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Analysis of Bhanpur Landfill Leachates : *Investigation and Recommendation*

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ABSTRACT

Landfill leachates are not geographically specific; rarely acknowledge the impact of site specific parameters such as age, water balance, type of waste, landfill operation, etc.; and cover such large ranges that they are often of little use. Analysis of data from lined landfills in Bhopal was needed to provide useful information for the design and management of landfill leachates. Analyses were designed to identify trends in the data and to determine the effects of climate, region or ocation, age of the fill, and waste characteristics on leachate quality.

KEY WORDS :

Leachate, Municipal solid waste leachate, Leachate analysis and leachate quality data.

INTRODUCTION :

Bhopal is the capital of Madhya Pradesh where Bhopal Municipal Corporation used to fill Municipal Solid Waste at Bhanpur landfill site. Sanitary landfilling is the preferred method of municipal solid waste (MSW) disposal due to its favorable economics. Within a landfill, a complex sequence of physically, chemically, and biologically mediated events occur. As water percolates through the landfill, contaminants are leached from the solid waste. This water, termed leachate, groundwater contamination from leachate were noted. Effective pollution control through the proper design of landfill and leachate management facilities requires an understanding of leachate quality.

The progress toward final stabilization of landfill solid waste is subject to the physical, chemical, and biological factors within the landfill environment, the age and characteristics of landfilled waste, the operational and management controls applied, as well as the site-specific external conditions.

Nonconservative constituents of leachate (primarily organic in nature) tend to decompose and stabilize with time, whereas conservative constituents will remain long after waste stabilization occurs. Conservative constituents include various heavy metals, chloride, and sulfide. Metals often are precipitated within the landfill are infrequently found at high concentrations in leachate, with the exception of iron.

Unfortunately, because of the variability in leachate quality, prediction of leachate characteristics as a function of time has been quite difficult. General trends in quality are possible, however these ranges are still large and prediction of the point in time at which each phase begins and ends is not possible as yet. Research in landfill management, such as the use of leachate recirculation, may make it possible to control waste decomposition and consequently make leachate characteristics more predictable.

FACTORS AFFECTING LEACHATE QUALITY

Leachate quality is highly variable. The variation in leachate quality can be attributed to many interacting factors such as the composition and depth of waste, the availability of moisture and oxygen, landfill design and operation, and waste age.

Waste composition

Municipal waste has great variation in composition and characteristics. The waste composition of refuse determines the extent of biological activity within the landfill (Chen and Bowerman, 1974). Rubbish, food and garden wastes, and crop and animal residues contribute to the organic material in leachate (Pohland and Harper, 1985).

Depth of Waste

Greater concentrations of constituents are found in leachates from deeper landfills under similar conditions of precipitation and percolation (Qasim and Chiang, 1994). Deeper fills require more water to reach saturation, require a longer time for decomposition, and distribute the leached material over a longer period of time (Qasim and Chiang, 1994; Lu et al., 1985). Water entering the fill will travel down through the waste. As the water percolates through the landfill, it contacts the refuse and leaches chemicals from the waste. Deep landfills offer greater contact time between the liquid and solid phases which increases leachate strength (McBean et al., 1995).

Moisture Availability

Water is the most significant factor influencing waste stabilization and leachate quality. Moisture addition has been demonstrated repeatedly to have a stimulating effect on methanogenesis (Barlaz et al., 1990), Moisture within the landfill serves as a reactant in the hydrolysis reactions, transports nutrients and enzymes, dissolves metabolites, provides pH buffering, dilutes inhibitory compounds, exposes surface area to microbial attack, and controls microbial cell swelling (Noble and Arnold, 1991). Lu et al. (1985) stated that high moisture flow rates can flush soluble organics and microbial cells out of the landfill and in such cases microbial activity plays a lesser role in determining leachate quality. Also, high moisture application rates can remove the majority of waste contaminants early in the life of the fill.

Available Oxygen

The quantity of free oxygen in a landfill dictates the type of decomposition (i.e. anaerobic or aerobic). Aerobic decomposition occurs during initial placement of waste, while oxygen is available. Aerobic degradation may continue to occur at, and just below, the surface of the fill (McBean et al., 1995). Chemicals released as a result of aerobic decomposition differ greatly from those produced during anaerobic degradation (Bagchi, 1990). During aerobic decomposition, microorganisms degrade organic matter to CO_2, H_2O, and partially degraded residual organics, producing considerable heat. High concentrations of organic acids, ammonia, hydrogen, carbon dioxide, methane, and water are produced during anaerobic degradation (McBean et al., 1995).

Temperature

Landfill temperature, a largely uncontrollable factor influencing leachate quality, has been shown to fluctuate with seasonal ambient temperature variations (Lu et al., 1985). Temperature affects bacterial growth and chemical reactions within the landfill. Each microorganism possesses an optimum growth temperature, and any deviation from that temperature will decrease growth due to enzyme deactivation and cell wall rupture. Solubility of many salts [e.g. $Ca_3(PO_4)_2$ and NaCl] increases with temperature. However, a number of compounds in leachate, such as $CaCO_3$ and $CaSO_4$, show a decrease in solubility with increasing temperature (Lu et al., 1985).

Age of Landfill

Leachate quality is greatly influenced by the length of time which has elapsed since waste placement. The quantity of chemicals in the waste is finite and, therefore, leachate quality reaches a peak after approximately two to three years followed by a gradual decline in ensuing years (McBean et al., 1995; Lu et al., 1985). Generally, leachate from new landfills will be high in BOD and COD and will then steadily decline, leveling off after about 10 years (Akyurek, 1995).

Nutrients

Ammonia concentrations between 50 and 200 mg/L have been shown to be beneficial to anaerobic processes. Ammonia concentrations between 200 and 1000 mg/L have been shown to have no adverse effects on anaerobic processes while concentrations ranging from 1500 to 3000 mg/L have been shown to have inhibitory effects at higher pH levels. Concentrations above 3000 mg/L were toxic to microorganisms (Pohland et al., 1992). Ammonia and organic nitrogen produced by decomposition of organics are stable in an anaerobic environment, and therefore represent a high percentage of the soluble nitrogen compounds in leachate (McBean et al., 1995). Leachates of older landfills generally have lower concentrations and percentages of these constituents (Robinson and Maris, 1979). Unlike ammonia concentrations, phosphate levels remain generally low throughout the life of the landfill. During later stages of waste stabilization, phosphorous may be limiting (Pohland and Harper, 1985).

Toxicity

Brown et al. (1991) investigated acute and genetic toxicity of municipal landfill leachate. Results of acute and genetic toxicity bioassays combined with chemical analyses and associated cancer risk assessment clearly showed that leachate from municipal solid waste landfills is just as toxic as leachate from landfills in which residential and hazardous wastes were codisposed. Leachate from MSW landfills even contained many of the same hazardous constituents as found in hazardous waste landfills. In addition, several researchers have found leachate to be quite toxic to rainbow trout and daphnia (Cameron and Koch, 1980; Atwater et al., 1983) and to have some toxicological impact on laboratory mice (Raddi et al., 1987).

Leachate Treatment

The quality of leachate directly affects viable leachate treatment alternatives. Leachate quality is quite variable from site to site and over time as a particular landfill ages. As a result, neither biological treatment nor physical/chemical treatment processes separately are able to achieve high treatment efficiencies (Keenan et al., 1984; Forgie, 1988; Copa et al., 1995). A combination of both types of treatment is the most effective process train for the treatment of leachate (Copa et al., 1995; Forgie, 1988).

The factor that most significantly affects the sequence and effectiveness of leachate treatment processes is the age of the landfill. Leachate from young landfills (first several years of operation) contains high concentrations of readily biodegradable organic matter e.g. volatile fatty acids (McBean et al., 1995). This young leachate is derived from complex biodegradation organics and simple dissolved organics. The high organic content of leachate produced at young landfills makes the leachate amenable to biological treatment (Venkataramani et al., 1974; Bagchi, 1990). Physical/chemical treatment processes used to treat leachate from young fills do not produce the same degree of organic removal that can be accomplished with biological treatment (Qasim and Chiang, 1994). Lema et al. (1988) determined that biological treatment is highly efficient in eliminating compounds with low molecular weight which are primarily found in young leachates. However, the concentration of several parameters contained in young leachate can inhibit biological treatment. To adjust the level of these constituents to an acceptable concentration for biological treatment, physical/chemical pretreatment of the leachate is frequently employed. For example, high concentrations of metals such as copper, zinc, and nickel cause biological inhibition and physical/chemical precipitation can be used to reduce the concentration of these heavy metals (McBean et al., 1995). Also, very high concentrations of ammonia (greater than 1000 mg/L) will inhibit nitrification (McBean et al., 1995). Through the use of physical/chemical methods, the ammonia level can be reduced to a more acceptable concentration prior to biological treatment (McBean et al., 1995).

It is apparent that neither biological nor physical/chemical treatment processes separately achieve high removal efficiencies because leachate is variable from landfill to landfill, and over time and space in a particular landfill. Physical/chemical processes are needed for the pretreatment of young leachate to make it amenable to biological treatment, and to hydrolyze some organics (refractory organics) found in leachate from older landfills. Biological treatment is primarily used to stabilize degradable organic matter found in young leachates.

TOXIC AND ORGANIC PARAMETERS

Many toxic and organic constituents have been detected in MSW landfill leachates. The toxic and organic parameters were separated into four categories: chlorinated compounds, aromatics, heavy metals, and miscellaneous constituents (parameters that could not be classified into the previous groups). A comparison of the number of detections in each category between the acidogenic and methanogenic phase was performed.

CONVENTIONAL PARAMETERS

The conventional parameters that were analyzed in this study were as follows:

- Biological Oxygen Demand (BOD),
- Chemical Oxygen Demand (COD),
- ammonia (NH_3),
- sulfate (SO_4),
- chloride (Cl),
- pH,
- manganese (Mn), and
- zinc (Zn).

CONCLUSION

1. BOD and COD concentrations appear to remain low throughout the life of the landfill, most likely due to dilution and stimulation of methanogenesis. The stimulation of methanogenesis is supported by elevated pH in the acidogenic phase, higher ratio for BOD relative to the other parameters, low BOD concentrations and significant gas production during the early years of landfill operation. No clearly determined chronological pattern in BOD and COD concentrations was observed.
2. Leachate from the waste fill has significantly higher concentrations of organic pollutants than leachate from the waste landfills as evidenced in the high COD and BOD levels.
3. A wide variety of toxic and organic compounds can be found in Bhopal landfill leachate. However, the concentration of these constituents is generally on the order of micrograms per liter.
4. Codisposal of ash with MSW does not appear to adversely impact leachate quality. Concentrations of heavy metals, BOD, COD, and ammonia in leachate from codisposal sites were not statistically higher than values reported for MSW sites. Chloride values were elevated in the ash leachate in the methanogenic phase because of the high chloride content of ash.

RECOMMENDATIONS

It was difficult compiling and analyzing the data obtained from the Ground Water Control Board (GWCB). Values for critical parameters such as BOD and COD were often missing. Also, many landfills only had available data for very limited periods of landfill operation. The limitations of the data could possibly affect the accuracy of the results. It is recommended that the GWCB require landfill sites to submit leachate data on disk in a standard format. This procedure would help reduce the quantity of missing data and would develop a complete database of all Bhopal leachate quality data. It would be ideal to have leachate data for many landfills from the time waste was first placed in the lined portions of the landfill. Further research of Bhopal leachate quality data is recommended using a more complete data set in order to develop more detailed time relationships for the organic as well as inorganic parameters. Extensive chronological analysis would aid in the design and operation of landfill systems and leachate treatment facilities. In addition, an improved database of operating parameters such as age of the landfill, waste composition, and depth of waste would be useful in identifying the affects of these site specific parameters on Bhopal leachate quality.

Bhopal leachate has low concentrations of organic constituents (e.g. BOD and COD) consequently requiring primarily physical/ chemical rather than biological treatment. Because it is dilute codisposal of Bhopal leachate and domestic wastewater at a Waste Water Treatment Plant (WWTP) would not adversely effect the WWTP. However, limited treatment of leachate constituents except for ammonia can be expected. Therefore, this method is suggested as a means of leachate treatment.

It is also recommended that an analysis of leachate quantities be conducted. This research could confirm that the nature of leachate produced at Bhopal landfills is a result of dilution from heavy rainfall, high degradation rates, or both. In addition, development of a more refined cluster analysis technique which incorporates standard deviations and complete data sets is suggested.

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