Applied Water Science (2022) 12:130
https://doi.org/10.1007/s13201-022-01653-z

REVIEW ARTICLE

Review article on impact of groundwater contamination due to dumpsites using geophysical and physiochemical methods

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Received: 2 July 2020 / Accepted: 14 March 2022 / Published online: 15 April 2022

Abstract

Dumpsite is a widespread land meant or designed for deposition of waste and unwanted materials from household, institutions, industries or the environment and is generally open or covered with soil layer with or without liner at the bottom. Dump/landfill is a major source of contamination of groundwater. This study is therefore designed to review studies on the impact of groundwater contamination due to dumpsites using geophysical and physiochemical methods. The geophysical methods adopted by the studies under review are Electrical Resistivity, Electromagnetic Induction using Very-Low-Frequency and Seismic Refraction methods. The results obtained using the resistivity methods showed zones or area with low resistivity as leachate plume and fractured subsurface as contaminant pathways. The result was complimented by other geophysical techniques applied. The results obtained with the application of physiochemical analyses of leachate inferred various degrees of severe contamination of groundwater due to organics, salts and heavy metals. As such, consumption of such water is dangerous to human health. The review also showed that age of the dumps and the migration distance of the leachate are important factors that require consideration because of the closer the dumpsite the higher the concentration of the contaminant.

Keywords Groundwater · Pollution · Dumpsite · Delineation · Leachate · Physio-chemical

Introduction

Dumpsite is a widespread land meant or designed for deposition of waste and unwanted materials from household, institutions, industry or environment and is generally open or covered with soil layer with or without liner at the bottom. These, most times lead to pollution and contamination of the environment. The presence of dumpsite in an area most times adversely affects the general condition of environment and residents of the area. It is worthy of note that when dumpsites are not covered (open) they attract flies, insects and other animals that would cause diseases or other public health problems to people living around such waste management facilities most especially scavengers (Dong et al. 2008).

In Nigeria and most other developing countries, solid wastes are disposed or dumped in barren lands and many are not properly managed if managed at all. Dumpsite could be classified as landfills and open dumpsites. Landfills are properly designed to offer a great advantage over the open dumpsites like minimization of environmental issues and reduction of health risks. However, they have been considered to be major contributors to groundwater pollution due to the leakage of solutions from leachate to the ground. This is a combination of contaminants having different chemical components that are toxic, (Yang et al. 2013; Regadío et al. 2012; Li et al. 2014). Leachates move through the dump to the bottom and sides beneath the soil until it gets to the groundwater zone or aquifer by pull of gravity. The contaminants from the leachate will first get to the unsaturated zone and later move to the groundwater table in the saturated zone. Hence, groundwater contamination from leachate migration due to dumpsite can be a major source of environmental problem and concern (Singh et al. 2008) but lined dumps on the other hand are better in terms of prevention of contamination, however, lined dumps could also be a source of problem to the quality of groundwater if the liners fail (Banu and Berrin 2015).

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Groundwater generally is an important and renewable source of water for human life and any form of economic development. It constitutes part of the earth's water system and the hydrologic cycle is incomplete without it. It occurs in permeable geologic formations called aquifers. These form structures that can store and transmit enough quantity of water to the wells as fast as possible. Groundwater plays an important role in agricultural irrigation particularly in the rural areas where it is mainly the key to provide additional resources for food security and in cities, it is an important source of quality water at relatively low cost where pipe borne water is not guaranteed. Groundwater is threatened by degradation due to contamination and also by misuse. The threat due to pollution as a result of disposal of chemicals to the land surface by agricultural, industrial and domestic dumps is of great concern to humanity.

Groundwater contaminations due to dumpsite are mainly due to contaminants potential of leachate from the waste body. The bye products of chemicals and biological reactions from dump wastes are associated with dissolved or suspended materials from leachate (Chian and Dewalle 1976). These leachates are mainly composed of organic or inorganic constituents of biodegradation of solid wastes flowing out from the refuse dumps, saturated with rainwater flowing through them (Kassenga and Mbluligwe 2009). Municipal solid wastes are mainly composed of industrial and household deposits resulting in leachate with high ion concentrations and hence very low resistivity. This in turn has a great impact on the chemistry of the resultant water.

The chemical composition of groundwater is determined by how suitable the water is for human and animal consumption, agricultural, industrial and other purposes (Babiker et al. 2007). Hence, proper maintenance, evaluation and monitoring of dumpsite especially around water environment are very essential in reducing leachate contamination and ensuring the quality of groundwater.

Many researchers have investigated groundwater pollution due to dumpsites adopting different methodologies like geophysical investigation and/or hydro-physiochemical analysis. The available geophysical methods among others include: Electrical resistivity, Seismic refraction, Magnetic and electromagnetic induction that have been found reliable and competent for such environmental and engineering studies, because most contaminants are conductive naturally (Atekwana et al. 2000; Olafisoye et al. 2013; Kassenga and Mbluligwe 2009; Ustra et al.2012).

A geophysical method is among the best approach for characterization of subsurface geology and hydrology without disrupting the natural arrangement of the subsurface geology. This was the method used by Pantelis et al. 2007 in their study to determine the electromagnetic, electrical, and acoustic properties of the sub-surface. (Olafisoye et al. 2013; Igboama, et al. 2021) on the other hand carried out their study using Schlumberger electrical array and interpreted the field data obtained by application of partial curve matching technique (Koefoed 1979) adopting master curves. Abdullahi, et al. 2011 carried out geophysical surveys of municipal waste dump using integrated geophysical method while Bayode, et al. 2011 in their study at Otutubiosun dumpsite, Akure, Southwestern Nigeria used two different geoelectric arrays: dipole–dipole and Vertical Electrical Sounding (VES) techniques. Hydro-chemical and geophysical methods were used in a study around Ajakanga dumpsite located in southwestern part of Nigeria by Ganiyu, et al. (2016). The results of this study combined with existing hand-dug wells around the dumpsite gave detailed empirical information about the dumpsite as well as the extent of leachate plume migration (Ganiyu, et al. 2016). All the above studies showed groundwater contamination by various applications of geophysical methods.

Several scholars have carried out research on groundwater contamination due to dumpsites based on hydrogeochemical or physiochemical analyses (Abd El-Salam and Abu-Zuid 2015; Armah et al. 2012; Afolayan et al.2012; Badejo et al.2013; Igboama, et al. 2021). A study by Oyelami et al. 2013 assessed the effect of a dumpsite on groundwater in Aduramigba Estate within Osogbo Metropolis, Nigeria. In their study, analysis of water samples was carried out for physiochemical parameters like ions, trace metals, electrical conductivity, temperature and pH using AAS, Iron Chromatographic, titrimetric methods, multi parameter and EC/pH meter.

In Central Poland, Piezometers mounted by Przydatek and Kanownik (2019) around a landfill were used to monitor and evaluate the water quality flowing into and around the area of the landfill site for a period of seven years. The investigation by Abd El-Salam and Abu-Zuid (2015) involved the analysis of leachate samples for characterizing and determining groundwater quality in Egypt.

In view of the above investigations, this study is therefore designed to review different studies done with the use of geophysical and physiochemical methods investigating the impact of groundwater contamination due to dumpsites.

Causes of groundwater pollution

A number of factors are responsible for groundwater contamination. Some of the factors are as follows:

- Natural Sources: Naturally some substances found in the soils and rocks can dissolve in water thereby causing contamination. Examples of these among others include: Iron, Copper, lead, Manganese, Mercury, Uranium, Chlorides, and arsenic

- Solid Waste: This is one major factor responsible for groundwater pollution. These wastes can be collected into dumpsites/landfills and products of degradation and chemicals from them are percolated into the groundwater through precipitation and surface runoffs. Examples include manure, garbage and industrial wastes.
- Grave yards: Leachate from decayed dead bodies also causes groundwater pollution.
- Septic Systems: These are another important cause of groundwater pollution. The pollutants are outflow from septic tanks, privies, cesspools, etc. Leakages from these when not properly designed release contaminants like oils, nitrates, chemicals and bacteria into groundwater.
- Hazardous Waste Disposal: Wastes like motor engine and brake oil, cooking oil, photographic chemicals, paints and chemicals from swimming pool are called hazardous waste. When these are disposed directly into the environment or through septic tanks cause serious contamination of groundwater.
- Chemicals for Agricultural Purposes: Agricultural chemicals such as fertilizers and pesticides when added in excess can lead to groundwater contamination. These chemicals seep deeper into groundwater with the aid of rainfall.
- Petroleum Products. Storage of petroleum products are done with the tanks either located underground or above the ground. Also, the conveyance of petroleum products is mainly done underground using pipelines. Leakages from these materials can lead to pollution and contamination of water. The chemicals spilled seep into the ground with water causing pollution of groundwater.
- Surface impoundments: These are shallow dishes used to store liquid wastes mainly from factories. They are designed to have clay liners or leachates to prevent leaching thus defective liners may lead to groundwater contamination due to leakage.
- Injection wells. There are various uses of injection wells like collection of disposable water from industrial and commercial effluents. The lack of proper regulation guiding its use can cause hazardous chemicals from injection wells to pollute groundwater.
- Mining Activities: This is another cause of pollution where soluble minerals can be leached through precipitation from the sites to the groundwater.

Generation of solid waste in Nigerian cities

In developing nations like Nigeria, where there is rapid increase in population, increase in socio-economic development, industrialization, technology advancements, change in lifestyles and consumption patterns, the administration and coordination of solid waste has become a big challenge. According to (World Bank 2012), the waste generated in some Nigerian cities is estimated at 0.65−0.95 kg/capita/day as shown in Table 1.

From Table 1, Lagos with a population of 21 million generates 7 million tones of waste annually at generation rate of 0.92 kg/capita/day. Also Ibadan with a population of 3.6 million generates 0.94 million tonnes per year giving 0.72 kg/capita/day. Abuja, the nation's capital with fast population growth has 1.9 million people with a generation rate of 0.95 kg/capita/day. Compared with other nations globally, Nigeria, like other developing countries, generates less waste but lacks effective waste management. This data is based on 2006 population Census implying that the solid waste generated at present should be much more with a population estimate of 220 million people and not much improvement in waste management.

Table 1 Quantity of solid waste generated in some Nigerian cities. Source: *Population estimation (NPC 2006)

City	Population estimation	Estimated kg/capita/day	Tonnes/day	Tonnes/year
Minna	346,524	0.68	235	86,007
Enugu	817,757	0.74	605	220,876
BirninKebbi	128,403	0.65	83	30,463
Lagos	21,000,000	0.92	119,320	7,051,800
Port Harcourt	1,363,596	0.85	1159	423,055
Bauchi	493,730	0.68	336	122,543
Abuja	1,857,298	0.95	1764	644,018
Ibadan	3,565,108	0.72	2566	936,910
Kaduna	1,582,102	0.70	1107	404,227
Onitsha	561,066	0.69	387	141,304
Sokoto	563,861	0.68	383	139,950
Jos	816,824	0.73	596	217,642
Benin City	1,125,058	0.78	877	320,304

The composition and nature of Solid waste is greatly affected by some factors such as standards of living, nature of foods and eating habits, social status, level of literacy, culture, rituals, rate of development and topographical conditions (Jin et al. 2006). Most Developing countries have high percentage of organic wastes, Nigeria inclusive. This is corroborated by Ike et al. (2018) whose study revealed that in Nigeria, 52% of wastes generated are organic in nature (food wastes), 44% is made up of recyclable materials like paper, metal, glass, textile and plastic if properly harnessed while the remaining 4% are classified as others. The organic wastes when decomposed bring together all forms of germs, insects and rodents and the consequential effect is pollution of the environment with bad odour and increase in health risk to the people in the environment.

Leachates, heavy metals and ground water pollution

Some wastes in a dumpsite could be industrial containing metals such as arsenic, lead (Pb), cadmium (Cd), copper (Cu), zinc (Zn), Nickel (Ni), which are called heavy metals. The concentration of these heavy metals varies from dump to dump and is dependent on the source of the waste that constitutes the dump and also on the natural soil content of the area. The solid waste from the industrial zones dumped in a dumpsite reacts with percolating rain water and other environmental conditions thereby resulting in leachate which is therefore the product of the reaction of the percolating rainwater, ions, trace elements and other degradable constituents of dump transferred to the water level. The leachate moves in accordance with the direction of groundwater and spreads across a large portion of the groundwater system thereby polluting the water. The rate of percolation of leachate and other properties are dependent on the following factors: composition of solid waste, level of compaction, size of particle, hydrology of site, age of dumpsite/landfill, moisture, temperature conditions and available oxygen.

In developing countries like Nigeria, some of the dumps and landfills are designed and constructed without engineered liners, leachate collection systems (pipes, tanks), collection equipment, or monitoring facility. The unavailability of these coupled with ineffective solid waste management system and uncoordinated dumping of Municipal Solid Waste (MSW) engaged for an open dump are the main reasons accountable for ground and surface water contamination at various places (Kumari et al. 2017; Rajkumar et al. 2010). Several studies have shown that groundwater close or adjacent to dumpsites is more vulnerable to contamination. One of such is the findings of (Oyelami, et al. 2013; Saarela 2003; Abd El Salam and Abu-Zuid 2015) who in their respective studies reported adverse effects of leachate due to dumpsite on surface and groundwater as well.

Method

Sources of data

The data used in this study were obtained from selected refereed studies on the delineation and effect of pollution on groundwater quality. This was done by considering studies on leachate contamination using geophysical methods and physiochemical analyses of groundwater due to dumpsites/landfills. Twenty one (21) refereed studies were used. The refereed studies are from different places and countries with different hydrogeological conditions and kinds of dumpsites/landfills.

Table 2 is the classification of water quality for drinking and domestic purposes using metal index according to Lyulko et al. (2001).

Single-Factor pollution index

Assessment of the heavy metals contamination of groundwater was done based on a single-factor pollution index formulated by Zhaoyong et al. (2015).

$$\textit{The Over limit ratio} = \frac{C}{S} \tag{1}$$

where C represents determined concentration and S represents standard of heavy metals.

Metal index

The metal index (MI) relation was employed in the evaluation of the water quality in each of the study areas for drinking purposes. The formula was developed by Tamasi and Cini (2004). The relation is as given in Eq. (2).

$$MI = \sum \{C/MAC\} \tag{2}$$

where MAC represents maximum admissible concentration and C represents determined concentration.

Table 2 Metal index and classification of water quality

MI	Characteristics	Class
<0.3	Very pure	I
0.3–1.0	Pure	II
1.0–2.0	Slightly affected	III
2.0–4.0	Moderately affected	IV
4.0–6.0	Seriously affected	V
>0.6	Seriously affected	VI

Geophysical data

This aspect of the study seeks to review studies that used geophysical methods to investigate the level and extent of contamination of groundwater by leachate generated at various dumpsites. The following geophysical methods such as Geo-electrical resistivity, Electromagnetic conduction and Refraction seismic were deployed in delineation of leachate pollution by the authors. The above Geophysical techniques according to Afolayan et al. (2004) could provide information on the depth to bedrock, the extent of saturation due to contamination and porosity of the materials.

Table 3 is a summary of the Refereed used in discussing the various results under review. The table showed that most of the authors used geo-electric method while a few combined it with other methods. Although geo-electric method may not be the best method for investigation of leachate contamination but it is less expensive and fast to handle informing its use by most of the authors. The table also showed that contamination due to leachate is associated with low resistivity (Rosqvist et al. 2003).

Analysis of data

Data analysis is an important aspect of geophysical study and can take the format used below for an investigation adopting electrical resistivity method. At the end of each geophysical survey using Schlumberger electrical array, a preliminary interpretation was done with estimation of the initial resistivity and thickness values of the various geo-electric layers at each VES point or location. These geoelectric parameters were iterated using Resist software (Vander Velpen 2004). The partial curve matching technique was employed on VES data and different layered models were revealed. The study carried out by Olafisoye et al., (2013), for instance, revealed a 3-layered model with H-type curve (resistive-conductive-resistive), as shown in Fig. 1. The resistivity, depth and thickness of the location of study were also revealed.

Figure 2 showed the result of the Geo-electric section of the study carried out by Lawal Olubanji et al. (2013) at Ijagun Odogbolu southwestern Nigeria. The results of the resistivity values obtained from the field surveys were interpreted qualitatively and quantitatively. The results of VES and 2-D were iterated using computer software. Different curve types were obtained based on the resistivity variation of the area.

The geo-electric section showed the vertical variation of the subsurface lithology in relation with their resistivity values. The area composed of topsoil, laterite, Peat, dry sand and sandstone with three to five layers. The geo-section showed that profiles 1 and 2 with low resistivity values of 16.4–36.0Ωm with depth of 4.6–5 m indicated the presence of the leachate pollution in VES 1 and 2 which can directly infiltrate into the groundwater through the highly porous and permeable (aquiferous) sandstone in subsurface layer. This result is in agreement with Barker, (1990) and Rosqvist et al. (2003). This method was also adopted by Olafisoye et al. (2013) and Akankpo et al. (2011) in their respective studies at Aarada Dumpsite Ogbomoso, Nigeria and Uyo, South-south Nigeria" respectively.

Abdullahi et al. 2011 used integrated geophysical techniques that involved Very Low Frequency-EM, 2D electrical resistivity/induced polarization imaging, and Seismic refraction to investigate Unguwan Dosa municipal solid waste site in Kaduna metropolis, Nigeria. The result obtained by his group using VLF technique showed that a high positive peak at crossover between the in-phase and quadrature with the

Table 3 Geophysical methods adopted by refereed researchers

Study	Method	Associated resistivity range (Ωm)	Depth (m)	Soil type/structure	Reference
1	ER, EM, SR	15.3–40.5	0.6–5.4	Clay reach zone	Abdullahi et al. (2011)
2	ER	About 4.5	10.0–20.0	Sand	Adeoti et al. (2011)
3	EM	–			Aduojo, et al. (2019)
4	ER	26.08–37.72	26.08–37.72	Clay and Sandy	Agbola et al. (2010)
5	ER	8.0–39.7	4.0–23.5	Sandy porous	Akankpo and Igbokwe
6	ER	3–55	2.7–8.7	Weathered fractured basement	Bayode et al. (2011)
7	ER	20	16	Fractured layer	Ganiyu et al. (2016)
8	ER	28.9–36	0.4–30.8	Peat	Lawal Olubanji et al. (2013)
9	ER	10.4–26.8	1.3–3.8	Sandy	Olafisoye et al. (2013)
10	ER, VLF, SR & H/V	Low resistivity	14–31	Unconsolidated material	Soupios et al. (2007)
11	ER	20.1	10	Sandy soil	Ugwu and Nwosu (2009)

ER = Electrical Resistivity, EM = Electromagnetic conductivity, VLF = Very Low frequency, SR = Seismic Refraction, H/V = Horizontal to vertical ratio.

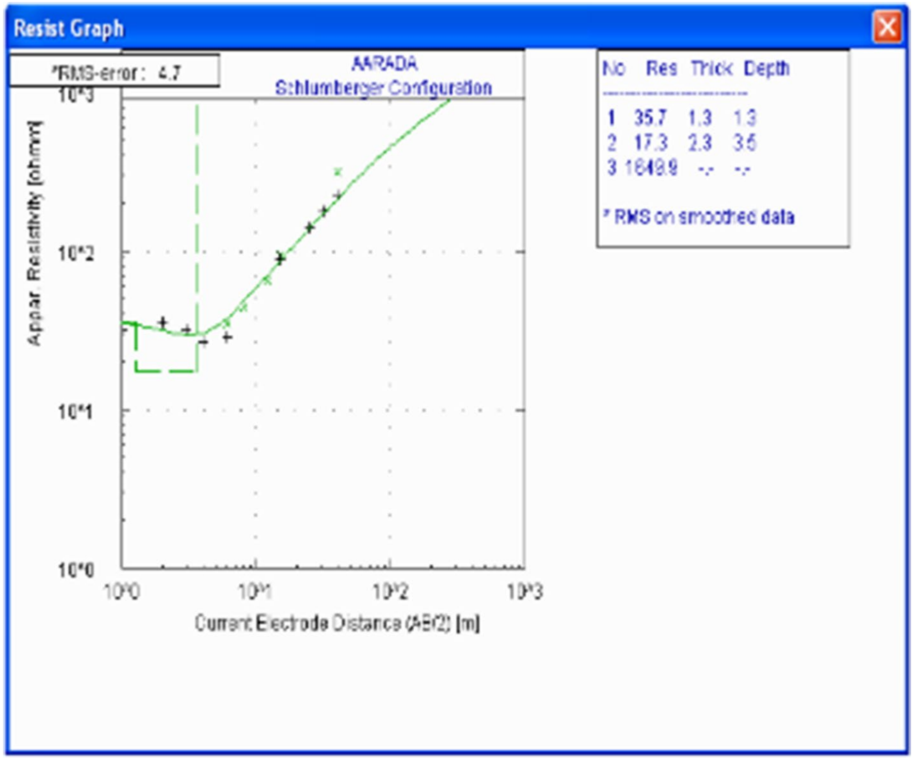

Fig. 1 Modeled Curve of a VES, Olafisoye et al., (2013)

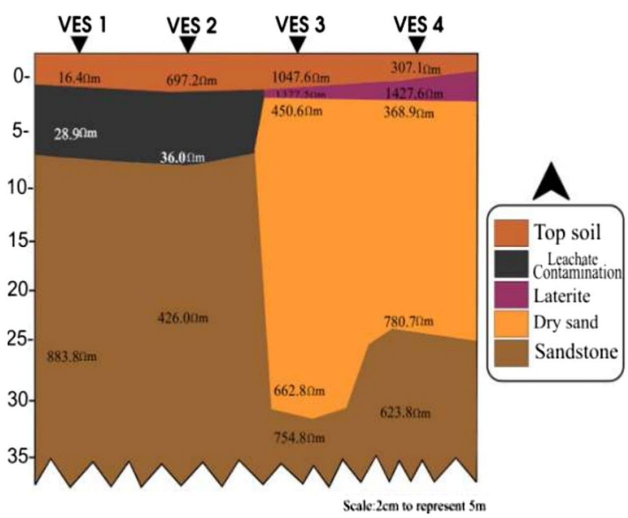

Fig. 2 Geo-electric section, after Lawal Olubanji et al., 2013

Fraser-filtered response is a favourable location for fracture (Sundararajan et al. 2007). There is a good correlation between the 2D resistivity model generated from the VLF data and the Fraser filtered responses of the VLF data. In the crystalline basement rock, the 2D resistivity model showed crossover point as indication of fracture. The area with low resistivity could be an indication of fracture filled with contamination plume.

In another study by Bayode et al. (2011) at Otutubiosun Dumpsite, Akure, Southwestern Nigeria, the authors deployed the dipole –dipole and Vertical Electrical Sounding (VES) techniques in their investigation. Figure 3 shows the outcome of the 2-D resistivity on one of the profiles investigated. Three subsurface layers as the topsoil, weathered layer and the basement bedrock were delineated by the inverted 2-D resistivity structures. The 2-D resistivity structure showed that beneath the dumpsite, the top soil has virtually merged with the weathered layer and this could be as a result of the overlapping of the low/high resistivity values and relative small thickness. Very low resistivity values of (3 –55 Ω-m) zones with bluish colour bands found in the second and third layers could be an indication of leachate saturation. The authors observed that thin porous overburden units overlaid the fresh bedrock and that the groundwater and leachate are hosted in fractured/fault bedrock as well. Therefore, the polluted groundwater in the vicinity of the dumpsite (fracture/fault zones) mainly controls the migration of the leachate plume (Bayode et al. 2011).

The study by Soupios et al. (2007) at Fodele landfill also adopted integrated approach involving four techniques as electromagnetic induction using very low frequencies, 2-D electrical resistance, electromagnetic conductivity (EM31), seismic refraction (SR), and ambient noise measurements (HVSR). Figure 4 is the result of the Seismic refraction of their study correlated with electrical resistance tomography for the same profile. They found that, saturated

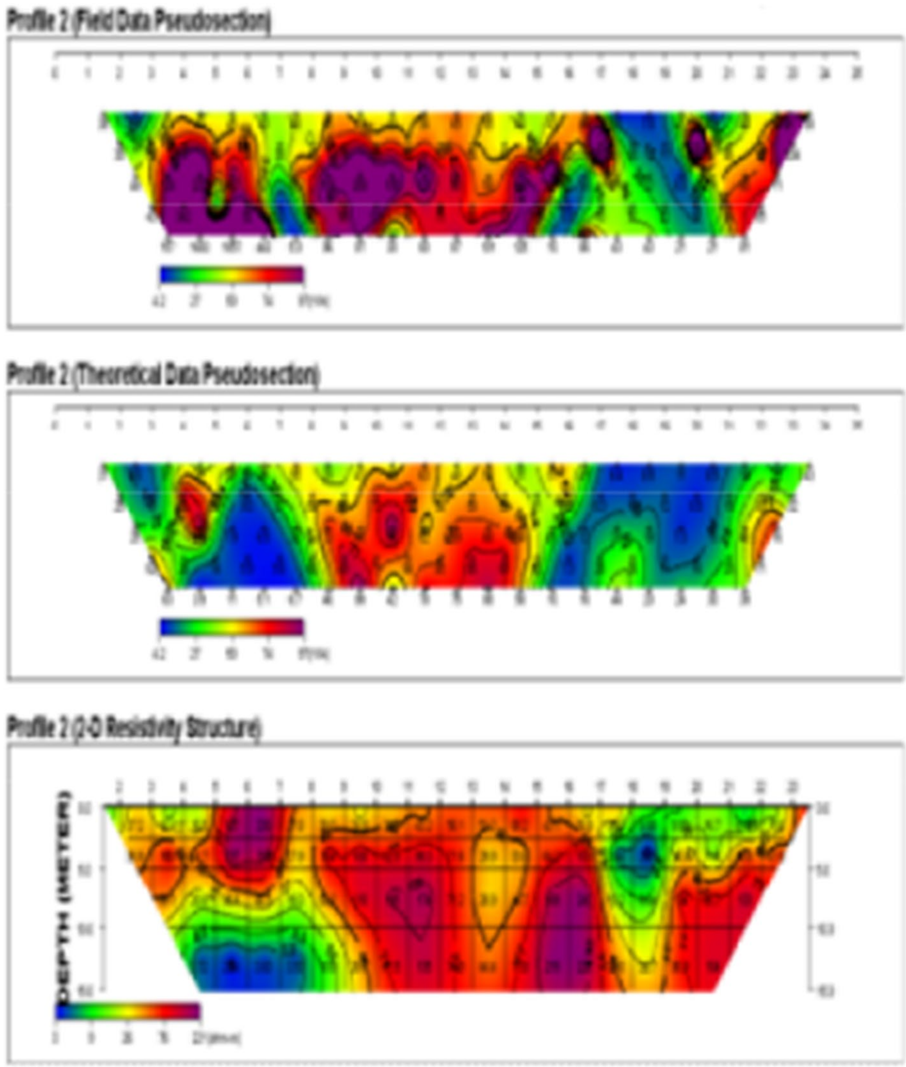

Fig. 3 2-D Resistivity Structure and Geoelectric Section along a Traverse, Bayode et al. (2011)

unconsolidated wastes occupied the second layer of their study area. The interface between the two layers was found to correlate very well with the interface between the layer of sand/gravels and other weathered materials used to cover the waste layer as shown in Fig. 4. They were able to conclude that, the theoretical saturated sediment velocity of P-wave is about 1,500 m/s that they could reasonably assume that the velocity of 1,670 m/s corresponds to saturated wastes. This is in agreement with the results of the geoelectrical resistivity tomography obtained for the same profile with a value of 0.20–6.00 Ohm. m corresponding to conductive leachates.

Aduojo et al. (2019) investigated Olushosun dumpsite at Ojota, Lagos using Radiometric and electromagnetic investigation methods. Electromagnetic conductivity surveys (three traverses) were conducted on the dumpsite, while two other traverses recorded at various distances from the dumpsite served as the control. Analyses of the data were carried out. The authors found, that the study area was characterized by high conductivity (60–680mS/m) up to a depth of 60 m based on the E.M. data acquired. This could be attributed to leachate contamination migrating into the subsurface and groundwater aquifers. The excavation of the lateritic materials within the study area before the commencement of dumping activities as was made known could have been responsible for the high level of contamination. This study further confirmed the applicability of electromagnetic induction method in mapping conductive plumes like landfill leachate or saltwater intrusion (Powers et al. 1999).

Physiochemical analyses

Table 4 is a record of the negative impact of dumpsites on groundwater as obtained by refereed studies used. It showed that Chromuim (Cr) with value of 2.59 mg/L in Abdullahi et al., (2011), has exceeded the standard limit of 0.05 mg/L recommended for drinking water by WHO, (2011). This high concentration could be attributed to the natural characteristics of topsoil and rocks, effluents from factories and paints

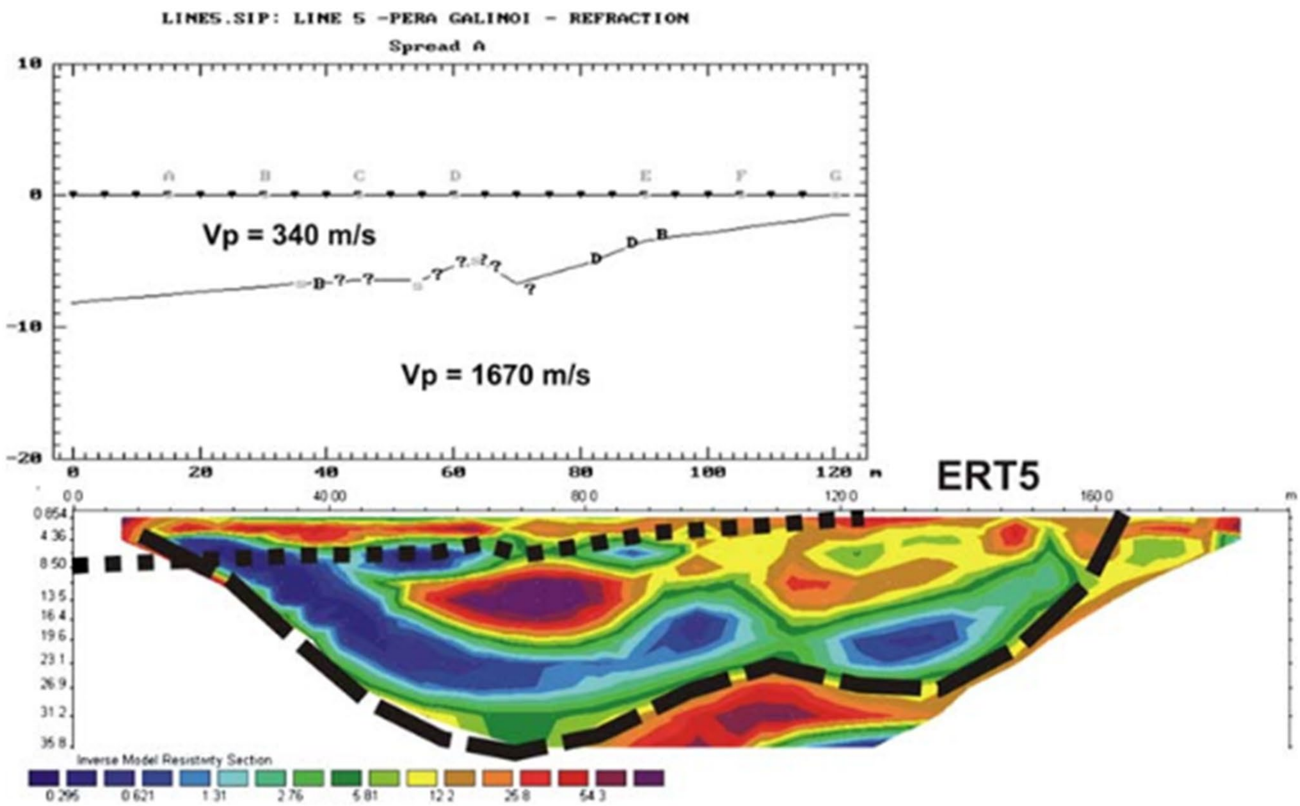

Fig. 4 Comparison of the refraction seismic (upper) and the geoelectrical tomography (lower) for the same profile after Soupios et al. (2007)

Table 4 Selected referred studies with heavy metal concentration at various dumpsites

Concentration of heavy metal (mg/L)									
Study	Cu	Mn	Zn	Pb	Fe	Cr	Cd	Ni	Reference
1	0.02	0.148	0.096	0.003	0.843	0.034	0.008	0.043	Abd El Salam &Abu-Zuid (2015)
2	–	–	–	0.865	–	2.59	0.14	–	Abdullahi et al. (2011)
3	–	–	–	–	–	–	–	–	Akankpo et al. (2011)
4	0.51	–	2.48	0.05	–	0.05	0.001	0.017	Azim et al. (2011)
5	0.08	–	0.25	0.054	1.34	0.043	0.013	–	Boateng et al. (2019)
6	–	–	–	–	–	–	–	–	Ganiyu et al. 2016
7	–	–	0.061	–	0.21	–	–	–	Nagarajan et al. (2012)
8	0.68	–	1.90	0.16	1.95	–	–	–	Olafisoye et al. (2013)
9	–	0.11	0.016	–	0.18	–	–	–	Oyelami et al. (2013)
10	0.32	–	0.372	0.372	2.017	0.006	–	–	Ugwu & Nwosu (2009)
	2	0.03	3	0.01	0.03	0.05	0.003	0.007	WHO (2004, 2011)

in the dumpsites/landfills. On the other hand, Azim et al. (2011) obtained a value of 0.05 mg/L which is at boundary while Boateng et al. (2019), got a value of 0.043 mg/L which is within the allowed limit. Among the studies under consideration, Olafisoye et al. (2013) and Boateng et al. (2019) revealed the highest values of 0.68 mg/L and 0.51 mg/L for copper (Cu) respectively. The WHO (2011), acceptable limit of Cu concentration was 2 mg/L for drinking water but the levels of Cu concentrations in most of the groundwater samples under consideration were below this value. Lead as one of the heavy and toxic materials showed high concentration in the studies by Abdullahi et al. (2011), Ugwu and Nwosu (2009), Boateng et al. (2019) and Azim et al. (2011) with values of 0.865 mg/L; 0.372 mg/L; 0.054 mg/L and 0.05 mg/L respectively. The concentration level of Lead in the groundwater is high; this could have resulted from dumping of materials that contain lead like batteries, pipes, paints and other metallic items at the landfill (Kale et al. 2009;

Smith 2009) and this calls for attention due to its associated health risk.

The concentration of Iron (Fe) according to Table 4 are 2.017 mg/L, 0.843 mg/L, 1.95 mg/L, and 1,34 mg/L obtained by the following researchers: Ugwu and Nwosu (2009), Abd El Salam et al (2015), Olafisoye et al. (2013) and Boateng et al. (2019) respectively. These values were above the WHO permissible limit of 0.03 mg/L for Fe but are lower than the 23.0 mg/L obtained by Chofqi et al., (2004) in their study at El Jadida, Morocco. The high concentration of Fe in the leachate samples could suggest the dumping of iron and steel scrap in large quantity in the landfills and could result to color change of groundwater (Rowe et al. 1995; Bendz et al. 1997).

The 0.148 mg/L concentration of Manganese obtained by Abd El Salam et al. (2015) is higher than allowable limit of 0.03 mg/L (WHO 2011) likewise the study in 2013 by Abu-Daabes et al. in Jordan which revealed high concentrations of manganese (Mn) (10.56–38.17 mg/L) in leachate samples. This may not be unconnected with unregulated disposal of old batteries in municipal solid wastes. The concentration of Cadmium (Cd) was found to be between 0.001 and 0.14 mg/L in the groundwater samples of some of the researchers as Abdullahi et al., (2011) recorded 0.14 mg/L while Boateng et al. (2019) recorded 0.013 mg/L. These values are higher than the permissible limit of 0.003 mg/L by W.H.O for Cadmium (Cd).

Table 4 showed values that are below the WHO allowable limit of 3.0 mg/L for Zinc (Zn) as Oyelami et al. (2013), Ugwu and Nwosu (2009), Abd El Salam et al. (2015), Olafisoye et al., (2013) Boateng et al. (2019) and Azim et al. (2011) reported 0.016 mg/L; 0.372 mg/L; 0.096 mg/L; 1.90 mg/L; 0.25 mg/L and 2.48 mg/L respectively.

None of the studies under review except that of Azim et al. (2011) on characteristics of leachate at Dhaka, Bangladesh recorded values for Nickel (Ni). According to their study, Nickel had concentration of 0.017 mg/L which is above the WHO 2011, drinking water standard of 0.007 mg/L and has a high potential for contaminating ground and surface water (Azim et al. 2011).

Generally, this review work has shown that there is great variation in heavy metal concentrations found in and around the dumpsites of the different sites under consideration which could be due to the differences in geological characteristics of the hosting environment between these dumpsites and in quantitative characteristics between the solid wastes within them.

Table 5 is a compilation of concentration of Inorganic matters with their respective standards in the selected studies. Seven pollutants were observed in the inorganic category. Sulphate concentration was obtained with the following values: 1.341 mg/L; 13.89 mg/L; 4.29 mg/L, 50.5 mg/L and 81.74 mg/L by the following researchers Oyelami et al. (2013), Ugwu and Nwosu (2009), Olafisoye et al. (2013), Ganiyu et al. (2016), and Nagarajan et al. (2012) respectively. All values are within the WHO 2011 permissible Standard except the one of 597 mg/L obtained by Abd El Salam and Abu-zuid (2015) which could be as a result of the decomposition of proteins.

Chloride was also reported in varying concentrations by most of the researchers referenced. The concentrations are as shown on Table 5. High values were recorded by Oyelami et al. (2013) and Abd El Salam and Abu-Zuid., 2015 with values of 268.87 mg/L and 11,387 mg/L respectively which are above the (WHO 2011) standard value of 250 mg/L. This could be as a result of recent treatment of the wells for drinking and other domestic purposes and could also be as a result of pollution (Loizidou and Kapetanois 1993).

Some of the researchers observed bicarbonate as one of the pollutants. The concentrations of bicarbonate are as shown on Table 5. The values obtained by Nagarajan et al. (2012) and Azim et al. (2011) were 468.1 mg/L and

Table 5 Concentration of inorganic matters in selected refereed studies, at various dumpsites

Concentration of inorganic matter(mg/L)										
Study	SO_4^{2+}	Cl^-	NO_3^{2-}	NH_4^+	HCO_3^{2-}	F	TN	TP	CN	Reference
1	663.5	5788	0.19	0.99	–	–	1.2	0.075	–	Abd El Salam & Abu–Zuid (2015)
2	–	220.7	–	–	–	–	–	–	–	Abdullahi et al. (2011)
3	–	11.8	–	–	–	–	–	–	–	Akankpo and Igbokwer (2011)
4	–	144.7	110.4	30.1	430.7	–	–	–	–	Azim et al. (2011)
5	–	–	–	–	–	–	–	–	–	Boatang et al. (2019)
6	50.5	48	5.34	–	177	–	–	–	–	Ganiyu et al. (2016)
7	81.74	201.8	7.93	–	468.1	0.8	–	–	–	Nagarajan et al. (2012)
8	4.29	30	35.77	–	19.56	–	–	–	0.2–2.25	Olafisoye et al. (2013)
9	1.341	268.9	1.073	–	58.22	–	–	–	–	Oyelani et al. (2013)
10	13.89	100.9	–	–	–	–	–	–	–	Ugwu & Nwosu (2009)
	250	250	50	200	250	1.5			0.5	WHO (2011)

430.74 mg/L respectively. These results are far higher than the WHO standard value of 250 mg/L for HCO_3^{2-}. Other values are however within the admissible limit. From Table 5 all the studies under review recorded concentration values lower than 50 mg/L of WHO for Nitrate except that by Azim et al. (2011) which recorded concentration value of (110.4 mg/L). Nitrate like chlorine is also an index of groundwater pollution thus when the concentration is high, it calls for attention. Olafisoye et al. (2013) in their study at Ogbomoso, Nigeria, obtained concentration of 0.2–2.45 mg/L for Cyanide (CN^-). This is above the WHO standard of 0.5 mg/L. The close proximity of some wells to cassava waste disposal site could be responsible for high CN^- concentration in some of the samples tested.

Ammonium (NH_4^+) was reported in the study by Abd El Salam and Abu-Zuid. (2015) and Azim et al. (2011) with concentrations of 0.99 mg/L and 30.1 mg/L respectively. The values here are within the limits of permissible WHO standard. Ammonium like chloride can be used as trace agents for groundwater contamination.

Table 5 also showed different values of (Total Dissolved Solids) TDS. High levels of TDS were indicated by the results of Ugwu and Nwosu (2009), Abd El Salam and Abu-Zuid (2015) as 3218 mg/L and 9308 mg/L respectively. These values are higher than the WHO standard for TDS which is 1000 mg/L. Improperly lined dumpsites/landfills could be associated with the increased total dissolved solids concentrations observed.

Table 6 shows a summary of the concentration of the following metals Na^+, Mg^{2+}, Ca^{2+} and K^+ as recorded by the referenced studies. This table does not include the heavy metals discussed earlier. The study by Nagarajan et al. (2012) carried out at Erode city, Tamil Nadu, India, recorded concentrations of 142.37 mg/L, 55.72 mg/L, 75 mg/L and 26.76 mg/L for Na^+, Mg^{2+}, Ca^{2+} and K^+ on groundwater respectively while Olafisoye et al. (2013) in their study at Ogbomoso, Nigeria, recorded 32.4 mg/L for K. These are higher than the WHO standard of 50 mg/L, 50 mg/L, 75 mg/L and 10 mg/L for Na, Mg, Ca and K respectively.

Table 7 is the summary of Physical and Organic properties at various dumpsites from the refereed studies on groundwater. The pH value found by most of the studies are within the permissible WHO (2011), standard of 6.5–9.5 except that reported in the study by Oyelami et al. (2013) and Akankpo et al. (2011) with respective values of 7.5, 10.8 and 4.35 which are tending towards alkalinity and acidity respectively. Neither of these pH levels is good for quality portable water.

The Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD) levels of the different dumpsites as reported by the authors refereed are as presented in Table 7. The following authors Abd El Salam and Abu-Zuid (2015) and Abdullahi et al. (2011) recorded high values of 74 mg/L and 726 mg/L respectively for COD and 52.5 mg/L and 241.2 mg/L for BOD respectively against the WHO standard

Table 6 Concentration of metals in groundwater at various dumpsites refereed

Concentration (mg/L)					
Study	Na^+	Mg^{2+}	Ca^{2+}	K^+	Reference
1		–	–	–	Abd El Salam & Abu–Zuid (2015)
2	–	–	–	–	Abdullahi et al. (2011)
3	–	–	–	–	Akankpo and Igbokwer (2011)
4	12	–	58.71	22.66	Azim et al. (2011)
5	–	–	–	–	Boatang et al. (2019)
6	19.3	17	5.3	3.5	Ganiyu et al. (2016)
7	142.4	55.72	84.74	26.76	Nagarajan et al. (2012)
8	24.21	14.62	–	32.4	Olafisoye et al. (2013)
9	11.75	4.39	23.42	5.66	Oyelani et al. (2013)
10	8.3	–	–	–	Ugwu & Nwosu (2009)
	50	50	75	10	WHO (2011)

Table 7 Physical and organic properties of groundwater at various dumpsites referred

Study	pH	Temp	EC	TDS	COD	BOD	TH	TSS	TS	Reference
1.	7.3–8.5	–	11,550	9308	74	52.5	–	1032	–	Abd El Salam & Abu–Zuid (2015)
2	6.6–7.1	–	283–1044	764	726	241.2	–	–	–	Abdullahi et al. (2011)
3	4.35	26.4	47.4	23.76	–	–	–	–	–	Akankpo and Igbokwe (2011)
4	7.03	–	457.8	288.5	4.85	–	–	–	–	Azim et al. (2011)
5	–	–	–	–	–	–	–	–	–	Boatang et al. (2019)
6	6.8–7.6	–	184–326	92–325	–	–	250	–	–	Ganiyu et al. (2016)
7	7.63	–	1463	862.3	–	–	441.4	–	–	Nagarajan et al. (2012)
8	7.3	27.2	934.2	760.6	3.15	3.4	56.7	1296	1599	Olafisoye et al. (2013)
9	7.5–10.8	27.4–31.5	199.4	142.2	–	–	–	–	–	Oyelami et al. (2013)
10	8.71	–	60	3218	–	–	–	–	–	Ugwu & Nwosu (2009)
	6.5–9.5	24.5–39.7	1400	500	40	10	500			WHO (2011)

of 40 mg/L and 10 mg/L for COD and BOD respectively. Low values of both quantities were also obtained by some researchers as indicated in the same table indicating the absence of organic contamination of leachate to the groundwater surrounding environment (Bandara and Hettiaratchi 2010). This assertion has been confirmed by Hassan and Ramadan (2005) in their study which revealed the absence of organic contaminations of piezometer wells around active cells of landfill. The high values of COD reported from some of the studies on the other hand suggest the presence of dumpsites/landfills leachate in wells/boreholes sited close to the sites and organic strength produced by it.

Electric conductivity (EC) is another important parameter in the discussion of contamination of leachate. The values obtained for this quantity is as shown in Table 7. The study by Nagarajan et al. (2012), showed high value of 1463.48 µS/cm for this parameter. Also Abd El Salam and Abu-Zuid, 2015 in their study recorded 11,549.5 µS/cm against the WHO (2011), allowable value of 1400 µS/cm. These high values of electric conductivity are indication of the presence of dumpsites/landfills leachate in wells/boreholes sited close to those sites.

All units are in mg/L except pH, EC (µS/cm) and Temp. (°C).

Metal and single factor indices in groundwater

The over-limit ratios of heavy metals with their pollution index were calculated using WHO (2011), water quality standards and the Over-limit ratio value > 1 according to Zhaoyong et al. (2015) indicates slight contamination. In most of the analysed water samples the Over-limit ratios of Mn, Pb, Cr, Ni, Fe and Cd. were above 1 making the water samples unacceptable for drinking while only Cu and Zn had values that were within the permissible limit.

Also, based on Lyulko et al. (2001), all the study areas were seriously contaminated with heavy metals as suggested by the metal index values that were greater than 6 in all the study areas. Two of the refereed studies do not have results on heavy metals (Table 8).

Bacteriological pollutants

Degradable pollutants in dumps which include complex organic substances like excrement of human and animals undergo biological decay by microorganisms. The products together with the degrading microorganisms then percolate into the ground with the aid of precipitation and rain water, contaminate groundwater and cause diseases ranging from mild to severe types when they infect plants and animals through the use of contaminated ground water. Consumption of such contaminated water causes water born diseases such as typhoid fever, paratyphoid fever, cholera, colitis and hepatitis A (Goel 1997). In one of the refereed studies considered, Olafisoye et al. (2013) in their study at Ogbomoso, Nigeria, found that the results of water samples analyzed for total coliform (0.04–3.1 cfu/ml) and faecal coliform(1.12–2.56 cfu/ml) bacteria indicated presence of bacterial contamination in the study area. Though the level of contamination may not be high, it could pose great danger and threat to health if not treated.

Age and distance of the dumpsite

The varying degree of contamination level of groundwater quality is dependent on factors such as: age, chemical content of leachate, rainfall, depth and distance of the well/borehole from the source (dumpsite/landfill) and all these facilitate leachate percolation. The rate of groundwater pollution varies with the change in dumpsite age. In the early stage of the dumpsite, the groundwater contamination is gradual and increases as time goes on. The contamination continues until it attains its peak and decreases gradually till it becomes stable (Renoua et al. (2008).

Distance is another important factor that determines the extent of groundwater contamination. According to

Table 8 Single-factor and metal index of groundwater samples from refereed studies

Study	Single factor index								Metal index
	Cu	Mn	Zn	Pb	Fe	Cr	Cd	Ni	
1	–	3.67	0.005	–	6.0	–	–	–	9.68
2	0.16	–	0.124	37.2	67.2	0.12	–	–	104.50
3	0.01	4.93	0.032	0.3	28.1	0.68	2.67	6.14	42.76
4	–	–	–	86.5	–	51.8	46.7	–	185.00
5	–	–	–	–	–	–	–	–	–
6	0.34	–	0.63	16	65	–	–	–	81.97
7	–	–	–	–	–	–	–	–	–
8	–	–	0.02	–	7	–	–	–	7.02
9	0.04	–	0.083	5.4	44.67	0.86	4.33	–	55.38
10	0.26	–	0.83	5.0	–	1.0	0.33	2.43	9.85

Nagarajan et al. (2012), the concentrations of contaminants varies inversely with the distance hence samples with high contaminant concentrations were found to be close to the landfills. Therefore, groundwater contamination drops as one moves away from the landfill sites. Specifically, groundwater contamination occurs within 900–1000 m of the dumpsite/landfill radius and most of the serious contamination takes place within 200 m (Han et al. 2016). As one moves away, the percolation of leachate becomes gentler. This has been accounted for by the natural attenuation, mainly controlled by factors like dilution, sorption, ion exchange and degradation processes (Banu and Berrin 2015, Han et al. 2016).

Conclusion

Despite the fact that dumpsites are very important in environmental management of waste, the pollution of the groundwater due to leachate accumulation from dumpsite is of great concern as most dumps and landfills are designed without the necessary components like liners, leachate collection systems (pipes, tanks), and landfill monitoring facility for efficient and effective management of waste. The unavailability of these coupled with ineffective management of waste and uncoordinated and in-proper dumping of Municipal Solid Waste (MSW) using open dumps are causes of ground and surface water contamination.

The studies showed that any or combination of two or more of the following geophysical methods: Electrical Resistivity, Electromagnetic induction using Very-Low-Frequency, Seismic Refraction could delineate leachate plume contamination due to dumpsite. The application of the integrated geophysical techniques deployed to determine different structural properties of the subsurface have greatly assisted in the characterization and consistent description of the subsurface. This is very important in studying the migration pathway of leachate contaminant.

This study revealed a number of pollutants due to leachate leakage found in groundwater near dumpsites or landfills and the resultant effect of the presence of these pollutants in groundwater is contamination of the latter. Consumption of such water poses danger to human health. The study also showed that age of the dumps and the migration distance of the leachate are important factors that require consideration because the closer the dumpsite the higher the concentration of the contaminant. In conclusion, Concluding, leachate leakage from dumpsite has been established to be a major source of groundwater pollution with organics, salts and heavy metals as pollutants.

Authors' contributions The authors contributed equally to the completion of the study. The authors have approved the submission of the manuscript.

Funding Not applicable.

Code availability Not applicable.

Data availability There is none.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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