Vulnerability Assessment of Groundwater Contamination from an Open dumpsite: Labete Dumpsite as a Case study

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Abstract. The assessment of leachate impact on groundwater is very crucial to human health and its environment. This research work aimed at assessing Labete dumpsite and its effects on groundwater integrity in the vicinity of the dumpsite. Soil samples were collected for leachate analysis at a depth of 0.5m from the earth's surface within the proximity of the dumpsite. Four different groundwater samples (GW1-GW4) were collected at radial distances from the dumpsite. Collected water samples were analyzed to examine their Cr, Fe, Cd, Pb, Zn, and Cu ions content. Physicochemical and bacteriological analysis were also considered and measured against NSDWQ and WHO standards for drinking water. The results showed that the level of groundwater contamination is directly proportional to the depth of the water table (collection) and the distance of the dumpsite from the shallow wells. GW1 and GW2 groundwater samples were not fit for consumption unless adequately treated.

Keywords: Dumpsite; leachate; groundwater; contaminant; electrical conductivity

1. Introduction
In developing countries, solid wastes are disposed of without effective management and consideration for groundwater contamination through leaching. In an engineered waste disposal system, groundwater contamination is inhibited by the introduction of a liner system [1]. Thus helps in the provision of safe drinking water. Globally, one of the primary human needs is safe drinking water. Most communities tap into the closest water source in their area, whether it is groundwater via a borehole or surface water such as a river [2]. The safety of drinking water is thus paramount and needs to be adequately monitored. In most developing countries, surface and groundwater are the primary sources of water for all basic needs. These water sources are also easily susceptible to contamination by human activities and, the degree of pollution from any of these sources is dependent on environmental control, waste management practices, and environmental protection laws in each area [3]. However, owing to several anthropogenic activities, land use [4], and consequently, high cost involved in its purification and distribution, the reliance of rural dwellers in developing nations on these water sources is on its lowest ebb. These reductions in consumption of surface water leading to increased dependency on the groundwater.
Groundwater, as defined by [5], is the water found in soil and rock cracks and crevices. It is stored in and moves slowly through geologic formations of clay, sand, and rocks called aquifers. It is everywhere, however, at varying depths, and its supplies are replenished by precipitation, which infiltrates and percolates through the cracks and crevices in soil and rock into the aquifer [5]. However, when permeable materials overlay the aquifer, it can be easily contaminated and polluted from the myriads of human activities [5, 6]. Of particular note is the contribution of waste management and disposal to groundwater contamination. In developing nations, un-engineered landfills and dumpsites are ubiquitous [7, 8]. These systems, if engineered, will help urban centers in effectively and efficiently managing the colossal waste generated through the myriad of activities taking place. However, engineered landfill adoption in developing countries is still lagging, hence contamination the groundwater resources [7, 9-11]. Mor et al. [12] explained that areas surrounding landfills and municipal dumpsites are at risk of groundwater contamination owing to the decomposition of different types of wastes; these wastes percolate into the aquifer during groundwater recharge or on gravity. Bishop [13] defined municipal solid waste as waste generated from single-family and multifamily residences and hotels. In developing nations, due to urbanization and industrialization, there arose significant accumulation of municipal solid waste [14-16]. In these nations, dump or tip, open placement of solid waste, or incineration is the usual practice due to the low budget for waste disposal and non-availability of trained human resources [15, 17]. Ali et al. [15], Kanmani and Gandhimathi [17], and Papadopoulou et al. [6] in their research identified the dangers of open dumpsites and environmental contamination inherent in its adoption. Management of solid waste and its disposal through various means such as landfills, open dumps, or incinerations release a significant quantity of metals into the environment and groundwater [17-22]. Samuding [23], in his research, stated that leachate, which contains organic compounds, inorganic compounds, and heavy metals in high quantities, is produced when precipitation comes in contact with the decomposed solid waste. These leachates infiltrate and percolate into the shallow aquifer and pollute it [24]. Due to leachate migration, soil-water becomes contaminated with heavy metals. These metals, due to their non-biodegradable properties, lead to health problems when consumed [25] and cause taste and odor problems and oxygen depletion in groundwater [25]. Hence, the need to assess the effect and contamination level of wells built in the circumference of a dumpsite. This study is unique in its focus on usable water and in its approach of considering water sources from the homes of community members close to pollutant sites.

2. Materials and Methods

2.1 Description of the Study Area

The Labete dumping site is located at Kajola, Oshogbo, Osun State, Nigeria, as shown in Figure 1. The dumpsite is about 17.5 meters square in size and bounded by Olodo, Ile sango, and Labete communities. This dumpsite is an open dumping site and has neither a leachate collection system nor an impermeable liner system. Due to the lack of or inadequate supplies of public water in the vicinity of the dumpsite, the majority of the inhabitants rely on shallow wells as their sources of water for domestic uses. From visual inspection, wastes deposited in this dumpsite includes; waste from single-family and multifamily residences, hotel. These consist of residential wastes, commercial and industrial wastes, and agricultural waste, as shown in figure 2a and b.
Figure 1. The layout of Kajola Osogbo (location of the dumpsite), Osun State

Figure 2 (a) Front view of the dumpsite (b) Transported waste to the downstream by erosion and wind

2.2 Field Survey

2.2.1 Determination of Well Distance and Depth

The distance of the wells was obtained by taking coordinate of the two points to be measured, using the GPS (Global Positioning System), from the geographical coordinate German 76 series handheld GPS. The GPS receiver obtained the longitude and latitude in World geodetic system datum, reference with UTM (Universal Transverse Mercator) zone 31 north. The depth of the wells was
determined by immersing a water supply pipe with a total length of 7.24m into the selected well. A measuring tape was used to measure the marked point on the pipe immediately before taking the next measurement.

2.2.2 Sampling of groundwater and soil for leachate test

Water samples were collected from four wells (GW1-GW4), as shown in table 1. Samples were collected in pre-treated 1L plastic bottles (pre-treatment of bottles was carried out by washing with distilled water) and rinsing thrice with the representative samples. The procedures followed the work of Aderemi and Falade [26]. Furthermore, soil samples were collected using digging set to excavate to a depth of 0.5m below the earth’s surface around the dumpsite’s vicinity during the dry season of January. The Samples were collected in a plastic bag and transported to the laboratory for leachate analysis. Leachate analysis was done in accordance with ASTM D4874.

2.2.3 Characterization of the selected samples.

Collected water samples were analyzed for metals, physicochemical, and microbial parameters, according to [27] and compared to Nigerian Standards for Drinking Water Quality (NSDWQ) and water quality parameters of World Health Organization (WHO). The concentrations of heavy metals were determined using an atomic absorption spectrophotometer (TAG 990 AS machine). Parameters such as pH, electrical, dissolved oxygen (DO), chemical oxygen demand (COD), biochemical oxygen demand (BOD), turbidity, total alkalinity, magnesium (Mg²⁺), calcium (Ca²⁺), chromium (Cr³⁺), copper (Cu²⁺), iron (Fe²⁺), zinc (Zn²⁺), cadmium (Cd²⁺), and lead (Pb²⁺) were analyzed in the leachate and groundwater samples.

Table 1. Average depth and distance Groundwater from Dumpsite

| Well     | depth(m) | distance(m) | distance/depth(m) | GPS location         |
|----------|----------|-------------|-------------------|----------------------|
| GW1      | 3.7      | 4.5         | 1.2               | 7.764667 N, 4.560783 E |
| GW2      | 4.9      | 18          | 3.7               | 7.764714 N, 4.561211 E |
| GW3      | 4.5      | 23.3        | 5.2               | 7.764380 N, 4.561376 E |
| GW4      | 4.7      | 19.6        | 4.2               | 7.764380 N, 4.561376 E |

3. Result and Discussion

3.1 Heavy metal analysis for groundwater and leachate sample.

The groundwater parameters analyzed are all within the permissible limit provided by WHO and NSDWQ except for cadmium, which was in higher concentrations for GW1 and GW2 wells with values of 0.06 and 0.02mg/l respectively as shown in Table 2. These values depict that cadmium levels in GW1 and GW2 wells and its environs are at an alarming stage, with high concentrations. World Health Organization [28] recommended a concentration of Cd ions below 0.003 mg/l in drinking water. Still, the results of these two wells had levels of the toxic metal that exceeded the recommended threshold. Furthermore, the position of the well plays an essential role in its contamination as GW3 and GW4, which were at the downstream, and a considerable distance shows no Cd contamination as opposed to GW1 and GW2.
Cadmium (Cd) ions contamination in water according to research by [29-32] is associated with the presence of either electronic waste, metal industries, sewage sludge, mining wastes, open-air waste burning, coal combustion, steel industry, concrete production, or artificial phosphate fertilizers in the dumpsite which thereby leach into the subsoil. Also, aquifer type contributes to the presence of these ions in a significant quantity [29]. Consequently, water with a high-level of Cd ions is carcinogenic [33, 34]. Hence, it adversely affects the vital organs in the human body. The presence of iron, lead, and zinc ion in the leachate signifies the presence of metal scraps, batteries, lead-based paints and lead pipes, fluorescent tubes, batteries, food wastes, and burning of tires at the dumpsite [35]. Furthermore, the presence of lead and cadmium in the samples can be attributed to the sites’ sub-surface geology [36, 37].

Table 2: Characteristics of heavy metal in leachate and groundwater samples

| Sample | Cr (mg/l) | Fe (mg/l) | Cd (mg/l) | Pb (mg/l) | Zn (mg/l) | Cu (mg/l) |
|--------|-----------|-----------|-----------|-----------|-----------|-----------|
| GW1    | 0.04      | 0.26      | 0.06      | ND        | 0.53      | 0.96      |
| GW2    | 0.02      | 0.10      | 0.02      | ND        | 0.34      | 0.87      |
| GW3    | 0.03      | 0.03      | ND        | ND        | 0.26      | 0.69      |
| GW4    | 0.03      | 0.17      | ND        | ND        | 0.22      | 0.64      |
| LS     | 2.67      | 10.62     | 3.045     | 2.39      | 10.61     | 6.91      |
| NSDWQ  | 0.05      | 0.3       | 0.003     | 0.01      | 3.0       | 1.0       |
| WHO    | 0.05      | 0.3       | 0.003     | 0.01      | NS        | 2.0       |

Note: All heavy metal values are given in mg/l
NSDWQ Values are the maximum permitted levels in the Nigerian Standards for Drinking Water Quality, ND- Not detected, NS- Not supplied and LS- leachate sample. WHO values are the maximum permitted levels in the WHO Drinking Water Quality Guideline

3.2 Physicochemical analysis
pH, a measure of acidity and alkalinity of a solid/liquid, it is an important parameter as it influences the rate of contaminants transportation, dissolution of minerals in the soil and the growth of microbes. A low and high pH value indicates acidic and alkaline water, respectively. As seen in Table 3, the water samples and the leachate had an acceptable pH value. Furthermore, calcium and magnesium ions, turbidity, dissolved oxygen, color, and electrical conductivity of the groundwater samples collected conformed to WHO water quality standards.

BOD and COD indicators in environmental studies indicate the pollutant strength of polluted water [38, 39]. Table 3 showed that the samples tested had high BOD, high COD, and alkalinity values, which is an indication of leachate infiltration into the subsoil.

3.3 Microbial analysis
Coliform is naturally present in the environment [11, 40, 41], fecal coliform and Escherichia-Coli (E. coli) are derived from human and animal waste [42]. As shown in Table 4, the presence of fecal coliform and E. coli in water the presence of human or animal waste. The presence of E. coli in groundwater is influenced by groundwater flow based on the topography of the area [42]. In groundwater, sources of total and fecal coliform may include run-offs from decomposed agricultural waste, effluents from a septic tank or sewage disposal, and infiltration of animal fecal
mater [43]. E-coli and total coliform were counted in the four wells, and the result presented in Table 4.

| Sample | GW1 | GW2 | GW3 | GW4 | LS | WHO | NSDWQ |
|--------|-----|-----|-----|-----|----|-----|-------|
| pH     | 7.90| 6.78| 6.90| 7.72| 6.45| 6.5-9.5| 6.5-8.5|
| EC (ms/cm) | -  | -   | -   | -   | 20.24| <5  |  |
| BOD5   | 8.50| 8.25| 7.75| 7.00| 6 | 6 | |
| Mg (mg/l) | 3.50| 3.00| 2.45| 3.10| 3.55| 50 | |
| DO (mg/l) | 0.32| 0.26| 0.23| 0.16| 4.11| 7.27| 13.05|
| Ca (mg/l) | 23.52| 22.55| 19.24| 17.45| 32.02| 75 | 75 |
| COD    | 5.30| 6.01| 5.10| 5.49| 7856.56| 1000 | |
| Alkalinity | 178 | 178 | 178 | 178 | 356 | 200 | |
| Turbidity (NTU) | 2.50| 3.00| 2.01| 3.50| 38 | 5 | |
| Color  | Colorless | Colorless | Colorless | Colorless | |

Table 4. Microbial analysis of the collected water samples

| Samples | $10^4$ (CFU/ml) Coliform | $10^4$ (CFU/ml) General Bacterial |
|---------|---------------------------|----------------------------------|
| GW1     | 3.57                      | 6.75                             |
| GW 2    | 2.62                      | 2.12                             |
| GW3     | 2.62                      | 2.17                             |
| GW4     | 1.55                      | 1.75                             |
| WHO     | 0                         | 0                                |
This result is expressed as (Coliform Microbial Unit) and indicates the extent of fecal matter present in it. Table 4 showed that the four wells had been contaminated with fecal material based on the coliform and bacterial content in comparison to the WHO standard; these microbes can cause a myriad of disease to the consumer if the water is not properly treated before consumption as [28] specified for drinking water quality, and water must utterly free from any colony.

In summary, based on the obtained results from the physicochemical, heavy metals and microbial analysis of the water samples and leachate, it can be deduced that the concentrations of the analyzed parameters have decreased with the distance from the landfill, which can be linked to biodegradation and dilution [44, 45].

4. Conclusion.
From the study conducted, the followings are the conclusions.

i The distance and depth of the wells from the source of leachate have a more significant impact on the degree and extent of contamination of groundwater and surface water. Therefore, wells with longer distances away from the dumpsite boundary and appreciable varying depth difference should be considered when planning for good construction in the future.

ii Groundwater samples from all the wells are unsuitable for drinking purposes owing to the elevated levels of cadmium and fecal waste in them.

iii Therefore, there is an urgent need to improve the waste management practices in the study area through the construction of proper engineered sanitary landfill sites to curtail the pollution of groundwater.

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