Groundwater Quality Mapping using GIS: A Case Study of Awka, Anambra State, Nigeria

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ABSTRACT
In recent years, increasing deterioration of groundwater quality has become a source of great concern, due to the environmental and health implications. In Awka, the Anambra state capital, access to adequate urban water supply from the state water corporation has become a serious challenge, forcing the inhabitants to depend mainly on groundwater resources, not minding the quality. Geographic Information System (GIS), a high performance computer based tool is playing a critical role in water resource management and pollution study. Mapping of groundwater contamination is an important tool for groundwater protection, land use management, and public health. In this study, the GIS software was used to analyze the quality of groundwater in Awka. Spatial variability map of different groundwater quality parameters were generated using interpolation operation in the software. Based on the Water Quality Index map, it was observed that the groundwater in the study area is good enough for drinking and domestic purposes except in the places like Akwata where the water quality was bad.

Keywords--- Groundwater, Geographic Information System, Water Quality, Awka

I. INTRODUCTION
Water is the elixir of life and plays a vital role in the earth’s ecosystem. Water is no doubt one of the most essential needs of human beings [1]. Fresh water sources include lakes, river and groundwater. Groundwater serves as the main sources of water in the urban environment, which is used for drinking, industrial and domestic purposes. In the past few decades, increasing anthropogenic activities especially industrialization has become a threat to the existence of mankind and the ecosystem. Improper waste management practices often lead to the degradation of groundwater, with attendant health and environmental implications. It was initially believed that the soil and sediment layers deposited above an aquifer acted as a natural filter that kept pollutants from the surface from infiltrating down to the groundwater. However, it has become widely understood that those soil layers often did not adequately protect aquifers and groundwater is inherently susceptible to contamination from anthropogenic activities and remediation is very expensive and sometimes not practical [1].

A lot of efforts have been made towards curbing the menace of pollution around the world, and there are many international conferences and protocols to this effect. The issues of environmental health are now being taken with utmost seriousness. However, in many parts of the world, particularly in the developing countries, human activities still impact negatively on the environment and appropriate facilities to ensure safe disposal of wastes in a manner that will not constitute a potential hazard to public health, animal health and the environment are lacking.

Residents of Awka capital city are heavily dependent on reservoirs, wells and boreholes for their daily water supply. This is due to lack of access to urban water supply from the state water corporation since 1999 [2]. This lack of pipe borne water and the proliferation in the use of water from alternative sources has lead to the utilization of water of questionable qualities for domestic activities and other purposes. According to UNESCO report [3], about 1.2 billion people globally lack safe drinking water, and 50% of the populace in developing countries still has no reasonable access to safe and sustained water supplies. The report estimated that 14.6 million children die annually as a result of water related diseases. For those who rely on groundwater for their daily supply, it is critical that their groundwater is unpolluted and relatively free from undesirable contaminants. Hence monitoring of ground water quality has become indispensable. Water quality monitoring programs are needed in order to raise the awareness of the public as regards to the problem of underground water pollution and
also to address the consequences of present and future threats of contamination to groundwater resources. Because monitoring is expensive especially for ground water over large areas, reliable and flexible tools are needed to assist with such monitoring strategies. By using flexible tools such as GIS, fewer observation wells are needed and the potential cost is reduced.

II. METHODOLOGY

2.1 Study Area

Awka capital city is in Awka South local government area of Anambra State. It is situated between latitude 6°06' and 6°15'N and longitudes 7°05'E and 7°15'E. Figure 3.1 shows the location map of the study area. Awka is in the rainforest zone of Nigeria and experiences two distinct seasons brought about by the two predominant winds that rule the area: the South Western Monsoon winds from the Atlantic Ocean and the North Eastern dry winds from across the Sahara desert. Seven months of heavy tropical rains (May - October) are followed by five months of dryness (November - March).

2.2 Physico-Chemical Analysis

Seven boreholes were selected for this study. The locations and coordinates of the sampling points are shown in Table 1. The samples were collected in a small plastic bottle of one (1) liter capacity rinsed with distilled water and sent to the laboratory for immediate analysis. Temperature and pH measurement was carried out in-situ at the site of sample collection using mobile thermometer and pH meter (Consort P107). Samples were analyzed for the following parameters: Turbidity, DO, BOD, Nitrate Nitrogen and Total Phosphorus using standard methods as described in APHA (1998) [4]. The coordinates of the sampling points were recorded by mobile GPS.

<table>
<thead>
<tr>
<th>Sample Code</th>
<th>Location</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>Akwatar Area</td>
<td>6° 12’49.11”</td>
<td>7° 03’30.59”</td>
</tr>
<tr>
<td>S2</td>
<td>Unizik Temp Site Area</td>
<td>6° 13’16.37”</td>
<td>7° 03’52.29”</td>
</tr>
<tr>
<td>S3</td>
<td>Ezioka Area</td>
<td>6° 12’21.05”</td>
<td>7° 04’29.72”</td>
</tr>
<tr>
<td>S4</td>
<td>St. Patrick’s Cathedral Area</td>
<td>6° 13’05.79”</td>
<td>7° 04’25.42”</td>
</tr>
<tr>
<td>S5</td>
<td>Amaenyi Area</td>
<td>6° 13’37.41”</td>
<td>7° 05’18.13”</td>
</tr>
<tr>
<td>S6</td>
<td>Nkwele Area</td>
<td>6° 13’06.95”</td>
<td>7° 05’25.16”</td>
</tr>
<tr>
<td>S7</td>
<td>Ifite Area</td>
<td>6° 14’08.36”</td>
<td>7° 05’29.97”</td>
</tr>
</tbody>
</table>

2.3 Water Quality Index (WQI)

Water quality index (WQI) is an important parameter for the assessment and management of groundwater. It provides a single number which expresses overall water quality at a certain location and time which is based on several quality parameters [5]. The overall water quality index was calculated as

\[ WQI = \sum W_X Q_X \]

(1)

\[ = W_{BOD} Q_{BOD} + W_{DO} Q_{DO} + W_{pH} Q_{pH} + W_{PHOSPHATE} Q_{PHOSPHATE} + W_{NITRATE} Q_{NITRATE} + W_{FC} Q_{FC} + W_{TDS} Q_{TDS} + W_{TEMP} Q_{TEMP} + W_{TURBIDITY} Q_{TURBIDITY} \]

(2)

Where,

- \( W_X \) = weight factors of the water quality parameters
- \( Q_X \) = q- value of the water quality parameters
- \( X \) = water quality parameters.

2.4 Geographic Information System (GIS) Analysis

Geographic Information System (GIS) is a computer-based information system for input, management, analysis, and output of geographic data and information. It deals with collection, storage, retrieval, manipulation, analysis, and display of spatially related information. GIS allows interpolation of the water quality parameter at unknown location from know values to create a continuous surface which will help us to understand the scenarios of water quality parameter of the study area. In the present study, the results of the physico-chemical analysis and the WQI were used as input data in QGIS 2.2. The sampling locations were integrated with the water quality data for the generation of spatial distribution maps using the Inverse Distance Weighted (IDW) interpolation method.
III. RESULTS AND DISCUSSION

3.1 Groundwater Quality Results

The WQI values calculated along with the quality parameters is exhibited in Table 2.

<table>
<thead>
<tr>
<th>Location</th>
<th>Lat</th>
<th>Long</th>
<th>pH</th>
<th>Temp</th>
<th>Turbidity</th>
<th>DO</th>
<th>BOD</th>
<th>Nitrate</th>
<th>Phosphorus</th>
<th>WQI</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>6.213642</td>
<td>7.058497</td>
<td>6</td>
<td>27.8</td>
<td>4</td>
<td>30.5</td>
<td>13.6</td>
<td>1.08</td>
<td>0</td>
<td>48.4</td>
</tr>
<tr>
<td>S2</td>
<td>6.221214</td>
<td>7.064525</td>
<td>5.9</td>
<td>26.4</td>
<td>3.8</td>
<td>29.8</td>
<td>11.2</td>
<td>0.06</td>
<td>0</td>
<td>51.97</td>
</tr>
<tr>
<td>S3</td>
<td>6.205847</td>
<td>7.074922</td>
<td>6</td>
<td>26.3</td>
<td>1.4</td>
<td>30.3</td>
<td>11.5</td>
<td>1.04</td>
<td>0</td>
<td>49.94</td>
</tr>
<tr>
<td>S4</td>
<td>6.218275</td>
<td>7.073727</td>
<td>6.5</td>
<td>22.3</td>
<td>0.8</td>
<td>31.8</td>
<td>12.2</td>
<td>0.05</td>
<td>0</td>
<td>56.83</td>
</tr>
<tr>
<td>S5</td>
<td>6.227058</td>
<td>7.088369</td>
<td>7.1</td>
<td>19</td>
<td>0.1</td>
<td>33</td>
<td>8.57</td>
<td>0.02</td>
<td>0</td>
<td>61.51</td>
</tr>
<tr>
<td>S6</td>
<td>6.218597</td>
<td>7.090322</td>
<td>7.2</td>
<td>21</td>
<td>0.32</td>
<td>33.5</td>
<td>9.06</td>
<td>0.08</td>
<td>0</td>
<td>61</td>
</tr>
<tr>
<td>S7</td>
<td>6.235656</td>
<td>7.091658</td>
<td>6.5</td>
<td>22.2</td>
<td>1.7</td>
<td>32.8</td>
<td>12</td>
<td>0.05</td>
<td>0</td>
<td>56.87</td>
</tr>
</tbody>
</table>

3.2 Spatial Distribution of Water quality parameters

Many thematic maps were created showing the spatial variability of different water quality parameters as presented in figures (1, 2, 3, 4 and 5). pH is an important parameter, which determines the suitability of water for various purposes. pH ranged between 5.9 at Akwata area and 7.2 at Nkwele area. Temperature ranged between 27.8 at Akwata area and 19 at Amenyi area. Turbidity fluctuated between 4.0 at Akwata area and 0.1 at Amenyi area. BOD fluctuated between 13.6 at Akwata area and 8.57 at Amenyi area. Nitrate ranged from 0.02 to 1.08 and Phosphorus was not detected in the samples. The calculated Water Quality Index fluctuated between 48.4 at Akwata area and 61.51 at Amenyi area. Based on the water quality ratings assigned to water quality index values, water from all the observed point were of medium quality except for water from Akwata area which was bad.
The groundwater pollution status of an area is influenced or controlled by some factors which include topographic slope, groundwater table variation, soil porosity, permeability of the aquiferous layers, the type and quantity of waste and land use activities [6]. The Water Quality Index was lowest at Akwata area probably due to the fact that area is amongst, if not the lowest point in the city. Also wastewater from the city’s major abattoir may be impacting negatively on the groundwater resource of the area.

IV. CONCLUSION

The study demonstrates the potentials of spatial analysis and interpretations of the groundwater quality of the study area using GIS methodology. A geographical information system is developed for spatial analysis and
mapping of the groundwater characteristics in Awka capital city. The estimated water quality parameters demonstrate that groundwater quality in some areas of Awka are not very satisfactory for drinking purposes without some level of treatment. The results indicate that Awka is currently suffering from groundwater pollution which is essentially caused by untreated domestic and industrial wastewater. As the city continues to develop, there seems not be an adequate plan to contain the spread and hazards of pollution, within the water bodies. This study offers the requisite information for the authority to pursue a sustainable approach to groundwater management and contamination prevention.

REFERENCES


