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Pollution Threat of Solid Waste Dump Sites on Ground Water

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Abstract
This paper presents the findings of a study on the impact of uncollected solid waste in urban areas on ground water quality. It documents the pollutant concentration of leachate from a solid waste dumpsite and the variation of the concentration of the constituents of the leachate with depth. Soil samples at varying depths below the dumpsite and solid waste samples at the dumpsite were subjected to synthetic leachate precipitation in the laboratory. The selected physical and chemical properties of the leachate were then measured. TDS, total hardness, conductivity, turbidity, and COD and nitrates concentration were found to decrease with an increase in depth while alkalinity, chlorides, pH and DO were found to increase as depth increased.

Keywords: *Solid Waste, Leachate, Migration, Pollution, Ground Water*

Introduction

Current global MSW generation levels are approximately 1.3 billion tonnes per year, and are expected to increase to approximately 2.2 billion tonnes per year by 2025 (World Bank, 2018b). This represents a significant increase in per capita waste generation rates, from 1.2 to 1.42 kg per person per day in the next fifteen years... When humans lived in small communities, the solid waste produced by these communities could easily be burned or buried. Chandran (1993), notes the potential environmental impact of this waste was minor because the material was rarely hazardous and was not being produced in large quantities. As towns and cities developed, people began to live in densely populated areas, and the production of waste became a health problem. In response to this threat, towns and cities designated dumping areas for solid waste, usually on the outskirts of the towns (Rotich et al 2005). All forms of solid waste were dumped, including industrial, medical, and household waste.

The adverse environmental impacts of these open dumps became apparent early in the 20th Century. Arntzen et al (2000) postulate that today, open dumps pose many risks to the environment and community health. In open dumps, rain water moves through the refuse and absorbs any organic and inorganic compounds (including metals, pesticides, and solvents) that are in the refuse. This liquid is known as leachate. This leachate then enters the soil below the dump and may eventually enter the ground water. For communities that depend on ground water to supply their drinking water, the formation and movement of leachate through the soil and into aquifers poses a risk to the environment and also to human health, especially if the leachate contains toxic chemicals.

Cointreau, (2004) highlights that open dumps also pose a risk to the environment in a different manner. Microorganisms present in the refuse use the refuse as a food source. Under the anaerobic (no oxygen) conditions typical in most dumps, these microorganisms convert the organic material in the refuse to methane and carbon dioxide. As the gas rises through the dump and escapes into the atmosphere, it sometimes picks up other organic compounds. The presence of large amounts of methane in this uncontrolled environment may result in explosions and fires. Additionally, this untreated gas may contain other compounds that pose a substantial health risk to nearby communities. As people learned more about what happens in dump sites, it became apparent that this initial attempt to manage solid waste disposal had created new problems. At some sites, these problems are still being addressed. It was obvious that an alternative method of disposal was essential.

Potential Environmental Impacts from Solid Waste Management Activities

The typical municipal solid waste stream (MSWS) will contain general wastes (organics and recyclables), special wastes (household hazardous, medical, and industrial waste), and construction and demolition debris (EMC 2007). Most adverse environmental impacts of solid waste management are rooted in inadequate or incomplete collection, or in inappropriate siting, design, operation, or maintenance of dumps or landfills (Rutherford et al 2000). Improper waste management activities can:

Impacts on Land

The accumulation of uncollected waste in undesignated land may lead to

- Reduction in flood retention areas due to a majority of disposal sites being located in low-lying areas such as marshy lands and abandoned paddy lands.
- Reduction and pollution of wetland habitats.
- Aesthetic impairment due to windblown litter and waste left uncovered.
- Degradation of land due to leachate seepage from uncontrolled dumping with adverse effects on soil fertility and productivity.
- Differential settlement in sites that are reclaimed for future development. With the decomposition of Municipal Solid Waste (MSW), settling is unpredictable with a possible risk of structural instability and collapse.

Impacts on Water Resources

In the absence of engineering methods to treat leachate generated from decomposing garbage, it enters groundwater and surface waters. The BOD (bio-chemical oxygen demand) of the leachate ranges from 2,000 - 30,000 mg/l (Tchobanoglous, et.al 1993), while the environmental authorities require that wastewater discharged to surface waters be treated to reduce BOD concentrations to no more than 30 mg/l. This gives an indication of the level of pollution generated by leachate likely to enter watercourses. This is particularly significant in areas where groundwater is the only source of potable water.

The impact of ground water contamination is generally irreversible. It is reported by the Secretariat for Infrastructure Development and Investment (SIDI) (1993) that the National Water Supply and Drainage Board (NWSDB) had considered the option of using groundwater to increase the supply of potable water to residents in the Greater Colombo area. However, due to the pollution of the ground water aquifers in the region, primarily caused by open dumping, the NWSDB was not able to proceed with this option. With Japanese funding amounting to Rs. 8.3 billion, the NWSDB has now initiated a project to tap the Kalu Ganga River (south of Colombo) as a source of water for the Greater Colombo Area (GCA).

Many Local Authorities dump MSW into or near rivers and streams with consequent contamination of potable water supply downstream. For example the Kelani River, which is the present source of potable water for the GCA, is polluted (SIDI 1993) by leachate from a number of dumpsites along the banks of the river. In instances where clinical waste is co-disposed of with other waste, there is a possibility of pathogenic organisms entering water courses, resulting in health risks to water users. Breeze (2012) reports in Dar es Salam at less than 40% of the solid waste generated in the city is collected for recovery or disposal. The remainder is illegally dumped in drains, rivers or by the road side. This results in increased flooding during the rainy season, risk of malaria carrying mosquitoes and greenhouse gas emissions. The incidence of illegal dumping is greatest in the unplanned and less affluent planned areas of the city where collection service is poor or doesn’t exist.

Impacts on the Ecosystem

Leachate from poorly managed solid waste contaminates water bodies. When solid waste is dumped into rivers or streams it can alter aquatic habitats and harm native plants and animals (Shamrukh et al 2001). The high nutrient content in organic wastes can deplete dissolved oxygen in water bodies, denying oxygen to fish and other aquatic life form. Solids can cause sedimentation and change stream flow and bottom habitat. Siting dumps or landfills in sensitive ecosystems may destroy or significantly damage these valuable natural resources and the services they provide. The waste also attracts vermin and scavenging animals, resulting in change in the ecological balance of the area. The poorly managed waste is thus a threat to the native species.

Impacts on Health

Zurbrügg (2003) reports some impacts of solid waste pollution to human health as;

- Insect/mosquito breeding in stagnant water pools on waste sites and in canals and waterways blocked or constricted with waste resulting in the spread of disease.
- Health hazards to workers and neighbouring residents: There are significant health risks due to the existence of vermin, insects, flies and scavenging animals particularly to workers on site and waste pickers. They are exposed to health hazards primarily by coming into contact with syringes, contaminated needles, other hospital wastes, faecal matter and hazardous wastes. Partly burnt organic compounds could also result in serious health problems.
- Nuisance caused to the neighbourhood due to odour, flies and constant movement of refuse transporting vehicles delivering waste to the site.
- Hazards associated with collapse of slopes where MSW is dumped in an uncontrolled manner with side slopes not maintained at IV: 3H. The structural failure of slopes can cause property damage and injury or loss of life.

Impact of landfill leachate on the groundwater quality

Leachate whether still acetogenic or older and methanogenic is in general quite capable of causing oxygen deprived conditions in watercourses which put at risk the natural ecology (Mufeed 2007). The ammoniacal nitrogen concentrations vary massively form site to site, but also rise during the later stages of the acetogenic stage, and at concentrations which vary according to the pH, but always by the time 100 mg/l ammoniacal nitrogen is reached will be toxic to fish and many other higher aquatic organisms (Fatta et al 1999). In groundwater the risk arises from the migration of leachate contamination into water supplies where the presence of ammoniacal nitrogen is and even its breakdown product nitrate will render the groundwater unsuitable for drinking. Nevertheless, the toxicity is not generally (if fact almost never) due to the presence of the sorts of chemicals thought of as "poisons", while some of the more highly poisonous chemicals are occasionally found, they are seen at minutely low concentrations, and the risk at these low levels is far lower than generally perceived by the public. Unfortunately, even dilute leachate which enter watercourses can cause the growth of "sewage fungus", and this can be the case on occasions where the leachate would not otherwise be significantly damaging. Sewage fungus grows to cover every surface, in the bed and all plant life. It is grey/white in colour and looks builds up to become a matted covering of fungal growth quite soon smothering the natural bed ecology.

Methods

Sampling – Excavation was made using augers. To ensure a good representation of the site characteristics, three sampling holes A, B and C were cut from near the edges of the waste pile on two opposite sides and from about the centre of the pile. Soil samples were collected at varying depths in each hole. The solid waste was sampled from different positions around the solid waste pile. These were then reconstituted to form the bulk sample for analysis.

In the laboratory - all the samples were air dried. The solid wastes were then sorted out to determine the compositions. The solid waste and the different soil samples were then subjected to the synthetic precipitation leachate procedure (to simulate the rainfall in the dump site). The solid waste sample that was used for leachate generation was prepared according to the recommendations of the USEPA, Office of Research and Monitoring. A total of 500g of the food waste, paper, unclassified, and sweepings with each component contributing a certain percentage mass equivalent to its total mass was prepared 500g of each of the soil samples obtained from different depths was used for the leachate study. The rate of application of water onto the samples was determined from the rainfall data. The elements that were tested for in the soil samples were determined by the quality of leachate generated from the solid wastes. The USEPA 1992, SW-846 Test Methods for Evaluating Solid Waste was used to analyse the samples.

Results

A graphical analysis of these data gave a clear representation of the variations as shown in the figure 1, figure 2, and figure 3.

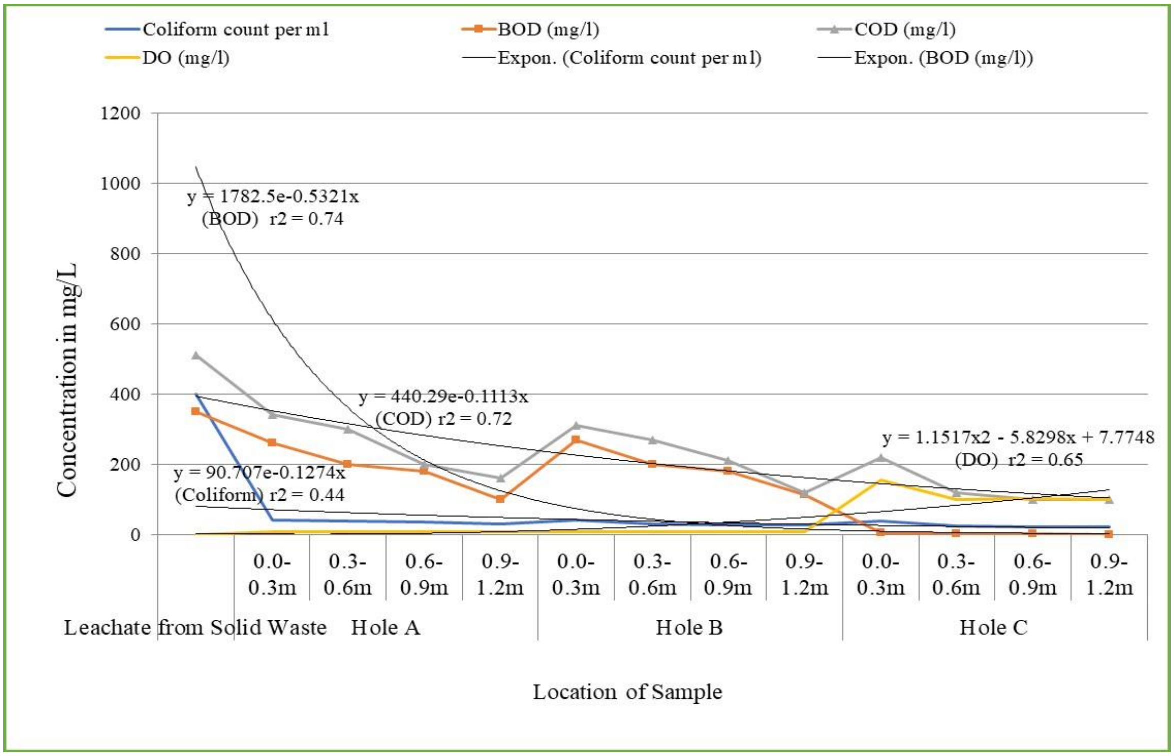

Figure 1: Variation of Coliform, BOD, COD and DO with Depth

The pollutants concentrations in the solid waste derived from the simulated rainfall was plotted in the same graph with that of the three test holes. The pollutant concentrations for the test holes were derived from the extraction from the soil cuts.

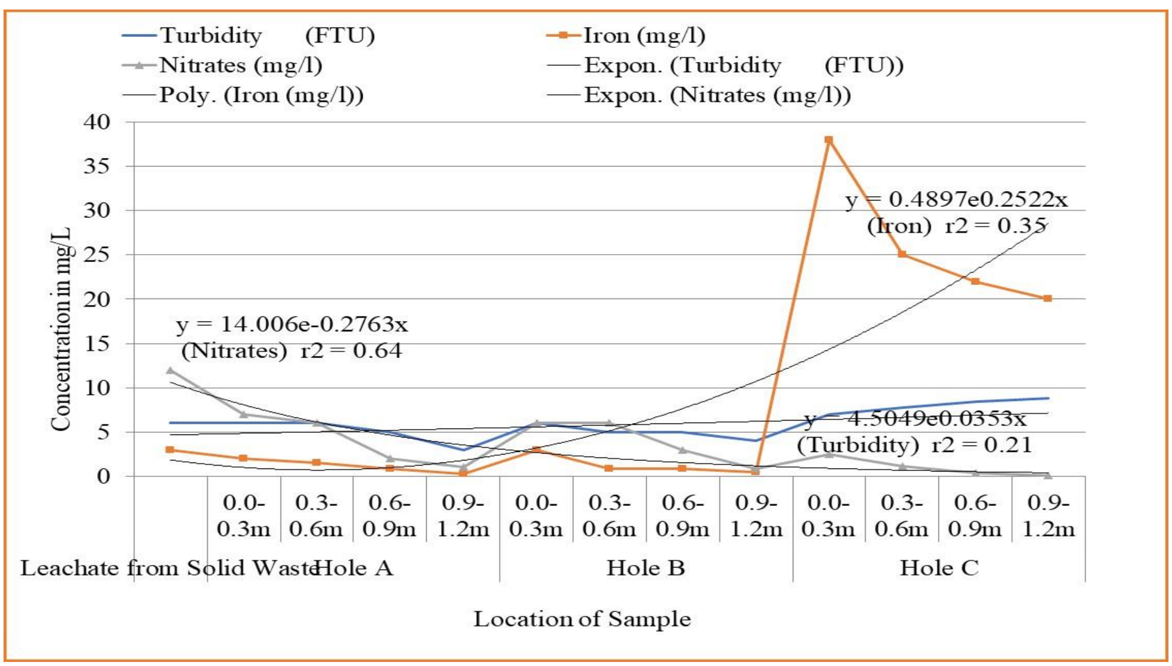

Figure 2: Variation of Turbidity, Iron and with Depth

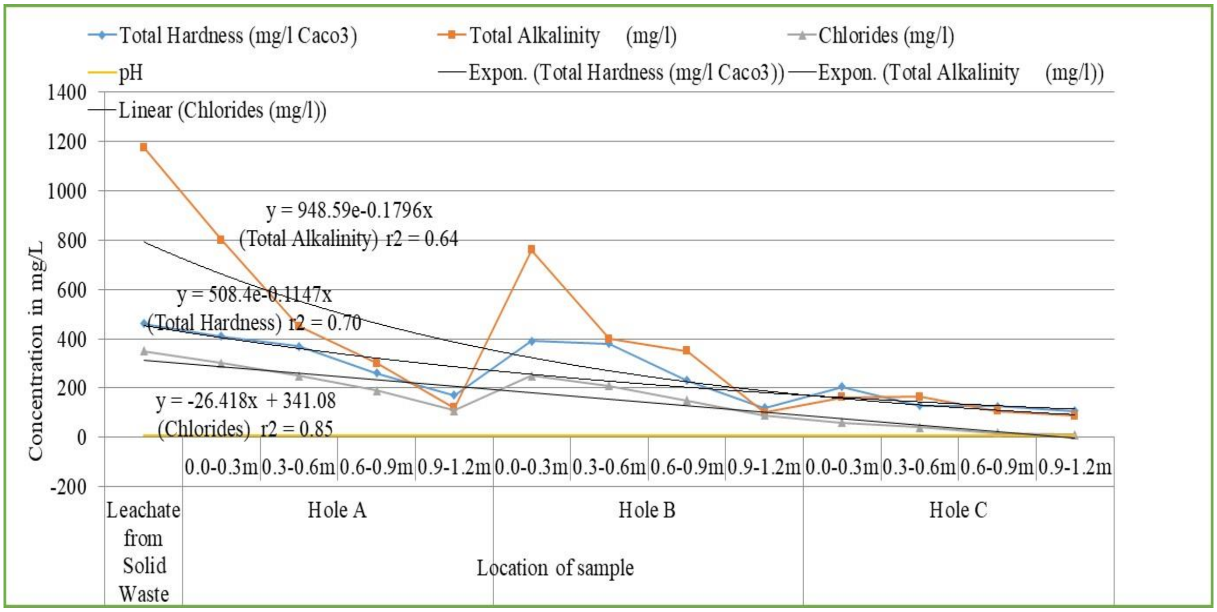

Figure 3: Variation of Total Hardness, Total Alkalinity, Chloride and pH with Depth

Discussion

Leachate composition and concentration is directly related to the composition of the solid waste that is dumped on the site. This was clearly portrayed from the concentration of leachates generated from the solid and soil samples. There was a 50 % reduction in pollutant concentration with increase in depth, for all the sampling holes. The figures also show evidence of the influence of site slope on the pollutant concentration. The sample holes B and C which are higher were higher in elevation, compared to sampling hole A which had lower pollutants concentrations. Variation of the different constituents depends on the element being considered. From this study, it was found that the concentration of COD, BOD, total hardness, TDS, Chlorides, nitrates, iron and conductivity were found to decrease with depth while those of DO, pH and alkalinity increased with depth. The decrease with depth was mostly associated with the attenuation process. This was directly related to the increase of the other elements.

Presence of these pollution indicators is an indication that leachate may be a source of ground water pollution. However, presence of these elements in the ground water does not necessarily mean that it is polluted and actually pollution criteria will depend on the type of use made of the water. The study further revealed that the level of the pollution indicators in the leachate generated from solid waste is higher than that when the leachate has infiltrated into the soil. This means that leachate washed directly to surface waters has higher potential to pollute than that percolating into the water bearing strata below the dumping site.

Leachate quality predicted by laboratory tests vary widely from the actual leachate obtained from a mature landfill (Bagchi, 1994). However, assessment of leachate quality is important for landfill design purposes. This helps in identifying whether the waste is hazardous, designing or getting access to a suitable leachate treatment plant, making a suitable landfill design and developing a list of chemicals for ground water monitoring programme.

The soil samples from the test holes exhibited a decline in total alkalinity, total hardness and chloride concentrations, with increase in depth. Hardness and total alkalinity were modelled exponentially, giving fits with coefficient of determination of 0.7 and 0.638 respectively. Chlorides exhibited a linear variation with a coefficient of determination of a 0.852.

The coliform counts, BOD and COD concentration reduced throughout the period of the study. As reflected in Figure 1, the coliform counts, BOD and COD trends were fitted exponentially with coefficient of determination of 0.436, 0.73 and 0.715 respectively. Notable variation was with the DO which was much higher in the samples from test hole C and a polynomial fit made on the data, resulting in a coefficient of determination of 0.647. In all samples the initial coliform count, BOD and COD concentrations of the solid waste was much higher than the first set of concentrations transmitted into the soil strata.. The parameters also showed reduced concentrations with their increase in depth and distance from the dump site.

In figure 2, the iron and nitrate concentrations dropped with depth in test holes A and B, but shot more than ten times in the iron concentration in test hole C. The same trend was noted as the sample point radius increased. In all samples the initial concentrations of the three parameters in the solid waste was much higher than the first set of concentrations transmitted into the soil strata. The total hardness accompanied by corresponding rise in turbidity in samples from test hole C. Though exponential fits were tried on the nitrates and turbidity, they were not good enough with values of the coefficient of determinant of 0.63 and 0.21 respectively.

The samples analysed in the study revealed that the concentration of COD, BOD, total hardness, TDS, Chlorides, nitrates, iron and conductivity decreased with depth while those of DO, pH and alkalinity increased with depth. Presence of these pollution indicators is clear evidence that leachates can be a source of ground water pollution. Presence of these elements in ground water does not necessarily mean that it is polluted; pollution criteria will depend on the type of use of the water. The study further revealed that the level of pollution indicators in the leachate generated from solid waste is higher than that for the leachate after it infiltrates into the soil. This means that leachate washed directly to surface waters has higher potential to pollute than that percolating into the water bearing strata below the dumping site.

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Author's Biography

Dr. Dulo Simeon Otieno is a Water Resources Engineer with over 25 years' experience as a Team Leader in Design, Supervision and evaluation of water and sanitation projects in Kenya and Rwanda. Dr. Dulo has served as a water sector Review Consultant, Hydrologist, Water Engineer and a consultant in various Consulting firms. He is currently a senior lecturer at the University of Nairobi.

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