Nature Environment and Pollution Technology
An International Quarterly Scientific Journal | ISSN: 0972-6268 | Vol. 13 | No. 1 | pp. 1-10 | 2014

Original Research Paper

A Study to Investigate and Compare Groundwater Quality in Adjacent Areas of Landfill Sites in Lahore City

Akhtar Malik Muhammad*, Tang Zhonghua*, Ammar Salman Dawood* and Muhammad Tayyab Sohail**
*School of Environmental Studies, China University of Geosciences, Wuhan 388 Lumo Lu, Wuhan 430074, Hubei Province, China PRC (Corresponding Author: Tang Zhonghua)
**School of Public Administration, China University of Geosciences, Wuhan 388 Lumo Lu, Wuhan 430074, Hubei Province, China PRC

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com
Received: 23-6-2013
Accepted: 24-7-2013

Key Words:
Contamination
Groundwater
Landfills
Leachate
Solid waste management

ABSTRACT

It is a hard and challenging but very important at the same time to ensure availability of potable quality water to the whole world population. Human activities like agriculture, industrial usage and disposal of harmful waste products is causing contamination of groundwater systems. This is not only deteriorating groundwater but is leading to a number of health problems. Although this is a global issue, however, the situation is more severe and alarming in developing countries, which can be related to poor management and lack of facilities. Current study was conducted to understand the impact of dumping sites on groundwater quality in adjacent areas of selected dumping sites and suggested appropriate measures. Lahore is facing serious environmental and groundwater problems. Mehmood Booti landfill (oldest) and Saggian landfill (biggest) sites impacts were investigated; ten observation locations of each sites were selected in nearby areas. Six parameters i.e., pH, turbidity, conductivity, total hardness, TDS and arsenic were analysed and compared for the years 2010-11 at both the sites. Pollutants value decreased as distance increase from landfill sites. Arsenic concentration in 100% and 15% samples was exceeded WHO and PSQCA limit, respectively. Landfill leachate and groundwater analysis results explored that groundwater chemistry has changed due to infiltration of landfill leachate. Overall groundwater quality in eastern part is detected more contaminated as compared to west part of Lahore city. However, arsenic concentration in whole area is high but Shadhara town is most affected area. Groundwater needs some treatment before use for domestic and drinking purpose.

INTRODUCTION

Water is one of the basic requirements of life and shortage of potable water supply or its low quality results in health-related issues. Poor water quality is a source for waterborne diseases and hazards associated with poor water quality claim the lives of more than 3.4 million people around the world per annum (Pakistan Millennium Development Goals Report 2005). The major contributors to groundwater contamination are disposal of solid waste and sewage, agricultural activities, urban runoff and polluted surface water (Jain et al. 1995). Continuous increases in the volume of municipal solid waste (MSW) generation underpin the benefits from recent technological advances in this area. MSW is solid waste collected and controlled by the local authority or municipality (McDougall et al. 2003). Typically, MSW consists of household, commercial and institutional wastes. Generally speaking, MSW is a complex combination of chemicals, hospital wastes, organic and inorganic materials and its composition changes continuously which primarily is time dependent. We know that the storage of any waste material in a landfill is a source of potential problems. One of the major problems is the transport of leachate that causes the contamination of the soil, groundwater and surface water (Kumar et al. 2002, Dong et al. 2009). The chemical quality of leachate is generally influenced by a number of factors including the composition of the waste material and the decomposition process. The qualitative and quantitative features of leachate are important in understanding the impact of a landfill in transferring leachate from the surface to the groundwater (Vasanthi et al. 2008). There is no doubt that existence of unorganized and unplanned landfills is alarming in some parts of the world, including Pakistan.

Pakistan is the sixth largest country in the world, with a population of more than 175 million and a population growth rate of 2.1% (NIPS 2006). Numerous reports suggest that Pakistan has sanitation coverage for about 91% and 59% of the total population, respectively (WHO & UNICEF 2008). Unfortunately, only about 66% of the population in Pakistan has access to safe drinking water (Pakistan Planning Commission 2005 Ref: Cheema 2005). The quantity of solid waste is increasing with time, with an increase of 120% recorded from 1970 to 1995 (Afzal et al. 1998). In Punjab province, like rest of the country, groundwater is the major source of water. The quality of groundwater is subjected to

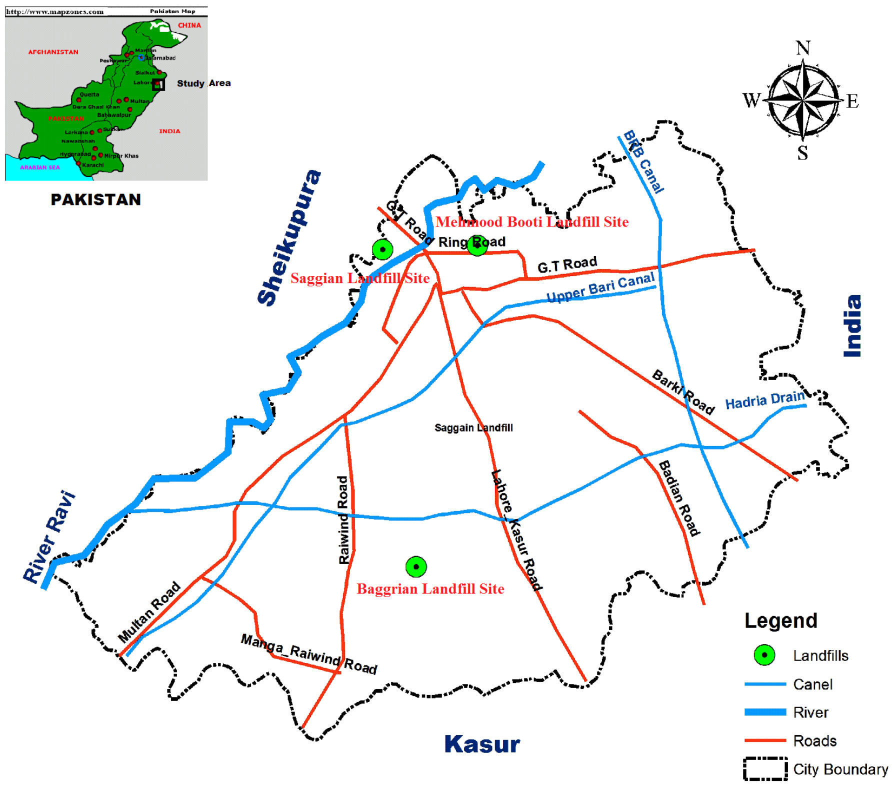


Fig. 1: Study area and landfills sites locations around Lahore city.

deterioration due to poor management. The main sources of groundwater contamination in Punjab are poor sanitation services, improper solid waste management (SWM), lack of wastewater treatment facilities, poor drilling of wells and the extensive use of fertilizers, pesticides and other chemicals for agricultural and industrial purposes.

Lahore, the second largest city of Pakistan and capital of Punjab province, has an approximated population of 10 million (Ahmad et al. 2012). The city is divided into nine major towns and has 150 union councils. The city is experiencing urban sprawl and rapid industrialisation, which is a leading contributor to the generation of a huge amount of solid waste. About 5,700 tons of solid waste is generated daily in Lahore city from different sources that contains a high percentage of organic matter (up to 67%) and this volume is equivalent to a generation rate of 0.84 kg/capita per day , which is lower than world's average of 1.2 kg/capita per day (Adila & Nawaz 2009). Improper disposal of solid wastes from sources like household waste, commercial activities, industries, hospital waste and animal waste can cause environmental and health hazards to citizens (Shimura et al. 2001). Particularly in Lahore, the groundwater is suspected of being polluted (Karim et al. 2010) due to untreated waste water and three dumping sites (the Mehmood Booti, Saggian and Baggrian landfills) located in various parts of the city.

These dumping sites are unplanned and have no proper and effective system to collect leachate. So it is suspected that leachate goes down through the soil and is mixed with groundwater because there is no proper mechanism to collect leachate and protect aquifer. This article evaluates water supply and quality issues of water supplied in Lahore city with reference to its groundwater quality. This article will be discussing contamination situation at landfill site and pollutants concentration potential vary with distance, and also compare groundwater quality in two different parts of Lahore city. A number of studies were reported poor standards of solid waste management in the city, and infiltration of leachate into the groundwater.

LANDFILL SITES AROUND LAHORE CITY

Landfills play a vital role in a large city like Lahore. It is understandable that in the absence of functional landfill areas, cities become garbage places and a source of public health problems. Ideally landfills should be located far from

Table 1: Composition of typical dumping material at landfills in Lahore city (based on Haydar et al. (2012) and LWMC Department).

Components	Tones/Day	% (w/w)
Vegetable & Fruit residues	1593.14	30.72
Dust, dirt, ashes, stones, bricks, etc.	1433.93	27.65
Leaves, grass, straws, etc	1038.24	20.02
Rags	386.36	7.45
Plastic & Rubber	291.97	5.63
Paper	140.02	2.7
Animal waste	131.21	2.53
Wood	64.31	1.24
Bones	53.42	1.03
Glass	36.3	0.7
Metals	16.6	0.32
Unclassified	0.52	0.01

populated areas and should be designed to reduce the impact of hazards.

The complex nature of waste materials (MSW, industrial waste and hospital waste) makes it challenging to protect people and as well as natural resources like groundwater from harmful effects of such materials. The scale of this threat depends on the composition and quantity of leachate and the distance of a landfill from water sources (Slomczynska & Slomczynski 2004). There are three active dumping sites around Lahore city that are old, unplanned, unsafe and not up to modern standards. At least three-quarters of the total waste generated (3800 tons per day) in Lahore is dumped at these sites without proper treatment. Fig. 1 shows the locations of three landfill sites, e.g. Mehmood Booti, Saggian and Baggarian.

The Saggian landfill site is located along the Ravi River and continually pollutes the soil, groundwater and river water. This is very hazardous from environmental point of view. This is the largest dumping site in the city with an area of 81 hectares. More than 1800 to 2200 tons of waste is brought to the site every day, primarily from the towns of Ravi, Samanabad, Data GunjBux and Gulberg. Mahmood Booti (located north of Bund Road) is the second major landfill site which spreads over 32 hectares, including 15 hectares of the Lahore Compost Plant (Lahore Compost ESIA 2008, Ref: Hayder et al. 2012). This site serves Ravi town, Shalimar, Gulberg and Aziz Bhatti by accepting 1100 tons of waste each day. Recently, the Mahmood Booti landfill has been recognised by the City District Government Lahore (CDGL), so this site is now owned by the solid waste management department. A computerized weigh bridge has been installed at the site to keep a record of daily waste. The third site is the Baggrian landfill located in Nishtar. It is a small site of only 5 acres within a 30 m depression. Approximately 300-350 tons of waste is dumped daily from the towns of Gulberg, Allama Iqbal and Nister. However, for current

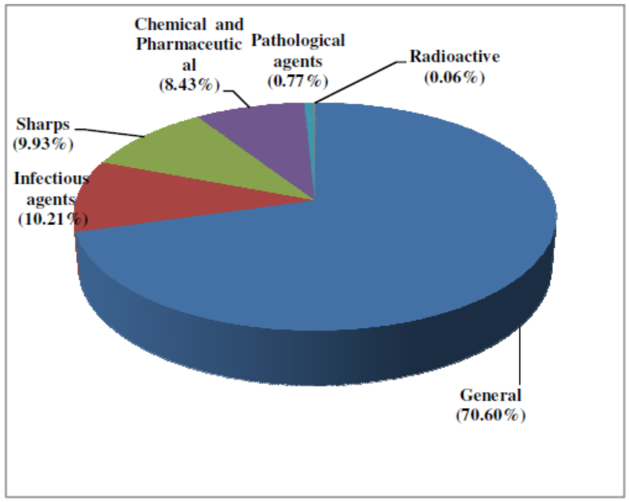


Fig. 2: Classification of elements in biomedical waste (percent on a weight basis) collected from hospitals in Lahore city. The diagram is constructed using data sourced from Solid Waste Management Plan 2007-2021 (Solid Waste Management Department, Lahore, Pakistan (SWMD 2007).

study Mehmood Booti and Saggian landfill sites were selected to evaluated impact on the groundwater system.

CONTAMINATION CONTRIBUTORS TO GROUNDWATER IN LAHORE

It is well documented that unorganized, uncontrolled and poorly built dumping sites cause serious deterioration to soil and groundwater and threaten human health directly and/or indirectly (Misra & Pandey 2005). Water soluble substances present in the waste material may eventually infiltrate to the groundwater. Therefore, an effective waste management process is needed to conserve resources and protect the environment (Sandulescu 2004). Unfortunately, MSW is highly neglected and poorly managed in all low and most developing countries (Murtaza & Rahman 2000) like Pakistan. We know that this poor management of waste streams is causing adverse environmental impacts and health hazards. Therefore, appropriate waste management strategies can substantially reduce the burden placed on the environment and to reduce resources depletion (Woodard et al. 2004).

The uncontrolled release of domestic, agricultural and industrial effluents in natural water resources are major culprits in the pollution problem in urban areas of Pakistan. All these pollution contributors have their own specific effects e.g., domestic sewage contains high levels of bacterial pathogens and organic material; industrial discharges are rich of toxic metals, organic loads, acids, and other less toxic substances; and run-off from agricultural lands contains pesticides and fertilizers. Solid waste disposal in Lahore city is not very well planned and stagnant water bodies are present

Table 2: Typical analysis of leachate from landfills located in Lahore city.

Parameter	Saggian Landfill Site	MehmoodBooti Landfill Site
pH	6.8	6
COD (mg/L)	2563	18,000
BOD (mg/L)	442	10,000
TDS (mg/L)	3717	3500
TSS (mg/L)	161.7	500
Conductivity, micromho/cm	5829	7154
Grease and oil (mg/L)	0. 5	
Phenol (mg/L)	0. 04	
Surfactant (mg/L)	1. 58	
Pb (mg/L)	0. 6	
Cu (mg/L)	2. 7	
As (mg/L)	0. 2	
Fe (mg/L)	9. 8	60
Sulphate (mg/L)		300
Total nitrogen (mg/L)		400
Chlorides (mg/L)		500
Total phosphorus (mg/L)		30

Source: Sadia et al. (2010) for Saggian landfill; Tchobangoglous et al. (1993) for Mehmood Booti landfill.

Table 3: Sampling points and aerial distance from both landfill sites.

Sampling Point	Distance from Saggian Landfill (km)	Sampling Point	Distance from Mehmood Booti Landfill (km)
SL.1	4	ML.1	4.2
SL.2	3	ML.2	1.27
SL.3	3.2	ML.3	2.4
SL.4	2.6	ML.4	5.2
SL.5	3	ML.5	4.5
SL.6	5.3	ML.6	6.5
SL.7	5	ML.7	7.5
SL.8	6.1	ML.8	8
SL.9	7.5	ML.9	8.1
SL.10	5.6	ML.10	7.8

in low lying areas which is a source of pollution for surface and subsoil water (Karim et al. 2010). Typically, solid waste from Lahore city contains vegetable and fruit residues, leaves, grass, straw, paper and plastic (Table 1). The problem of MSW has become more severe over the last few years due to increased amounts of waste generation. There are no nationally or internationally accepted concentration limits for metallic elements in sewage sludge and MSW. Heavy metals in the MSW and the sewage sludge/water of Lahore city are of significant concern because of their environmental impact as toxic metals after accumulation in soils.

Another serious issue is the non-existence of a separate waste disposal site for waste that comes from industrial estates, hospitals or other hazardous sources. Such type of waste materials pose much more severe health risks to workers and the general public. Moreover, solid waste segregation is lacking because of the shortage of human resources, inadequate tools and equipment, lack of awareness, poor infrastructure, poor town planning, inappropriate placement of containers and shortage of educated and skilled professionals. These all are factors which are responsible for poor management. 'The Hospital Management Rules' were introduced in 2005 stating yellow-bagged waste shall be disposed off after burning by burial in a landfill or through any other method approved by the Federal or Provincial agencies concerned.

Unfortunately, ineffective implementation of such rules is allowing majority of the hospitals (in both the public and private sectors) in Lahore to dispose their solid waste off improperly and mostly mixed with general or non-clinical waste. Analysis shows that waste collected from hospitals contains infectious and hazardous elements (Fig. 2) which are extremely dangerous when dumped without incineration or proper treatment.

The present practice of solid waste disposal in Lahore is not properly organized and planned. This poor standard and practice of handling and disposing of untreated polluted industrial and municipal waste is creating multiple environmental problems and challenges in Lahore.

The Ravi River plays an important role in recharging the aquifer serving groundwater supplies in Lahore city and the surrounding districts. It is now well documented that the river water has a high level of faecal contamination (Manan 2008) and poor microbiological quality. In a similar manner, organic and inorganic pollutants are getting into the river water directly or indirectly and then to aquifers. The severity of this problem can be judged from the fact that more than 1,000 industrial units and municipalities are directly discharging more than 5,500 cusecs of untreated toxic effluent into the drains, rivers and natural water channels in the Punjab province. The level of pollution varies from district to district and the Lahore district is the most polluted one. The nature of this effluent varies from toxic to hazardous.

Several studies examining leachate samples from landfill sites (Table 2) showed that most of the parameters such as colour, conductivity, TSS, TDS, BOD, COD, NH_3-N, PO_4-P, SO_4^{-2}, Cl^{-1} and Fe were at high levels. The organic load was quite high since the COD concentration was in the range of 2530-18000 mg/L. In addition, the low BOD/COD ratio (0.172-0.55) confirmed that the majority of this organic matter was not easily biodegradable. A survey conducted by Naeem et al. (2007) also indicated higher concentration of various constituents. The groundwater near the landfill sites was characterized as non-potable and not suitable for other domestic uses.

MATERIALS AND METHODS

Sampling area: There are three active landfills present in Lahore city, but among them Mahmood Booti is the only authorized dumping site owned by the City District Government Lahore (CDGL) and rest of two sites are organised under private sector. These non-stationary sites are totally unorganised and developed without considering future impact on local environment. Environmental point of view this practice is extremely undesirable and highly risky for local community health. The main demerit of the dump site is situated along the River Ravi and continually polluting the surface water, soil and groundwater.

As regards the characteristics of dumping site, it is pertinent to mention that it is neither a stable nor a controlled type site. The solid waste is presently being openly dumped and no measures are being exercised to control or treat the leachate produced. For current investigation, Mehmood Booti landfill site and Saggian landfill site are selected along both sides of River Ravi. To determine the effect of leachate produced from biodegradation of organic matter in dumping sites on groundwater, ten observation locations of each site were selected for the evaluation of groundwater quality. Location plan of these tube wells is shown in Fig. 3.

Water samples from selected tubewells were collected and analysed to evaluate their physical and chemical quality. To evaluate contamination concentration to and far from landfill sites, five sampling points (ML.1 to ML.5 and SL.1 to SL.5) were selected within 5km range and rest of five (ML.6 to ML.10 and SL.6 to SL.10) more than 5km from landfill sites. This is best technique to explore contamination potential with distance from these sites. Aerial distance of selected points from both dumping sites is given in Table 3.

Solid waste at Lahore city is not properly segregated before dumping, therefore, organic, inorganic, heavy metals, vegetables and other materials get through without any preliminary treatment. These sites are not covered with clay layer to avoid rain water penetration. Thus, rain during monsoon season, falling on the solid waste could have increased the amount of leachate entering the sub-surface water (Haydar 2012). Therefore, in order to take into account the possible effect of leachate on groundwater over the years, two successive years data were used in this paper.

Sampling and analysis methodology: Sampling was done in a way to eliminate chances of any external contamination which could affect the test results. Clean plastic polyethylene bottles, rinsed with distilled water, were used for physico-chemical parameters. Water was allowed to run for at least 10 minutes from the tap before the sampling bottles were filled without splashing. The bottles were immediately closed and sealed after taking samples to avoid any external contamination. All the apparatus used in this study was washed with chromic acid and washing reagent and then dried in an oven. To prepare reagents double distilled water was used. Analytical grade chemicals and reagents were used in this study without further purification. Inorganic chemicals were kept in the oven at the temperature of 120°C to remove moisture wherever necessary.

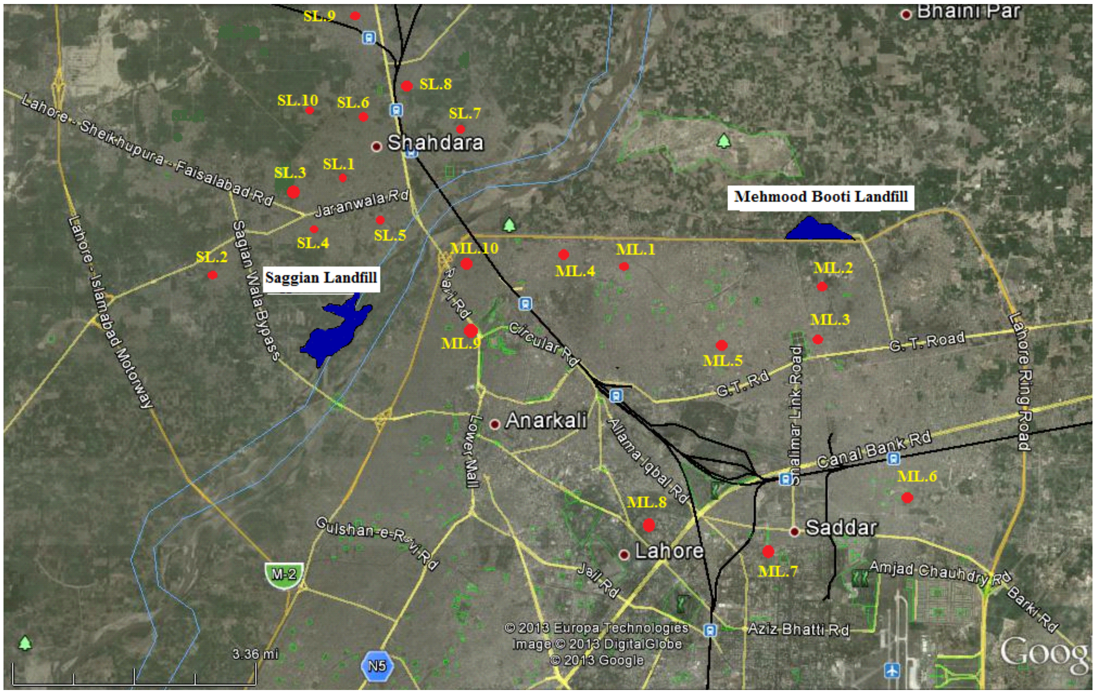
Samples of drinking water were collected from selected points of Lahore in 500mL and 100mL capacity glass bottles for chemical and bacteriological analyses. For bacteriological analysis, sampling taps were cleaned with ethyl spirit followed by a flame to avoid contamination from external environment. Tests for *E. coli*, pH, turbidity, conductivity and TDS were performed within one hour of collection. For the chemical analysis of trace metals 100mL water from 500mL glass bottle was transferred to 100mL flask with stopper and 5mL of nitric acid was added as preservative. For nitrite test 1mL of 1% boric acid solution was added as a preservative to 100 mL sample. For other parameters there was no need of any preservative. Atomic Absorption Spectrophotometer method was applied to determine heavy metals (Analyst 800).

RESULTS

Groundwater analysis results are presented to know pollutant concentration potential on all observation points. 2010 and 2011 data were compared and evaluated water supply quality as standard of WHO as well as PSQCA. This evaluation was implemented on both landfill sites, however, demography and hydrogeological systems are completely different on both sides of River Ravi. Sample analysis results indicate that water contamination level is higher near dumping site. The pollutants have changed groundwater water chemistry, and landfill leachate has a significant contribution to it. Table 2 contains values of various parameters in landfill leachate in different periods from different researchers. Currently, these pollutants are part of groundwater (Figs. 4 to 15). Landfills are not properly maintained until recently, therefore, it is highly expected that pollutant concentration will keep increasing over the time in groundwater. There is cone developed in groundwater system due to over exploitation (Gabriel 2011), this is one of the major factors for pollutant transportation from vicinity areas to main business area of Lahore city.

DISCUSSION

Mehmood Booti landfill site: Figs. 4 to 9 depict groundwater contamination level at ten selected locations within 10km randomly around Mehmood Booti landfill site. pH was detected in all samples but within WHO and PSQCA limit except ML.3 in 2010, however high concentration value was explored in samples collected within 5km to landfill site as compared to rest of the points. With time value was



.Fig. 3: Selected locations near Mehmood Booti landfill and Saggian landfill.
Note: ML (groundwater sampling location near Mehmood Booti landfill) and SL (groundwater sampling location near Saggian landfill).

fluctuated in whole area but no big change was noted. Three observation points (ML.2, 5, 10) show turbidity level under prescribed criteria in WHO and PSQCA, while at rest of the points concentration exceed PSQCA. Turbidity trend was observed same as higher near landfill site as compared to other points. Observation points within 5km range show very high concentration of conductivity, TDS and total hardness (Figs. 6, 7, 8) and gradually decrease with increasing distance from dumping site. TDS values within five kilometres depict concentration over PSQCA (500mg/L), which is risky for general public health and its values reduced with increasing distance. However, TDS and total hardness contamination level was within WHO range. Arsenic data is presented only for 2010 due to unavailability of data for 2011. High concentration of arsenic was discovered near River Ravi (points ML.9 and ML.10), which is caused due to high polluted effluents flow; all the values were higher than WHO (10µg/L) guideline. Arsenic is considered as poison, therefore, a little quantity of arsenic in potable water is dangerous for human health. Arsenic comes from various sources such as agriculture, industrial waste and urban sewage, so landfill sites are also regarded as arsenic contamination sources.

Saggian landfill site: Shahdara town is an undeveloped area with poor living standard but developing in presence of various unhygienic activities such as different small and big industries, open effluent drains, agriculture and unorganised solid waste management. Municipal, industrial and agriculture waste is being dump, and this practice is unhealthy from environmental point of view for surface water, soil and groundwater because the landfill site is located on bank of River Ravi. pH satisfied WHO and PSQCA criteria in all selected locations, however, its value is also high at outstrip area due to groundwater recharge from polluted drains and river. Therefore, no definite correlation between the distances of dumping site with the increase of pH can be established. Turbidity is significantly high near landfill and only one sample within PSQCA standard but all samples show its level below WHO (Fig. 11). Vicinity area of landfill site contains high values of conductivity, TDS, total hardness and arsenic, and with increasing distance concentration is decreased. Surely, groundwater quality is affected due to dumping site leachate. TDS and total hardness concentration level is within prescribed standard of WHO and PSQCA in all samples, while arsenic values are dangerously high.

All samples were having arsenic concentration over WHO (10µg/L) standard, and three samples higher than PSQCA (50µg/L) limit. Major reason for high arsenic contamination is caused by solid waste dump without segregation, drains, sewerage leakage and agriculture activities in

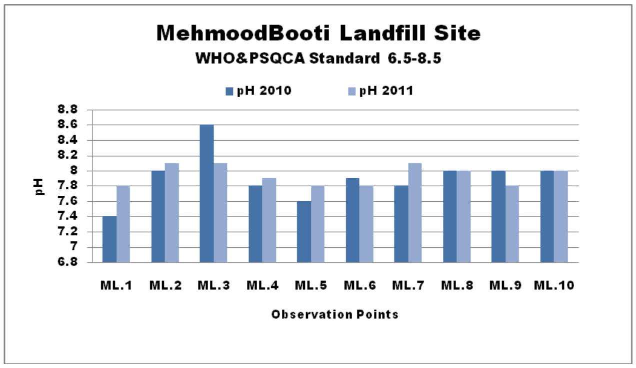


Fig. 4: Comparison of pH values at selected locations.

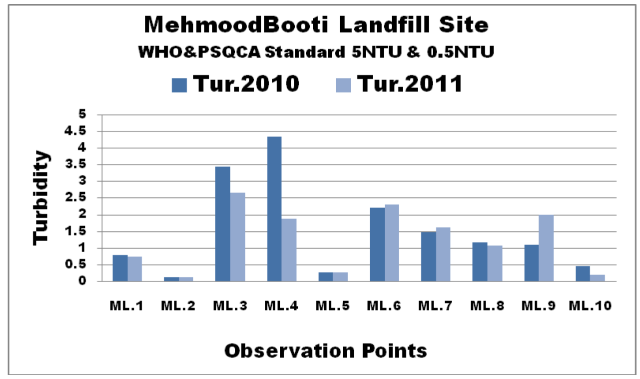


Fig. 5: Comparison of turbidity values at selected locations.

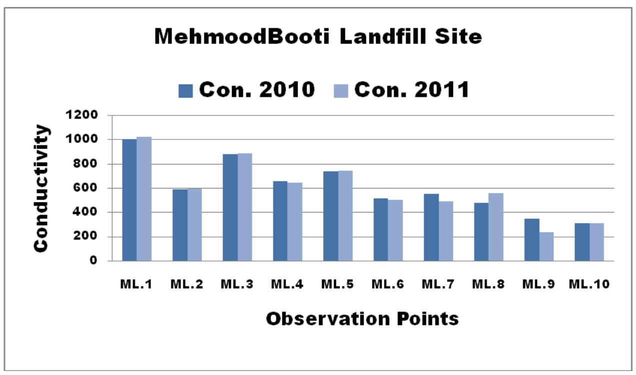


Fig. 6: Comparison of conductivity values at selected locations.

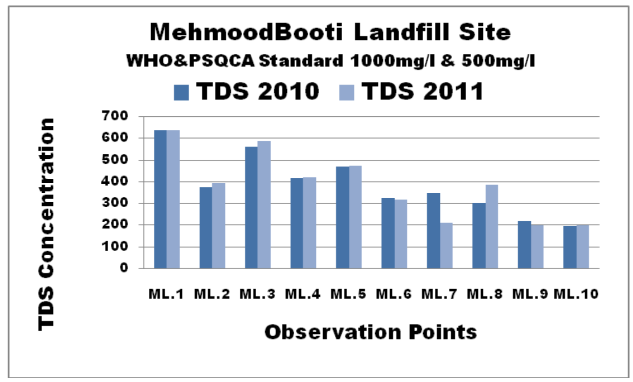


Fig. 7: Comparison of TDS values at selected locations.

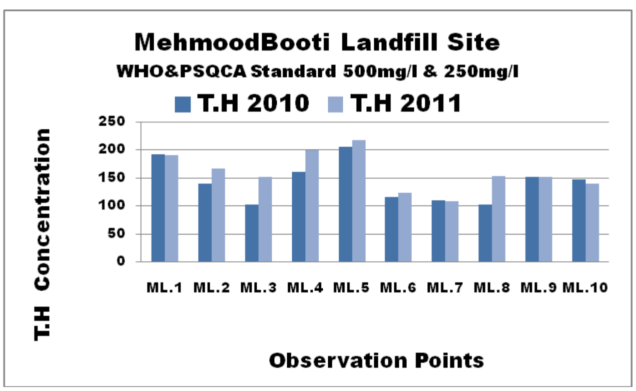


Fig. 8: Comparison of total hardness values at selected locations.

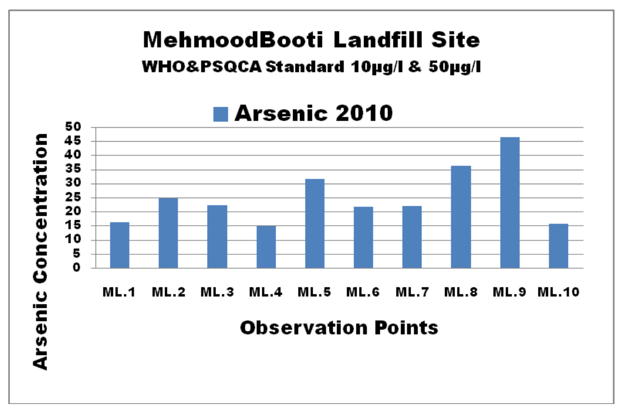


Fig. 9: Arsenic values at selected locations.

the study area.

Comparison: On the basis of groundwater analysis results, it has been proved that landfill sites have significant effect on groundwater. However, oldest Mehmood Booti dumping site has affected ground water resource to a great extent as compared to Saggian dumping site. The five parameters (pH, conductivity, turbidity, TDS, total hardness) out of six show high pollutant concentration in main business area of Lahore city. The presence of high arsenic contamination level in Shadhara town is caused by agricultural activities, industrial effluents and improper solid waste management. According to our analysis and understanding, the reason behind this is the formation of cone in underlying aquifer due to over-extraction, and movement of pollutants from vicinity area towards main city area due to the cone.

Present study has proved that groundwater is receiving variety of toxic pollutants without interruption. So, it can be declared unfit for drinking and other domestic purposes.

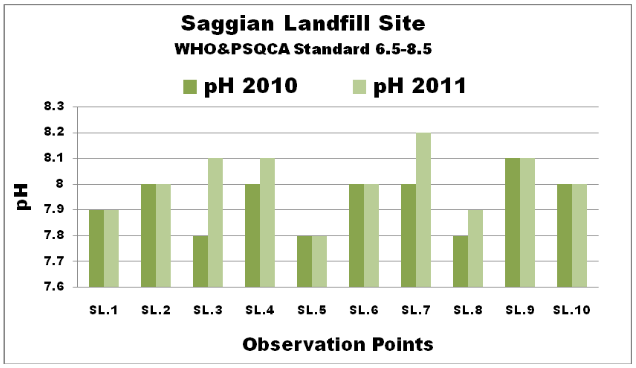


Fig. 10: Comparison of pH values at selected locations.

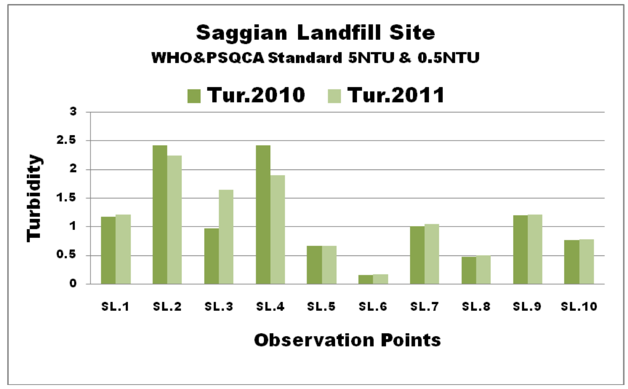


Fig. 11: Comparison of turbidity values at selected locations.

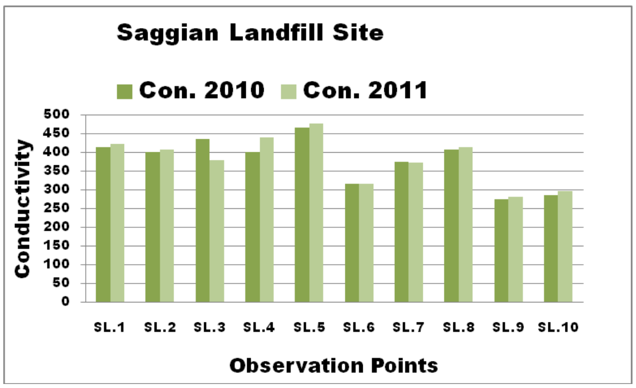


Fig. 12: Comparison of conductivity values at selected locations.

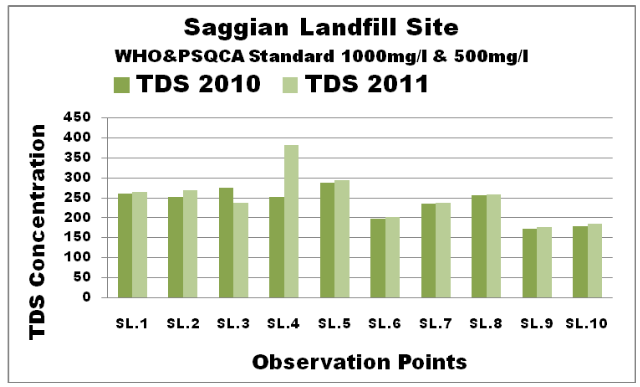


Fig. 13: Comparison of TDS values at selected locations.

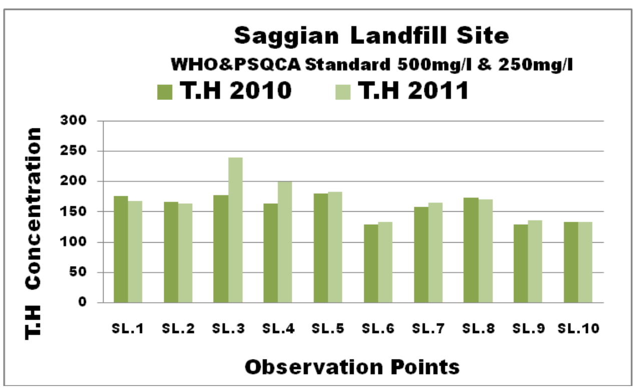


Fig. 14: Comparison of total hardness values at selected locations.

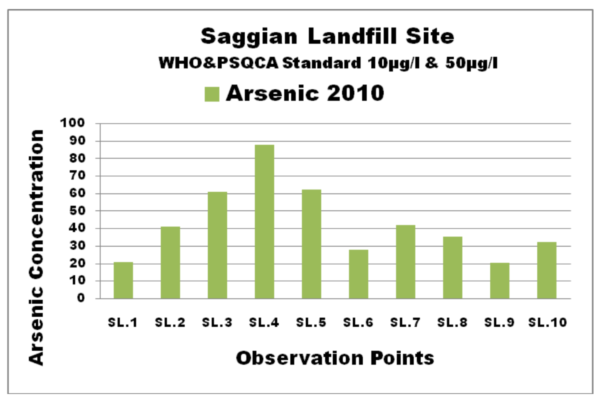


Fig. 15: Arsenic values at selected locations.

Numerous studies verified poor quality of Lahore aquifer.

According to Daily newspaper (20 May, 2008) ,United Nations Environmental Programme (UNEP), reported that about 47% drinking water in Lahore city was contaminated due to presence of various hazardous toxic elements. A non-governmental organization (Al-Khidmat Foundation) conducted an investigation to compare bacteriological quality of groundwater and found 37.2% groundwater contaminated. During the study they collected water samples from 539 different parts of city in which most developed area Gulberg showed 64% water samples contamination, 57.1% in Multan Road, and 56.4% in Shadbagh area (Manan 2008).

IMPACTS OF GROUNDWATER CONTAMINATION ON GENERAL PUBLIC

Untreated municipal and industrial wastes are placing health risks to city inhabitants and surrounding communities within the catchments area of River Ravi. Environment Protection Agency (EPA) conducted a study to investigate water supply quality by WASA in Lahore city and found that 20 locations were highly contaminated and unsuitable for drinking (Doger 2008). A petition in Lahore High Court against government due to arsenic contaminated water supply is filed by local public and claimed health issues such as gastrointestinal diseases in children and hepatitis and kidney failure in adults. Over 2,50,000 children die every year in Pakistan as a result of diarrheal diseases caused by contaminated water (Doger 2008).

Generally, the health of residents is badly affected as low quality water from polluted stretches of river invades the aquifer, leading to high pollution levels of potable water (Kamrul & Burgess 1999, Dhakyanaika & Kumara 2010). Communities with poor sanitation and contaminated water supply are at the risk of acquiring waterborne infections like hepatitis A and E, cholera, diarrhoea, dysentery, typhoid and parasitic diseases (Saeed & Bahzad 2006). A recent report indicated that 100% of water samples collected from injector pumps installed at shallow depths of 120 to 150 feet were polluted with *E. coli* due to the intrusion of sewage water (Ahmad et al. 2012). The management situation is the worst problem but none of the authorities seems to be moved by the plight of people who are facing different kinds of ailments including tuberculosis, gastro-intestinal problems, asthma, dysfunctional lungs, different types of cancers and other deadly diseases due to the pollution. "Waterborne diseases are common and no water lines meet the World Health Organisation standards" is stated after a series of studies conducted in Lahore (WHO 2004).

CONCLUSIONS AND RECOMMENDATIONS

Current study was carried out to investigate the effect of local landfill sites on groundwater system through six selected parameters and evaluated groundwater quality on both the sides of river. Landfill sites are regarded serious threat to the surrounding local urban environments. Unplanned and mismanaged landfill activities are major contributor to degrade groundwater quality; even various other infiltration factors exist in the study area. Unfortunately, government agencies' lack of good planning, coordination and resources to treat waste scientifically are transferring hazardous elements to the groundwater. General public is facing health issues due to polluted water supply. The main findings of the present study are as following:

1. Groundwater is contaminated but near landfill sites concentration of pollutants is high.
2. East part of the study area (surrounding Mehmood Booti landfill) is more degraded as compared to Shahdara town region (near Saggian landfill).
3. pH, turbidity, conductivity, TDS and hardness values are within WHO guideline, while arsenic maximum concentration 90μg/L was noted (over WHO & PSQCA criteria).
4. TDS contamination potential in ML.1 (633.7mg/L) and ML.3 (558.1mg/L) is higher as prescribed in PSQCA. 75% groundwater samples contain turbidity value over 0.5NTU (PSQCA Standard). 100% and 15% samples exceeded arsenic limit as WHO and PSQCA standard, respectively.
5. Without treatment, groundwater use will be dangerous for health. Pollutant quantity will be enhanced over time. This situation needs urgent attention to stop further deterioration of water resources as well as public health.

Effective measures should be undertaken to design an adequate method of disposal for domestic waste to mitigate the effects of leachate contamination. Awareness amongst the residents about the adverse effects of solid waste contamination, the introduction of low cost technologies for treating water supply, the installation of composting plants to utilize biodegradable material such as fertilizer and developing sanitary landfills for the disposal of hazardous solid waste are some of the actions that would help to slow down the deterioration of water quality. The following are some suggestions to improve groundwater quality:

1. Government should promote the segregation of solid wastes effectively by using advanced measures through large organizations. This will be a useful step towards a better solid waste management.
2. Effective training programs for operational/field staff and public awareness campaigns about water related issues should be launched.
3. All landfills and dumping sites should be regulated by the government under the supervision of qualified and skilled personnel.
4. Recycling of the material has great potential as an industry and should be promoted. It is a useful way to reduce waste, create employment, and produce economical and useful products.
5. It is necessary to install water filtration plants according to population requirements and educate all people about safety measures to avoid water pollution, e.g. boiling water.
6. Disinfection of water at source (water supply) is strongly recommended to stop bacteriological contamination. Chlorination equipment must be installed at every tubewell to ensure its effective operation and maintenance.

ACKNOWLEDGEMENT

We thankfully acknowledge the cooperation of Water and Sanitation Agency (WASA), Lahore, and Lahore Waste Management Company (LWMC) for providing data as well as much needed technical assistance. The encouragement and assistance from my (AAM) supervisor Prof. Tang, Zhonghua is gratefully acknowledged.

REFERENCES

Adila, S.B. and Nawaz, M.C. 2009. Municipal solid waste management in Lahore City District, Pakistan. Waste Manag., 29(6): 1971-1981.

Afzal, S., Farooq, M., Khan, M.H.A., Khan, M.I. and Ali, K. 1998. Nitrate, faecal coliform and pesticides in shallow groundwater of Raiwand, Lahore, Pakistan. Proceedings of Pakistan Engineering Congress, Vol.XXV, Lahore, Pakistan. 14-22.

Ahmad, S.R., Khan, M.S., Khan, A.Q., Ghazi, S. and Ali, S. 2012. Sewage water intrusion in the groundwater of Lahore, its causes and protections. Pak. J. Nutri., 11(5): 484-488.

Cheema, I.A. 2005. A profile of poverty in Pakistan. Centre for Research on Poverty Reduction and Income Distribution, Islamabad Planning Commission.

Dhakyanaika, K. and Kumara, P.P. 2010. Effects of pollution in River Krishni on hand pump water quality. J. Engg. Sci. Technol. Rev., 3(1): 14-22.

Dogar, B. 2008. Lahore: 20 localities getting contaminated water. Newspaper "The Nations" http://www.lahorerealestate.com/pakrealestatetimes/showthread.php?tid=413

Dong, S., Tang, Z. and Liu, B. 2009. Numerical modelling of the environment impact of landfill leachate leakage on groundwater quality - A field application. Proceedings of International Conference on Environmental Science and Information Application Technology, pp. 265-268.

Gabriel, H.F. 2010. An Appraisal of Climate Responsive Urban Groundwater Management Options in a Stressed Aquifer System. PhD Thesis, Faculty of Science, Charles Sturt University, Australia.

Haydar, S., Haider, H., Bari, A.J. and Faragh, A. 2012. Effect of Mehmood Booti dumping site in Lahore on ground water quality. Pak. J. Engg. Appl. Sci., 10: 51-56.

Jain, C.K., Bhatia, K.K.S. and Vijay, T. 1995. Ground water quality monitoring and evaluation in and around Kakinada, and Hrapradesh. Technical Report, CS (AR) 172. National Institute of Hydrology, Rorkee, pp. 1994-1995.

Kamrul, M. and Burgess, W. 1999. The vulnerability of the Dupi Tila aquifer of Dhaka, Bangladesh. Proceedings of IUGG 99 Symposium HS5, Birmingham, UK. IAHS Publ., pp. 91-98.

Karim, S., Nawaz, M.C., Ahmed, K. and Adila, S.B. 2010. Impacts of solid waste leachate on groundwater and surface water quality. J. Chem. Soc. Pak., 32(5): 606-612.

Kumar, D., Khare, M. and Alappat, B.J. 2002. Threat to groundwater from the municipal landfills in Delhi, India. Proceedings of the 28th WEDC Conference on Sustainable Environmental Sanitation and Water Services, Kolkata (Calcutta), India, pp. 377-380.

Lahore Composite ESA 2008. Environmental and social impact assessment (ESIA) and environmental management plan (EMP).for In: Ltd. Tcpotlc (ed.), Lahore.

Manan, A. 2008. *E. coli* affecting groundwater quality. Newspaper "The Daily Time". http://www.dailytimes.com.pk/default.asp?page=2008%5C05%5C20%5Cstory_20-5-2008_pg7_42

McDougall, F., White, P., Franke, M. and Hindle, P. 2003. Integrated Solid Waste Management: A Life Cycle Inventory. 2nd ed., Blackwell Publishing.

Misra, V. and Pandey, S.D. 2005. Hazardous waste, impact on health and environment for development of better waste management strategies in future in India. Environ. Int., 31(3): 417-431.

Murtaza, G. and Rahman, A. 2000. Solid waste management in Khulana City and a case study of a CBO: AmaderParibartan. In: Maqsood Sinha, A.H.Md., Enayetullah, I. (Eds.), Community Based Solid Waste Management: The Asian Experience. Waste Concern, Dhaka, Bangladesh, (32 Pages).

Naeem, M., Khan, K., Rehman, S. and Iqbal, J. 2007. Environmental assessment of ground water quality of Lahore area, Punjab, Pakistan. J. Appl. Sci., 7(1): 41-46.

NESPAK 1993. Groundwater Resources Evaluation and Study of Aquifer under Lahore. Supplementary Report, National Engineering Services Pakistan (Pvt.) (NESPAK) Limited and Binnie & Partners Consulting Engineers, London, UK.

NIPS 2006. Population growth and its implications. National Institute of Population Studies Islamabad, Government of Pakistan. http://www.pap.org.pk/statistics/population.htm.

Pakistan Millennium Development Goals Report 2005. Government of Pakistan Planning Commission, p. 62. (http://un.org.pk/undp/publication/PMDGR05.pdf, accessed on 13 August 2012).

Saeed, M. M. and Bahzad, A. 2006. Simulation of contaminant transport to mitigate environmental effects of wastewater in River Ravi. Pak. J. Water Resour., 10(2): 43-52.

Sandulescu, E. 2004. The contribution of waste management to the reduction of greenhouse gases emissions with applications in the city of Bucharest. Waste Manag. Res., 22(6): 413-426.

Shimura, S., Yokota, I. and Nitta, Y. 2001. Research for MSW flow analysis in developing nations. J. Mat. Cyc. Waste Manag., 3: 48-59.

Sidra, K., Nawaz, M.C., Khurshed, A. and Adila, B. 2010. Impact of Solid Waste Leachate on Groundwater and Surface Water Quality. J. Chem. Soc. Pak., 32(5): 606-612.

Slomczynska, B. and Slomczynski, T. 2004. Physicochemical and toxicological characteristics of leachates from MSW landfills. Polish J. Environ. Stud., 13(6): 627-637.

SWMD 2007. Solid Waste Management Plan 2007-2021. In: S. W. M. Department (Ed.), Lahore, Unpublish Report.

Tchobangoglous, G., Theisen, H. and Vigil, S. 1993. Integrated Solid Waste Management: Engineering Principles and Management Issues. McGraw Hill, USA.

Vasanthi, P., Kaliappan, S. and Srinivasaraghavan, R. 2008. Impact of poor solid waste management on ground water. Environ. Monit. Assess., 143: 227-238.

WHO 2004. Ground water and public health, Chapter 1, p. 2. World Health Organization, Geneva. (resourcesquality/en/groundwater1.pdf, 2004, Accessed on 4 September 2012).

WHO and UNICEF 2008. Joint Monitoring Program. World Health Organization and United Nations Children's Fund.

Woodard, R., Harder, M.K. and Stantzos, N. 2004. The optimization of household waste recycling centers for increased recycling - A case study in Sussex, UK. Waste and Energy Research Group (WERG), School of the Environment, University of Brighton, Lewes Road, Brighton, Sussex, U.K. 43(1): 75-93.