JOURNAL OF ENVIRONMENTAL SCIENCE AND HEALTH
Part A—Toxic/Hazardous Substances & Environmental Engineering
Vol. A39, No. 2, pp. 375–384, 2004

Landfill Surface Runoff and Its Effect on Water Quality on River Yamuna

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ABSTRACT

During 2000, the estimated quantity of solid waste generated in Delhi, India was more than 9000 tones per day. This is one of the biggest sources of environmental degradation in capital city of India. Since 1950's over 12 large landfill have been packed with all kinds of nonbiodegradable and toxic waste of Delhi. The area covered is at least 1% (14.83 square kilometer) of total Delhi's area. All the landfill sites except Tilak Nagar, Hastal, and Chattarpur are located very closely (0.5–6 km) to the river Yamuna. It contributes the pollution to river Yamuna in a significant way in a form of surface runoff from landfill site especially in rainy season. The chemical analysis of leachate produced by these landfill sites and corresponding river section (at five river points) has been performed for 16 selected parameter (Temperature, Odor, pH, Turbidity, Conductivity, COD, Total Solids, Sulphide, Chloride, Nitrate, Iron) in the first stage and for 8 parameters (pH, Conductivity, COD, Total Solids, Chloride, Nitrate, Iron) in second stage. The study was conducted between August to October, 2000 (rainy season). It is clear from the study that the river water quality is affected by

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DOI: 10.1081/ESE-120027529
1093-4529 (Print); 1532-4117 (Online)
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the presence of landfill surface runoff. Its impact can be seen in the region where the drains are meeting the river. This is one of the causes of river pollution apart from other major municipal and industrial sources.

Key Words: Landfill; Leachate; Runoff; River; Solid waste; Water quality.

INTRODUCTION

The river Yamuna in Delhi is the only major source of surface water in capital city of India. The river water is unfit for direct use because the Yamuna River receives at least 700 million gallons of wastewater everyday, three fourths of which is untreated. The river also carries highly toxic wastes, containing high level of heavy metals and pesticides indiscriminately discharged by about half a million industrial units. The biggest problem the river is facing today is due to the vast pollution and industrialization along its banks. River Yamuna is found to be clean only in a stretch of 522 km, out of 1044 km, which shows that it is polluted for half of its length. It has a stretch of about 22 km between Wazirabad and Okhla barrage in Delhi. Pollution load from Delhi renders it severely polluted downstream.

The water of river Yamuna continues to be polluted by domestic sewage and industrial effluents from Delhi while the water quality at the point where the river enters Delhi is within acceptable limits. Pollution load of the river, in terms of BOD, in the Delhi stretch has increased from 117 tones per day during 1982 to 211 tones per day during 1998; which means the pollution level of Yamuna has increased two-folds between 1982 to 1998.[1]

In Delhi, Yamuna water quality is so bad that the photosynthesis processes are absent. BOD removal mainly takes place by the settling of organic matter.[2] The present water quality of river between Wazirabad and Okhla Barriage is of E category; that is, suitable for irrigation and industrial cooling only against the required category B, which is suitable for bathing. Most of the previous studies are having the details about BOD, DO, total *E-coli*, pH and free ammonia in order to classify the river Yamuna at some critical locations identified by the Central Pollution Control Board (CPCB) of India.[3]

Delhi is generating more than 9000 TPD (tones per day), which is highest by any Indian city. Since 1950's over 12 large landfills have been packed with all sorts of nonbiodegradable and toxic waste of Delhi. The area thus covered by landfills is at least 1% (14.83 square kilometer) of total Delhi's area.[4] Most of the landfills are located very closely to the river. All the landfill sites except Tilak Nagar, Hastal, and Chattarpur are located very closely (0.5–6 km) to the river Yamuna. It contributes pollution to Yamuna in a significant way in form of surface runoff from the landfill site especially in rainy season.

This article examines the effect of leachate runoff from landfill on the water quality of river Yamuna in an 8 km long stretch at five selected river point in rainy season. The effect of rainfall on the water quality (in the stretches of the river near the landfill sites) will be examined. The change in chemical characteristics of leachate due to rainfall within the landfill will also be examined.

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BACKGROUND

The mega city of Delhi is referred to as the National Capital Territory of Delhi. It has 1485 sq. km area with a population more than 10 million. The density of population is 6319 per sq. km. The temperature varies as follows: January 30°C–15°C; April –May 27.5°C; July 30°C–32.5°C; October below 25°C. The annual rainfall ranges from 40 cm–200 cm. The mega city has dry winter, hot summer followed by heavy rains. The only river flows through the city is Yamuna, which is the main source of drinking water for the population.[5]

The Okhla landfill has been in operation since 1994. Though the expected life span was till 1997–1998, garbage is being dumped to that landfill site even now. It is located in the South of Delhi, adjacent to heavy populated residential area and is one of the biggest industrial areas of close proximity to river bank. This site has 7.2 hectare area and is currently receiving more than 800 tons of solid waste per day. The Gazipur landfill site is in operation since 1984. It is the largest active landfill site in Delhi covering 28 hectare area with a life span till 2004. This site is receiving 1300 TPD of solid waste.[6] Also, liquid waste is mixed with all other type of wastes and no proper compaction of solid waste is carried out at the site. It was noted during site investigation that at the landfill site, a proper scientific method of disposal is not adopted. Site is not prepared before use for waste disposal and the underground drainage system; liner cover system and leachate collection system were found absent. Due to the lack of information on the leachate plumes at these sites, a trial and error method was implemented as per the United States Environmental Protection Agency (USEPA) guidelines for selecting the leachate collection points. There was no collection system for leachate at the landfill site. All the leachate samples were collected from the leachate drain below the waste piles.

METHODOLOGY

The Okhla landfill site and Gazipur landfill sites were selected for the present investigation due to its close proximity to the river Yamuna. Approximately 8 kilometer long river section was selected to study the effect of landfill runoff in rainy season. The two selected river point were Nizamuddin Bridge and Kalindi Kunj as they are nearest to the landfills location. It was also insured that at least one drain from the landfills meet the river point before the observation/sampling river point. Five drains were found to meet this selected river stretch. These were Barapula drain, Drain number 14, Maharani Bagh drain, a drain near Apollo Hospital, and a drain near Bharat Bottling. Barapula and drain number 14 bring runoff of Gazipur landfill. Maharani Bagh drain meets the river Yamuna after Nizamuddin Bridge; so its effect cannot impact the result of first critical observation/sampling river point (Nizamuddin Bridge). The impact of Maharani Bagh drain would be minimal on Kalindi Kunj river point as it is approximately 6 kilometer from Kalindi Kunj. The two drains which bring the leachate runoff from Okhla landfill into river were a drain near Apollo Hospital and a drain near Bharat Bottling. This was found out by the study of flow path of these drains with the help of drainage map of south Delhi. The physical distance of the two drain's meeting points with river Yamuna is

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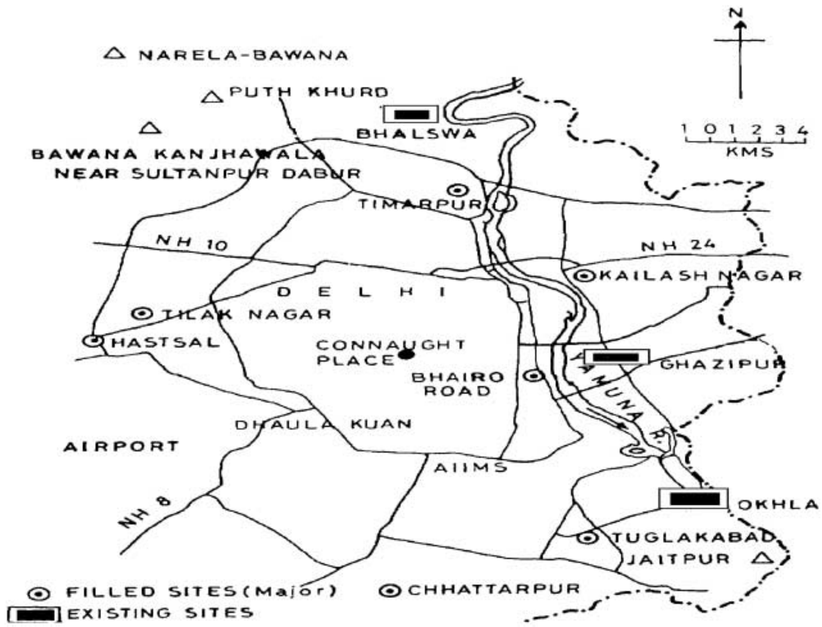

Figure 1. Landfill locations in Delhi along with river Yamuna.

approximately 500 m. The second critical river point, Kalindi Kunj, was taken at approximately 200 m distance from the Bharat bottling drain to give the time of proper mixing of pollutant in the river. The samples were taken at the bank side where the drains meet the river. The landfill locations in Delhi along with river Yamuna is presented in Fig. 1. First stage river water sampling and leachate sampling were performed before the rainy season; i.e., in the first week of June, 2000 and second stage river and leachate samplings were performed in the first week of September, 2000. The leachate samples were collected from Okhla landfill and Gazipur landfill exactly one day before the river sampling.

Sampling

The correct and representative sampling was the key of this study. The principal objective of all the sampling was to ensure that the measurement was sufficiently reliable and purpose intended. Reliability was acquired by controlling the errors introduced during the sampling procedure. Grab sampling was done at the sampling points. Sample containers were submerged or transferred below the water surface to avoid collecting floating debris or other products. The upstream water was not disturbed while collecting sample from the flowing watercourse. All the samples were collected, by standing the downstream side. All the samples were collected in the fastest flowing part of the watercourse. Stagnant or low flowing parts were avoided. At each location, 3 samples were taken at an interval of 10 min. The sampling

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containers were made up of Polythene Terephthalate (PET). Care was taken to ensure that no contamination of the sample occurs during storage after sampling and during transportation back to the laboratory facilities.

Three locations for the collection of leachate samples were identified at both Okhla landfill and Gazipur landfill sites to get homogeneous and representative samples as there was no leachate collection system and monitoring boreholes were present.

From each location, a 1000 mL sample was collected. Before sampling, these bottles were properly washed with a phosphate-free detergent, HNO_3 and HCl, and then rinsed several times with deionized distilled water. Samples were stored at 4°C in the laboratory and unpreserved samples were analyzed immediately. All the laboratory tests were performed according to the accepted procedures for analysis outlined in "Standard Methods for Examination of Water and Wastewater."[7]

RESULT AND DISCUSSION

The study examines the impact of rainfall on leachate quality in unlined and old landfills, landfill runoff production and pollutant loading into the river and their impact on the river water quality parameters.

Leachate Quality

Large variations in the quality of leachate produced from different landfills have been reported in the literature.[8–11] The temperature of landfill leachate has increased after rainfall 17.77% at Okhla landfill site and 11.63% at Gazipur landfill sites. The pH of leachate was noted 7.1 at Okhla landfill site and 7.3 at Gazipur landfill in June. After rainfall the leachate became more alkaline and alkalinity was increased by 5.63% at Okhla and 11.63% at Gazipur landfill sites in September. The organic strength of leachate has increased by 85% in Okhla landfill and 30.3% after rainfall. The significant increase may be possible due to percolation of rainwater and it takes all the organic and inorganic content with itself by advection and diffusion transport process from refuse piles. The color has become more dark after rainfall which is apparent from high hazen value of leachate in both the landfills in month of September. The hardness, Nitrate, Chloride and Iron were noted very high in both landfill leachate. Odor was continued to be very offensive pre and post rainfall months. Moreover, MPN was noted almost constant for all the landfills in pre and post rainfall months. The results of chemical analysis for two landfills are provided in Table 1.

River Water Quality

In first stage, the critical river points (Nizamuddin Bridge and Kalindi Kunj) were studied along with the lechates from both the landfills. The water quality analyses were performed for 16 parameters on collected river samples. Details of the

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Table 1. Leachate characteristics at Okhla and Gazipur landfill sites.

	Okhla landfill site			Gazipur landfill site		
Parameter[a] (mg/L)	Pre-rainfall June, 2000 (first stage)	Post-rainfall Sep., 2000 (second stage)	% change	Pre-rainfall June, 2000 (first stage)	Post-rainfall Sep., 2000 (second stage)	% change
pH	7.1	7.5	5.63	7.3	7.6	4.11
Temperature	45	53	17.77	43	48	11.63
Odor	Very offensive	Very offensive	N/A	Very offensive	Very offensive	N/A
Color	4100	5000	21.95	3800	5400	42.10
COD	40,000	74000	85	33000	43000	30.30
Turbidity	7500	8500	13.33	5400	6600	22.22
Conductivity	18.1	21.7	19.89	13.7	20.3	48.17
TDS	2785	3288	18.06	2108	3076	45.92
Sulphide	630	432	−31.43	340	540	58.82
Hardness	3300	4600	39.39	3000	3900	30
Chloride	4398	5670	28.92	3350	3600	7.46
Nitrate	430.2	190	−55.83	240	356	48.33
Iron	67.7	85.6	26.44	37.6	56.0	48.93
MPN	240 per 100 mL	240 per 100 mL	N/A	240 per 100 mL	240 per mL	N/A

[a]Except pH, temperature (°C), color (hazen), turbidity (NTU), conductivity (mS/cm).

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Table 2. River water quality analysis in first stage (pre-rainfall) at critical river points.

Parameter[a] (mg/L)	Nizamuddin bridge	Kalindi Kunj
pH	7.30	7.04
Temperature	31.5	32
DO	0.60	0.65
BOD	27	23
COD	110	100
Hardness	125	120
Oil and grease	0.068	0.062
Total solids	3420	5470
Total dissolved solids	3600	3700
Electrical conductivity	2.34	2.4
Iron	0.680	0.630
Nitrates	1.220	1.438
Sulphide	10	12
Chloride	36.48	30.34
Turbidity	75	70
MPN	24000 per 100 mL	20000 per 100 mL

[a]Except pH, temperature (°C), conductivity (mS/cm).

first stage water quality analysis were presented in Table 2. The river water was found to be heavily polluted at all the river points. The low DO, high COD and presence of oil and grease show that industrial effluents also pollute the river. High bacterial concentration indicated the presence of untreated municipal effluents and human waste in the river.

The effect of runoff was examined in second stage of extensive river sampling in the month of September. River samples were taken from selected stretch from IP power plant and after Kalindi Kunj river point. A total of 5 river water quality monitoring stations were fixed to take the samples. It is clear from Table 3 that all the selected parameters have attained some increase at critical river points (Kalindi Kunj and Nizamuddin Bridge) where the drains from landfill runoff meets the river. Electrical Conductivity, Total Solids, COD, Iron and Nitrates have increased at the critical locations. The landfill runoff was found as one of the factors for this increase apart from other factor. Temporal variation of the parameters at critical location shows that there was a significant increase in the level of pollution after rainfall at critical locations. Except Chloride and Iron, all the selected parameters increased after rainfall at Nizamuddin Bridge. Similar trend was noted at Kalindi Kunj river point where except Total Solids and Iron all the parameters were found increased after rainfall. The more detailed results are presented in Tables 2–4.

Landfill Runoff Production and Loading on River

The rational formula was used to estimate the expected runoff from both the landfills. It is still probably the most widely used method for the design to storm

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Table 3. River water quality analysis in second stage.

Parameter[a] (mg/L)	After Kalindi Kunj	Kalindi Kunj	Maharani Bagh	Nizamuddin Bridge	IP Thermal
pH	7.2	7.1	7.2	7.34	7.3
COD	100	120	120	135	132
Electrical conductivity	2.2	2.5	2.4	2.4	2.35
Total solids	3400	3600	3450	4500	3900
Sulfides	15.6	15	14	12	17
Chlorides	11.5	39.16	30.14	34	32.47
Iron	0.420	0.860	0.097	0.626	0
Nitrates	2.144	1.780	0.670	1.618	0

[a]Except pH, conductivity (mS/cm).

Table 4. Effect of landfill surface runoff on river water quality.

Parameter[a] (mg/L)	Nizamuddin bridge			Kalindi Kunj		
	Pre-rainfall	Post-rainfall	%	Pre-rainfall	Post-rainfall	% change
pH	7.3	7.34	0.54	7.04	7.1	0.85
COD	110	135	22.72	100	120	20
Electrical conductivity	2.34	2.4	2.56	2.4	2.5	4.166
Total solids	3400	4500	32.35	5470	3600	−34.18
Sulfides	10	12	20	12	15	25
Chlorides	36.48	34	−6.79	30.34	39.16	29.07
Iron	0.680	0.626	−7.94	12	0.860	−92.83
Nitrates	1.220	1.618	32.62	1.438	1.780	23.78

[a]Except pH, conductivity (mS/cm).

sewers.[12,13] The assumptions associated with the estimated runoff method are: The computed peak rate of runoff at the outlet point is a function of the average rainfall rate during the time of concentration, that is, the peak discharge does not result from a more intense storm of shorter duration. Rainfall intensity is constant thought the storm duration. The assumed runoff coefficient was 0.51 which is for undeveloped, cultivated land with a average slope of 2–7% with 100 year return period.[14] The monthly rainfall data were recorded at each landfill sites during the study (June, July, August and September, 2000) with assistance from Safdarjung Metrological Station, New Delhi. The runoff from Okhla and Gazipur landfills and the pollutants loading rates are presented in Tables 5 and 6. The high loading rate, despite the low runoff, is a cause of concern due to the high concentration of pollutants in the leachate.

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Table 5. Runoff production at Okhla landfill site and loading of selected water quality parameters.

Month (2000)	Rainfall (mm)	Runoff (m^3/d)	Pollution loading (max.) kg/day				
			COD	TDS	Fe	Cl	NO_3
June	129.4	157.25	11626.36	722.72	13.45	890.83	67.58
July	295.8	359.59	26662.63	1657.41	30.84	2042.93	155.0
August	151.4	184.03	13657.8	848.99	15.79	1046.43	79.40
September	27.2	34.56	2448.61	152.21	2.83	187.62	14.24

Table 6. Runoff production at Gazipur landfill site and loading of selected water quality parameters.

Month (2000)	Rainfall (mm)	Runoff (m^3/d)	Pollution loading (max.) kg/day				
			COD	TDS	Fe	Cl	NO_3
June	128.0	604.22	26029.11	1860.76	33.88	2177.74	215.35
July	294.0	1387.84	59786.67	4274.0	77.81	5002.087	494.65
August	153.0	722.24	31113.48	2224.22	40.49	2603.13	257.42
September	30.4	143.50	6182.02	441.94	8.045	517.22	51.15

CONCLUSIONS

Landfill leachate is a very harmful liquid for both surface water and groundwater. The runoff produced from the landfill leachate can affect the receptor water quality in a significant way in the rainy months. The strength of leachate within the landfill sites was found to increase after the rainfall month. The increase of leachate temperature may be because of the rigorous reaction/digestion that is taking place due to availability of water that is getting mixed up. The reaction rate of physical, chemical and biological processes within the landfill may be increased in rainfall month. The behavior of leachate formation in unlined and old landfills is very complex due to presence of varying age of refuse piles all over the landfill area. The varying degree of compaction of top layer and absence of cover system at some area, generate a condition for easy mixing of atmospheric oxygen and rainfall water into the landfill site. The runoff from landfill is small in volume but the pollutant loading is very high which increases the pollution concentration in river Yamuna. The river water pollution was found high where the drains from landfills meet the river. The water quality of the river was found influenced by the presence of landfill runoff but exact degree of influence was out the scope of this study. A complete environmental mapping of river Yamuna covering all the seasons with respect to landfill locations along with the river bank should be conducted to find out the exact behavior of influence of landfill leachate and runoff on river Yamuna. Landfill

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leachate and runoff certainly influence the river water quality apart from other major factors.

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