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# Groundwater Quality Assessment near a Municipal Landfill of a Planned City of Punjab, India

**Dr. Shakti Arora and Er. Maninder Kaur Sidhu**
Environmental Engineering Department, PEC University of Technology
Sector – 12, Chandigarh
**E-mail :** mandy7599@gmail.com

**Abstract :** The current research examined the level of groundwater contamination near a municipal landfill site in Mohali, Punjab. Water quality parameters (physico-chemical and heavy metals) of leachate and groundwater samples were analyzed. The mean concentrations of all measured parameters except TDS, Chloride, alkalinity, Hardness, Nitrate and Heavy metals confirm to the stipulated World Health Organization water standards and B.I.S Standard for Drinking Water Quality. The current results show significant impact of the landfill operations on the groundwater resource. The existing soil stratigraphy at the landfill site consisting of clays and silty clays have significantly influenced natural attenuation of leachate into the groundwater resource. It is however observed that in the absence of a properly designed landfill and leachate collection system, uncontrolled accumulation of leachates at the base of the landfill pose potential contamination risk to groundwater resource. The research recommends an upgrade of the non-engineered landfill to a standard that would guarantee adequate protection of both the surface and the groundwater resources in the city.

**Keywords:** landfill, aquifer, leachate, contamination, groundwater, heavy metals.

## INTRODUCTION

Groundwater is an important source of drinking water for most of the World's population and the proper assessment of groundwater quality has not been given due consideration due to which water borne diseases have become very common. About 80 percent of the diseases in the world are the result of poor quality of drinking water[22]. Thousands of drinking water wells across the USA have already been shut down due to the contamination from landfills [14].

Today, the disposal of wastes by landfilling is the ultimate fate of all the solid wastes such dumping of waste in a non-engineered landfill site usually leads to the generation of Leachate which poses a significant threat to water resources.Leachate contains high concentration of organic and inorganic contaminants and if it is not properly treated and safely disposed, it could become a potential source of surface and groundwater contamination as it may percolate through soils and sub soils [20]. Landfills have been identified as one of the major threats to groundwater resources. There are many instances where leachate interact and mix with aquifers. There are instances where the groundwater transport pollutants up to a distance of 1000 m from the landfill site (Christensen et al.[4]).

## MATERIAL AND METHODS

The main objective of the study is to assess the impact of leachate percolation on Groundwater Quality from the unlined landfill site located in Mohali.

### Site Specification

Mohali is a city adjacent to Chandigarh,18th District in Punjab, India. Mohali is geographically located at 30º 78´N and 76º 69´E on the map of the World. Following the success of Chandigarh's sector design, Mohali city was similarly planned and Mohali houses many state-local companies like PTL (Punjab Tractor Limited), ICI Paints, and the Godrej Group, Quark, Philips, Sebiz Infotech, as a home for large, multinational corporations.

There is an increase in the spurt of industries which in turn also increase the environmental pollution due to emissions and waste generated from these industries. The landfill site in Mohali is non-engineered open dump. The land on which the waste is dumped was historically productive agricultural land located on the side of Patiala ki Rao seasonal rivulet. Dumping site spreads over an area of approximately 3 Kilometre square. The landfill site, sector 74, lies in the vicinity of Industrial Area of Mohali, so there is a possibility of the presence of toxic contaminants in the soil and the ground water because before the set up of Common hazardous waste dumping site in NIMBUA, Derabassi, industrial waste was dumped along with the general municipal solid waste.

### Sampling

In an effort to study the extent of the groundwater contamination, A total of 9 samples of groundwater were collected representing Shallow (Sample No. 2,3,5,6,7,8) and Deep groundwater (Sample No. 1,4,9) within an area of 2 km of landfill site. Similarly, Samples for Leachate Characterisation were collected from two different locations (L-1, L-2). L-1 is 50m away from site and L-2 collected onsite. All the samples were sealed at site to avoid any change in chemical character due to time lapse between sample collection and laboratory analysis. Samples collected from each sampling site was used for the analysis of major physico-chemical parameters viz. pH , EC , Temperature , Colour, Chlorides, COD, Nitrate-N, Ammonical-N, Phosphate, Alkalinity, Hardness, Ca, Mg, $SO4^{2-}$, $F^-$, Sodium, Potassium, Aluminium, Bromine and Heavy Metals viz. Lead, Nickel , Iron, Copper, Zinc. The analysis of the water samples was done as per the guidelines given in APHA[1] 1994.The Physico-Chemical parameters were determined by using UV Double Beam 2203 Spectrophotometer (Systronic). The amount of Pb, Cu, Zn, Al, Br, Na, K, Fe and Ni were determined using Photometer by Merck, Spectroquant Nova 60 .

## RESULTS

### Groundwater Characterization

The groundwater of the site is mainly used for Domestic purposes. Analysis results of water samples drawn from various locations reveal that waters occurring at different depth are neutral in nature with pH ranging from 7 to 8 (Fig.1).The Electrical Conductivity of these water ranged from 688 $\mu$S/cm to 1317 $\mu$S/cm at 25°C.

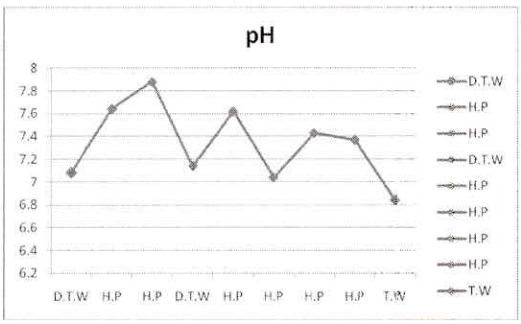



**Fig. 1:** pH range in various samples

Where,

D.T.W- Deep Tube well (depth 350 mbgl / 1150 feet)

H.P – Hand pump (depth 40 feet to 100 feet )

The high conductivity values obtained from the hand pump near the landfill site in an area of 50metres is an indication of the effect of the site on the water quality. The range of TDS at all sites fall between 440 to 1070 ppm. The TDS was found to be remarkably high at sites 2,3,5,8,9 As per the classification of Rabinove[21],based on TDS , Sample no. 2 is found to be Slightly saline and rest all non- saline. The high value of TDS may also be due to the leaching of various pollutants into the groundwater. An excess of chloride is usually taken as an index of pollution and considered as tracer for groundwater contamination .The concentration of Chloride in the groundwater samples varied from 50 mg/l to

229 mg/l. All the samples crossed the desirable limit of the alkalinity. In comparison to deep tubewell samples, hand pump waters were found to be more alkaline.

TH is normally expressed as the total concentration of Ca and Mg in mg/l, equivalent of CaCO3 and its concentration varied from 440 mg/l to 860 mg/l. Twort et.al[19] classified the water with respect to total hardness as shown in table 1. As per the classification 100% of the samples fall in the category of very hard water.

**Table 1.** Classification of Samples According to TH by Twort[19]

| Description | Total Hardness mg/l | Samples in this category |
|---|---|---|
| Soft | <75 | - |
| Moderately hard | 75-150 | - |
| Hard water | 150- 300 | - |
| Very hard | >300 | 1,2,3,4,5,,6,7,8,9 |

Calcium concentrations in the groundwater ranged from 52mg/l to 208mg/l, with the minimum level of calcium occurrence in D.T.W and 90% of the hand pumps have calcium value exceeding the permissible limit of 75mg/l (Fig. 2).

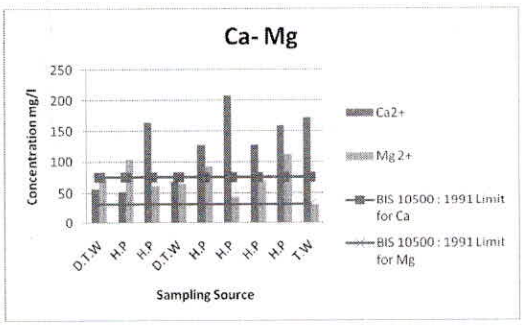
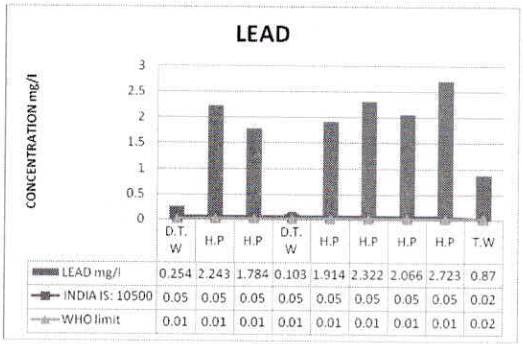
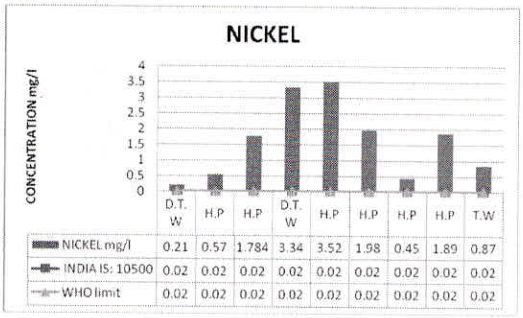


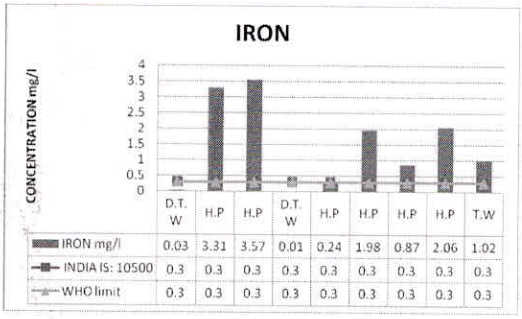

**Fig. 2 :** Concentration of Calcium and Magnesium in various samples

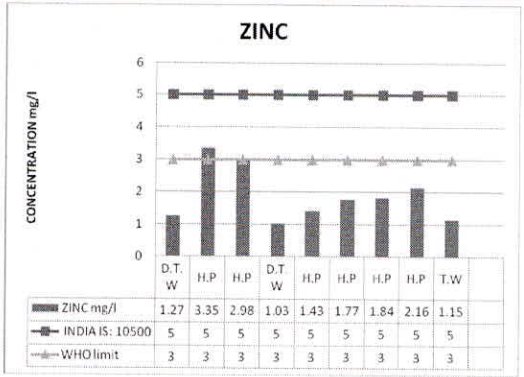
Fluoride concentration was found to be below detectable levels in the samples. The maximum permissible limit of nitrate concentration in water for various purposes especially for drinking is 45 mg/L according to WHO[23] (1998). The data reveal that the groundwater from H.P 8 contains high level of nitrate (78.25 mg/l), which is not within permissible limits for drinking purposes. The $PO_4^{2-}$ concentration of groundwater samples were found in concentration exceeding 0.10mg/l and the range of sulphate varied from 36mg/l to 121.12mg/l. BOD values were found to be less than 2mg/l except in HP-2,3 which was 2.54 mg/l and 2.89mg/l respectively. The COD level in the groundwater samples varied from 4 to 36 mg/l, indicating the presence of organic contaminants in the water and can be used as organic indicators to assess the groundwater pollution caused by landfill.

The level of pollution with heavy metals of groundwater is high (Figure- 3). The Nickel concentration is above 0.02mg/l (WHO,BIS limit) in all the samples. The lead standard value 0.05mg/l in IS: 10500-1991 is used as a tolerable limit for drinking water. The highest lead concentrations 2.72mg/l, 2.24mg/l were in shallow groundwater of residential area near landfill and industrial area respectively (Figure 4). The WHO and B.I.S permissible level of iron (0.3 mg/l) is exceeded in more than 70% of the samples. Iron levels range from 0.01 to 3.57mg/l in the sampled wells. D.T.W samples range lies within the permissible limit while for hand pumps it exceeded significantly. Except in Deep Tube wells, no. 1 and 4, rest of the hand pump samples exceeded the desirable limit for copper (Figure - 3). High concentrations of heavy metals ,namely, Ni, Cu, Pb, Fe were found to be above the desirable limits , which can be hazardous for health. It also indicates that the contamination have seeped down up to certain depth of 150 feet where as the tube wells with depth more than 1000 feet are safe from the contamination.



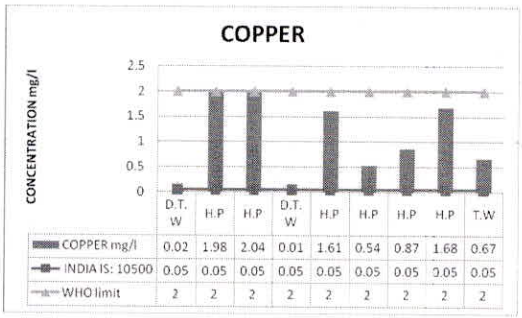




**Fig 3 :** Concentration of Heavy metals (Pb, Fe, Ni, Zn, Cu) in Groundwater.

## Leachate Characterization

The leachate having pH value between 5 and 7 indicates lower pH which occurs during the hydrolysis and acidification phase. Electrical Conductivity (EC) highest value is obtained at the Second site with the value of 1819 $\mu$S/cm which indicates the presence of inorganic material in the samples. The concentrations of Total Dissolved Solids (TDS) between these leachates showed different values (Figure -4). The greatest concentration content of 1250ppm is measured at the L-2, whereas the lowest concentration content of 490ppm is measured at the first site. Acidity and Alkalinity were within range of 115-135mg/l at L-1 and 550 – 580mg/l at L-2 respectively. The Fluoride concentrations measured were B.D.L (below detectable limit) i.e. in both the samples they were below 0.10mg/l. High Cl- content of 634.8 mg/l was measured at L-2. The concentration of nitrogenous compounds indicates the occurrence of extensive anaerobic bacterial activities. The concentration of ammonical - N for the L-1 is 1.05 mg/l and the L-2 is 3.09 mg/l. Among all the cations analysed, Na and Ca showed high concentration levels in the landfill leachate. The highest concentration of $Na^+$ was measured at L-2 with 133 mg/l. Aluminium and Bromine were determined to be in high concentration at L-2 site. The concentration of Aluminium in the studied

samples was 0.04 mg/l at L-1 and >0.12mg/l at L-2. Similarly Bromine is 0.35 at L-1 site and 1.19 mg/l at L-2.

The BOD/COD ratio tends to decrease as the age of leachate increases, varying from 0.5 for a relatively "fresh" leachate to 0.2 for an older (more stabilized) one. BOD/COD ratio was found to be 0.48 which indicates relatively fresh leachate as the landfill site is < 5years old.

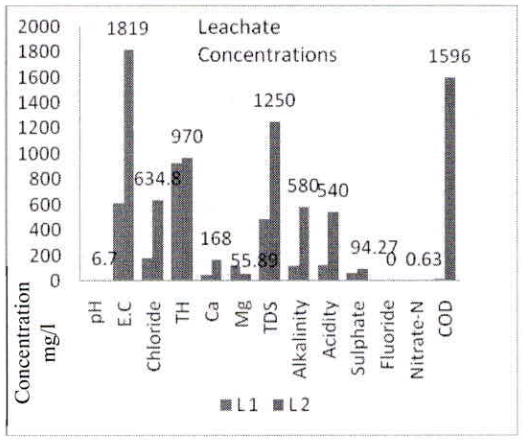



**Fig.4 :** Concentrations of pH, EC, Chloride, TH, TDS, Alkalinity, Sulphate, Nitrate and COD

The high concentration of Zn was found in L-2 with a value of 2.56mg/l where as in L-1 Zn is present in negligible amount. So, high concentration of Zn in L-2 might have leached down from the waste. The results of Ni and Cu for L-2 are higher than the results obtained from L-1. The Ni and Cu concentration both are in the range of 0.13 and 0.56 repectively as shown in fig. 5.

## Suitability of water for drinking Purpose

India and WHO has recommended desirable and permissible limits for chemical constituents that are essential or toxic to human health. Comparison of concentration values obtained for various constituents analysed in water samples from the area, with these recommended concentration limits, it is found that values for

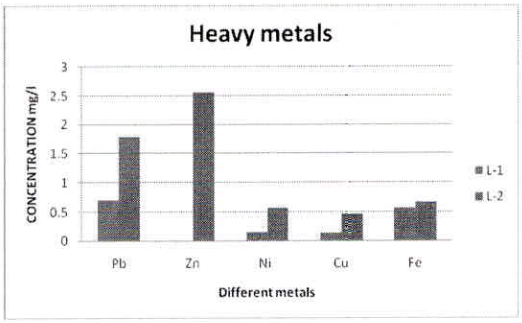



**Fig. 5** : Concentration of Heavy metals (Pb, Zn, Ni ,Cu , Fe) in leachate.

mainly all the constituents are above the permissible levels.

In case of heavy metals, the concentration of all the determined metals Pb, Ni, Cu, Fe is above the desirable limit except Zinc. In case of Iron and Copper, Samples from D.T.W -1 and D.T.W -4 are within the desirable limit of less than 0.3mg/l for Iron and 0.05 for Copper as per the specification of B.I.S . In each unit however, lead concentrations are greater than 0.05 mg/l have been recorded for the water sampled from wells, hand pumps indicating the existence of contamination. On contrary, the samples obtained from hand pumps have crossed the prescribed limits and are not safe for domestic purposes.

## Effect of Depth and Distance

The Extent of contamination of groundwater Quality due to leachate percolation depends upon a number of factors like leachate composition, rainfall, depth and distance of well from the pollution source, the landfill site in the present case.

Water samples selected from shallow as well as deeper depth were analyzed for this study. Though no water contamination was found in the samples collected from two deep tube wells whose depth is 1150feet , most of the parameters were within the permissible limits as compared with

B.I.S and WHO drinking water standards where as the samples collected from the Hand pumps varying from depth of 50 feet to 150 feet have shown significant contamination level (Table- 3), which clearly indicates that water at shallow depth are much more contaminated which may be due to the seepage of landfill leachate .

**Table 3 :** Comparison of Samples collected from different Distance and Depth

| Para-meters (mg/l) | Site 1 (at 60 metres, depth 1150 ft) | Site 3 (at 5 m, depth 50 feet ) | Site 5 at 1000m, depth 30 feet ) | Site 2 (at 1000m , depth 1200 feet) | BIS 10500 : 1991 (Desirable) |
|---|---|---|---|---|---|
| EC µS/cm | 668 | 1096 | 1017 | 745 | - |
| Cl- | 50 | 219 | 125 | 62 | 250 |
| TH | 440 | 660 | 700 | 480 | 300 |
| Ca | 56 | 164 | 128 | 62 | 75 |
| Mg | 72.9 | 60.8 | 92.4 | 64 | 30 |
| TDS | 440 | 860 | 670 | 485 | - |
| Iron | 0.03 | 3.57 | 0.24 | 0.01 | 0.3 |
| Lead | 0.254 | 1.784 | 1.914 | 0.10 | 0.05 |

Similarly, when the water quality of the wells situated at different distances from the landfill site but having the same depth was compared. Groundwater samples collected from the wells situated close to the landfill and towards the western side (sample 9.)are found to be more contaminated than that of the well situated farther away from the site.

It obviously follows the fact that the Gravitational movement of the viscous fluid, leachate is hindered due to the mass of solid soil matter.

## REMEDIAL MEASURES

Strictly speaking, one should avoid using groundwater drawn from hand pumps located in close proximity of the waste dumping site. If this is unavoidable, deeper drilling and frequent analysis of water samples are desirable. Efforts should be made to supply clean water through pipelines from distant sources. Moreover, the site remediation techniques like various physic-chemical, biological methods and Phytoremediation techniques may be applied to rectify the same.

Mohali landfill site is non-engineered landfill. It is neither having any bottom liner nor any leachate collection and treatment system. Therefore, all the leachate generated finds its path into the surrounding environment. This study emphasizes the need for periodical monitoring of Groundwater to assess its suitability for drinking purposes and to avoid further deterioration by setting up of sanitary landfill, having the provision of proper landfill gas and leachate collection system. Efforts should be made to convert the existing open dumps into the sanitary landfills.

## CONCLUSION

India is one of the developing country suffering from water pollution. Landfill is one of the source of water pollution. There are several boreholes located close to Mohali landfill used for drinking water. A study of composition of landfill leachate and groundwater pollution was conducted at Mohali landfill and following statements can be concluded from the study conducted.

The low resistivity observed in groundwater is mainly due to the presence of contaminant metals such as Fe, Cu, Pb and Zn along with leaching of cations and anions like potassium, chloride, sodium, bicarbonate, sulphates etc., So, there is an impact on ground water contamination due to migration of landfill leachate . The

resistivity values of the shallow aquifer zones shows that there is inorganic pollution in the ground water at the shallow level.

The high concentration of EC, $Cl^-$, Nitrate, $Na^+$, TH, Ammonical Nitrogen, in groundwater near landfill deteriorates its quality for drinking and other domestic purposes. The groundwater quality improves with the increase in depth and distance of the water from the pollution source. Although the concentrations of few contaminants do not exceed drinking water standard like F-, Na, K, Phosphate etc even then the groundwater quality represent a significant threat to public health.

Further, the presence of heavy metals (Pb, Ni, Cu, Fe, Zn). Pb, Fe, Zn and Ni to be noted as outstanding elements which were found to be in abundance. In more than 85% of the samples have been reported above the prescribed limit while rest are within the permissible limits as per WHO and BIS drinking water standards. The presence of heavy metals clearly indicates the presence of inorganic contaminants in water.

Looking at the present status it can be concluded that the ground water contamination level is on the verge to surpass the permissible limits. Mohali Administration should make efforts to control this deterioration and also to comply with the statutory requirements.

## REFERENCES

**1 APHA-AWWA-WPCF, 1994.** Standard Methods for the Examination of Water and Wastewater, 15th Eds *American Public Health Association*, Washington, DC, USA.

**2 Kobus and Kinzelbach, Balkema, Rotterdam,** Approach to Model the Transport of Leachates from a Landfill Site including Geochemical Processes, Contaminant Transport in Groundwater. pp. 183–190.

**3 Atul Sharma, Srikanth Meesa, Somali Pant, Babu J. Alappat,** Formulation of a landfill pollution potential index to compare pollution potential of uncontrolled landfills, ISSN 0734–242X *Waste Management & Research* 2008: 26: 474–483

**4- Christensen, T. H., Kjeldsen, P., Albrechtsen, H.-J., Heron, G., Nielson, P. H., Bjerg, P. L. and P.E. Holm, 1994.** Attenuation of Landfill Leachate Pollutants in Aquifers. *Critical Reviews in Environ. Science and Technol.* 24, 119-202.

**5- Dinesh Kumar and Babu J. Alappat,** Evaluating leachate contamination potential of landfill sites using leachate pollution index, *Clean Techn Environ Policy* (2005) 7: 190–197

**6- EsmailA lSabahi, S. AbdulRahim** et al. Leachate Composition and Groundwater Pollution at Municipal Solid Waste Landfill of Ibb City, Yemen, Sains Malaysiana 38(3)(2009): 295–304

**7 Fatta D., A Papadopoulos and M., Loizidou, 1999.** A study on the landfill leachate and its impact on the groundwater quality of the greater area. *Environ. Geochem. Health* 21 (2): 175-190.

**8- Fatta D., A Papadopoulos and M., Loizidou, 1999.** A study on the landfill leachate and its impact on the groundwater quality of the greater area. *Environ. Geochem. Health* 21 (2): 175-190.

**9 Integrated solid waste management"** book by Tchobanoglous, Hilary Theisen and S.A Vigil.[Mcgraw hill international editions]

**10 J.Wiszniowski · D. Robert · J. Surmacz-Gorska ·K. Miksch · J.V. Weber 2005.** Landfill leachate treatment methods: *A review, Environ Chem Lett* (2006) 4: 51–61

**11- Kelley, W.E., 1976.** Groundwater pollution near a landfill. *Journal of Environmental Engineering Division*, Proceedings of the ASCE 102, 1189–1199

**12- Kumar, D., & Alappat, B. J. (2005).** Evaluating leachate contamination potential of

landfill sites using leachate pollution Index. *Clean Technologies and Environmental Policy*, 7, 190–197

**13- Loizidou, M., and E. Kapetanios, 1993.** Effect of leachate from landfills on underground water quality. *Sci. Total Environ.*, 128, 69–81.

**14- Masters, G. M.** "*Introduction to Environmental Engineering and Science*" Prentice-Hall of India. Private Limited, New Delhi, India (1998)

**15- Mor,S., Ravindra, K., Dahiya, R. P., & Chandra, A. (2006).** Leachate characterization and assessment of groundwater pollution near municipal solid waste landfill site. *Environmental Monitoring and Assessment,* 118, 435–456

**16- Abu-Zeid N., G. Bianchini, G. Santarato and C. Vaccaro** ' Geochemical characterisation and geophysical mapping of Landfill leachates: the Marozzo canal case study (NE Italy)', *Environmental Geology*, Volume 45, Number 4 / February, 2004, Springer Berlin / Heidelberg

**17- Solid Waste Management,** *M.o.U.D.* Standing Committee on Urban Development, Editor.2008, Lok Sabha Secretariate: New Delhi. p. 85

**18- Subhasish Chattopadhyay a, Amit Dutta b, Subhabrata Ray.** Municipal solid waste management in Kolkata, India – A review, *Waste Management* 29 (2009) 1449–1458

**19- Twort, A. C. , Hoather, R. C. and Law, F. M. (1974)** *Water Supply*. Edward Arnold Publ. Ltd, London, UK

**20- Tatsi A. A. and A. I. Zouboulis, 2002.** A field investigation of the quantity and quality of leachate from a municipal solid waste landfill in a Mediterranean climate (Thessaloniki, Greece), *Adv. Environ. Res.* 6, 207-219.

**21- Rabinove C. J., R. H. Long Ford, and J. W. BrookHart, 1958.** Saline water resource of North Dakota U.S. Geol. Sur. *Water Supply* Paper 1428, 72.

**22- Rao N S, Hydrological Sci.J/J des Sci Hydrologiques, 2003,** 48(5), 835-847

**23- WHO (World Health Organization). 1997.** Guideline for drinking water quality, 2nd ed., Vol 2 Health criteria and other supporting information, *World Health organization*, Geneva, pp 940-949.

**24- Jamie F. VanGulck , R. Kerry Rowe 2004.** Influence of landfill leachate suspended solids on clog (biorock) formation, *Waste Management* 24 (2004) 723–738

**25- Jodie Duggan, 2005.** The potential for landfill leachate treatment using willows in the UK—A critical review, *Resources, Conservation and Recycling* 45 (2005) 97–113

**26- Hilary Theisen Integrated and S.A Vigil.** solid waste management" book by Tchobanoglous, [Mcgraw hill international editions]

**27- Vincent O. Ogunro and Hilary I. Inyang,** Relating Batch and Column Diffusion Coefficients for Leachable Contaminants in Particulate Waste Materials, *Journal of Environmental Engineering* © ASCE / October 2003.