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Research article

Evaluations of groundwater contamination by leachates around Olusosun open dumpsite in Lagos metropolis, southwest Nigeria

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ABSTRACT

A major cause of groundwater pollution in urban areas is contamination by leachates emanating from municipal solid waste dumpsites. The study evaluated the quality of water of selected boreholes and wells around Olusosun open solid waste dumpsite in Lagos metropolis, using water quality index (WQI) rating and geospatial techniques. Water samples were randomly collected from fifteen boreholes and five wells downslopes of the dumpsite. The samples were analysed for the physico-chemical parameters and heavy metals. Factor Analysis was employed to analyse the information content of the water quality indicators to determine their appropriateness for indexing. The spatial distribution of the WQIs determined using Inverse Distance Weighting (IDW) interpolation procedure. Results showed that the waters were generally acidic with 85% of pH values below the range suggested by WHO for drinking water. All samples contained concentration of dissolved oxygen (DO) in quantities higher than the recommended limit of 2.0 mg/l (average = 4.97 mg/l), while 40% of the samples contained concentration of K above the recommended limit. The concentration of heavy metals was generally low. The major cations (Mg, Na, and K) were highly positively correlated, and were positively correlated with pH, TA, TAL, TH and Cl. Negative correlations were observed between TDS, NO_3^- and PO_4^{3-}; NO_3^- and Ag; and DO with the heavy metals. Eighteen parameters consisting of pH, EC, TDS, TA, TAL, TH, Cl, NO_3^-, PO_4^{3-}, Mg, Na, K, Zn, Mn, Fe, Cd, Ag and Pb were found to be the main indicators of groundwater pollution caused by landfill leachate percolation. Evaluation of the WQIs indicated that 35% of the water samples were unsuitable for consumption, while 15%, 15% and 35% were in the good, very good and excellent categorises, respectively. The degree of suitability of the borehole and well waters was closely related to proximity to the dumpsite. It is imperative that appropriate remediation strategies are adopted to forestall further contamination of the groundwater by leachates in the area.

1. Introduction

Groundwater is one of the major sources of fresh water for drinking in communities around the world. It is an important renewable resource with several advantages over surface water. Groundwater is typically less polluted compared to the surface water because of its high self-cleansing ability and ease of treatment (Oluyemi et al., 2009). However, due to human development activities, this valuable source of water is vulnerable to pollution. One of the leading causes of groundwater pollution in urban areas is contamination by leachates emanating from municipal solid waste dumpsites. A large number of organic, inorganic and microbiological pollutants in groundwater have been reported in several researches in different parts of the world (Christensen et al., 2001; Han et al., 2014; Liu et al., 2010; Oluyemi et al., 2009; Rapti-Caputo and Vaccaro, 2006), and much resources have been committed to efforts to remediate the problems.

Waste disposal is a global problem, particularly in developing countries due to increase in population, economic growth, urbanization and industrialization, coupled with poor waste management practices. Uncontrolled dumping of municipal solid waste particularly in non-engineered open dumps is a major practice in many developing countries. In particular, inadequate solid waste management is a major environmental problem in Lagos metropolis where properly designed waste facilities are inexistent (Ikem et al., 2002; Kola-Olusanya, 2010; Oyelami et al., 2013). Wastes are typically deposited in non-engineered dumpsites from where emanating leachates containing dissolved organic matters,

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inorganic compounds (such as ammonium, calcium, magnesium, sodium, potassium, iron, sulphates, chlorides and heavy metals like cadmium, chromium, copper, lead, zinc and nickel) and xenobiotic organic substances can enter the soils to pollute surface and ground water. The scale of this threat depends on the concentration and toxicity of the contaminants, type and depth of water table, and direction of groundwater flow (Aderemi et al., 2011).

There have been many studies in different parts of the world on the environmental impact of waste. Rapti-Caputo and Vaccaro (2006) evaluated the geochemical evidences of landfill leachate in groundwater in Ferrara Province, Northern Italy, and found that the propagation of the polluting fluids in the deeper aquifers can be attributed to the deeper propagation of the leachates. Liu et al. (2010) investigated the impact of Municipal Solid Waste landfill on the contamination of phthalate esters (PAEs) in nearby environment in Wuhan, China. They found that the landfill had an obvious effect on the contamination of PAEs in groundwater. Han et al. (2014) examined groundwater inorganic contamination around a municipal landfill site in Zhoukou city, Henan province, China, and found that the shallow groundwater (within 30 m depth) around the landfill is not suitable for drinking, and recommended improvement of pollution control. Peng et al. (2014) investigated the occurrence and ecological potential of pharmaceuticals and personal care products in groundwater and reservoirs in the vicinity of municipal landfills. It was found that pharmaceutical and personal care products contaminants and subsequent ecological risks in the groundwater and surface water near the landfills might be of serious concern. Porowska (2015) determined the origin of dissolved inorganic carbon in groundwater around a reclaimed landfill in Otwock (Poland) using stable carbon isotopes. She found that in the leachate-contaminated groundwater, about 20–53% of the dissolved inorganic carbon was derived from organic matter degradation of natural origin, and 80–47% from biodegradation of organic matter stored in the landfill. Little studies, particularly in the study area (Oladimeji et al., 2010; Oluyemi et al., 2009; Oyelami et al., 2013) have explored the use of water quality indexing techniques to evaluate the phenomenon of municipal solid waste leachates into the groundwater. In addition, there is dearth of literature on the use of geospatial technique in modelling the spatial characteristics of contaminants in the study area. The use of geographical information system (GIS) is of great value in the storage, retrieval, processing and analysis of multifunctional and multidisciplinary data and has greatly simplified assessment of natural resources. In groundwater studies, GIS is commonly used for site suitability analysis, manage site inventory data; estimate groundwater vulnerability to contamination; model groundwater flow, solute transport and leaching; and integrate groundwater quality assessment models with spatial data to create spatial decision support systems. GIS can be a valuable tool in understanding the spatial pattern and migration of contaminants and can help in tracking site treatment and remediation progress (Engel and Navavulur, 1999; Johnson, 2008). This study evaluated the groundwater quality around Olusosun open solid waste dumpsite in Lagos metropolis using water quality index rating and geospatial techniques. This is with a view to understanding the level of contamination and spatial pattern quality of groundwater around the site. The efforts should aid water pollution remediating strategies and groundwater resources management of the area.

2. Materials and methods

2.1. Description of the study area

Olusosun dumpsite is located in Ojota area of Lagos metropolis between latitudes 2°42′ E and 3°42′ E, and longitudes 6°23′ N and 6°41′ N (Fig. 1). The site was originally located at the outskirt of the city, but it is now within the city due to urbanization. The dumpsite is the largest in Lagos state covering about 42 ha and collects more than 50% of the waste generated. Large numbers of scavengers live and make earnings on the dumpsite (Balogun and Longe, 2010).

The environment of Lagos metropolis consists of four aquiferous units (Bale et al., 2004). The upper aquifer consists of alteration layers of clay and sand, and extends from the ground level to about 12 m from the ground surface. Because it is shallow, the unit is of minor importance for dependable water supply purposes. Shallow hand-dug wells in the area are prone to contamination by surface pollutants. The second aquifer is between 20 and 100 m below the ground around Ikeja and Ojota area. The zone is of greater importance for water supply purposes because it is deeper and less prone to pollution (Bale et al., 2004). The groundwater of the third and fourth aquifers can be encountered between 130 m and 160 m and 450 m below the sea level, respectively. These aquifers are more expensive to abstract due to their great depth.

Lagos area is generally low-lying, flat towards and gently slopes seaward. The coastal plain is underlain by sedimentary sequence of varying ages, which overlie the crystalline basement of Precambrian to lower Palaeozoic age (Bale et al., 2004). The coastal plain sand consist of extensive red earths and loose poorly sorted sands mixed with abundant clay (Afolayan and Ogundele, 2012). The area is characterised by reddish brown loamy soils known as nitrisols. The deeply weathered soil type is formed by hydromorphic and organic soils which lie across the lagoon depressions, and are generally considered to be fertile (Afolayan and Ogundele, 2012).

The study area is known for industrial and commercial activities, which are concentrated in Oregun and Ojota areas. Field observations showed that boreholes and wells are the major source of water. Government-supplied pipe-borne water serves only a small proportion of the population, and it is irregularly supplied.

2.2. Field and analytical procedures

The choice of sampling for this study took into topography consideration (Leung and Jiao, 2006). Before the samples were collected, the slope map of the study area was generated from DEM and the partitioned into upslope and down slope. Samples were randomly collected from wells and boreholes located down slopes of the dumpsite at distances ranging from 120 m to 2 km (Fig. 2). A sample was taken in a residential area outside the study area (i.e. from the dumpsite) as control location where the influence of leachates from the dumpsite was considered irrelevant to groundwater quality (Amadi et al., 2012). The site was chosen to exclude areas where impacts of anthropogenic factors such as industrial, agricultural and commercial activities are negligible.

Water Temperature, electrical conductivity (EC) and pH were measured in situ with portable digital meter and pen type pH meter (PH-03 (1)), respectively. Twenty (20) samples comprising five from hand-dug wells and fifteen from boreholes were collected. Collection bottles were rinsed with water taken from the sample point before the samples were taken. The samples were labelled and stored chilled en-route the laboratory where the physic-chemical constituents were analysed. The geographic locations of the sample points were determined using a hand-held GPS (Germain GPSmap 76).

The water samples were analysed for physical parameters, appearance, total suspended solid (TSS), total dissolved solid (TDS) and turbidity. The general chemical parameters include total acidity, total alkalinity, total hardness and electrolytic conductivity. The major ions analysed includes; chloride (Cl^-), nitrates (NO_3^-), phosphate (PO_4^{3-}), magnesium (Mg^{2+}), sodium (Na^+), Potassium (K^+), and the heavy metals analysed include; zinc (Zn), manganese (Mn),