American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-8, Issue-5, pp-337-343
www.ajer.org
Research Paper Open Access

Characteristics and health risks of domestic wastewater in Dawaki ward, Bauchi. Bauchi State-Nigeria.

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ABSTRACT: *Domestic wastewater generation and disposal are one of the biggest challenges associated with the growth of informal settlements. Wastewater here is regarded as a combination of one or more of domestic effluent consisting of black-water (excreta, urine, and faecal sludge) and grey-water. As such, the potential impact of wastewater on human health is a growing concern.Composite samples of wastewater were collected from five (5) major drains in the study area. Samples were collected on a weekly basis during the period of the study. 20 composite samples each of wastewater (4 samples each of wastewater per location) were collected throughout the sampling period. Temperature, Total Dissolved Solids (TDS), and pH were measured in-situ with a PC 300 Waterproof pH/TDS/Temperature meter while Dissolved Oxygen (DO) was measured with a WTW Oxi 340 oximeter.The characteristics of domestic wastewater show that only pH, Copper, Lead and Zinc with 7.38±0.46 mg/L, 0.74 ±0.074 mg/L, 0.074±0.01 mg/L, and 0.34±0.11 mg/L respectively do not exceed the National Environmental (Surface and Ground Water) Regulations (NER), 2009 effluent guidelines as developed by National Environmental Standards Regulations and Enforcement Agency. All other parameters assessed significantly exceeded the concentration required by the guideline. The high- level coliforms in the domestic wastewater are particularly undesirable to the environment but potentially to human health as well.Domestic wastewater generated should be managed and disposed-off properly in order to avoid disease outbreak on the inhabitant and create an aesthetically pleasing and functionally efficient healthy environment.*

KEYWORDS: *Domestic, Environment, Environmental Health, Human, Wastewater*

Date of Submission: 10-05-2019 Date of acceptance: 27-05-2019

I. INTRODUCTION

Domestic wastewater generation and disposal are one of the biggest challenges associated with the growth of informal settlements (slums) in the developing world (1, 2). In Sub-Saharan Africa, 62% of the urban population lives in slums. The most alarming statistics can be found in countries emerging from conflict and in West Asia, where the proportion living in slums has increased from 67% to 77% and 21% to 25%, respectively (3).

Water pollution occurs when unwanted materials enter into water and changes the quality of water; this can be harmful to the environment and human health (4). According to the World health organization (WHO) cited in (5), 80% of diseases are water borne and 3.1% of death globally occur due to polluted water. It is also reported that 75% to 80% water pollution is caused by domestic sewage, domestic sewage contain toxicants and bacterial contaminants and these causes pollution of water (6)

Wastewater is regarded as a combination of one or more of domestic effluent consisting of black-water (excreta, urine, and faecal sludge) and grey-water (used water from washing and bathing); water from commercial establishments and institutions, including hospitals; industrial effluent, storm water and other urban runoff; and agricultural, horticultural and aquaculture runoff (7). Wastewater can be beneficial for human through increased food security and socio-economic development, for instance, (8) documented that at least 20 million hectares in 50 countries globally are irrigated with raw or partially treated wastewater that is around 10 percent of irrigated land. Additionally, In Hanoi, Vietnam, for instance, up to 80 percent of vegetables produced are irrigated with wastewater (9). Thanks to wastewater, it is possible (and commonly the only way) to produce food and increase income in poor areas, thus also increasing nutrition and the quality of life. Malnutrition plays a significant role in the death of 50 percent of all children in developing countries {10.4 million children under the age of five die annually from it, according to (10)}. A study in Tanzania showed that a village where a rice irrigation scheme had been developed with wastewater had more malaria vectors than a nearby savannah village but a lower level of malaria transmission. The village with the irrigation scheme had more resources to buy food, children had a better nutritional status, and the villagers were more likely to buy and use mosquito nets (8). The situation is completely different in poor areas lacking in job opportunities, where water reuse represents the only possibility of improving living standards by increasing income and ensuring food supplies. In areas where wastewater is an important production factor, people use up to 50–80 percent of their income on food (11); thus, even in small plots and with inappropriate water quality, agricultural production contributes to supporting families and complementing their diets (12). For these reasons, 15 % (in Hanoi) and 68% (in several cities of India and Africa) of poor cities practice urban agriculture using raw wastewater. The mean annual net income per farmer using wastewater to irrigate varies from US$155 in Africa's Yaoundé, Cameroon, to $2,800 in Hyderabad, India (11). In fact, the possibility of having wastewater to irrigate instead of freshwater made land rents in the El Mezquital Valley, Mexico, increased from $171 to between $351 and $940 per year, because, besides increasing yields, irrigating with wastewater enables three crops to be harvested per year instead of one (8). For most of these communities, food security and nutrition are more important than infectious disease transmission.

Wastewater can also be detrimental to human health through increased pathogen virulence and facilitation of new communicable diseases (13, 14). The most environmentally resistant pathogens are *helminth*(parasitic worm) eggs, and they are recognized as the main health risk in the use of wastewater for irrigation because of their resistance and persistence (15), particularly for developing countries where levels found in wastewater are seven to 80 times greater than those found in developed countries' wastewater (16).

Helminthiases (infestation with parasitic worms) are common diseases with an uneven distribution around the world. In developing countries, the affected population is 25–33 percent, whereas in developed ones it is less than 1.5 percent. The problem is more severe in regions where poverty and poor sanitary conditions prevail; under these conditions, *helminthiasis* reaches 90 percent of the population (17). There are several kinds of *helminthiasis*; *ascariasi*s is the most common and is endemic in Africa, Latin America, and the Far East. There are 1.3 billion infections globally. Furthermore, even though it is a disease with a low mortality rate, most of the people affected are children under 15 years with problems of faltering growth and/or impaired fitness. Approximately 1.5 million of these children will probably never catch up, even if treated (18). As such, the potential impact of wastewater on human health is a growing concern (13,19). In the same vein, wastewater causes environmental problems including pollution of surface water, groundwater, and soil by nutrients, pathogens, organic matter, and heavy metals, as well as emissions of ammonia, odour, and greenhouse gases (20,21,22). Considering the wide range of contaminants and different exposure routes, concern remains about the potential human health risks (13,23,24,25).

The Dublin Statement and Agenda 21 represent a starting point in the search for more innovative and sustainable approaches to managing wastewater and the environment. In a follow-up meeting at Bellagio, Italy, from 1–4 February 2000, an expert group brought together by the Environmental Sanitation Working Group of the Water Supply and Sanitation Collaborative Council agreed that current waste management policies are abusive to human well-being, economically unaffordable, and environmentally unsustainable. Specifically, the Belagio Statement (Water 21, April 2000) raised the following issues that are of interest to our research. They states that "export of wastes from the source of generation should be minimised to promote efficiency and reduce the spread of pollution, wastewater should be recycled and added to the water budget and waste should be managed as close as possible to its source. (26)''.

The potential exposure routes from wastewater, contaminated underground water, soils, and food sources include intentional and accidental ingestion, dermal contact and inhalation (27-32). In slums, the incidence of diarrhoea, dysentery, and gastroenteritis is especially high in immune-compromised groups that include children, the elderly and pregnant women and is attributed to person-to-person contact as well as faecally contaminated water and soil (33,34,35).

A critical issue, which limits the possibility of establishing adequate policies for water quality, is the lack of available data about wastewater (1). In Sub-Saharan Africa, little quantitative data are available about wastewater generation, disposal, risk, treatment, use, characteristics, and effects. Information is available only for Senegal, Seychelles, and South Africa, with data from Seychelles and South Africa dating back to early 2000 (36). It is in the light of the above that this research seeks to assess the pollution characteristics and environmental health risks of domestic wastewater in Dawaki Ward, a slum in Bauchi. Nigeria.

II. MATERIALS AND METHODS

The pollution characteristics of the study area were assessed through wastewater sampling and analysis. Composite samples of wastewater were collected from five (13) major drains in the study area. Samples were collected on a weekly basis during the period of the study. 20 composite samples each of wastewater (4 samples each of wastewater per location) were collected throughout the sampling period. The samples were collected into 1.0 litre clean plastic bottles. Temperature, Total Dissolved Solids (TDS), and pH were measured in-situ with a PC 300 Waterproof pH/TDS/Temperature meter while Dissolved Oxygen (DO) was measured with a WTW Oxi 340 oximeter. Samples were preserved in an ice box and transported to the laboratory where other analyses were carried out. Ortho-phosphate, Nitrogen-Ammonia, Nitrate-Nitrogen, Potassium, Magnesium, Sulphur-Oxide, Calcium, Sodium, and Aluminum were measured with a DR/2400 Spectrophotometer using appropriate reagent pillows. A bacteriological examination (Escherichia coli and Total coliforms) was conducted by the Pour plate method using nutrient Agar as culturing medium. All the methodologies for field and laboratory analysis were conducted according to the Standard Methods for the Examination of Water and Wastewater (1999). Analyses of heavy metals namely Cadmium, Mercury, Lead, Copper and Zinc were carried out with a Buck Scientific Model 210 VGP Flame Atomic Spectrophotometer. 5mL of concentrated HNO_3 was initially added to 500mL of the samples to prevent adsorption of the metals to suspended solids. Digestion was carried out with a di-acid mixture composed of HNO_3: $HClO_4$ in the ratio of 9: 4 on a hot plate and filtered with Whatman No. 1 filter paper. The resulting mixture was diluted to 50mL with distilled water for the spectrophotometric analysis. The results compared with the National Environmental (Surface and Ground Water) Regulations, 2009 as developed by the National Environmental Standards Regulations and Enforcement Agency.

III. RESULTS

In order to assess the characteristics of the wastewater in Dawaki ward, weekly composite samples were taken at different times and samples were analysed in the laboratory. Average and standard deviation of results of the composite samples are given in Table 1, as compared with the National Environmental (Surface and Ground Water) Regulations (NER), 2009 as developed by National Environmental Standards Regulations and Enforcement Agency.

Table 1: Characteristics of Domestic Wastewater in Dawaki Ward and National Environmental (Surface and Ground Water) Regulations (NER), 2009 as developed by National Environmental Standards Regulations and Enforcement Agency.

Parameters	Units	Mean±S.D of Concentrations	Acceptable limit NER, 2009
pH		7.38±0.46	6.5-9.2
Temperature	^oC	30.14±1.24	<40^{o}C
Dissolved Oxygen	mg/L	0.22±0.067	6.0
Total Dissolved Solid	mg/L	1163.2±101.29	1,500
Total Suspended Solid	mg/L	256.2±31.18	30
BOD_5 at 20^{o}C	mg/L	329±29.22	50
COD	mg/L	1630.4±215.80	30
K	mg/L	34.08±5.18	50
Mg	mg/L	8.94±0.65	40
SO_4	mg/L	211.78±52.62	500
NO_3	mg/L	153.49 ±42.91	40
N	mg/L	43.86±9.81	20
PO_4	mg/L	41.06±4.65	3.5
NH_3	mg/L	58.98±16.12	2.0
Ca	mg/L	118.7 ±11.91	180
Na	mg/L	142.6±20.07	120
Cu	mg/L	0.74 ±0.074	0.01
Pb	mg/L	0.074±0.01	0.1
Zn	mg/L	0.34±0.11	0.2
E-coli	10^8CFU/100mL	49.74±7.71	0.0
Total coliforms	10^8CFU/100mL	4.39 ±0.81	10

Source: Field Survey, 2018

IV. DISCUSSION

Table 1 revealed that domestic wastewater from Dawaki ward showed a slightly alkaline pH during the study period possibly attributable to the presence of detergents and soapy water. On the average, pH of the wastewater was (7.38±0.46) which is within the NER, 2009 (National Environmental Regulations) value of 6-9 for discharge into Surface and Ground Water (37). This is acceptable since wastewater with low pH is difficult to treat by biological means and may also alter the concentration in natural waters (38).

Also, the average temperature value of 30.14±1.24 was recorded during the study period for domestic wastewater. This is relatively higher than the city's average ambient temperatures of 29.3°C. The discharge of heated effluents may considerably modify the ecology of the receiving stream as well as decrease the solubility of oxygen in the water (39). Domestic Wastewater in Dawaki ward during the study was generally anaerobic due to high levels of organics and low levels of dissolved oxygen (DO). Due to the low DO (0.22±0.067mg/L) in the wastewater during the study, it showed a characteristic black-colour accompanied by foul and objectionable odour (40). The low DO of the domestic wastewater is harmful to human health and aquatic life when discharged into adjoining water bodies since it has the potential to cause a drop in DO levels in the water, depending on the volume. In the same vein, dissolved oxygen waters with extremely low DO are not able to support aquatic life (41).

Furthermore, the mean Total Dissolved Solid of the domestic wastewater during the study is 1163.2±101.29mg/L, does not exceed the National Environmental Regulations (NER) effluent discharge value of 1,500mg/L. On the other hand, higher levels of Total Suspended Solid (TSS) were recorded in the domestic wastewater in the area as compared to the NER effluent discharge value during the study. The average TSS value (256.2±31.18mg/L) was about 5 times greater than the NER effluent discharge value of 30mg/L. The high levels of TSS in the wastewater could be attributed to erosion of soil particles in the earth drains as the domestic wastewater flows through and the organic matter resulting from food waste, and other forms of human and animal waste. Total Suspended Solids are made up of either mineral or organic solids (42). Consequently, the decomposition of the organic component depletes the dissolved oxygen in the water, resulting in anaerobic conditions and unpleasant odours (39). This affirms the foul and objectionable odour in the domestic wastewater in the study area.

In addition, the BOD5 level in the domestic wastewater was 329±29.22 mg/L which is higher than the NER effluent discharge value of 50mg/L. COD also showed the same level, 1630.4±215.80mg/L high compared to a NER effluent discharge value of 30mg/L. On the average, the COD/BOD value of the domestic wastewater was 4.95. COD/BOD values of wastewater indicate how biologically degradable the wastewater is and hence its suitability for biological treatment (43). If COD/BOD value is less than or equal to 2, the substances present in the wastewater can easily be degradable while high values indicate that the substances are difficult to break down. For the COD/BOD values recorded, it means that the domestic wastewater contains substances that are not easily degradable such as polythene and thus will make biological treatment difficult. BOD is the level of organic content in wastewater measured by the demand for oxygen that can be consumed by living organisms in the wastewater (44) whereas COD measures the amount of oxidizable matter present in wastewater (40). The breaking down or stabilization of such constituents consequently utilizes the dissolved oxygen in the water causing its depletion resulting in the generation of odour. Thus, domestic wastewater with high BOD content is characterized by low oxygen content and high biological activity. This low level of BOD and COD in the domestic wastewater during the study shows the potential risks the wastewater poses to human health and aquatic environments.

More so, potassium (K), magnesium (Mg), and sulphate(SO_4), their concentration is 34.08±5.18mg/L, 8.94±0.65mg/L, and 211.78±52.62mg/L respectively does not exceed NER effluent discharge value of 50mg/L, 40mg/L, and 500mg/L respectively. The low concentration of magnesium cations (Mg^{2+}) may be attributed to the presence of acids of SO_4^{2-} or Cl^- in wastewater. Where, the chemical process between Mg^{2+} and SO_4^{2-} or Cl^- produces chemical solids as $MgSO_4$ or Mg (CO_3)…etc. The solids are sediment and become a part of the soil (45). The average concentration of Nitrogen-ammonia in the domestic wastewater during the study was 58.98±16.12mg/L against the NER effluent discharge value of 2.0mg/L. Also, the average concentration of Nitrogen-nitrate was 153.49±42.91mg/L as against the NER effluent discharge value of 40mg/L. The higher concentrations indicate pollution resulting from sewage. This can be injurious to pregnant women, children and the elderly.

Also, Phosphorus (in the form of orthophosphate) in the domestic wastewater had the average value of 41.06±4.65 mg/L. Although phosphorus is an essential nutrient for plant growth and for biological metabolism, (46) argues that excessive discharge into aquatic environments can result in excessive algae growth, eutrophication and the depletion of oxygen in water bodies. Phosphorus is usually associated with plant remains, animal waste and fertilizer (47). Other potential sources of phosphates in wastewater as stated by (46) include, cleaning products, cosmetics, medicated shampoos, food products, faeces, and urine. All these sources (except fertilizer), as observed in the study area, contribute to the high levels of phosphorus in the wastewater and poses a potential deleterious risks to aquatic life in the receiving water bodies.

The presence of inorganic contaminants in surface water resulting from domestic wastewater affects aquatic life primarily due to their non-bio-degradable and toxic nature. While some of these contaminants like

Copper and Zinc are important micronutrients for plants and microorganisms, others such as Cadmium, Mercury, and Lead pose deleterious health effects above certain thresholds (48). The levels of Copper, Lead and Zinc concentrations (0.74 ±0.074mg/L, 0.074±0.01mg/L, and 0.34±0.11mg/L respectively) in the domestic wastewater were below their respective NER effluent discharge value of 0.01mg/L, 0.1mg/L and 0.2mg/L respectively. Though in small quantity, the presence of these toxic heavy metal in the domestic wastewater can kill the micro-organisms that are needed for biological treatment of wastewater and therefore stop the treatment process. When ingested, Lead inhibits enzymes and also damages the nervous system and the kidneys (49,50).
The levels of E. coli and total coliforms concentration $49.74 \pm 7.71 X10^{8}$CFU/100mL and $49.74 \pm 7.71 X10^{8}$CFU/100mL respectively were higher than the NER effluent dischargevalues of 0 and 0 respectively. The presence of faecal coliforms is an indicator of faecal contamination (51). Thus, the higher levels of E-coli in domestic wastewater are attributable to runoff conveying human and animal waste in the study area. Although most microorganisms (bacteria, protozoa) are responsible and also beneficial for biological treatment processes of wastewater (52,53), researchers argue that depending on the dose and susceptibility of the host, some of these organisms found in domestic wastewater can cause diseases of the gastrointestinal tract such as typhoid and paratyphoid fever, dysentery, diarrhoea and cholera (54). Therefore, levels of E-coli in the domestic wastewater were found to be within the range of infectious dose (10^{6}-10^{10}) indicating the serious health threat it poses to human life.

V. CONCLUSION

Determining the pollution characteristics and environmental health risk is acceptable is difficult. We are exposed to many different environmental health threats simultaneously, especially those associated with domestic wastewater. Furthermore, people consider some dangers tolerable but dread others especially those that are common and whose effects are known to science. The situation is complicated by the fact that the media gives us a biased perspective on some risks, while our personal experience and our sense of our own abilities are often misleading. It is important however to note that the severity of these environmental health risks related to domestic wastewater is not to be taken for granted. Therefore, domestic wastewater generated should be managed and disposed properly in order to avoid hazards on the people and create an aesthetically pleasing and functionally efficient healthy environment.

ACKNOWLEDGEMENTS

The authors would like to appreciate AbubakarTafawaBalewa University, and the good people of Dawaki ward, Bauchi for their sincere cooperation throughout this research.

REFERENCE

[1]. United Nations World Water Development Report (UN- WWDR), (2017).
[2]. Aliyu, A. (2018). Environmental Health effects of Domestic Wastewater in Dawaki ward, Bauchi. An unpublished Mtech thesis Dept. of Environmental Management, AbubakarTafawaBalewa University, Bauchi.
[3]. UN-Habitat (United Nations Human Settlements Programme). (2012). State of the World’s
[4]. Cities Report 2012/2013: Prosperity of Cities. World Urban Forum Edition. Nairobi, UN-Habitat. sustainabledevelopment.un.org/content/documents/745habitat.pdf
[5]. Alrumman SA, El-kott AF, Kehsk MA (2016). Water pollution: Source and treatment. American journal of Environmental Engineering. Vol. 6(3):88-98.
[6]. Pawari MJ, Gawande S (2015). Ground water pollution & its consequence. International journal of engineering research and general science. Vol. 3(4):773-76.
[7]. Mehtab H, Muhammad FM, Asma J, Sidra ,Nayab A, Sharon Z. and Jaweria H (2017). Water Pollution and Human Health, Journal of Environmental Risk Assessment and Remidiation. Retrieved on 12/60/2018.http://www.alliedacademies.org/environmental-risk-assessment-and-remediation/
[8]. Raschid-Sally, L. and Jayakody, P. (2008). Drivers and Characteristics of Wastewater
[9]. Agriculture in Developing Countries: Results from a Global Assessment. IWMI Research Report No. 127. Colombo, International Water Management Institute (IWMI).
[10]. Jimenez, B. (2005a). Treatment technology and standards for agricultural wastewater reuse: A case study in Mexico. Irrigation and Drainage Journal 54 (1): 23–35
[11]. Ensink, J., T. Mahmood, W. van der Hoek, L. Raschid-Sally, and F. Amerasinghe. (2004). A nationwide assessment of wastewater use in Pakistan: An obscure activity or a vitally important one? Water Policy journal6:197–206.
[12]. Rice, A., L. Sacco, A. Hyder, and R. Black. (2000). Malnutrition as an underlying cause of childhood deaths associated with infectious diseases in developing countries. Bulletin of the World Health Organization78:1207–1221.
[13]. Raschid-Sally, L., R. Carr, and S. Buechler. (2005). Managing wastewater agriculture to improve livelihoods and environmental quality inpoor countries. Journal of Irrigation and Drainage54:11–22.
[14]. Ratta, A., and J. Nasr. (1996). Urban agriculture and the African urban food supply system. African Urban Quarterly1996: 11 (2and 3): 154–161.
[15]. Jones, B.A; Grace, D.; Kock, R.; Alonso, S.; Rushton, J.; Said, M.Y.; McKeever, D.; Mutua, F.; Young, J.; McDermott, J.; Pfeiffer, D.U. (2013). Zoonosis emergence linked to agricultural intensification and environmental change. Proc. Natl. Acad. Sci. USA, 110, 8399–8404.

[16]. WHO. (2015). Research Priorities for the Environment, Agriculture and Infectious Diseases of Poverty: Technical Report of the TDR Thematic Reference Group on Environment, Agriculture and Infectious Diseases of Poverty. Available online: http://apps.who.int/iris/bitstream/10665/ 78129/1/ WHO_TRS_976_eng.pdf.

[17]. World Health Organization (WHO). (1989). Guidelines for the safe use of wastewater in agriculture. Geneva: WHO.

[18]. Jimenez, B. (2005b). Helminths removal for agriculture and aquaculture water reuse. Proceedings of the 5th International Symposiumon Wastewater Reclamation and Reuse for Sustainability, November 8–11, at Jeju, Korea, International Water Association(IWA).

[19]. Bratton, R., Nesse, R. (1993). Ascariasis: An infection to watch for in immigrants. Postgraduate Medicine Journal93:171–178.

[20]. Silva, N., M. Chan, and A. Bundy. (1997). Morbidity and mortality due to ascariasis: Re-estimation and sensitivity analysis ofglobal numbers at risk. Tropical Medicine & International Health 2 (6): 519–528.

[21]. Ilea, R.C. (2009). Intensive livestock farming: Global trends, increased environmental concerns, and ethical solutions. J. Agric. Environ. Ethics, 22, 153–167.

[22]. Raschid-Sally, L.; van der Hoek, W.; Ranawaka, M. Wastewater Reuse in Agriculture in

[23]. Vietnam: Water Management, Environment and Human Health Aspects. In Proceedings of a Workshop held in Hanoi, Vietnam 14 March 2001; International Water Management Institute, Colombo, Sri Lanka, 2001.

[24]. Gerber, P.; Chilonda, P.; Franceschini, G.; Menzi, H. (2005). Geographical determinants and environmental implications of livestock production intensification in Asia. Bioresource Technol., 96, 263–276.

[25]. Do-Thu, N.; Morel, A.; Nguyen-Viet, H.; Pham-Duc, P.; Nishida, K.; Kootattep, T. (2011).

[26]. Assessing nutrient fluxes in a Vietnamese rural area despite limited and highly uncertain data. Resour. Conserv. Recycl., 55, 849–856.

[27]. Aneja, V.P. (2003). Agricultural ammonia emissions and ammonium concentrations associated with aerosols and precipitation in the southeast United States. J. Geophys. Res., doi: 10.1029/ 2002JD003214.

[28]. Arksey, H.; O'Malley, L. (2005). Scoping studies: towards a methodological framework. Int. J. Soc. Res. Methodol., 8, 19–32.

[29]. Burkholder, J.; Libra, B.; Weyer, P.; Heathcote, S.; Kolpin, D.; Thorne, P.S.; Wichman, M. (2007). Impacts of waste from concentrated animal feeding operations on water quality. Environ. Health Perspect., 115, 308–312.

[30]. Nhapi I., H.J. Gijzen and M.A. Siebel. (2003). A conceptual framework for the sustainable management of wastewater in Harare, Zimbabwe.

[31]. Stanek, E.J. and Calabrese, E.J. (1995) Daily estimates of soil ingestion in children. Environmental Health Perspect 103, 276–285.

[32]. Haas, C.N., Rose, J.B. and Gerba, C.P. (1999) Quantitative Microbial Risk Assessment. New York, USA: John Wiley & Sons.

[33]. Howard, G., Pedley, S., Barret, M., Nalubega, M. and Johal, K. (2003) Risk factors contributing to microbiological contamination of shallow groundwater in Kampala,Uganda.Water Res 37, 3421–3429.

[34]. Steyn, M., Jagals, P. and Genthe, B. (2004). Assessment of microbial infection risks posed by ingestion of water during domestic water use and full-contact recreation in a mid-southern Africa region. Water SciTechnol 50, 301–308.

[35]. Westrell, T., Sch€onning, C., Stenstr€om, T.A. and Ashbolt, N.J. (2004) QMRA (quantitative microbial risk assessment) and HACCP (hazard analysis and critical control points) for management of pathogens in wastewater and sewage sludge treatment and reuse. Water SciTechnol 50, 23–30.

[36]. Schonning, C., Westrell, T., Stenstr€om, T.A., Arnbjerg-Nielsen,K., Hasling, A.B., Høibye, L. and Carlsen, A. (2007). Microbial risk assessment of local handling and use of human faeces. J Water Health5, 117–128.

[37]. Victora, C.G., Smith, P.G., Vaughan, J.P., Nobre, L.C., Lombard, C., Teixeira, A.M.B., Fuchs, S.C., Moreira, L.B.B. et al. (1988) Water supply, sanitation and housing in relation to the risk of infant mortality from diarrhoea. Int J Epidemiol 1, 651–654.

[38]. Muoki, M.A., Tumuti, D.S. and Rombo, G.O. (2008). Nutrition and public hygiene among children under five years of age in Mukuru slums of Makadara Division, Nairobi. East Afr Med J 85, 386–397.

[39]. Alirol, E., Getaz, L., Stoll, B., Chappuis, F. and Loutan, L. (2010). Urbanisation and infectious diseases in a globalized world. Lancet Infect Dis 10, 131–141.

[40]. Sato, T., Qadir, M., Yamamoto, S., Endo, T. and Zahoor, A. (2013). Global, regional, and country level need for data on wastewater generation, treatment, and use. Agricultural Water Management, Vol. 130, pp. 1–13. dx.doi.org/10.1016/j.agwat.2013.08.007.

[41]. Nation Environmental (Surface and Ground Water) Regulations, (2009). Developed by National Environmental Standards Regulations Enforcement Agency. Abuja, Nigeria.

[42]. Metcalf and Eddy (2003), "Wastewater Engineering Treatment and Reuse", McGraw – Hill, New York.

[43]. Weiner, R.F., Matthews, R., Peirce, J.J. and Vesilind, P.A. (2003), "Environmental Engineering", Butterworth Heinemann Publications, New York, USA.

[44]. Spellman, R.F. (2003), "Handbook of Water and Wastewater Treatment Plant Operations", Lewis Publishers, CRC Press Company, Florida, USA.

[45]. USEPA (2000), "Aquatic Life Criteria for Dissolved Oxygen - (Saltwater) Cape Cod to Cape Hatteras. Fact Sheet".

[46]. Bartram, J. and Ballance R. (1996), "Water Quality Monitoring - A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programmes", United Nations Environment Programme and the World Health Organization, pp. 302.

[47]. Stendahl, K. (1990), "Handbook on Water Treatment", KemiraKemi AB, Helsingborg, Sweden.

[48]. Reynolds, J.P., Jeris J.S. and Theodore, L. (2002), "Handbook of Chemical and Environmental Engineering Calculations", John Wiley and Sons, Inc., New York, USA.

[49]. EasaAlnos And Ashraf Abou-Rayan (2010) Domestic Wastewater Effect On The Pollution Of The Groundwater In Rural Areas In Egypt.Fourteenth International Water Technology Conference, Cairo, Egypt.

[50]. Tjandraatmadja, G., Pollard, C., Sheedy, C. and Gozukara, Y. (2010), "Sources of Contaminants in Domestic Wastewater: Nutrients and Additional Elements from Household Products. CSIRO: Water for a Healthy Country National Research Flagship, Australia.

[51]. Salvato, J.A., Nemerow, N. and Agardy, F. (2003), "Environmental Engineering", John Wiley and Sons, Inc. New Jersey, USA.

[52]. Kar, D., Sur, P., Manda, S.K., Saha, T. and Kole, R.K. (2008), "Assessment of heavy metal pollution in surface water" Int. J. Environ. Sci. Tech, Vol 5. No. 1, pp. 119-124.

[53]. Holm, O., Hansen, E., Lassen, C., Stuer-Lauridsen, F. and Jesper, K. (2002), "Heavy Metals in Waste – Final Report", European Commission, Denmark.

[54]. Akan, J.C., Abdulrahman, F.I., Ayodele, J.T. and Ogugbuaja, V.O. (2009), "Impact of Tannery and Textile Effluent on the Chemical Characteristics of Challawa River, Kano State, Nigeria", Australian Journal of Basicand Applied Sciences, Vol. 3 No. 3, pp. 1933-1947.

[55]. Strauss, M. (2000), "Health (Pathogen) Considerations Regarding the Use of Human Waste in Aquaculture", Swiss Federal Institute for Environmental Science and Technology (EAWAG), Department of Water and Sanitation in Developing Countries (SANDEC). Duebendorf, Switzerland.
[56]. Liu, D. (1999), "Environmental Engineers' Handbook", CRC Press LLC. Florida, USA.
[57]. Lee, C.C. (2007), "Handbook of Environmental Engineering Calculations", McGraw-Hill
[58]. Professional Publishing, New York.
[59]. Awuah, E. (2006), "Pathogen Removal Mechanisms in Macrophyte and Algal Waste
[60]. Stabilization Ponds", Doctoral Dissertation, UNESCO-IHE Institute for Water Education, Taylor and Francis Group/Balkema, Rotterdam, The Netherlands, pp. 2-10.

A.Aliyu" Characteristics and health risks of domestic wastewater in Dawaki ward, Bauchi. Bauchi State-Nigeria.'American Journal of Engineering Research (AJER), vol.8, no.05, 2019, pp.337-343