An assessment of groundwater contamination around a solid waste disposal site in Kano, Nigeria

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Abstract

Open dumping and uncontrolled landfilling of solid wastes are the most widely practiced waste disposal methods in many cities of the less-developed regions, especially those in sub Saharan Africa. These practices are unsustainable and pose a major threat to the environment and public health. Of particular concern is the leachate produced at the disposal sites, which is concentrated with biological and chemical substances that could contaminate the soil, surface and groundwater sources in the environs. The effects of leachate percolation on the quality of groundwater sources is of great concern especially in sub Saharan Africa, where untreated self-supply groundwater options represent a major source of water supply for many inhabitants. Given this perspective, the physicochemical characteristics of some groundwater samples from wells around a major waste disposal site; *Gyadi-gyadi* in Kano metropolis, Nigeria, were examined. The samples were collected from the north, east, south and west directions around the disposal site and analysed for parameters that include: pH, turbidity, total dissolved solids, electrical conductivity, total alkalinity, total hardness, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, NO_3^{-}, SO_4^{2-}, Cl^{-}, Cu^{2+}, Fe^{2+} and Mn^{2+}. Significant concentrations of most parameters were revealed, often above the WHO recommended thresholds. Accordingly, some measures were highlighted towards protecting, preserving and sustaining groundwater quality as a strategic source of water supply in the area and beyond.
Keywords: solid waste, open dumping, landfilling, leachate, groundwater contamination, water quality, Kano-Nigeria.

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1 Introduction

It is well established in many sources of literature, such as Gleick and Palaniappan [1] that about half of the world's human population relies almost exclusively on groundwater sources for potable water supplies. These include the inhabitants of some of the largest urban centres in less-developed regions. For most of these cities, such as Jakarta (Indonesia), Lagos and Kano (Nigeria), groundwater is considered primarily an affordable alternative to the piped water systems that are often difficult for the local authorities to provide (King [2]). While the significance of groundwater resources to the sustenance of human societies and ecosystems is increasingly being recognised, it is a cause for concern that groundwater aquifers in urban areas are continuously being impacted by the wide-ranging anthropogenic activities.

Landfilling of solid wastes has been identified as one of the major threats to the quality of groundwater resources [3–9]. Of particular concern is the leachate produced at the disposal sites, which contains significant concentrations of biological and chemical substances that could contaminate the soil, surface and groundwater sources in the near environs. The effects of leachate percolation on the quality of groundwater sources pose a substantial risk to local resource users and to the natural environment. This is particularly of great concern in sub Saharan Africa, where untreated self-supply groundwater options represent a major source of water supply for many inhabitants.

It should be noted that once groundwater is contaminated, restoration of its quality is technologically difficult and economically expensive. In fact, full restoration of groundwater quality is even impossible in some cases (UNEP [10]). It should be noted that, if groundwater resources are to continue to play an important role as dependable sources of water supplies, they must be protected from the increasing threats of over-exploitation and contamination. Therefore, assessment of groundwater pollution is an essential step towards providing better understanding of the actions required to protect effectively its quality against degradation and to ensure sustainable water resource development (Dimitriou *et al.* [11]).

Against this background, the present study aims to examine the physicochemical characteristics of groundwater samples collected from hand dug wells around a major waste disposal site; *Gyadigyadi* in Kano metropolis of Nigeria. The findings would be useful in determining the factors affecting the overall quality of the ground water in the area, and to provide a guide for policy makers and other stakeholders towards making informed decisions in relation to solid waste management, water resource management and sustainable development.

2 Materials and methods

2.1 Description of the study area

Kano metropolis covers an area of about 600 km^2 located between longitude 8° and 9°*E* and latitude 10° and 12°*N*. It is the administrative capital of Kano State and the commercial centre of northern Nigeria. With a population of around

4 million and an average annual growth rate of 3.9%, Kano is the second largest urban setting in Nigeria (Ahmed [12]). In this study, the *Gyadigyadi* disposal site was selected and investigated for impacting on the quality of surrounding groundwater resources. This disposal site is situated in the centre of residential and commercial settlements along Court Road in the south-western *Gyadigyadi* district of the metropolis, and receives waste from residential, industrial and commercial sources including sewage and animal waste.

2.2 Sampling and analyses

Groundwater samples were collected from four hand-dug wells located in the north, east, south and west directions around the selected solid waste disposal site for physico-chemical analyses. The samples were stored in a cooler box (at approximately 4℃) immediately after collection and then transferred to the laboratory and analysed without delay. The parameters analysed include; pH, turbidity, total dissolved solids (TDS), electrical conductivity (EC), total alkalinity (TA), total hardness (TH), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), nitrate (NO_3^-), sulphate (SO_4^{2-}), chloride (Cl^-), copper (Cu^{2+}), iron (Fe^{2+}) and manganese (Mn^{2+}). The experimental analyses were conducted in accordance with the standard procedures prescribed by the American Public Health Association APHA [13].

3 Results and discussions

Findings of this study highlight a noticeable variation in physico-chemical characteristics of the different groundwater samples analysed. Summary of the results and the applicable WHO recommended guideline values for drinking water quality are presented in Table 1.

Table 1: Groundwater quality.

	Samples ➡	GN	GE	GS	GW	WHO
Parameters	Units	May-10	May-10	May-10	May-10	Guide
pH	-	6.60	7.40	7.10	6.39	6.5-8.5
Turbidity	*NTU*	13.00	12.00	19.00	12.00	5
Total Alkalinity	*mg/l as CaCO3*	190.00	215.00	105.00	155.00	
Total Hardness	*mg/l as CaCO3*	306.00	245.00	352.00	210.00	
Total Dissolved Solids	*mg/l*	684.00	714.00	526.50	538.20	
Conductivity	*µS/cm*	1194.35	936.68	963.24	1124.62	
Sulphates	*mg/l*	390.00	94.00	112.00	136.00	500
Nitrates	*mg/l*	49.00	30.00	39.30	9.50	50
Chlorides	*mg/l*	390.00	217.00	213.00	129.00	250
Sodium	*mg/l*	193.00	206.00	216.00	128.00	
Potassium	*mg/l*	41.00	56.00	47.00	27.00	
Calcium	*mg/l*	175.00	59.00	84.00	108.00	
Magnesium	*mg/l*	64.00	145.00	100.00	90.00	
Copper II	*mg/l*	0.17	0.34	0.63	0.78	2
Iron II	*mg/l*	0.67	0.81	0.41	0.00	0.3
Manganese II	*mg/l*	0.56	0.67	0.10	1.05	0.4

The values of pH observed in all the samples varied from 6.39 in sample *GW* to 7.40 in sample *GE*. Most of the samples fall within the neutral pH range and the WHO recommended guideline values except for sample *GW*, which appears to be slightly acidic. On its own, however, pH has no direct effect on human or animal health, but because it is so closely associated with other chemical constituents of water, is often regarded as having an indirect effect on health (WHO [14]).

The whole samples were significantly turbid, showing values that are well above the WHO recommendation. The turbidity values range from 12 NTU in samples *GE* and *GW* to 19 NTU in sample *GS*. It should be noted that, increased levels of turbidity can impart an aesthetically displeasing appearance to water, and the materials that cause turbidity can provide adsorption sites for contaminants that may be harmful or cause undesirable tastes or odours. The values of TA in all the samples varied between 105 mg/l equivalent $CaCO_3$ in sample *GS* and 215 mg/l equivalent $CaCO_3$ in sample *GE*, and are all considered to be considerably high (i.e. TA > 100 mg/l as $CaCO_3$). Although there are no WHO recommended guideline values for TA, its high concentrations in drinking water may result in an unpleasant taste, and may be harmful to human health (WHO [14]).

The concentrations of Na^+ and K^+ in the samples varied from 128 mg/l in sample *GW* to 206 mg/l in sample *GS*, and between 27 mg/l in sample *GW* and 56 mg/l in sample *GE* respectively. The amounts of both Na^+ and K^+ in drinking water are normally not a concern to health according to the WHO guidelines, but may affect acceptability to consumers. Likewise, the concentrations of Ca^{2+} and Mg^{2+} are not of health concern in drinking water, but are easily precipitated. In particular, they react with soap to make it difficult to remove scum; therefore, they are the primary contributors to TH. In this study, Ca^{2+} and Mg^{2+} concentrations in all the samples ranged from 59 mg/l in sample *GE* to 175 mg/l in sample *GN* and from 64 mg/l in sample *GN* to 145 mg/l in sample *GE* respectively. TH concentrations are usually expressed as the total concentration of Ca^{2+} and Mg^{2+} in mg/l equivalent $CaCO_3$. For all the samples of this investigation, TH values range from 210 mg/l equivalent $CaCO_3$ in sample *GW* to 352 mg/l equivalent $CaCO_3$ in sample *GS*. TH is also not of health concern as per the WHO guidelines for drinking water, but at concentrations above 200 mg/l may cause scale deposition in the treatment works, distribution system and pipe work and tanks within buildings (WHO [14]). Accordingly, all of the samples were above the WHO threshold.

As a valuable indicator of the levels of dissolved minerals in water, EC values in the studied samples ranged from 936.68 μS/cm in sample *GE* to 1194.35 μS/cm in sample *GN,* and were found to be high in most of the samples. The observed high conductivity values indicate contamination that has likely been caused by movements of leachates from surrounding SWD site. As in the case of EC, TDS concentration is also not a health concern as per the WHO guidelines, but may affect the acceptability of drinking water. Hence, EC and TDS are often used as rapid indicators of water quality (WHO [14]). The values of

TDS for all the samples ranged between 526.50 mg/l in sample *GS* and 714 mg/l in sample *GE* and were considered to be high in the majority of the samples.

Chloride concentrations ranged from 129 mg/l in sample *GW* to 390 mg/l in sample *GN*. Chloride is not of health concern at levels normally found in drinking-water, but may affect consumer acceptability at concentrations above 250 mg/l (WHO [14]). While only sample *GN* has concentration above that threshold, the remaining samples contain noticeably high chloride content (above 125 mg/l). Elevated chloride content is regarded usually as an indicator of contamination; often from anthropogenic sources, such as landfill leachates (Venkatesan and Swaminathan [4]).

Sulphate concentrations in all the samples ranged between 94 mg/l in sample *GE* and 390 mg/l in sample *GN*, and were all found to be within the WHO guideline threshold value of 500 mg/l for acceptability in drinking water. The concentration of nitrates in the whole samples ranged from 9.50 mg/l in sample *GW* to 49 mg/l in sample *GN* among the whole samples. Although the values are all within the WHO health-based guideline value of 50 mg/l for nitrates in drinking water, the majority of the samples have noticeable concentrations, suggesting the possibility of contamination.

The amounts of Cu^{2+} in all the samples varied from 0.17 mg/l in sample *GN* to 0.78 mg/l in sample *GW*. The WHO acceptable limit of Cu^{2+} in drinking water is 2 mg/l; therefore, the whole samples of this study are acceptable. The concentrations of Fe^{2+} and Mn^{2+} ions varied from not detected in sample *GW* to 0.81 mg/l in sample *GE*, and from 0.10 mg/l in sample *GS* to 1.05 mg/l in sample *GW* respectively. Most of the samples (75%) had manganese content above the WHO health-based guideline value of 0.4 mg/l, and high iron content above the WHO acceptability threshold value of 0.3 mg/l.

4 Conclusion and recommendations

The results of this investigation revealed that most of the groundwater samples studied had high concentrations of the physico-chemical parameters examined. They were often found to have concentrations above the guideline values recommended by the WHO for drinking water quality. This indicates that the groundwater sources have been contaminated likely as a result of anthropogenic activities. The primary suspect is the downward migration of concentrated leachates generated in the nearby *Gyadigyadi* disposal site, which have neither been engineered nor equipped with leachate collection and treatment facilities.

Considering the significance of groundwater sources in potable water supply to the population of Kano metropolis, it is imperative that any development of groundwater resources in the area should include quality protection measures. A key objective of groundwater protection strategy is to preserve its quality and sustainability as a strategic source of water supply and supporter of terrestrial ecosystem, by controlling its overexploitation and quality degradation. Therefore, in order to ensure sustainability of this vital resource, any form of pollution should be avoided and a balanced water budget for groundwater systems ensured. This process requires an effective precautionary plan for the various forms of land use and human activities, such as solid waste management, which can be used as a guide for the regulation and supervision of groundwater operations.

References

[1] Gleick, P. H. & Palaniappan, M., Peak Water: Conceptual and Practical Limits to Freshwater Withdrawal and Use. Proceedings of the National Academy of Sciences (PNAS), Washington, D.C, 2010.

[2] King, C., *Urban Groundwater Systems in Asia*, United Nation University, 2003.

[3] Mor, S., K. Ravindra, R. Dahiya & A. Chandra, Leachate Characterisation and Assessment of Groundwater Pollution near Municipal Solid Waste Landfill Site. *Environmental Monitoring and Assessment*, 118(1–3): pp 435–456, 2006.

[4] Venkatesan, G. & Swaminathan, G., Review of chloride and sulphate attenuation in ground water nearby solid-waste landfill sites. *Journal of environmental engineering and landscape management* 17(1), 2009.

[5] Suresh, T. & Kottureshwara, N. M., Assessment of groundwater quality of borewells water of hospet taluka region, karnataka, India. *Rasayan J. Chem*, 2(1): pp 221–233, 2009.

[6] Karunakaran, K., Thamilarasu, P. & Sharmila, R., Statistical Study on Physicochemical Characteristics of Groundwater in and around Namakkal, Tamilnadu, India. *E-Journal of Chemistry*, 6(3), 2009.

[7] Akudo, E. O., Ozulu, G. O. & Osogbue, L. C., Quality Assessment of Groundwater in Selected Waste Dumpsites Areas in Warri, Nigeria. *Environmental Research Journal*, 4(4): pp 282–285, 2010.

[8] Rajkumar, N., Subramani, T. & Elango, L., Groundwater Contamination Due to Municipal Solid Waste Disposal – A GIS Based Study in Erode City. *International Journal of Environmental Sciences*, 1(1), 2010.

[9] Umadevi, A. G., George, M., Dharmalingam, P., Jose P. A., Rajagopalan M., Dhanya B., Haridasan, P. P. & Pillai P. M. B., An Investigation of the Quality of Underground Water at Eloor in Ernakulum District of Kerala, India. *E-Journal of Chemistry*, 7(3), pp 908–914, 2010.

[10] UNEP, *Africa Water Atlas. Division of Early Warning and Assessment (DEWA).* United Nations Environment Programme (UNEP). Nairobi, Kenya, 2011.

[11] Dimitriou, E., I. Karaouzas, K. Sarantakos, I. Zacharias, K. Bogdanos, A. Diapoulis & A. G. Umadevi, Groundwater risk assessment at a heavily industrialised catchment and the associated impacts on a peri-urban wetland. *Journal of Environmental Management*, 88 (2007), pp 526–538, 2007.

[12] Ahmed K., The Kano Physical Environment, 2008. Online at http://www.kanostate.net/physical.html.

[13] APHA, AWWA, WPCF. *Standard Methods for the Examination of Water and Wastewater.* 20th Edition. American Public Health Association, American Water Works Association, Water Pollution Control Federation, Washington, DC, 1998.
[14] WHO, *Guidelines for drinking-water quality.* 4th ed. WHO Press Geneva, Switzerland. 541p, 2011. Online at http://www.who.int/water_sanitation_health/publications.