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CATCHMENT SCALE ASSESSMENT OF POLLUTION THREATS TO WATER QUALITY IN RELATION TO PREVALENCE OF WATER-BORNE DISEASES IN SOME COMMUNITIES IN OMU-ARAN, NIGERIA

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ABSTRACT

Water quality assessment, especially in relation to prevalent waterborne diseases is necessary to ensure that clean and safe drinking water is delivered and sustained to reduce water-borne disease and other public health issues that are associated with the use of unsafe water. Little has been documented about the relationship between water quality and prevalence of waterborne diseases in Omu-Aran, Nigeria. In this wise, eighteen (18) water samples were collected from the available drinking water sources in the three densely populated communities in the study area, Ifaja, Ihaiye and Aran. The microbiological analysis of the water samples was performed by the determination of total coliform, according to the modified methods while the physicochemical parameters were determined by Standard Methods (APHA, 2005). Questionnaires were administered to 100 respondents in the selected communities to elicit information on water sourcing, collection, storage, treatment and prevalence of waterborne diseases treatment. Eighteen (18) water quality parameters cutting across physico-chemical and biological traits were investigated. All parameters were found to be within the WHO limit except microbial parameter (coliform count). The contamination risk from the household activity assessment were found to be severe for water source and water storage while it is moderate for water collection and water treatment and hygiene practices. The prevalence of common waterborne diseases are 9%, 35% and 56% for cholera, typhoid and Diarrhea respectively. The correlation coefficient between microbial parameter and prevalence waterborne diseases are 0.02, -0.5 and 0.86 for cholera, typhoid and cholera respectively. This is indicative of the water quality potential to be inherently laddened with waterborne diseases.

I. INTRODUCTION

Perhaps, the most significant environmental problem and threat to public health in developing countries today is inadequate access to clean water and poor sanitation practices. More than 2.6 billion people across the globe were reported [1] to lack access to improved sanitation facilities consequent upon traditional poverty, economic poverty, and degradation of the water sources. In the developing countries, prevalent diseases are water-related, ranging from skin infections to organs damage. According to [2-3], the shortage or even lack of water affects more than 40 % of the world population due to political, economic and climatological reasons. Despite the millennium development goal (MDG) plans of United Nations (UN) on quality water supply, [4] indicates that more than 25 % of the population still suffers from water-related health problems especially in the developing countries of Africa, Asia and Latin America with attendant loss in productivity. The total global water available for consumption was estimated to be only 0.7% of the worldwide water resources of which 97.5% is salt water and 2.5% is fresh water according to a release by [5].

The quality and "net availability" of water is reported to be predicated on anthropogenic "pressure" occasioned by industrialization, urbanization and demographic growth [6]. The United Nations' World Water Development Report [7] details the pressures that impair the water body's capacity against self-cleansing, ecological integrity, sustenance and other beneficial uses. The beneficial uses of water in a river reach are defined by [8] to include municipal or domestic supply, propagation of aquatic and wildlife, irrigation, watering of livestock, and recreation activities. The effects of these pressures in sub-Saharan African countries have resulted in "economic water scarcity" which in the context of water resources studies is a result of poor management of the available water resources and lack of coordinated efforts to integrate riparian management into aquatic ecology preservation. Slash and burn agricultural procedures coupled with deforestation underscore the traditional poverty being experienced. The consequent erosion effects produced heavily silted and turbid rivers that are inherently laddened with disease vectors. There are also the associated problems of increased salinity and nutrient enrichment in the water bodies which are known factors for the growth and propagation of eutrophication. Eutrophication is another pathway of measuring the health of surface water body. [9-10] explained that eutrophication is a symptom that an aquatic ecosystem has exceeded its assimilative capacity of nutrients from anthropogenic inputs. There is equally a burden of "economic" water scarcity which can be measured by examining the physical existence of water in nature and by laboratory analysis of the biochemical composition as fit for sustaining both aquatic and terrestrial lives. Once this objective cannot be met in space and time, the situation can be classified as experiencing scarcity. The scarcity pressure requires an objective analysis of historic and future scenarios of the water quality, availability and water management practices to sustain life. Hence, the submission of [11] on the assessment of future needs and water crisis issues as things of great concern. The implications of the above thoughts were strengthened by strategic desires in most developed and developing countries to develop a Water Framework with the basic goal to achieve "good status" of both surface and ground waters with a strong focus on the ecological criteria and by strategic integrated management. This involves management and research activities that clearly focus on integrated water resources management and the development of harmonised tools to support it. The European Union determined its long-term policy of water resource management within the river basins in Europe by a fundamental document "European Water Framework Directive 2000/60/EC, 2000" (WFD) with the basic principle encompassing harmonization of legal regulations, institutional organization regarding water and environmental protection, provision of finances etc., to concrete plans regarding preventive measures, water resources and ecosystem rehabilitation and realization of water use projects in accordance with sustainable development principles. This Framework has since be the target of many countries, which they replicate in part or in whole, through establishing water agencies at various administrative levels. This is equally in use to promote and enforce water quality policies and by extension to protect public health which has direct consequences on economic security.

Table 1: Pollution sources and pollution stressors.

Section	Affected Environment	Water Quality	Facility Sitting	Protect Species	Effluent Disposal
i	Climate	✓	✓	✓	✓
ii	Soil, relief and gradient	✓	✓		✓
iii	Water Resources	✓	✓	✓	✓
iv	Water Quality	✓	✓	✓	✓
v	Ecological Habitat	✓	✓	✓	✓
vi	Urbanisation	✓	✓	✓	✓
vii	Recreation	✓	✓		✓
viii	Land-use and Planning	✓	✓	✓	✓

Source: Authors, (2021).

II. THEORETICAL REFERENCE

II.1 GLOBAL CHALLENGES

Major noted source of pollution in water bodies is the indiscriminate discharge of municipal wastes and industrial effluents into the environment. Over recent decades, [12] observed that stricter environmental regulations and drastically reduced sewage discharge into river systems have led to significant improvements in water quality of some studied UK rivers and lakes. However, there are still some river sites, such as the Lauffen weir of the River Neckar in Germany, as noted by [13] that is well-known for high level of contamination with specific pollutants such as cadmium. The Mississippi river in the United States is considered genuinely the most polluted river as it lacks the diluting action [14].

The United Kingdom Department of Environment Food and Rural Affairs [15] remarked that the implementation of the European Union Water Framework Directive (WFD) (2000/60/EC) has given added impetus to efforts requiring catchment scale assessment of threats to ecology and water quality, and the formal development of management strategies (River Basin Plans) to address pollution. [16] noted that the US geological survey (USGS) began using an innovative, continuous estimate of real-time nutrient and bacteria concentrations to establish and monitor total maximum daily load (TMDL) in their waterways as mandated by the Clean Water Act of 1972 [17] said quantifying sources of pollution is becoming increasingly important when characterising river catchments in their entirety as a prerequisite for environmental management.

Cost assessment of environmental management and river water quality issue has been kept throughout in a context of environment health and disease burden especially on the developing countries of the world [18]. There is a need to expand the horizon to cover productivity and economic effects on society as depicted in the Conceptual loop on Environmental, health and economic security in Figure 1.

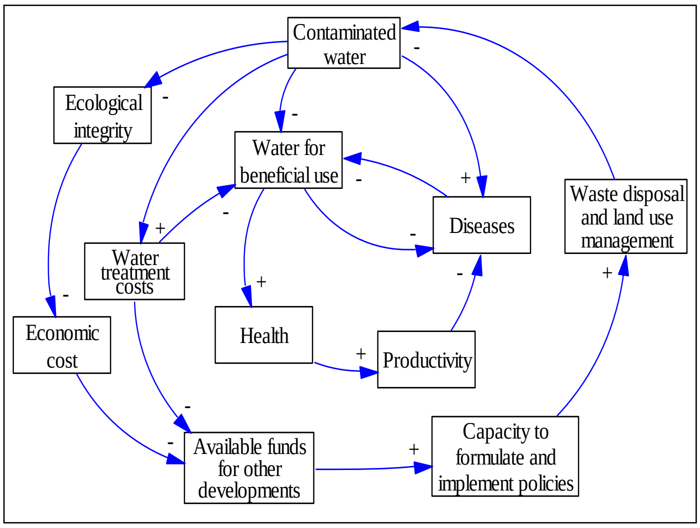

Figure 1: Causal loop on Environmental health and Economic security (The concept of adaptative sytem dynamics depicting impact of waste disposal and land management on health and economic security.
Source: [18].

This concept reflects the interaction between catchment environment and the cost of quality water within the context of policy issues. Therefore, it is being proposed here that the problem of water quality should be outlined in the context of socio-economic development and possibly should equally be quantified on the basis of an economic index.

II.2 LOCAL CONSIDERATION AND MOTIVATION FOR STUDY

There are issues with availability and accessibility water of satisfactory quality to meet human and environmental needs in Irepodun Local Government [19-20]. Households are often compelled to travel long distances to collect water to be stored in vessels or containers for use. Since the water is mostly stored in plastic drums, metal tanks and barrels over long periods, it is susceptible to contamination by harmful bacteria and hazardous chemicals due to poor water handling practices, poor sanitation and poor waste management practices with the attendant effect of water-borne diseases such as dysentery, cholera, typhoid etc., when consumed. According to [21], the water in Omu-Aran is prone to pollution from unhygienic disposition of wastes on land and into water bodies. The streams were reported to be highly contaminated with heavy metals such as Cd, Mn and Fe [22] (Abdus-Salam et al., 2016). The high prevalence of cases of water borne diseases, most especially cholera outbreak, within the corridor of study is alarming. In 2001, cholera epidemic claimed not less than 40 lives and many others were hospitalized [23]. In June 2017, another reported episode had 12 deaths recorded in less than 5 days [24]. It is in view of these factors that this study seeks to assess the quality water in relation to prevalence waterborne diseases in Omu-Aran and its environs. The study seeks to help in devising a policy framework that is beneficial to water resources stake holders in protecting usable sources of water from degradation by anthropogenic activities with the following considerations:

- assessment of the microbial and physio-chemical parameters in household drinking water sources.
- determination of the prevalence of common waterborne diseases in the study area.
- assessment of the relationship between the water quality and the prevalence waterborne diseases in the study area.

III. MATERIALS AND METHODS

III.1 THE STUDY AREA

This study was conducted in Omu-Aran, a metropolitan town with the third largest population, approximately 150,000 [25] in Kwara State, Nigeria. It is surrounded by some rural communities like Oko, Ipetu, Rore, Aran-Orin and Ilofa. The town lies between 8° 8' 0" North, 5° 6' 0" East of prime meridian [21]. The mean annual rainfall and temperature in area ranges from 1234.9mm-1468.5mm and 32.3 - 36.4 oC respectively, while the annual mean relative humidity ranges from 47.6-52.4 [26] (Sojobi et al., 2015). The major economic activities include farming, petty trading and small-scale businesses.

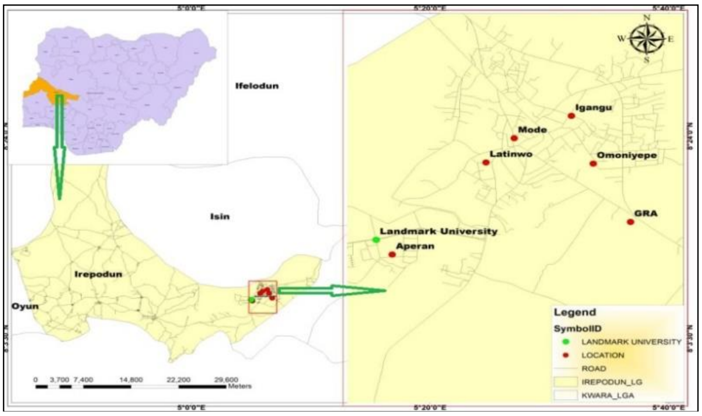

Figure 2: Map of the study area.
Source: Authors, (2021).

Six (6) communities, Latinwo, Mode, Igangu, GRA, Aperan and Omoniyepe in Omu-Aran were selected for the scheme. A multi-stage sampling technique including the administration of questionnaires was used to obtain samples and information in the study area. The six study areas were grouped into three (3) due to their vulnerability in terms of water availability and accessibility. The sample size was calculated using equation (1) on the assumption that no work on water quality assessment in relation to prevalence waterborne diseases in the study area has ever been done

a) Proportion with good knowledge, attitude and practice of water quality assessment = 85%
b) Precision limit = 10%
c) 95% level of significance.

$$N = \frac{Z^2}{\Delta^2} pq \quad (1)$$

where
N = Sample size;
Z = Confidence interval at 95% which is 1.96;
p = Proportion with good knowledge, attitude and practice of water quality assessment =27.7%;
q = 1-p = 1-0.277 = 72.3%;
Δ = precision limit = 10%.

Therefore,

$$N = \frac{1.96^2}{0.1^2} \times 0.277 \times 0.723 = 77 \quad (2)$$

Sample size calculated for household was 77. For convenience, a total of 100 people from different household were interviewed and 25 water samples were taken from household water source.

III.1.1 Methods of Assessment

Pre-testing of questionnaire, inclusion and exclusion criteria

The questionnaires were verified for accuracies and comprehensiveness before administration. To minimize errors, pre-testing of the data collection tools was done on 10% of the sample size in a nearby community. Revision of the questionnaires was done based on the results of the pilot study. The findings of the pre-test were used to improve the validity of the data collection tools and the reliability of the research findings. The inclusion criteria were households that formed part of the random sample within the six (6) selected communities in the study area. These are the people that were available at the time of sampling. The exclusion criteria were households with individuals who for some reasons would not be available during the questionnaire administration.

Laboratory analyses

Sample analysis was carried out in duplicates and the data presented as means. Turbidity, pH, electrical conductivity (EC), total dissolved solids (TDS) and temperature were tested in-situ for physical parameters, while chemical parameters included nitrate, arsenic, fluoride, iron and manganese. Bacteriological samples (E. coli and thermotolerant coliform, TTC) analysis were transported on ice pack in an ice chest to the laboratory within 6 hours of collection and stored in a refrigerator at 4 ºC prior to analysis. The assessment of the levels of microbial contaminants in the sample was by membrane filtration (MF) technique. This technique gives an immediate tally of thermotolerant and total coliforms that may be present in given water sample. A measured volume of water is filtered through a membrane filter comprising a cellulose compound with a uniform pore size of 0.45µm or 0.2µm in diameter. After the filtration procedure, bacteria are retained on the surface of the membrane filter. The membrane filter was placed in a Petri-dish containing a selective differential culture medium and incubated at a suitable temperature. Characteristic colonies indicating thermotolerant coliforms develop and are directly tallied.

An Erlenmeyer flask with side-arm was connected to a vacuum source and the porous support placed in position. The filtration unit was assembled by placing a sterile membrane filter on the porous support, using forceps sterilized by flaming and the upper container positioned to secure it. 10 mL of water sample was poured into the upper container and filtered by applying the vacuum. After filtration the membrane filter was placed in the Petri dish containing Chromogenic coliform agar with the grid side up using the sterile forceps and making sure that no air bubbles were trapped between the pad and the filter. The Petri dish was left at room temperature ranging between 35 and 37 °C for 2–4 hours, for resuscitation of stressed microbes. It was then transferred into an incubator at 44 ± 0.5 °C for 24 hours with 100% humidity for thermotolerant coliforms [27]. The colonies of thermotolerant coliform bacteria were identified from their characteristics on the medium used. The number of thermotolerant coliforms per 100 ml was given by: Thermotolerant coliforms per 100 mL = No. of thermotolerant coliform counted x 100 Vol in (mL) of sample filtered.

Table 2: Physical analysis of water samples.

	Iharye		**Ifaja**		**Aran**		
Parameter	**Igangu**	**GRA**	**Mode**	**Latinwo**	**Aperan**	**Omoniyepe**	**WHO**
Turbidity	2.3±0.6	1.3±0.0	2.0±0.0	1.3±0.0	0.0±0.0	0.0±0.0	5.0
Conductivity	630±5	70.3±0.3	469.3±0.6	96.4±0.1	130.9±0.1	498.0±0.0	1000
TDS	313±2.6	35.4±0.2	234.3±0.6	123.7±0.3	65.5±0.1	249.0±0.0	500
Ph	6.5±0.0	6.7±0.0	6.1±0.0	6.5±0.0	7.2±0.0	6.1±0.0	6.5-8.5

Source: Authors, (2021).

Table 3: Chemical analysis of some water samples collected from the sampling points.

	Ihaiye		**Ifaja**		**Aran**		
Parameter	**Igangu**	**GRA**	**Mode**	**Latinwo**	**Aperan**	**Omoniyepe**	**WHO**
T. Hardness	91.0±1.0	64.3±0.6	60.0±0.0	60.3±0.6	77.7±0.6	84.0±.0	150
Magnesium	47.7±2.3	20.3±0.6	41.3±0.6	16.0±0.0	27.3±0.6	77.7±0.6	75
Sulphate	13.3±1.5	7.7±0.6	7.0±0.0	16.0±0.0	6.0±0.0	8.0±0.0	100
Nitrate	10.3±0.6	5.0±1.0	6.0±0.0	11.7±0.6	4.7±0.6	10.0±0.0	50
Chloride	41.7±2.9	4.9±0.1	32.0±0.0	1.2±0.1	5.3±0.1	36±0.0	250
Phosphate	2.8±0.1	2.3±0.1	1.5±0.1	4.1±0.0	1.3±0.1	2.0±0.1	250
COD	72.0±2.6	120.0±1.0	110.0±0.0	170.0±0.0	80.0±0.0	75.0±0.0	1000
BOD	26.0±3.6	39.7±1.5	33.0±0.0	55.0±5.0	23.0±0.0	25.0±0.0	0
Calcium	16.3±0.6	27±0.0	18.3±0.6	24.3±0.6	31.3±0.6	35.0±0.0	250
E. Coli	62.3±1.2	34.7±8.5	38.3±7.6	34.0±4.0	10.3±4.5	34.0±4.0	0

Source: Authors, (2021).

Table 4: Compliant of some Water quality sampling data for the study area.

SN	Quality Variable	Total Samples	WHO guideline value	%Compliant
1	Bacteriologic Pipe-borne	200	<1 cfu/100ml	83
2	Coliform count in lined well	150	<1 cfu/100ml	30
3	Commercial water tankers	100	<1 cfu/100ml	52
3	Arsenic	550	0.01mg/L	60
4	Nitrate as NO_3	550	50mg/L	62
5	Fluoride	550	1.5mg/L	85
6	Iron	550	0.3mg/L	82
7	Turbidity	550	<5NTU	45
8	pH	550	6.5-8.5	72
9	Electrical Conductivity	550	1400µS/cm	55

Source: Authors, (2021).

IV. RESULTS AND DISCUSSIONS

A total of 100 respondents participated in the survey pertaining to water quality, sanitation and hygiene. The corresponding responses are Ihaye (39%), Ifaja (31%) and Aran (30%). Majority of the local community rely on two major water sources (boreholes and hand dug wells) with percentage reliance on bore-hole, 45.1%; hand-dug wells, 43.1% public water supply, 9.8%; rain harvesting and streams, 2.0 %. The general practice involves water collection and storage in all manner of containers in a bit to gain ready access and forestall scarcity. This is done with little or no preference for treatment prior to consumption. In general, 1.2 % of borehole users report that they have experienced one or more water related illness within the last three years, 34.1 % of respondents who make use of shallow wells and 30% of use public water supply reported related illness. However, none of the respondents with reported use of rain water had related illness.

In the survey result, (Table 3) the general compliance with the WHO standard was lowest for turbidity with an average value of 45%, and a value of 30.0 % for thermo-tolerant coliforms in lined wells in the survey of conventional water supply options (pipe-borne water, borehole, hand-dug lined well, vehicle tanker) that were examined.

V. AUTHOR'S CONTRIBUTION

Conceptualization: Omotoso Toyin.
Methodology: Omotoso Toyin.
Investigation: Omotoso Toyin and O Ibitoye.
Discussion of results: Omotoso Toyin.
Writing – Original Draft: Omotoso Toyin and O Ibitoye.
Writing – Review and Editing: Omotoso Toyin and O Ibitoye.
Resources: Omotoso Toyin and O Ibitoye.
Supervision: Omotoso Toyin.
Approval of the final text: Omotoso Toyin and O Ibitoye.

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