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The challenges of domestic wastewater management in Nigeria: A case study of Minna, central Nigeria

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Abstract

The main objective of the study is to examine the challenges and risk of domestic wastewater management. The methodology adopted involves the use of questionnaire, field survey, government documents, Global Positioning System (GPS) and sampling of the wastewater for laboratory analysis. The result showed that the wastewater generated is mostly from bathing and laundry. The daily amount of wastewater generated is 36,493,920 litres (36,494m^3). The physico-chemical composition of the domestic wastewater shows that pH has a range of 7.5 and 8.7, Temperature 29^{o}C and 30.1^{o}C, Salinity 1051mg/l and 1329mg/l, Chloride 240mg/l and 280mg/l, Sodium 152mg/l and 178.7mg/l, Potassium 84.35mg/l and 99.34mg/l, Calcium 24.01mg/l and 48.1mg/l, Magnesium 24.4mg/l and 39.04mg/l, sulphate 10mg/l and 19mg/l, Carbonate 370.5mg/l and 525mg/l and Bicarbonate 945.75mg/l and 1462.5mg/l. Environmental implications of domestic wastewater include medium growth for pathogens like mosquito parasite. The public are exposed to these pathogens via contaminated drinking water, water bodies or eating contaminated food. Common ailments that afflict the inhabitants include malaria, typhoid and cholera. Wastewater treatment and re-use is recommended as a complement for water use and also as a disaster risk reduction strategy. The wastewater can be reused for fire protection, irrigation/fish farming and for aquifer recharge.

Keywords: Wastewater, Management, Reuse, Treatment, Environment

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1. Introduction

Any water that has been adversely affected in quality due to human activities can be regarded as wastewater (Burton and Stensel, 2003). It includes domestic liquid waste from residences, industries or agriculture. It encompasses a wide range of contaminants which can be potentially harmful or concentrations that can lead to degradation in water quality. These potential contaminants include soaps and detergents from bathrooms, food scraps and oil from kitchens and other human activities that involve the use of water. Potable water becomes wastewater after getting contaminated with all or some of the above mentioned potential contaminants.

Wastewater that comes from human waste (feaces, urine or other body fluids), also known as blackwater, includes water from lavatories, septic tanks or soakaway, and washing water; while greywater is wastewater that comes from urban rainfall runoff from roads, roofs, and sidewalks. Wastewater can be contaminated with different components which mostly include pathogens, synthetic chemicals, organic matter, nutrients, organic compounds and heavy metals. These occur either in solutions or as particulate matter.

If wastewater is not properly managed it could become a point source of pollution which could be a hazard for the health of human populations and the environment. The environmental impact of wastewater degradation may result in physical changes to receiving waters, increased level of dissolved oxygen, bioaccumulation in aquatic life, release of toxic substances and increased ground water quality (Mahmood and Maqbool, 2006). Diseases caused by bacteria, viruses and protozoa are the most common health hazards associated with untreated wastewater. Many microbial pathogens in wastewater can cause chronic diseases with long-term effects such as degenerative heart disease and stomach ulcer (Paillard et al., 2005). These debilitating ailments can be fatal and have been known to impair human productivity. Wastewater also consists of vast quantities of bacteria, most of which are harmless to man. However, pathogenic forms that causes diseases such as typhoid, dysentery and other intestinal disorder may be present in the wastewater (Absar, 2005).

Urban growth impacts on infrastructure in developing countries are extremely pressing. In many cities of Asia, Africa and Latin America, engineered sewage collection systems and wastewater treatment facilities are often non-existent. For developing countries, particularly in arid areas, wastewater is simply too valuable to waste. It contains scarce water and valuable plant nutrients, and crop yields are higher when crops are irrigated with wastewater than with freshwater. Farmers use untreated wastewater out of necessity and, unfortunately, it is a reality that cannot be denied or effectively banned (Looker, 1998).

Wastewater is a complex resource that is both advantageous and inconveniencing in its use. It is a renewable resource that once used can be reclaimed and used again for different beneficial uses. The quality of the once used wastewater and the specific type of reuse determine the level of subsequent treatment needed. The reclaimed wastewater can be used for purposes, other than drinking, such as; irrigation of public parks, athletic fields, recreation centers, school yards and playing fields, reservations of highways, irrigation of landscaped area surrounding buildings, fire protection, as well as toilet and urinal flushing in public buildings (Hespanhol, 1992). This will greatly reduce the overstretching of potable water. The lack of freshwater resources large enough to meet the demand of a burgeoning population led to the emergence of wastewater reclamation and reuse as components of wastewater management (Asano et al., 1998). Water conflicts arise mostly as a result of the need to manage the resource which is becoming scarcer with time. Benefits of water reclamation and reuse are recognized as a method of preventing the pollution of surface and ground waters (Hespanhol, 1992).

Even though wastewater and its nutrient contents can be used for crop production, thus providing significant benefits to the farming communities and society in general, its use could however also impose negative impacts on communities and on ecosystems. The use of wastewater containing toxic wastes coupled with the lack of adequate finances for treatment is likely to cause an increase in the incidence of water borne diseases as well as more rapid environmental degradation. Although the harmful effects of using contaminated wastewater effluents could go undetected for several years, it however adversely affect groundwater quality when nutrients leach down the soil into the groundwater system (Mahmood and Maqbool, 2006). Near surface aquifers in intensely irrigated areas using wastewater can indeed become polluted, thus reducing the aquifer potability.

Minna is the capital of Niger State and lies between latitudes 9°32' and 9°41' N and longitude 6°28' and 6°37' E covering an approximate surface area of 105km². The town has an estimated population of 304,113 in the 2007 census. The geology of Minna comprises mainly of rocks belonging to the Pre-Cambrian Basement Complex system of Nigeria.

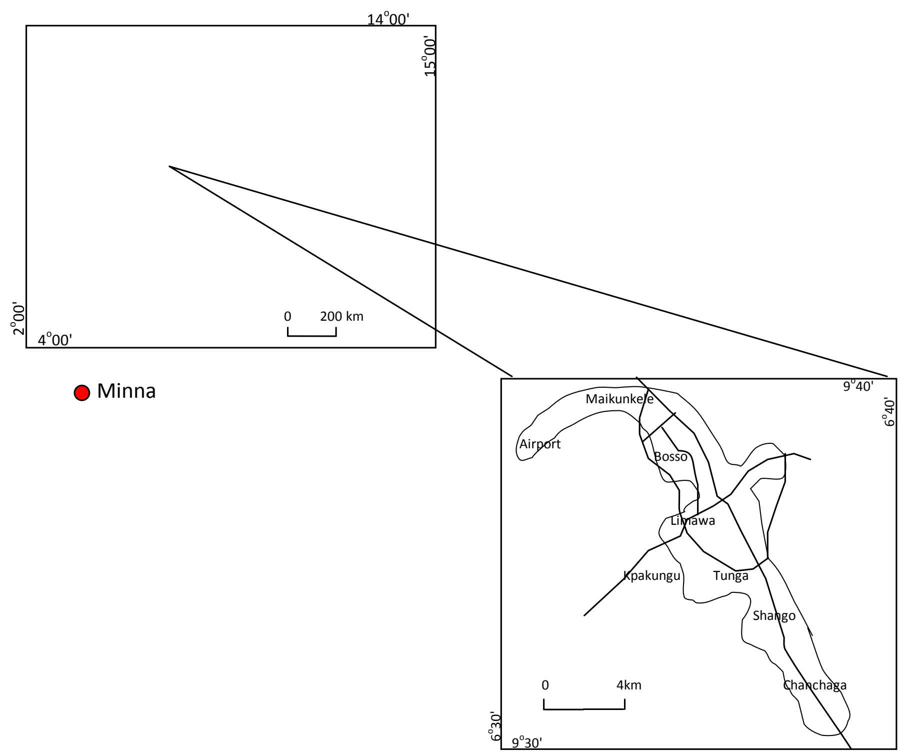

Figure 1. Location map of study area

2. Aim and objectives

The aim of the study is to examine the risks/hazards and challenges caused by the improper wastewater management on the environment in Minna, central Nigeria. The specific objectives are:

1) To examine the challenges involved in domestic wastewater management
2) To examine the environmental and health implications of domestic wastewater
3) To estimate the quantity of domestic wastewater generated
4) To determine the physico-chemical composition of domestic wastewater
5) To determine wastewater management strategies.

3. Environmental and health impacts of domestic wastewater discharge

The effluents generated from domestic activities or wastewater constitutes the major sources of the natural water pollution load. This is a great burden in terms of wastewater management and can consequently lead to a point source pollution problem and could also introduce a wide range of pollutants and microbial contaminants to water sources (Eikelboom and Draaizer, 1999). This includes groundwater pollution in wells and boreholes. This has created negative environmental impacts and increased the health risk of the residents. Wastewater that is directed to the environment is the prime breeding sites for mosquitoes, houseflies, rodents, and other vectors of communicable diseases such as dysentery, diarrhea and. The two fundamental reasons why wastewater should be properly managed includes the prevention of pollution of water sources and the protection of public health by safeguarding the environment against the spread of diseases. Wastewater management is presently poorly done or even nonexistent in Nigeria and most other developing countries.

The quality of domestic wastewater effluents is one of the main causes of degradation of the receiving water bodies such as rivers, lakes, streams etc. The potential health hazards of polluted wastewater effluents on the quality of receiving water bodies are many and depend on the volume of the wastewater discharge, the microbiological and chemical concentration of the effluents. It also depends on the type of discharge, for example, the amount of suspended solids or hazardous pollutants like heavy metals or organic matter (Owuli, 2003). By extension, using the water for recreational purposes and anyone else coming into contact with the degraded water is at risk, children playing around contaminated wastewater are most vulnerable to getting infected with diseases. The impact of such degradation may result in physical changes to receiving waters, release of toxic substances, decreased levels of dissolved oxygen, increased nutrient loads and bioaccumulation in aquatic life (Environmental Canada, 1997). The increasing release of domestic wastewater containing hazardous substances and the lack of adequate finances for treatment may likely cause an increase in the incidence of water borne diseases as well as more rapid degradation of the environment.

Wastewater more often than not forms stagnant pools in the neighborhood since mostly the drainage channels are either nonexistent or blocked. Poorly drained wastewater could collect at the foot of buildings, commonly along fence lines, building frames and foundations leading to cracks and eventually collapse of the structure.

The most common health hazards associated with domestic wastewater includes disease caused by viruses, bacteria and protozoa that may get washed into drinking water supplies or receiving water bodies (Kris, 2007). Microbial pathogens have been identified as critical factors contributing to numerous waterborne disease outbreaks. Many of these pathogens found in domestic wastewater can cause chronic disease with long term health effects such as stomach ulcer and degenerative heart disease.

The detection and identification of the different types of microbial pathogens in domestic wastewater are always difficult, expensive and time consuming. To overcome this problem indicator organisms are commonly used to determine the risk of the possible presence of a particular pathogen in wastewater (Paillard et al., 2005). Chronic exposure toxins produced by these organisms can lead to health problems like liver damage, gastro-enteritis, skin irritation, nervous system impairment and liver cancer in animals (Eynard et al., 2000). According to Toze 1997 and Okoh et al., 2007, viruses are considered as been among the most important and potentially most hazardous pollutants in domestic wastewater. They found out that they are generally more resistant to treatment; most infectious, more difficult to detect and require smaller doses to cause infections. Bacteria are also one of the most common microbial pollutant in domestic wastewater. They cause a wide range of infectious diseases such as dysentery, diarrhea, skin and tissue infection etc, such bacteria found in wastewater include E. Coli, Salmonella, Leptosporosis, etc. These cause mostly dysentery and typhoid fever which is very endemic in the developing world Nigeria inclusive.

4. Wastewater characteristics

The effective management of any wastewater flow requires an accurate knowledge of its characteristics. These characteristics, according to Burks and Minnis, 1994, are necessary to facilitate the effective design of wastewater treatment and disposal system, and also to enable the development and application of water conservation and waste load reduction strategies. The quality of wastewater may be defined by its physical, chemical and biological characteristics. Physical parameters include; temperature, pH, electrical conductivity, colour, odour, and turbidity. Insoluble contents such as oil and grease, solids (suspended or dissolved) and inorganic fractions also fall into this category (Burks and Minnis, 1994).

Chemical parameters associated with the organic content of domestic wastewater include Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Total Organic Carbon (TOC) and Total Oxygen Demand (TOD). Inorganic chemical parameter include alkalinity, salinity, hardness, acidity as well as concentrations of cations such as Manganese, Iron and anions such as sulfates, chlorides, nitrates and phosphates. Bacteriological parameters include fecal coliforms, coliforms, algae, protozoas, specific pathogens and viruses (Metcalf and Eddy, 2003).

Management of wastewater involves identifying the source and type of wastewater, ways in which it can be harnessed for potential reuse and ways in which the potential risk posed by wastewater can be eliminated or reduced. Major challenges faced by wastewater management include infrastructure, pollution of water bodies, choice of appropriate technology, sludge production and reuse.

5. Materials and methods

The data for this study was collected from both Primary and Secondary sources. Primary sources involve generation of data using direct data acquisition methods like questionnaires, fieldwork, and sampling. While secondary data obtained from both published and unpublished information and data from Government agencies were utilized.

Closed ended questionnaire were formulated and used as a vital instrument for data collection. The questionnaire was standardized, so that every respondent answered exactly the same questions which made it a reliable data collection instrument. The questionnaire was divided into sections relating to population information in each household, water generation and usage, public health and potential reuse of wastewater. Possible answers were provided in which the respondent were required to choose the one that best suits them.

A comprehensive field survey or reconnaissance survey was carried out in order to gather information and access the condition of the different infrastructure such as wastewater drainage, housing types, access roads, water source and situation where major health and environmental hazards will be present. Potentially polluted areas, collection points for wastewater, channeling systems were also studied.

Topographical map was obtained from Niger State Geographical and Information System (NIGIS) while satellite maps were obtained from Google maps, 2012. The maps provided highly detailed information about the natural and man-made aspects of the terrain, elevation changes, and water bodies such as streams, roads buildings and vegetation. Information on water supply was obtained from Niger State Water Board (NSWB), which provided an estimate on water generation and supply. Hospitals within the study area were also contacted on the cases of health effects and diseases due to wastewater pollution.

A hand held GPS, Garmin Etrex Legend was used for the study to identify sample points. The method of data analysis was the frequency percentage method. This method was chosen because it is principally the most suitable and appropriate technique for analyzing questionnaires. Data presentation was in the form of tables, charts and graphs. The frequency percentage technique involves the analysis of response based on the number of questionnaires filled and returned viz-a-viz the standard percentage of 100. Critical interpretations, inferences and deductions were made based on the responses made by the respondents.

6. Results and interpretation

Table 1. Summary of Questionnaire Results

Parameter Question		**Response**	
		Frequency	**Percentage**
Household type (Bedroom)	Single 2 bedroom 3 bedroom 4 bedroom	137 151 46 5	39 43 13 5
Household size (Person)	1 2 – 4 4 – 6 >6	35 63 109 175	10 18 31 50
Marital Status	Single Married with children	88 263	25 75
Parameter Question		**Response**	
		Frequency	**Percentage**
Water Source	Water Board Borehole Hand dug well Water Vendor	42 140 123 42	13 40 35 12
Daily water requirement (Litres)	<50 50 – 200 200 – 400 >400	86 175 70 16	25 50 20 5
Water use	Cooking Dish washing Laundry Bathing	14 35 130 172	4 10 37 49
Period of time water most used	Morning Afternoon Evening	123 53 174	35 15 50
Discharge of wastewater	Public drain Soakaway Open surface	179 123 49	51 35 14
Common ailments	Diarrhea Malaria Cholera Typhoid	91 158 28 73	26 45 8 21
Environmental concern on wastewater	Not concerned A little Sometimes Always	126 53 109 63	36 15 31 18

Table 2. sample point description for physic-chemical analysis

	Location	Coordinate N E	Altitude (m)	Sample type	Description
1.	Chanchaga	9⁰ 01' 31" 7° 34' 0.24"	446.5	Wastewater	Stagnant water mixed with debris in an open drain
2.	Tunga	9° 01' 53" 7° 34' 22"	463.0	Wastewater	Slow moving water in an open channel in the middle of residential area.
3.	Limawa	9° 02' 0.01" 7° 34' 36"	445.5	Wastewater	Flowing water from open drain in the middle of a residential area.
4.	Bosso	9° 01' 52" 7° 34' 38"	448.7	Wastewater	Stagnant water from an open drain mixed with debris
5.	Maitumbi	9° 01' 39" 7° 34' 23"	444.4	Wastewater	Flowing water from an open channel in the middle of a residential area.
6.	Maitumbi	9° 01' 26" 7° 34' 05"	447.6	Borehole	Commercial borehole for water vendors

Figure 2 is the graph of the physical parameters of Temperature, pH, Conductivity, Salinity, Hardness and Alkalinity of the samples wastewater.

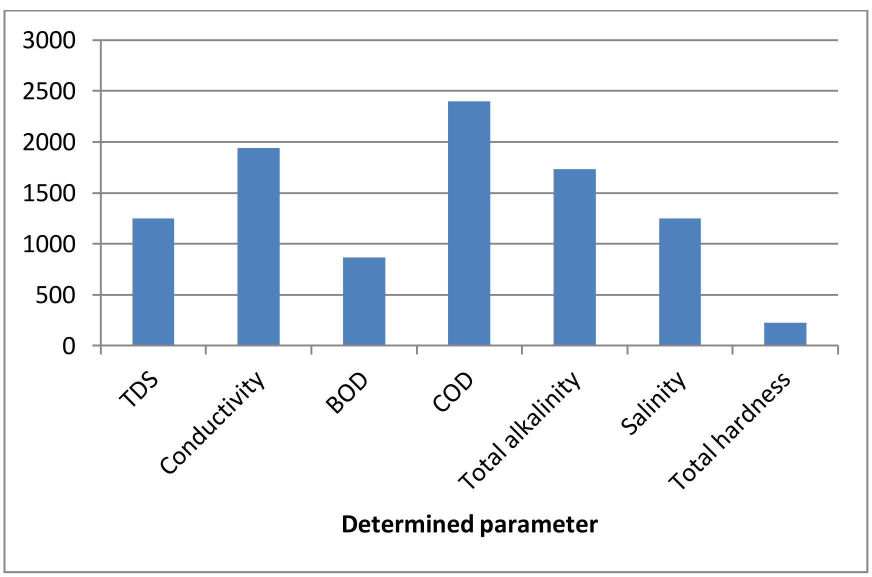

Figure 2. Physical parameters of wastewater in Minna

Table 3. Chemical composition of wastewater and borehole

Parameter	Unit	Chanchaga	Tunga	Limawa	Bosso	Maitumbi	Mean Values	Borehole
Temp	^oC	29	29.5	29.9	29.8	30.1	29.66	29.1
TDS	mg/L	1052.23	1315.88	1315.88	1230.8	1329.3	1249	ND
Cond	µS/cm	1964	1964	1964	1837	1894	1943	779
DO	mg/L	1.37	0.48	0.35	0.84	0.37	0.68	3.74
BOD5	mg/L	870	1020	600	473	373	867	ND
COD	mg/L	2900	3400	2000	1690	2010	2400	ND
Total hardness	mg/L	160	260	260	180	280	228	162
Chloride	mg/L	250	270	280	250	240	258	64.5
Total alkalinity	mg/L	1316.25	1978.44	1652.9	1852.5	1852.5	1731	516
Nitrite	mg/L	0.339	0.048	0.248	0.215	0.407	0.3	0.101
Nitite as Nitrogen	mg/L	0.069	0.01	0.05	0.014	0.083	0.05	0.031
Salinity	mg/L	1051	1316	1316	1230.79	1329.28	1249	ND
Iron	mg/L	0	0.05	0.49	0.13	0.98	0.33	0
Sodium	mg/l	152.03	174.73	178.68	173.74	176.7	171	8
Potassium	mg/L	84.35	99.34	95.53	86.22	99.34	93	0.97
Calcium	mg/L	24.01	40.01	24.05	32.06	48.1	34	63.5
Magnesium	mg/L	24.4	39.04	48.8	24.8	39.04	35	4.39
Sulphate	mg/L	10	11	11	19	18	14	23
Copper	mg/L	2.7	4.3	0	0	0	1.4	0
Phosphorous	mg/L	1.5	2.08	1.85	2.15	1.5	1.8	ND
Phosphate	mg/L	4.58	6.33	5.75	6.55	4.55	6	0.75
Bicarbonate	mg/L	945.75	1453.6	1301.9	1404	1462.5	1314	171
Carbonate	mg/L	370.5	525	351	448.5	390	417	ND
Turbidity	NTU							1.22
Coliforms	cfu/100ml							0
E.coli	cfu/100ml							0

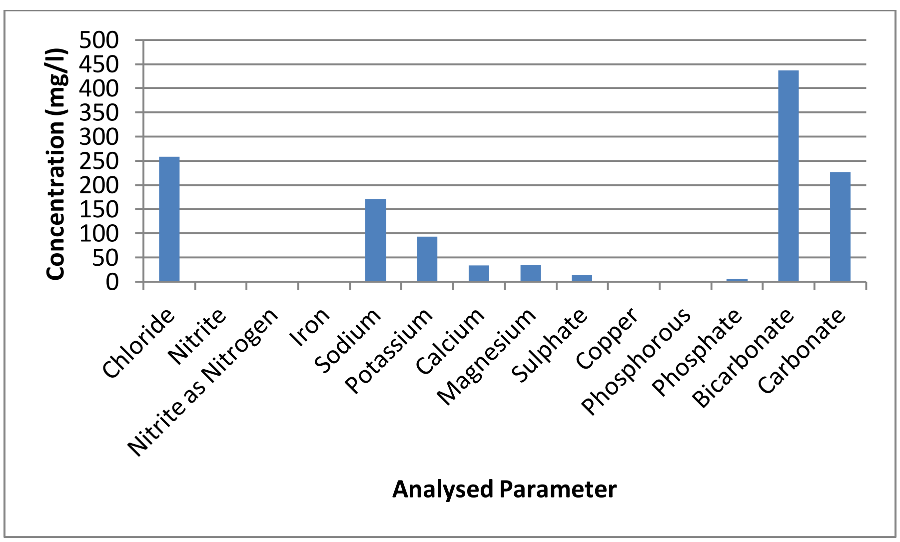

Figure 3. Mean concentrations of analyzed chemical parameters

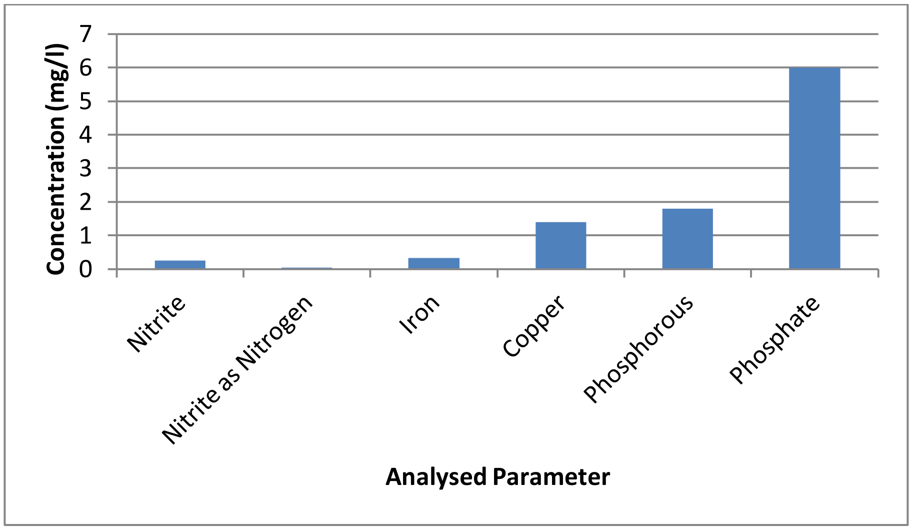

Figure 4. Mean concentrations of analyzed chemical parameters

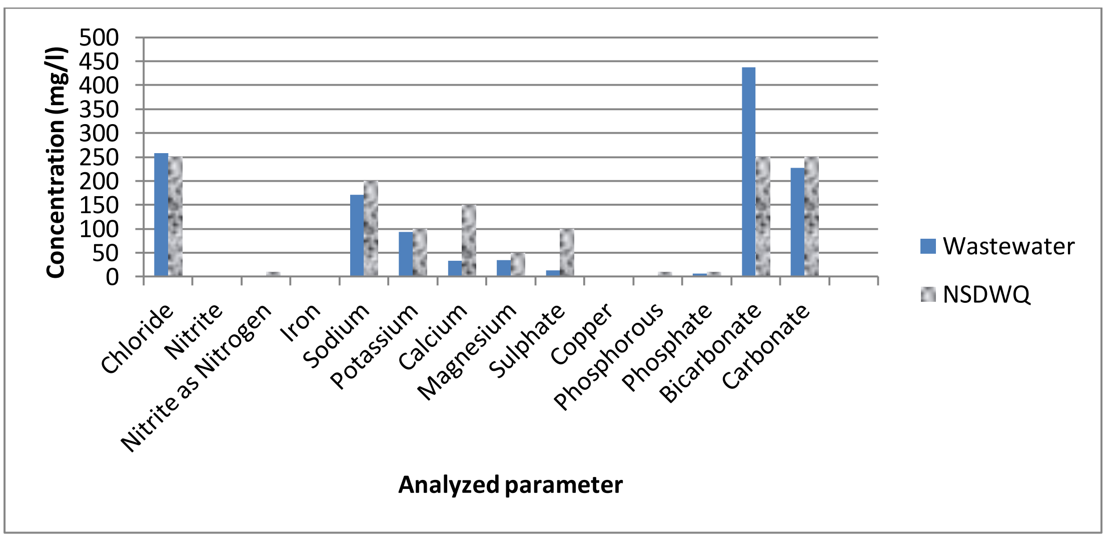

Figure 5. Comparison of chemical concentration of wastewater with the Nigerian Standard (2007)

7. Discussion of results

The discussions are principally based on the stated objectives. The broad aim of the research is centered on the challenges and risk of domestic wastewater management. Water generation and usage, public health and environmental implications of wastewater, and potential re-use of wastewater was determined through the analysis of questionnaires.

Domestic wastewater management involves the determination of domestic wastewater, its threat to the environment, collection systems and reuse. An improperly managed domestic wastewater has the potential to negatively impact on the natural environment, on human health as domestic wastewater contains disease producing micro organism and chemicals and on the economic environment.

Presently domestic wastewater management in the area consists of the use of septic tanks, unplanned and partially planned open drainage systems. While 35% of domestic wastewater generated goes into the septic tank, the remaining 65% flows freely and sometimes pond on the surface forming stagnant pools. The inhabitants in some areas resort to manually digging channels to convey wastewater away from residential areas. Both the unplanned and partially planned drainage system end up forming pools of water at the terminal end since there are no systems in place to collect the wastewater. Even though 37% of the respondents in the area seem to be concerned about how wastewater is being discharged in the area, majority (63%) of the respondents seem not to be concerned as long as the wastewater is conveyed away from their immediate residence. This implies that majority of the people are not aware of any consequences of wastewater as a threat to them and the environment and are not even sure if it could be put to any other purpose.

Virtually all the residents say they are not aware of any government regulations on wastewater management. These by implication shows that government at all levels have not been doing much in terms of wastewater management. Also the health problems that have been identified include malaria, typhoid and diarrhea. These have been found to be directly or indirectly linked to wastewater. For example stagnant pools of wastewater form a good habitat for vector reproduction and growth. Wastewater in the area is also associated with odour which is what the inhabitants are more concerned about and aesthetically not a pleasing sight to behold

Wastewater infrastructure is generally poor and in some cases nonexistent. The large volume of wastewater generated in this area with proper infrastructure can be channeled and treated for reuse even though most of the inhabitants do not believe it can be reused for any other purpose. As shown in Table 1, some respondents that thought it could be reused believe it can be reused for agriculture/irrigation and in the industry but certainly not for household use. In more developed countries, wastewater reuse has found a wide application in both direct and indirect potable reuse, industry and the environment.

Public water supply in the study area is via 10,000,000 litre (10 million litres) reservoir which supplies 8,000,000 litres (8 million litres) to the inhabitants twice a week (Niger state Water Board). This public water supply which is grossly inadequate is complemented by individual efforts like privately owned boreholes, hand-dug wells and water vendors (meiruwa). The average daily water supply by the public water service is 2,286,000 litres/ day. (i.e 8,000,000 litres twice a week= 16,000,000 litres divided by 7 days in a week). Since this represent only 13% of the total available water for domestic use, the remaining 87% coming from other sources.

Based on the fore going, using a sample population of 304,113 inhabitants for the area and an average of 6 people to a household, the total number of household is 50,686. Taking an average of 50-200 litres, the average daily water requirement per person is 125 litres and per household is 750 litres (125 litres multiply by 6 persons). At an average of 50,686 households, the total amount of water available for domestic use in the area is 38,014,500 litres.

Theoretically, all water except that used for food preparation returns to the sewer as wastewater. From the studies, bathing, laundry and dish washing accounts for 96% of the total water use while only 4% accounts for food preparation. Since it is only this 4% that goes into consumptive water use, 96% is available as wastewater which translates into 36,493,920 litres.

Thirty five percent of the wastewater generated goes into the planned/unplanned soak away pit while the remaining 65% of the wastewater flows on the surface in planned/unplanned drainage system. The volume of wastewater therefore that goes into the soak away pit is 12,772,872 litres. Annual wastewater discharge in unplanned/planned drainage system in Minna is 23,721,048,000 litres. (23,721,048 cubic meters). This is indeed an enormous volume of water to be allowed to waste.

The concentration chart of Figure 2 shows that COD is high which is indicative of organic pollution of the water. The concentration chart of the analyzed chemical parameters in Figure 3 shows that bicarbonates have a very high concentration followed by carbonates, chloride and sodium. These are all constituents of what is used in the urbanized areas for laundry (washing agents e.g. soap) and feaces. These are constituents that have been classified as high concentration constituents in the research work. Those with medium concentration include Phosphate and Phosphorous.

A comparison of borehole water with wastewater shows that apart from calcium and sulphate which occur in higher concentration in the borehole, all other analyzed parameter (Nitrite, Nitrite as Nitrogen, Iron and Copper) shows a higher concentration in the wastewater. A similar comparison with the NSDWQ, 2007 in Figure 5, shows that with the exception of bicarbonates, carbonates, potassium and chloride all other parameters (Nitrite, Nitrite as Nitrogen, Iron, Copper, Sodium, Magnesium, Phosphate, Phosphorous and Calcium) are below the maximum permitted NSDWQ standard. This implies that with minimal treatment the wastewater can actually be re-used for other purposes other than drinking and cooking such as bathing, laundry, recreation and in the industry

8. Conclusion

As a result of the volume of wastewater generated in this area and the challenges posed to the environment and to the inhabitants, coupled with the fairly good physico-chemical composition, this wastewater can be re-used for other purposes. The benefits of collecting wastewater in this area are numerous; the collected wastewater could be recycled for all domestic activities except cooking and drinking which fortunately accounts for only 4% of water usage in the study area. Wastewater re-use involves passing the wastewater through a treatment system, which involves the removal of solids, inorganic and organic compounds, bacteria and algae and subsequent conversion into economically acceptable water. Wastewater re-use in this area will allow effluents to be disposed of without danger to human health or unacceptable damage to the natural environment.

It is therefore highly recommended that domestic wastewater re-use be adopted as a disaster risk reduction strategy for urbanized areas in developing countries like Nigeria.

The treated water can thus be safely used for the following purposes;

1) Fire Protection. This can be achieved through running a series of pipes into the area and installing fire hydrants. A short lateral line will be designed to connect each fire hydrant to a distribution main. Shutoff valves will be located at strategic points throughout the system to provide control of any section or service outlet, including hydrants. These valves will serve the purpose of isolating the system for required maintenance and to ensure that a main break affects only a small section.
2) Irrigation and fish farming. As a result of the prevailing climatic conditions in the area, two seasons are clearly identifiable; a seven months of rainy season and five months of dry season. During the dry season water becomes very scarce and the food security of the area and even the country becomes challenged. Treated wastewater can effectively be harnessed for irrigating farmland for dry season production of crops and vegetables. These can be grown at local levels for households or community cooperative bodies with little parcels of land for cultivation. This will go a long way in creating employment, maintaining the environment and boosting the food requirement of the country. This can readily be achieved by piping the treated water to the farm through the series of mains and other distribution network. Fish farmers have to struggle to get water for the farm from wells and boreholes since treated water, especially the one that has undergone both secondary and tertiary treatment has an adverse effect on the fish, and wastewater that has undergone primary treatment only can be used comfortably for this purpose without having any adverse effect on the fish.
3) Aquifer Recharge. An aquifer is a subsurface reservoir that transmits water to wells and boreholes. Hand dug wells and boreholes obtain their water from underground reservoirs which in turn get their water from rainfall through infiltration into the ground. However groundwater recharge is limited by so many factors chiefly of which is climatic, rainfall, and geology. During the long dry season this reservoir becomes depleted as a result of pressure from overuse. This vital resource can be recharged artificially. The main purpose of artificial aquifer recharge technology is to store excess water for later use. The method will ensure that groundwater levels are maintained while improving the water quality of the wastewater as it undergoes natural treatment before joining the groundwater system.

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