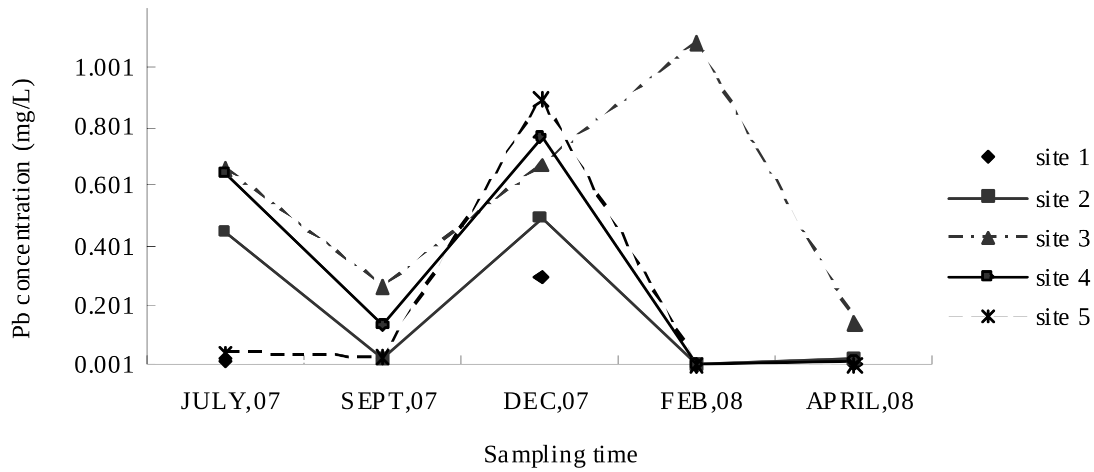

Fig. 9 D. Seasonal variations in Pb concentration in different month

Table 3. The comparison of experimental results with the standard values

Parameter	Observed values Range	NEQS*	WHO**	EC***
pH	5.9~9.1	6~9	NA	NA
Temperature	9~42	≤3 °C	NA	NA
TDS	230~13.5x10^6	3500	NA	NA
Conductivity	531~27,440	NA	NA	NA
Dissolved Oxygen	0.00~12.4	NA	NA	NA
BOD	114~565	80	NA	35
COD	3~10,865	150	NA	11.3
Fecal Coliform count	1.5~8.10 x10^3	NA	100	69.6
Total Coliform count	4.6~1.03 x10^5	NA	100	81.9

* National Environmental Quality Standards of Pakistan
** World Health Organization standards for Drinking Water
*** European Community Standards for Drinking Water
NA= Not available

disposed into a river or into any other receiving water body However, enforcement of these laws is not always very strict. Enforcement seems to be related to the economy of the country and thus differs significantly between wealthy industrialized and poor developing countries.

The concentration analysis of various parameters studied showed that during the dry season some constituents and parameters had large concentrations that exceeded standards, and consequently might have jeopardized the health of the stream's aquatic ecosystem (Laureano and Navar, 2002). Moreover, the drought episodes would probably worsen the concentration of some constituents and parameters typically decreased during the rainy season. A serious concern identified was the discharge of loads of fecal coliform bacteria from landfill leachate to Salhad stream which is a potential human hazard for the communities utilizing stream water for drinking water. Due to extreme shortage of drinking water, the local communities depend on the springs and stream water for daily use without any treatment. The aquatic communities of fish, insects, and other organisms are already under stress (Laureano and Navar, 2002). It was observed in this study, that many parameters exceeded the water quality standards; therefore, the process of eutrophication can be expected to accelerate depleting dissolved oxygen concentrations in the river and promote changes in the aquatic biota. The biochemical oxygen demand exceeded the European Community standard for drinking water and NEQS in all the samples analyzed. The susceptibility of fish to damage by toxic substances (e.g., heavy metals) increases when the level of dissolved oxygen depletes (Brooks *et al*., 1992). An effective management of Salhad stream water resources, a continuous and systematic monitoring of relevant parameters is required to prevent further contamination and the sustainable management of Salhad stream. Successful measures should be undertaken for a rational disposal of domestic waste to mitigate the effects of leachate contamination. Additional measures include; awareness among the residents about the adverse effects of solid waste contamination, introduction of low cost technologies for treating water supply in rural areas, installation of composting plant to utilize biodegradable material as fertilizer and developing a sanitary landfill for the disposal of hazardous solid waste.

CONCLUSION

The investigation illustrates the influence of injudicious discharge of untreated landfill leachate on chemical, bacteriological, and physical parameters of water quality of Salhad stream. This may result in serious surface and ground water pollution. The parameters exceeding the allowable limits of WHO, EC and National Environmental Quality Standards included pH, TDS, BOD, COD, total bacterial counts and total coliform counts. Heavy metals like Pb, Cd and Cu were released from the leachate into the Salhad stream which might affect the sustainability of the aquatic life. Therefore, some precautionary measures should be taken and the solid waste dumping site must be kept away from the natural water resources. Integrated, multi-sector approaches are required to deal with the contamination problem and sustainable management of the Salhad stream waters.

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