Impacts of Solid Waste Leachate on Groundwater and Surface Water Quality

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Summary: The present investigation was carried out to assess the impacts of solid waste leachate on groundwater and surface water quality at unlined dumping site. Six leachate samples collected from different locations have average values of COD and BOD 2563 mg/L and 442 mg/L, respectively. Surface water samples were collected in two different seasons (rainy and non- rainy). Samples collected during non-rainy season were found to be more contaminated than rainy season. Soil samples collected from the depth of 1.5 m are contaminated with heavy metals (Cd, Cr, Fe & Zn) and E.coli. Presence of E.coli shows that leachate has deteriorated groundwater quality.

Introduction

The present practice of the solid waste disposal in Lahore is not planned at all. It comprises of illegal open dumping at numerous locations scattered inside and around the city. Solid waste management department is also dumping waste on the shoulders of the approach road leading from Bund road to Saggian Bridge. This practice is highly undesirable, from both aesthetic as well as environmental points of view.

The main surface water resource in the project area is river Ravi. The river Ravi is presently contaminated owing to unchecked disposal of domestic and industrial untreated effluents. As river approaches Saggian dumping site its contamination level is elevated due to inclusion of leachate into river *via* estuaries on riverbank and sub-surface flow.

Besides contaminating surface water another devastating effect of dumping site is on groundwater quality by the formation of leachate [1, 2]. Leachate is a liquid that leaches from a landfill /dump [3, 4].

It varies widely in composition along with its age [5]. Municipal Solid Waste leachate contains a large microbial population, and may be heavily contaminated with pathogenic microorganism [6-8].

The municipal water supply of Genesco, Illinois, was polluted by leachate from a garbage dump located about 500 m north of water wells, and the private wells located about 200 m from a landfill in Kane Country, Illinois, showed bacterial and Chemical pollution [9].

The most typical detrimental effect of leachate discharge into the environment is ground-water pollution. Once a groundwater formation is contaminated, it is very difficult for it to be restored. Due to same reasons several drinking wells across the United States have been shut down [8].

Leachate by seepage and infiltration not only deteriorates soil quality but also renders the associated aquifer unreliable and unfit for drinking purposes [4]. Discharge of raw municipal leachate into streams impacts aquatic life and causes degradation of water quality [10, 11]. In Hong Kong, the principal concerns regarding leachate are related to the pollution potential of uncontrolled leachate migration into the local surface water, groundwater or the Sea [12].

The main objectives of the present investigation are (1) to investigate various constituents of leachate produced in dumping sites, (2) to estimate the groundwater quality nearest to the solid waste dump site and far away from the dump site, (3) to assess soil contamination and (4) to investigate surface water (River Ravi) contamination by leachate.

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Results and Discussion

Leachate Characterization

Leachate was characterized for both microbial (Total viable counts, Total coli form and E.Coli) and chemical parameters (pH, COD, BOD, Grease & Oil, Phenol, Surfactants, TDS, TSS, TOC, Conductivity, Pb, Cu, As, and Fe). Results are shown in Tables-1 and 2. Test results show that leachate is highly contaminated with different inorganic, heavy metals and microbial population. While migrating through the waste, the liquid dissolves salts, picks up organic constituents, and leaches heavy metals. The organic strength of landfill leachate can be greater than 20 to 100 times the strength of raw sewage.

Containing hundreds of different chemicals, the characteristics of municipal leachate vary greatly within an individual landfill over space and time. Also leachate characteristics vary considerably from one landfill to another. Many factors influence the leachate composition including the types of wastes deposited in the landfill, composition of wastes, moisture content, the particle size, the degree of compaction, the hydrology of the site, the climate, and age of the fill [13, 14].

Surface Water Contamination

To assess surface water contamination by leachate water samples from river Ravi were collected in two different rainy and non- rainy periods. The results of both seasonal periods were compared to assess the variation in contamination level. Four sampling points were selected to assess contamination level during rainy period. One point on head of Saggian dumping site, two in middle and one on the tail of dumping site were sampled. To assess water contamination by Leachate during non-rainy periods three sampling points were selected, one on the head, one in the middle and one on tail of Saggian dumping site. Collected samples were analyzed for the selected parameters *i.e.* pH, Sulfates, Nitrates, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Conductivity, Chlorides, Fluorides, and Total Hardness as given in Tables 3-5.

The samples collected during non-rainy seasons were found to be more contaminated than the samples collected during rainy period when contamination level reduces owing to dilution. Moreover, the samples collected from downstream of river Ravi were found to be more contaminated than the samples collected from upstream.

Table-1: Test results of microbial analysis of leachate.

Sample	L1	L2	L3	L4	L5	L6
Location	31°33'59N 074°16'02E	31°34'00N 074°16'00E	31°34'00N 074°16'01E	31°33'56N 74°16'02E	31°34'00N 74°16'00E	31°33'56N 074°16'02E
Total viable counts(cfu/mL)	TNTC	TNTC	50×10^3	94×10^3	89×10^3	TNTC
Total Coliform(MPN/100 mL)	800	1000	400	600	1200	1150
E.Coli	*Present*	*Present*	*Present*	*Present*	*Present*	*Present*

TNTC: Too numerous to count
MPN: Most probable number
Cfu: Colony forming unit

Table-2: Test results of chemical analysis of leachate (all values in mg/L except pH).

Leachate samples	DL	L1	L2	L3	L4	L5	L6	Mean	Std.Dev
pH		6.4	6.3	7.1	7.4	6.9	6.9	6.8	0.4
COD		1130	1124	176	559	1119	1101	2563	4297
BOD		576	550	104	318	503	605	442	194
Grease & Oil	1	2	1	BDL	BDL	BDL	BDL	0.5	0.8
Phenol	0.01	0.06	0.09	BDL	BDL	BDL	0.08	0.04	0.04
Surfactant	0.01	3	2	BDL	1	1.5	2	1.58	1.02
TDS		4402	5170	378	1158	5649	5549	3717	2339
TSS		207	157	130	60	207	209	161.7	59.5
TOC		38.5	30	13	21	101	102	50.9	40
Conductivity		6772	8206	540	1782	8431	9248	5829	3724
Pb		0.28	0.3	0.2	0.5	0.9	1.7	0.6	0.6
Cu		3.0	4.1	0.1	0.14	4.3	4.8	2.7	2.1
As		0.25	0.15	0.01	0.01	0.2	0.25	0.2	0.1
Fe		9.1	10.5	2.1	3.4	17	17	9.8	6

BDL: Below detection limit
DL: Detection Limit

Table-3: Test results of microbiological analysis of surface water.

Sample #	Total Coli Form	Faecal Coliform	F.Strecptococci
SW1	TNTC	13	Absent
SW2	TNTC	10	Absent
SW3	TNTC	09	Absent
SW4	TNTC	14	Absent

TNTC:Too numerous to count

Table-4: Test results of chemical analysis of surface water (River Ravi) for rainy season.

Sample	DL	SW1	SW2	SW3	SW4	Mean	Std.Dev	NEQS
pH		7.01	6.68	6.86	7	6.89	0.15	6-9
Conductivity		283	273	264	264	271	9	-
TDS		211	198	194	193	199	8	3500
TSS		54	45	47	50	49	3.9	200
Chlorides(Cl^{-1})		18	13.2	14.2	17.5	15	2	1000
COD		67	59	51	53	57	7	150
BOD		47	45	41	42	43.8	2.8	80
Grease and Oil	0.5	BDL	BDL	BDL	BDL	0.00	0.0	10
Total Hardness		130.4	140.1	146.7	130.4	136.9	8	-
Fluorides(F^{-1})		1.1	0.06	0.06	0.07	0.3	0.5	20
Sulphates (SO_4^{-2})		34	27	30	31	30.5	2.9	600
NO_2^{-2}	0.05	BDL	BDL	BDL	BDL	0.0	0.0	-
NO_3^{-1}	0.01	4	2.5	3	2.5	3	0.7	-
Arsenic(As)	0.005	BDL	BDL	BDL	BDL	0.0	0.00	1.0
Iron (Fe)	0.1	0.2	0.1	0.3	0.2	0.18	0.1	8
Copper(Cu)	0.01	0.01	0.01	0.02	0.01	0.01	0.01	1.0
Lead	0.01	ND	ND	0.01	ND	0.002	0.005	0.5

ND: Not detected
BDL: Below detection limit
DL: Detection Limit

Table-5: Test results of chemical analysis of surface water for non- rainy season.

Parameters	SW1	SW2	SW3	Mean	Std.Dev	NEQS
pH	7.9	7.6	8.05	7.85	0.23	6-9
COD	12300	12545	13001	12615	355	150
BOD	5763	5800	5807	5790	23.6	80
Grease & Oil	3	3	2	2.67	0.58	10
Phenol	0.6	0.8	0.09	0.5	0.4	0.1
Surfactants	5	7	7	6.33	1.15	-
TDS	5402	5900	6170	5824	389.6	3500
TSS	307	363	357	342	30.7	200
TOC	40	45	48.5	44.5	4	-
Conductivity	8712	10245	10824	9927	1091	-
Pb	0.68	0.72	0.9	0.77	0.12	0.5
Cu	6.0	6.1	6.3	6.1	0.15	1.0
As	0.20	0.23	0.25	0.23	0.02	1.0
Fe	9.1	9.9	11.00	10.0	0.95	8

Almost all the parameters tested during non-rainy period exceed the National Environmental Quality Standards (NEQS). Values of Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), TSS, TDS, Conductivity, Pb, Cu, and Fe showed that river Ravi is highly contaminated due to waste disposal and Leachate. Figs. 1 and 2 showed variation in BOD and COD levels from rainy to non-rainy seasons.

Ground Water Contamination

Threats to groundwater from the unlined and uncontrolled landfills exist in many parts of the world, particularly in the underdeveloped and developed countries where hazardous industrial waste is also co-disposed with municipal waste and no provision of separate landfills for hazardous waste exist. A number of incidences have been reported in the past, where leachate had contaminated the surrounding soil and polluted underlying ground-water aquifer or nearby surface water.

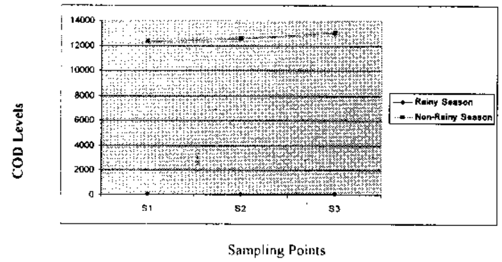


Fig. 1: Variation in COD level from rainy season to non-rainy season.

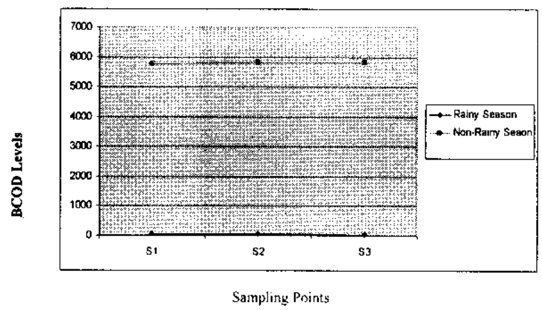


Fig. 2: Variation in BOD level from rainy season to non-rainy season.

To assess the impacts of solid waste leachate on groundwater quality five samples were collected from the area for analysis of both microbiological and chemical parameters as shown in Tables-6 and 7.

World Health Organization (WHO) guidelines for drinking water state that total or faecal coli forms must be absent and are not tolerated in potable water. Test results showed that the groundwater of the site is contaminated with faecal coli form rendering it unfit for drinking purposes. The presence of faecal coli forms lead to many water-borne diseases like ear infection, dysentery, and typhoid fever. Water contamination is attributed to the percolation and infiltration of Leachate into

Table-6: Test results of microbial analysis of groundwater.

Samples	G1	G2	G3	G4	G5	WHO Guidelines
Total Colony Count	502	641	410	390	469	<500cfu/ml
Faecal Coli form	Absent	2	5	Absent	3	0/100ml
F.Stepto cocci	Absent	Absent	Absent	Absent	Absent	0/100ml

Table-7: Test results of chemical analysis of groundwater.

Parameters	G1	G2	G3	G4	G5	Mean	Std. Dev	WHO Guidelines
pH	7.48	7.22	8.22	7.43	7.4	7.55	0.39	6.5-8.5
TDS	258	221	250	321	217	253	41.8	1000
TSS	BDL	BDL	BDL	BDL	BDL	0.00	0.00	-
Cl^-	14.6	10.4	8.33	14.6	16.7	12.93	3.44	250
$SO4^-$	38	28	19	25	23	26.6	7.2	250
As	BDL	BDL	BDL	BDL	BDL	0.0	0.00	0.01
Total Hardness	123.9	117.4	176	187	111	143.0	35.6	-
Ca Hardness	86.1	76.3	119.7	126.8	71	95.98	25.6	-
Mg Hardness	37.8	41.1	56.3	60.2	40	47	10	-
Ca	34.4	30.5	47.9	50.7	28	38	10	-
Mg	9.2	10.0	13.7	14.7	9.8	11.5	2.5	-
Conductivity	369	330	363	487	314	372.6	67.9	-
Nitrites	BDL	BDL	BDL	BDL	BDL	0.00	0.00	3
Nitrates	0.07	BDL	BDL	0.13	BDL	0.00	0.06	50
Flourides	0.09	0.04	0.07	1.1	0.02	0.26	0.47	

groundwater. Soil of the area is composed of poorly graded sand and silt as shown in Fig 3. Percolation of Leachate through such soil texture is much easy.

Soil Contamination

Soil at the dumping site also gets contaminated due to leachate percolation. As the soil of the area is very fertile and rich in nutrients transported by river Ravi, the farmers use this soil for growing crops. Test results showed that the soil is highly contaminated with heavy metals like Cd, Fe, Cu, and Zn, and microbial population. Cultivating crops on contaminated soil may lead to serious health hazards because the crops may uptake heavy metals and other contaminants [15]. Presence of heavy metals and microbial population in soil render it unfit for agriculture purposes. Soil contamination can have significant harmful consequences for vegetation. Contaminants typically alter plant metabolism and most commonly reduce crop yield.

Table-8: Test results of microbial analysis of soil sample.

Soil Sample	S1	S2	S3
Location	31° 34'02N 74°16'02E	31°34'02N 74°16'02E	31°34'03N 74°16'02E
Total Viable counts(Cfu/g)	90×10^3	8.9×10^3	64×10^3
Total Coli form MPN/100ml	>1600	900	1400
E.Coli	Present	Present	Present

MPN: Most probable number

Table-9: Test results of chemical analysis of soil sample (mg/Kg, unless defined).

Soil Samples	DL	S1	S2	S3	Mean	Std.Dev
Location		31°34'02N 74°16'02E	31°34'02N 74°16'02E	31°34'03N 74°16'02E		
pH		6.5	6.9	6.5	6.6	0.2
Cd		2.5	3.7	20	8.7	9.8
Cr		20	35	29	28	7.5
Fe		926	943	944	937.6	10
Hg	0.01	BDL	BDL	BDL	0.0	0.0
Cu		15	20	17	17	2.5
Organic matter (%age)		2.38	2.00	2.1	2.2	0.2
Zn		56.25	59	59.3	58	1.7

DL: Detection limit
BDL: Below detection limit

As Saggian dumping site is located on active flood plain of river Ravi, it poses a great risk to both groundwater and surface water resources .It is recommended that further open dumping should be strictly prohibited and dumping site should be shifted to another suitable site, where risk is negligible to both environment and human health.

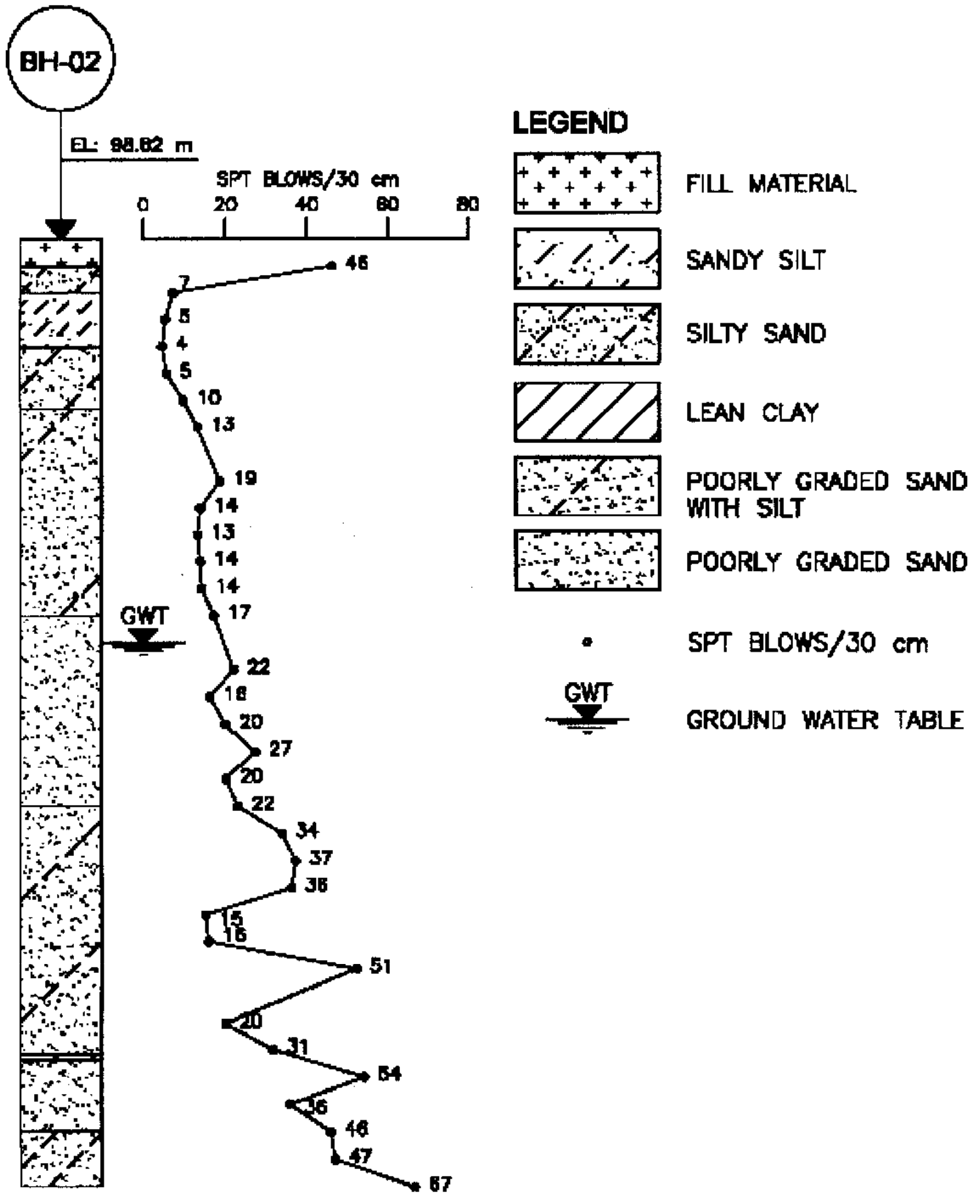
Experimental

The samples were analyzed in accordance with 'Standard Methods of Examination of Water and Wastewater' [16]. Well cleaned polyethylene bottles of 300 mL and 100 mL pyrex glass bottles were used to collect samples of leachate, surface water and groundwater. Glass bottles were sterilized prior to bacteriological sampling. Soil samples were collected in polyethylene bags.

The water samples were collected in accordance with SOPs (Standard Operating Procedures) based on methods of United State Environmental Protection Agency (USEPA) and American Public Health Administration (APHA) methods for sampling and analysis

Samples were collected by grab sampling. Fig. 4 shows line diagram depicting sampling site. For characterizing leachate, six random samples were collected from different locations at the dumping site.

For groundwater testing four samples (G1, G2, G3, and G4) were taken from donkey pumps at the depth of 130-150 feet and one sample (G5) was taken from Hand pump at the depth of 70-90 feet. These samples were analyzed for the selected parameters *i.e.*, Sulfates, Nitrates, Nitrites, Total Suspended Solids, Total Dissolved Solids, Sulphates,



Source: NESPAK

Fig. 3: Bore hole diagram of Saggian dumping site showing underground Geology.

Chlorides, Arsenic, Total Hardness, Calcium Hardness, Magnesium Hardness, Calcium, Magnesium and Conductivity.

To assess soil contamination three samples were collected randomly at the site from the depth of 1.5 M. Boring was carried out by using auger. Sample location was determined by GPS (Global Positioning System). Soil samples were tested against following microbial and chemical parameters, respectively: Total viable counts, Total coli form, E.coli, pH, Cd, Cr, Fe, Hg, Cu, Organic matter, and Zn. Test results are shown in Tables-8 and 9.

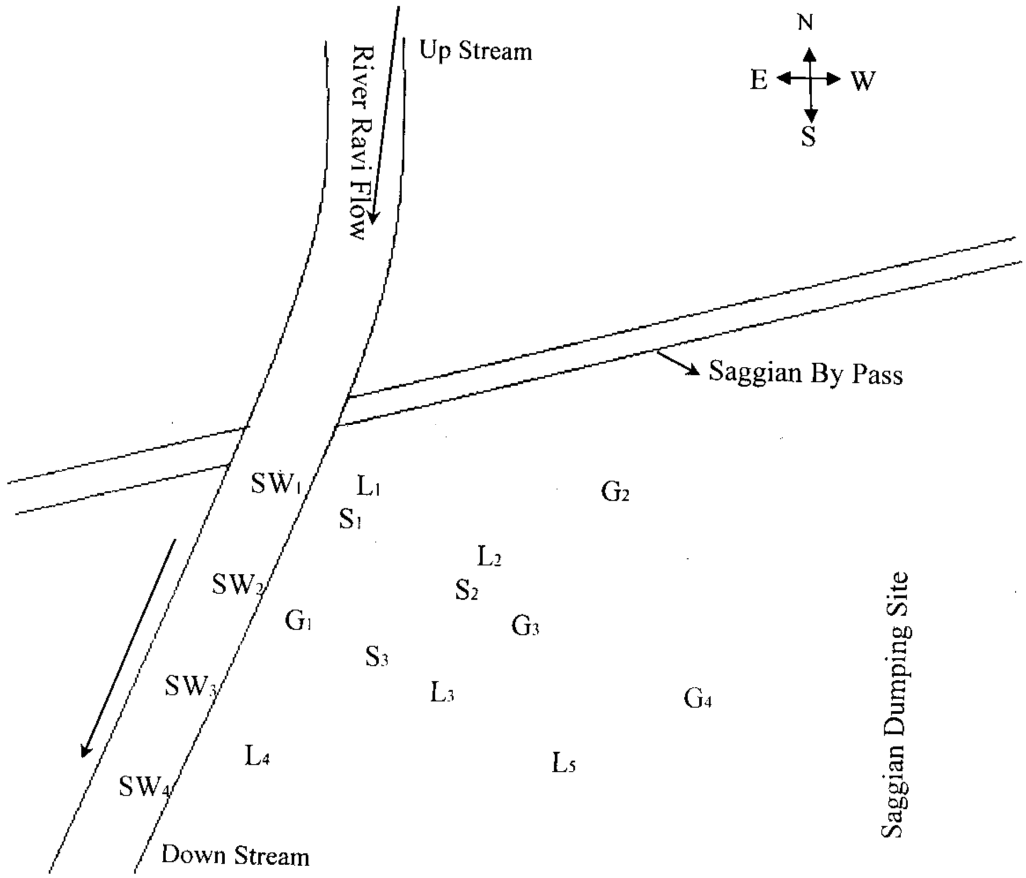


Fig. 4: Line diagram showing sampling sites.

Soil Samples: S1, S2, S3
Surface Water Samples: SW1, SW2, SW3, SW4
Leachate Samples: L1, L2, L3, L4
Groundwater Samples: GW1, GW2, GW3, GW4

Conclusion

Test results show that leachate is highly contaminated with different inorganic, heavy metals and microbial population. Test results of groundwater analysis showed that almost all the selected parameters were within WHO guidelines. But the presence of faecal coli form shows that the ground water of the site has been contaminated due to percolation and infiltration of leachate rendering it unfit for drinking purposes.

The surface water samples collected during rainy season were found to be less contaminated than the samples collected during non- rainy season. Moreover, samples collected from downstream of river Ravi found to be more contaminated than the samples collected from upstream. Presence of heavy metals, Total colony count and E.coli show that leachate has deteriorated soil quality of the area.

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