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RESEARCH ARTICLE

Leaching of overloaded and unlined drains through the ground water in Delhi

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SUMMARY : Delhi, the capital of India is one of the fastest growing and developing cities in the world. There are sixteen drains which are carrying about 1900 MLD (million litres per day) municipal and domestic waste water and 392 MLD industrial effluent and discharge into the Yamuna river (Government of India, Ministry of Environment and Forests, 2010). The drains in Delhi are unlined and hence the risk of ground water contamination increases multifold. Lysimetric experiment was setup for the analysis of physico-chemical and microbial contamination of ground water through leaching from the saturated zone of soil profile near to drain site. The drain samples were collected from Okhla, Delhi. The physico-chemical parameters like colour, odour, presence of particle, pH, temperature, total dissolved solid (mg L^{-1}), total suspended solid (mg L^{-1}), total hardness ($CaCO_3$) (mg L^{-1}), alkalinity (mg L^{-1}) and dissolved oxygen (mg L^{-1}) of groundwater sample were tested, which indicated the positive physico-chemical and microbial contamination in ground water leachate and drains sample. Total heterotrophic bacterial contamination observed in ground water (0.20 x10^2 cfu/ml), drain sample (25.70 x 10^2cfu/ml), control leachate (19.00 x10^2 cfu/ml) and drain leachate (48.00 x 10^2 cfu/ml) which is exceeding the limit of 1.0x0^2 cfu/ml. In addition, the plates for Eosin Methylene Blue agar (EMB) showed the faecal coliform as well as pathogenic bacteria colony in ground water (0.0 cfu/ml)), control leachate (8.2 x 10^2cfu/ml), drain sample (7.80 x10^2 cfu/ml)) and drain leachate (1.28 x10^2 cfu/ml) showed the maximum. The results pose serious concern for ground water through unlined drains and make science-based decisions on the risks associated with groundwater.

Key Words :
Microbes, Coliform, Faecal coliform, Leaching, Industrial effluent

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Increasing human population has exerted an enormous pressure on the provision of safe drinking water especially in developing countries Umesh *et al.* (2005). Delhi is one of the developing cities in the world which has a great interest for the microbial population in drinking water due to exposure of unrestricted unlined drain/sewage wastewater flow, which may have a major and serious unpredicted problem for the ground water contamination through the soil profile as well as other sources. In India, Delhi is one of the largest Municipal solid Wastes (MSW) generating cities. Sixteen drains are discharging about 1,900 MLD of municipal sewage and wastewater into the Yamuna river. The industrial effluent load is 320 MLD. Municipal solid waste generation is estimated to be 5,000 mt per day (Anonymous, 1997).

It is evident that many parts of the industrial areas in India are colonized and are in very close vicinity of the industries are using groundwater for drinking, cleaning, bathing, domestical and other agricultural practices. In the close vicinity of this industrial area, there is dense population of residents who generally use underground water for most of their domestic purposes (Wequar and Sharma, 2009). Historically, groundwater supplies were thought to be free of pathogenic microbes due to the natural filtering ability of the subsurface environment and the distance a microbe would have to travel in order to reach the groundwater source. Contaminants that find their way into groundwater may originate due to lack of treatment, improper management of wastewater disposal, septic tank contamination, underground storage tank or landfill leaks, mismanagement of animal waste disposal or many other reasons.

Because of their small size and ease of transport in the subsurface, bacteria were traditionally thought to be the most likely pathogens to be found in groundwater. A faecal coliform (sometimes faecal coliform) is a facultative-anaerobic, rod-shaped, gram-negative, non-sporulating bacterium. Faecal coliforms are capable of growth in the presence of bile salts or similar surface agents, are oxidase negative, and produce acid and gas from lactose within 48 hours at 44 ± 0.5^{0}C. Coliforms include genera that originate in feces (e.g. *Escherichia*) as well as genera not of faecal origin (e.g. *Enterobacter*, *Klebsiella*, *Citrobacter*). In general, increased levels of faecal coliforms provide a warning of failure in water treatment, a break in the integrity of the distribution system, or possible contamination with pathogens. When levels are high there may be an elevated risk of waterborne gastroenteritis. Nearly 90 per cent of diorrheal-related deaths have been attributed to unsafe or inadequate water supplies and sanitation (WHO, 2004) conditions affecting a large part of the world's population (Hughes and Koplan, 2005). An estimated 1.1 billion persons (one sixth of the world's population) lack access to clean water and 2.6 billion to adequate sanitation (WHO, 2005 and Hughes and Koplan, 2005).

The presence of faecal coliform in aquatic environments may indicate that the water has been contaminated with the faecal material of humans or other animals. Faecal coliform bacteria can enter rivers through direct discharge of waste from mammals and birds, from agricultural storm runoff, and from human sewage. Some waterborne pathogenic diseases that may coincide with faecal coliform contamination include ear infections, dysentery, typhoid fever, viral and bacterial gastroenteritis, and Hepatitis A (Dada *et al.*, 1999). The presence of faecal coliform tends to affect humans more than it does aquatic creatures, though not exclusively.

Downstream at Okhla, the DO level declines to 1.3 mg L-1 with the BOD at 16 mg L-1, indicating considerable deterioration in water quality in the stretch due to discharge of sewage and industrial effluents (Anonymous, 1997).

Okhla is the major industrialized and densely populated area of Delhi, which generates lots of industrial and house hold effluents. Drain in okhla region is unlined and overloaded with industrial effluents and sewage containing chemical, feacal and nonfeacal pollutants. The wastes consist of mainly organic materials (60%) obtained from various sources like domestic, vegetable markets, hotels, commercial areas etc. (E.I.S., 2002). The drain sites are not provided with any lined materials for avoiding percolation of leachate from the solids and possibility of contamination of groundwater. In order to estimate the levels of groundwater contamination in these localities, a research project on the monitoring of ground water worth around solid waste disposal of Okhla, Delhi has been taken up.

In the light of these points, the present study was designed to find out the major and minor ways of ground water contamination for phisico-chemical and microbial population from the leachate of soil and to evaluate the concentration level of faecal and non-faecal coliform in groundwater and sewage water.

EXPERIMENTAL METHODOLOGY

Sampling of drain water and soil sample:

Samples of sewage water and ground water from tube well were collected in sterile plastic containers at a point where the effluents are discharged into the sewage drain of Okhla, Delhi, India in January, 2012. Nearly 200 kilograms of soil from the drain site was collected from three different depths representing the first profile (P1), second profile (P2) and third profile (P3). 100 litres of sewage sample of Okhla drain and groundwater sample were also collected. Samples for wet laboratory were analyzed within 48 hrs (maximum transit time – 24 hrs, maximum process time – 48 hrs).

Lysimetric setup:

The lysimeter setup was performed within 6 hrs (maximum transit time – 4 hrs, maximum process time – 6 hrs) after collection of soil and drain water sample from Okhla, Delhi. The leachate sample from lysimeter was collected after 24-28 hrs, and leachate sample were collected in amber coloured bottle and finally stored at 4^{0}C.

Water samples were analyzed for physic-chemical and bacteriological quality. The pH and temperature was measured at the point of collection using pH meter (Model-pHep$^@$, Hanna instruments) and mercury thermometer (300^{0}C) (Kwality Research), respectively. The preliminarily tests for colour, presence of particles and odor were analyzed.

Electrical conductivity is the capacity of water to conduct electric current which directly relates to the concentration of salts and metal ions dissolve in water. Therefore electric conductivity determines the amount of TDS in water. Higher electrical conductivity corresponds to more TDS in water. Dissolve solids dissociates into charge ions and conduct electric conductivity therefore EC and TDS are used to determined the quality of water. Sewage water contains chloride, phosphate, nitrates and many other metals ions. The conductivity and total dissolved solid was measured by conductivity meter, TDS meter, respectively (AN ISO 9001-2000 CERTIFIED CO.).

Water hardness is due to the presence of dissolved slats of multivalent metallic ions like calcium, magnesium and other mineral salt such as iron. Hard water is not safe for drinking, cooking and other household purposes. The use of hard can cause problems in digestive system and can form of calcium oxalate in urinary bladder.

Calcium and magnesium are the minerals that cause hardness; therefore total hardness can be expressed as:

$$\underset{(\text{mg L}^{-1}\text{ as CaCO}_3)}{\textbf{Total hardness}} = \underset{(\text{mg L}^{-1}\text{ as CaCO}_3)}{\textbf{Calcium hardness}} + \underset{(\text{mg L}^{-1}\text{ as CaCO}_3)}{\textbf{Magnesium hardness}}$$

$$= 2.50 \text{ x Calcium conc. (mg L}^{-1}\text{ as Ca}^{2+}) + 4.12 \text{ x Magnesium conc. (mg L}^{-1}\text{ as Mg}^{2+})$$

Hardness can also be determined from the carbonate and non carbonate hardness. Carbonate hardness is primarily caused by the carbonate and bicarbonate salts of calcium and magnesium. Non-carbonate hardness is a measure of calcium and magnesium salts other than carbonate and bicarbonate salts (such as calcium sulphate, $CaSO_4$ or magnesium chloride, $MgCl_2$). Therefore total hardness can also be expressed as:

$$\underset{(\text{mg L}^{-1}\text{ as CaCO}_3)}{\textbf{Total hardness}} = \underset{(\text{mg L}^{-1}\text{ as CaCO}_3)}{\textbf{Carbonate hardness}} + \underset{(\text{mg L}^{-1}\text{ as CaCO}_3)}{\textbf{Non-carbonate hardness}}$$

Alkalinity is the quantitative capacity of water sample to neutralize a strong acid and is important during softening, magnesium and sodium. Many of the chemicals used in water treatment, such as alum, chlorine or lime, cause changes in alkalinity. Alkalinity is also used to calculate corrosivity of water and estimate carbonate hardness. The high value of alkalinity indicates the presence of weak and strong base such as carbonates, bicarbonates and hydroxides in the water body (Abassi *et al.*, 1999). The high values of alkalinity may also be due to increase in free carbon dioxide in water sample. The alkalinity of water samples was measured by titration with sulphuric acid (0.02N) by using phenolphthalein and methyl orange indicator (E.I.S., 2002).

Dissolve oxygen (DO) levels in water body indicate the ability to support aquatic flora and fauna. The high DO in water indicates that the rate of oxygen replenishment in water is greater than the oxygen utilization and is necessary for good water quality. Dissolved oxygen levels between 3.0 and 8.0 mg L^{-1} are satisfactory for survival and growth of aquatic organisms. The modified Winkler-azide method (Anonymous, 1998) was used to determine the dissolved oxygen (E.I.S., 2002).

The bacteriological analysis of water determines the potability of water. The Heterotrophic/Total plate count (HPC or TPC), formerly known as the standard plate count, is a procedure for estimating the number of live heterotrophic bacteria (requiring organic compounds of carbon and nitrogen for nourishment) in water. This test can provide useful information about water quality and supporting data on the significance of coliform test results.

The most commonly used indicator microorganisms are coliform bacteria which are found in large in the intestinal tracts of warm-blooded animals. Masses of coliform bacteria are discharged along with the animals' faeces and get mixed with the sewage water. The coliform bacteria in the sewage will be carried along and will survive in the water for long periods of time. Thus, the presence of coliform bacteria provides evidence that water has been polluted with sewage, and also indicates the possible presence of pathogenic microbes.

The media used for the bacteriological analysis of water sample include Plate Count Agar (PCA), Nutrient Agar (NA), and Eosin Methylene Blue agar (EMB). All the media used were weighed out and prepared according to the manufacture's specification, with respect to the given instructions and directions. The water samples were then inoculated separately on different Plate Count Agar (PCA) and Eosin Methylene Blue (EMB) Agar and the plates were incubated at 37^0C for 24-48 h for evidence of growth (Prescott, 2002).

Statistical analysis:

The results were expressed as the mean S.E. for each group. Statistical difference were evaluated using a one way analysis of variance (ANOVA) followed by Turkey t-test. Results were coordinated statistically at >0.01 and <0.05.

EXPERIMENTAL FINDINGS AND DISCUSSION

The physical properties of the groundwater, leachate and sewage samples are shown in Table 1. Leachate and drain samples were not up to the standard limits of water.

In the preliminary examination of ground water, Okhla control leachate, Okhla drain sample, Okhla drain leachate were compared along with maximum permissible limit recommended by World Health Organization (2004). Preliminary examinations showed that the ground water which only complies with standard limit except a deviation sample of control that is slightly offensive. The control leachate showed the entire properties as colour, presence of particles, pH and temperature in acceptable range except the offensive odour. The drain leachate showed pale yellow colour, slight offensive odour and few particles, while the pH and temperature as recorded nearly too standard limit. In other hand the drain water sample was observed to vary from standard limit for yellowish colour, slight offensive odour and suspended solid except recorded pH and temperature value. The temperature as well as recorded pH value were in a range of 6.87-7.07 and 25.7-26.0^0C, respectively, that is under permissible limit of WHO standard and showing non-significant from the ground water (Table 1). Disposal of domestic, municipal and industrial effluents enhances the microbial populations and makes sewage water offensive. This reveals that, the drain sample contains

Table 1: Physical properties of groundwater, leachate and drain water sample

Sample	Colour	Odour	Presence of particle	pH	Temperature (^{0}C)
Ground water	Colourless	Odorless	No visible solids	6.87±0.03	25.7
Okhla control leachate	Colourless	Slight offensive	No visible particle	7.07±0.07	25.7
Okhla drain sample	Yellowish	Offensive	Suspended solids	7.07±0.07	26.0
Okhla drain leachate	Pale yellow	Slight offensive	Few particle	7±0.15	25.7
Standard limit	Colourless	Not offensive	No visible solids	6.5-8.5	NA

NA- not applicable

significant amount of heterotrophic bacteria and fungi.

The values of conductivity, total hardness ($CaCO_3$), alkalinity and total dissolved solid in ground water sample, Okhla control, Okhla drain sample, Okhla drain leachate were reported much above the WHO standard limits.

In the Lysimetric analysis of Okhla drain, the EC (2010µs/cm) and TDS (994.67mg L^{-1}) value were much above to the WHO standard permissible limit that is 400µs/cm. In the control leachate, the value of EC (5446.66 µs/cm) and TDS (2730.0 mg L^{-1}) were higher than drain sample. Electrical conductivity (5446.6633µs/cm) and total dissolved solid (2730 mg L^{-1}) value in control leachate were found higher when compared with ground water (2153.33µs/cm and 1091.33mg L^{-1}) that is significant value from ground water and above to the permissible limit prescribed by WHO standard. Since the value for EC and TDS in control leachate and drain leachate were higher when compared to ground water and drain sample respectively, and point toward that the soil of Okhla contained superior for concentration of salts and metal ions that is pre-accumulated in soil and leached down to the ground water aquifer (Table 2).

The total hardness ($CaCO_3$) of Okhla control was recorded 4366.67 mg L^{-1} which is highest when compared with Okhla drain leachate (3616.0 mg L^{-1}), ground water (909.33 mg L^{-1}) and drain sample (702.67mg L^{-1}). The control leachate as well as drain leachate showed hardness much higher than ground water and drain sample and signified that soil of Okhla was saturated with dissolved slats and mineral salt *i.e.* leached out from soil crust into the water bodies.

In the present investigation, the alkalinity of Okhla drain sample (800.0mg L^{-1}) that is highest when complied with drain leachate (400.0mg L^{-1}), control leachate (283.34mg L^{-1}), and ground water (300.0mg L^{-1}), all exceeding from the standard limit of WHO, 1984 that is 200.0mg L^{-1}. Alkalinity in water is due to presence of carbonates, bicarbonates and hydroxides of calcium, magnesium, and sodium. Alkalinity was also recorded in leachate of drain (50% of drain sample) and control leachate (>90% of ground water), means that soils of Okhla were not contributing the alkalinity factor to the water rather it allows pass through the soil crusts.

Dissolve oxygen (DO) levels in water body indicate the ability to support aquatic flora and fauna. The high DO in water indicates that the rate of oxygen replenishment in water is greater than the oxygen utilization and is necessary for good water quality. Dissolved oxygen levels between 5.0 and 8.0 mg L-1 are satisfactory for survival and growth of aquatic organisms. In the present analysis, the dissolved oxygen contents of Okhla control leachate, Okhla drain sample and Okhla drain leachate were 8.8mg L^{-1}, 0.0mg mg L^{-1} and 9.67mg L^{-1}, respectably. Dissolved oxygen in drain leachate was recorded as 9.67mg L^{-1} while there were no DO level in drain sample that indicated that the oxygen in leachate would mixed from the soil aeration present in column or it might be from imprison of microbial population through soil crust. However, extensive studies are required for the final conclusions.

High concentrations of the general bacterial population may hinder the recovery of coliform. Most of the bacteria associated with drinking water systems, are heterotrophs. Heterotrophic Plate Count (HPC) is a microbial method that uses colony formation on culture media to approximate the levels of heterotrophic flora. HPC does not, however, give an indication of the types of organisms present or their sources. It should also be noted that the results obtained using an HPC test are not an accurate assessment of total heterotrophic concentrations but, instead, are indications of culturable organisms present. The total plate count for bacterial contamination of Okhla control leachate (1.9 x 10^{3}cfu/ml), Okhla drain sample (2.57 x 10^{3}cfu/ml) and Okhla drain leachate (4.8 x 10^3 cfu/ml) are exceeding the WHO standard limits of 1.00 x 10^{2}cfu/ml. The maximum concentration for heterotrophic plate count was recorded in Okhla drain leachate followed by Okhla drain and control leachate. The bacterial contamination in drain leachate is much higher when compared with Okhla drain. The maximum colony form unit for heterotrophic bacterial count in drain leachate, indicated that the drain sample as well as Okhla soil would have the bacterial population in a maximum concentration and possibility to presence of faecal and non-faecal coliform bacterial population. The drain of Okhla is unlined therefore it would increase the possibility for microbial population to pass out from soil crust to the ground water in a limited series.

Faecal coliform count was determined, using Eosin Methylene Blue medium with pour plate technique and further confirmed by the ability of the organism to ferment lactose at

Table 2: Physico-chemical properties of Okhla ground water, control leachate, drain sample and leachate sample

Parameters	Ground water sample	Okhla control leachate	Okhla drain sample	Okhla drain leachate	WHO standard
Conductivity (µs/cm)	2153.33±3.33	5446.66±143.33	2010±50	4810±215.48	400
Total dissolved solid (mg L^{-1})	1091.33±1.45	2730±64.30	994.67±19.8	2433.33±102.69	500 ppm
Total hardness ($CaCO_3$) (mg L^{-1})	909.33±0.67	4366.67±3.45	702.67±0.45	3616±3.20	500
Alkalinity (mg L^{-1})	300±3.05	283.34±2.33	800±5.57	400±6.12	200
Dissolved oxygen (mg L^{-1})	10.07±0.13	8.8±0.10	0.00	9.67±0.49	3 ppm
Total plate count (cfu/ml)	20±0.33	1900±13.92	2570±18.50	4800±99.60	1.0x10^2
Faecal coliform (cfu/ml)	0.0	8.2 X 10^1	7.80 X 10^2	1.28 X 10^2	NA

44.5^{0}C. Faecal coliform counts of Okhla drain, Okhla control leachate and Okhla drain leachate were 7.80x10^{2}cfu/ml, 8.2x10^{1}cfu/ml and 1.28x10^{2}cfu/ml, respectively (Table 2). Disposal of domestic, municipal and industrial effluents enhances the microbial populations and make sewage water offensive. This reveals that, the drain sample contains significant amount of faecal coliform bacterial population. Microbial population in control leachate was more than ground water sample that would indicate that the contamination in control leachate is due to saturated zone for microbial population of bacteria in soil, where it is easily pass out from earth crust to ground water bodies.

As the total plate count and faecal coliform counts are reported in the leachate samples, it can be noted that the microbes can also leached down the earth crust to contaminate the groundwater ecosystem. However extensive studies are required for the final conclusions.

The above result is indicating that the soil of Okhla drains of Delhi was highly contaminated in comparison to Okhla drain sample and the possibility for accumulation of ions and bacterial population in soil sample would be the reason for ground water contamination. Therefore, in conclusion, prevent human's activities to control the sewage discharge directly in environment and entering water body is the keys to the avoiding bacterial as well as chemical contamination of drinking water. It is evident that water borne diseases are due to improper disposal of refuse, contamination of water by sewage, surface runoff etc. Therefore, programmes must be organized to educate people on the proper disposal of refuse, treatment of sewage and the need to purify our water to make it fit for drinking because the associable organisms are of public health significance being implicated in one form of infection or the other. In areas lacking the tap water as in rural dwelling, educative programmes must be organized by researchers and government agencies to enlighten the villagers on the proper use of surface water.

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