JJEES

JJEES (2020) 11 (2): 93-97
ISSN 1995-6681

Jordan Journal of Earth and Environmental Sciences

Risk Assessment of Traditional Faecal Pollution Markers in Three Streams in a Suburb of Akure, Nigeria

Olalemi Adewale*, Ogundare Temitope, Yusuff Olanrewaju, Ajibola Temitope

Federal University of Technology, School of Sciences, Department of Microbiology, Nigeria

Received 12 August 2019; Accepted 3 December 2019

Abstract

This investigation was carried out to determine the concentration of faecal indicator bacteria (***Escherichia coli*** and faecal coliforms) in water samples collected from three streams in Akure, Nigeria at different times of the day. This risk assessment is of great significance to human health protection against waterborne diseases. Results revealed high concentrations of *E. coli* (1.20×10^3 colony forming unit per 100 milliliters 'cfu/100 ml') and faecal coliforms (8.50×10^2 cfu/100 ml) in the water samples. In addition, the levels of *E. coli* exhibited positive relationship with total dissolved solids, turbidity, dissolved oxygen, electrical conductivity, and negative relationship with temperature, pH, and alkalinity. The findings from this study suggest that effective faecal pollution control specific procedures may include the improvement of the quality of residential buildings with adequate sanitation in the area surrounding the streams, direction of sewer channels away from the streams, construction of ridges around agricultural farm lands to prevent runoff, campaigns against direct defecation and indiscriminate disposal of animal wastes from poultry birds, cattle, sheep, goats and domestic dogs. These faecal pollution control actions may offer improved ways to protect human health.

Keywords: Faecal indicator bacteria, human health, surface water, sustainable development goals, waterborne diseases

1. Introduction

The number six goal highlighted in the United Nation's new 2015 Sustainable Development Goals (SDGs) is to provide clean water and sanitation by 2030. To achieve this goal, reliable and accessible methods are needed to measure the concentration of *E. coli* and other faecal coliforms in water (Sobsey, 2016). Understanding and monitoring water quality of a region remains a better tool towards promoting sustainable development of water resources and the prevention of waterborne diseases (Aderibigbe et al., 2008; Hiremath et al., 2011). Drinking water should contain less than one *E. coli* or faecal coliform CFU/100 ml, whereas water intended for bathing, recreation or aquaculture should contain less than or equal to 100 *E. coli* or faecal coliforms CFU/100 ml (CEU, 2006). The human health is under tremendous threat due to undesired changes in the physical, chemical, and the biological characteristics of water. Increase in human population, industrialization, use of fertilizers, and anthropogenic activities result in the pollution of water with different harmful contaminants (Patil et al., 2012). This study is aimed at determining the concentration of faecal indicator bacteria (*E. coli* and faecal coliforms) in water samples collected from three streams in Akure, Nigeria at different times during the day. These water sources are prone to faecal contamination especially from direct defecation, close proximity to sewer channels, and runoff from agricultural farm lands during wet periods. In addition, the outbreak of waterborne diseases such as diarrhoea and dysentery have been reported in the vicinity of these water sources. Therefore, this risk assessment was conducted to gain a better understanding of the microbial quality of the streams which may help in identifying specific targets for effective pollution-control actions in a bid to meeting the United Nation's new 2015 Sustainable Development Goals of bringing microbially safe and clean water to all.

There are many places worldwide where humans suffer and die from waterborne diseases, because the water (drinking water, recreational water, crop irrigation water, pond water, shellfish growing and harvesting water, untreated or partially-treated wastewater) (Shittu et al., 2008, Olalemi et al., 2016a) is not protected from, treated against, or tested for faecal microorganisms (Sobsey, 2016). The continuous use of faecally-contaminated water for domestic purposes presents a significant risk to human health, because it may contain pathogenic microorganisms such as viruses and bacteria mostly members of the family *Enterobacteriaceae* that are aetiological agents of many human diseases such as typhoid, cholera, dysentery etc. (Exner, 2015). Generally, the microbial quality of water deteriorates as a result of direct discharge of untreated or partially-treated wastewater into rivers and streams, and the inefficient management of closed and protected water distribution and storage systems. Microbially contaminated water has critical impact on all biotic components of the ecosystem and this could affect its use for drinking, bathing, irrigation, purposes etc.

Globally, about 80% of all diseases and deaths in low-income and lower-middle-income countries are water-related as a result of polluted water (WHO, 2014). Often, these waters are obtained from wells, boreholes, streams, rivers and they may not be pure chemically and/or microbially safe. For

* Corresponding author e-mail: waleolas2002@yahoo.com

instance, rain water which flows into streams may contain dissolved materials from the air and suspended dusts that microorganisms are attached to, and may also lead to urban or agricultural runoffs into the streams. The assessment of human activities (such as sewage disposal, sanitation, and hygiene practices etc.) capable of affecting the quality of water within an area is important. This is necessary, since the demand for water is increasing while accessibility to available freshwater is on the decrease because of pollution from point and non-point sources.

2. Materials and Methods

2.1 Description and Selection of the Study Area

Three different streams located in Aba (sampling point A 'stream 1') and Apatapiti (sampling points B 'stream 2' and C 'stream 3') in Akure, Nigeria were used for the study. The streams are approximately 1.2 – 2.5 meters wide and 0.9 – 1.5 meters deep. The streams are tributaries of River Ala which has a total length of about 57 km flowing downwards from the North to the South of Akure metropolis (Figure 1). The sampling sites were selected based on anthropogenic activities (that included animal rearing involving poultry birds, cattle, sheep, goats, and domestic dogs), direct defecation, close proximity to sewer channels and agricultural farm lands.

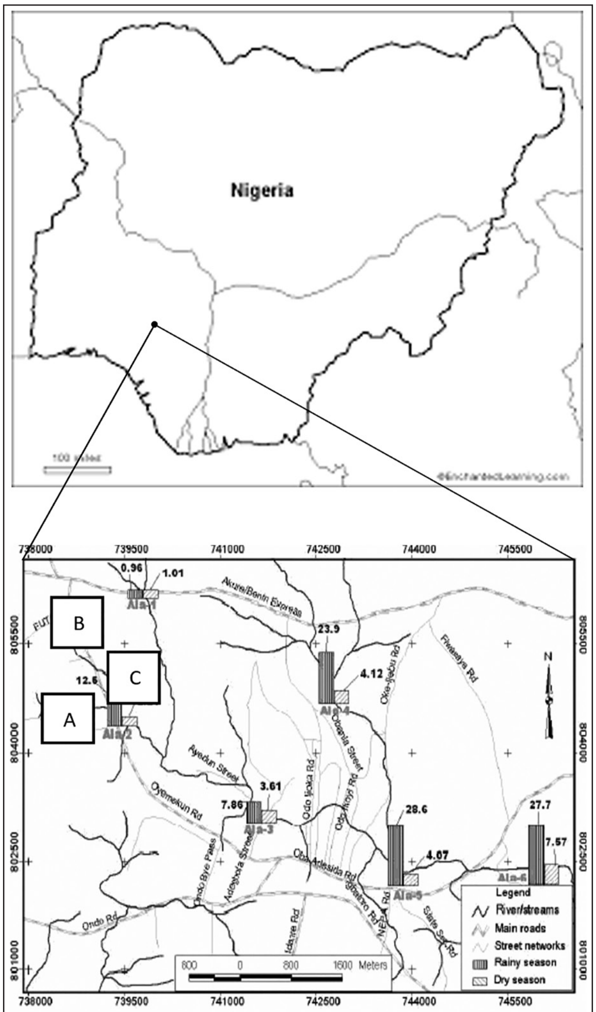

Figure 1. Locality map showing the streams and the sampling points (A, B, C) in Akure, Nigeria.

2.2 Collection of Water Samples

Water samples were collected from the three streams for five consecutive weeks. All water samples were collected at a depth of about 20 – 30 cm below the water surface at the midstream in the direction of flow using sterile, screw-capped 500 ml plastic bottles in the morning (8 – 10 am) and afternoon (1 – 3 pm). A total of 60 grab samples of water were taken from the three streams (i.e., 20 water samples were collected from each stream, of which ten water samples were taken in the morning and the other ten samples were taken in the afternoon). Water samples were coded with names on-site, and then transported to the laboratory in a cool box within one hour.

2.3 Enumeration of Faecal Indicator Bacteria in the Water Samples

Faecal indicator bacteria (faecal coliforms and *E. coli*) were examined using standard microbiological methods. Using the membrane filtration method (ISO 9308-1) (Anon., 2014), a measured volume of the water sample (1 ml) was diluted in one-fold (9 ml) of peptone water and filtered through 0.45 µm cellulose acetate membrane filters in a set-up connected to a vacuum pump that allows easy filtration of the water. The filters were, thereafter, placed on freshly-prepared selective media (Membrane faecal coliform agar 'm-FC' and Membrane lauryl sulphate agar 'MLSA'). The plates were incubated at 37˚C for twenty-four hours (MLSA) and 44˚C for twenty-four hours (m-FC). Yellow colonies on MLSA were sub-cultured onto Eosin methylene blue agar 'EMB' plates and incubated at 37˚C for twenty-four hours to confirm the presence of *E. coli*. Bacterial colonies were counted and expressed as CFU/ 100 ml.

2.4 Determination of Physicochemical Properties of the Water Samples

The physicochemical parameters inherent in the water samples from the three streams were measured using standard methods and recorded appropriately (Anon., 2012). These include temperature (Celsius), pH, alkalinity (milligrams per litre), salinity (milligrams per litre), turbidity (nephelometric turbidity units), electrical conductivity (microsiemens per centimeter), dissolved oxygen (milligrams per litre), and the total dissolved solids (milligrams per liter).

2.5 Statistical Analysis

Data obtained were examined using descriptive statistics and single factor analysis of variance (ANOVA) at 95 % confidence level, while significant means were separated with the Duncan's New Multiple Range Test (DNMRT). Further statistical analyses were undertaken to determine whether there were positive correlations between the concentration of the faecal indicator bacteria and physicochemical properties of the water samples from the streams.

3. Results

3.1 Detection of Faecal Indicator Bacteria in the Water Samples

The concentration of *E. coli* ranged from 0.4×10^2 to 4.3×10^2 cfu/100 ml in stream one, 1.0×10^2 to 1.2×10^3 cfu/100 ml in stream two and 0.6×10^2 to 5.3×10^2 cfu/100 ml in stream three. In general, the concentration of *E. coli* appeared to be higher in the samples collected in the morning compared to those collected in the afternoon, although with a few exceptions i.e., 60%, 10%

and 10% of the water samples from streams one, two, and three respectively, showed higher concentration of *E. coli* in the afternoon samples than in the morning samples (Figure 2).

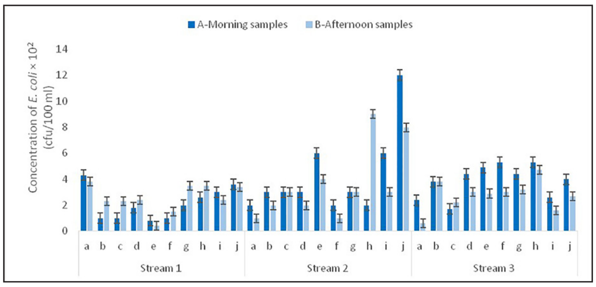

Figure 2. Mean concentration of *E. coli* in water samples from the three streams over the period of study

Key: Water quality standard – Drinking water should contain less than one E. coli CFU/100 ml (CEU 2006)

The concentration of faecal coliforms ranged from 0.7 × 10^2 to 8.5 × 10^2 cfu/100 ml in stream one, 2.0 × 10^2 to 13.0 × 10^2 cfu/100 ml in stream two and 0.9 × 10^2 to 7.2 × 10^2 cfu/100 ml in stream three. Similarly, the concentration of faecal coliforms appeared to be higher in samples collected in the morning compared to those collected in the afternoon, with the exception of stream one where 50% of the samples showed higher concentration of faecal coliforms in the afternoon samples than in the morning samples (Figure 3).

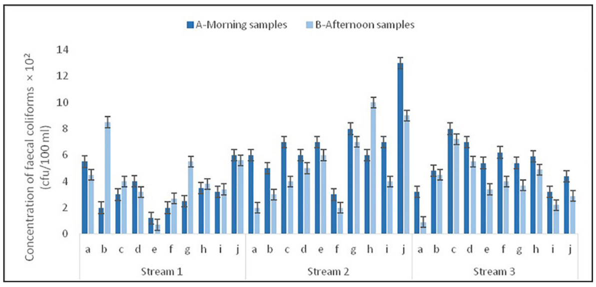

Figure 3. Mean concentration of faecal coliforms in water samples from the three streams over the period of study

Key: Water quality standard – Drinking water should contain less than one faecal coliform CFU/ 100 ml (CEU 2006)

3.2 Physicochemical Characteristics of the Water Samples

In stream one, water temperature ranged from 28 to 31 ˚C, while pH ranged from 6.9 to 7.1, whereas electrical conductivity ranged from 4.4 × 10^2 to 5.5 × 10 µS/cm. In stream two, alkalinity ranged from 6.9 to 25.7 mg/l, while salinity ranged from 24.9 to 63.7 mg/l. The total dissolved solids ranged from 0.1 to 0.5 × 10^2 mg/l and the amount of dissolved oxygen ranged from 2.2 to 6.3 mg/l. Similarly, in stream three, water temperature ranged from 28 to 31 ˚C, while pH ranged from 7.0 to 7.6 and electrical conductivity ranged from 3.9 × 10^2 to 6.0 × 10 µS/cm (Table 1).

Table 1. Physicochemical characteristics of the water samples from the three streams over the period of study

Physicochemical parameters	Stream 1	Stream 2	Stream 3
Temperature (˚C)	29.9 ± 0.9 (28.0-31.0)	29.5 ± 0.4 (27.0-32.0)	29.5 ± 0.4 (28.0-31.0)
pH	7.0 ± 0.0 (6.9-7.1)	7.4 ± 0.1 (7.2-7.8)	7.3 ± 0.2 (7.0-7.6)
Salinity (mg/l)	34.2 ± 0.7 (24.0-49.7)	39.1 ± 0.5 (24.9-63.7)	55.8 ± 12.9 (30.0-79.8)
Total Dissolved Solids ×10^2 (mg/l)	0.2 ± 0.1 (0.1-0.5)	0.3 ± 0.12 (0.1-0.5)	0.4 ± 0.1 (0.2-0.7)
Dissolved oxygen (mg/l)	3.2 ± 0.7 (2.0-4.8)	3.5 ± 0.17 (2.2-6.3)	3.8 ± 0.6 (1.6-6.3)
Alkalinity (mg/l)	13.4 ± 0.3 (9.1-25.7)	11.1 ± 0.20 (6.9-21.4)	15.6 ± 0.3 (9.4-25.7)
Electrical conductivity ×10 (µS/cm)	4.8 ± 0.3 (4.4-5.5)	4.9 ± 0.50 (4.4-6.0)	5.53 ± 0.7 (3.9-6.0)

Key: Values are expressed as Mean ± Standard Deviation (n = 20) (Range: Minimum - Maximum)

3.3 Relationship between Observed Physicochemical Characteristics and Faecal Indicator Bacteria in the Water Samples

The relationship between the concentrations of *E. coli* and those of the physicochemical properties of the water samples were analyzed using scatter plots. Levels of *E. coli* in stream three demonstrated a negative relationship with temperature (R^2 = 0.2211) (Figure 4), whereas levels of *E. coli* in stream two showed a positive relationship with turbidity (R^2 = 0.2579) (Figure 5).

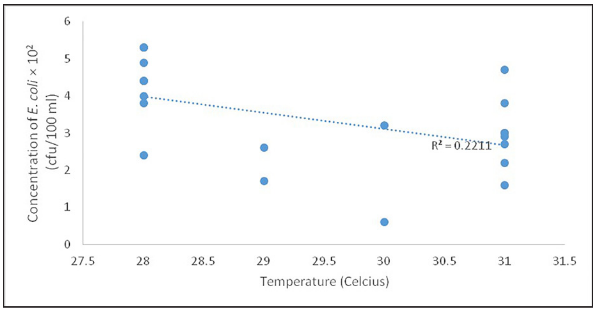

Figure 4. Negative relationship between temperature and mean concentration of *E. coli* in water samples from stream three

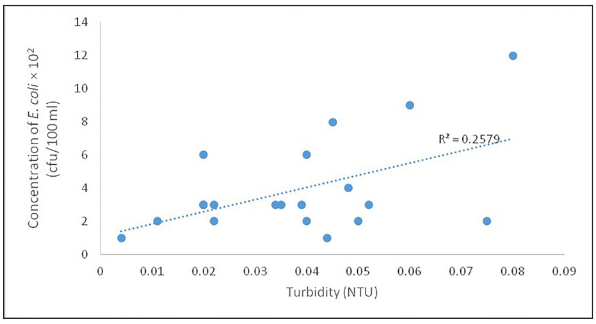

Figure 5. Positive relationship between turbidity and mean concentration of *E. coli* in water samples from stream two

4. Discussion

The first step in microbial risk assessment (hazard evaluation) was carried out by examining the concentration of faecal indicator bacteria in water samples collected from three different streams in Apatapiti and Aba area, Akure, Nigeria at different times of the day. Understanding the microbial quality of the streams is important to identify specific targets for effective pollution control actions in order to achieve one of the goals set by the United Nation in the new 2015 Sustainable Development Goals that is, providing clean water for all by 2030.

In this study, stream two appeared to be the most contaminated because it contained very high levels of *E. coli* and faecal coliforms compared to streams one and three. Clearly, the waters from the three streams do not meet the acceptable limit of *E. coli* and faecal coliforms in water quality standards, where drinking water should contain less than one *E. coli* or faecal coliform CFU/100 ml, whereas water intended for bathing, recreation, or aquaculture should contain less than or equal to 100 *E. coli* or faecal coliforms CFU/100 ml (CEU, 2006). Waterborne pathogens from faecal pollution continue to be a major cause of infectious disease in many parts of the world. The incidences of these infections are higher in low- and middle-income countries than in high-income countries as a result of inadequate water, sanitation and hygiene (WHO, 2014). The high concentration of *E. coli* and faecal coliforms in the three streams in this study, may be as a result of anthropogenic activities (that included animal rearing, as well as close proximity of the streams to agricultural farm lands. It may also be as a result of surface runoffs following rain and storm events that carry faecal wastes into the streams, thus, increasing the level of microbial pathogens and ultimately impacting the sanitary quality of the stream negatively (Wilkes et al., 2013). There is also the likelihood of indiscriminate discharge of partially-treated or untreated wastewater into the flowing streams, including seepage from poorly functioning septic tanks from close residential buildings. These identified point and non-point sources of faecal contamination of the streams may best be described to originate from both human and non-human sources.

Physicochemical parameters were investigated to determine their contribution to the fate and survival of the faecal indicator bacteria in the streams. Water temperature values exhibited a negative relationship with the concentration of *E. coli* in the streams. Bacteria of enteric origin have been reported in many studies to be inactivated by solar radiation (Chandran and Hatha, 2003; Olalemi, 2015). This may be responsible for the observed trend in this study, where the concentration of *E. coli* appeared to be higher in samples collected in the morning compared to those collected in the afternoon. Alkalinity also showed a negative relationship with the levels of faecal coliforms in the streams. The results obtained in this study, showed that the level of turbidity demonstrated a positive relationship with the concentration of *E. coli* in the streams. This is in agreement with Pommepuy et al. (1992) who observed that enteric bacteria are able to survive for longer period of time in highly turbid waters. The values of electrical conductivity and total dissolved solids showed a similar trend. In all of the streams, counts of faecal indicator bacteria increased with the increase in turbidity and reduced with the increase in temperature. This is in agreement with the observation of many previous studies (Diston et al., 2012; Wilkes et al., 2013; Olalemi et al., 2016b) demonstrating that physicochemical parameters may provide useful information in water quality monitoring for human health protection.

Whilst the United Nations Millennium Development Goals (MDGs) of reducing the number of people worldwide lacking access to microbially-safe water by 2015 was effective to a large extent. Today, many people still lack access to microbially-safe water, most especially in low- and middle-income countries (Sobsey, 2016). Hence, the high burden of waterborne diseases (including diaorrhea) which lead to ill health, morbidity, and mortality in these countries. With the United Nations new 2015 Sustainable Development Goals (SDGs), it is hoped that microbially safe water will be accessible to all by 2030.

5. Conclusions

The sources of faecal contamination of the streams originate mainly from anthropogenic activities (that included animal rearing involving poultry birds, cattle, sheep, goats, and domestic dogs), direct defecation, and runoff from agricultural farm lands. The findings from this study suggest that specific targets for an effective faecal pollution control may include the improvement of the quality of residential buildings with adequate sanitation in the area surrounding the streams, direction of sewer channels away from the streams, construction of ridges around agricultural farm lands to prevent runoff, advocate against direct defecation and indiscriminate disposal of animal wastes from poultry birds, cattle, sheep, goats, and domestic dogs. These faecal pollution control actions may offer improved ways to protect human health.

Acknowledgements

The authors are grateful to the Department of Microbiology, School of Sciences, Federal University of Technology, Akure for providing a conducive environment for the research.

References

Aderibigbe, S. A., Awoyemi, A. O., Osagbemi, G.K. (2008). Availability, adequacy and quality of water supply in Ilorin metropolis, Nigeria. European Journal Scientific Research 23:528-536.

Anon (2012). Standard methods for the examination of water and wastewater (22nd ed.) APHA/AWWA/WEF: Washington DC, USA.

Anon. (2014). ISO 9308 – 1. Water Quality. Detection and Enumeration of Escherichia coli and Coliform Bacteria – Part 1: Membrane Filtration Method for waters with low bacterial background flora. Geneva, Switzerland: International Organization for Standardization.

Chandran, A. and Hatha, A.M. (2003). Survival of Escherichia coli in a tropical estuary. The South Pacific Journal of Natural and Applied Sciences 21 (1): 41-46.

Commission of the European Union (CEU 2006) Council Directive 2006/113/EC of 12 December 2006 on the quality required of shellfish waters (codified version). Official `Journal of the European Communities, L 376: 14–20.

Diston, D., Ebdon, J.E., Taylor, H.D. (2012). The effect of UV-C radiation (254 nm) on candidate microbial source tracking phages infecting a human-specific strain of Bacteroides fragilis (GB124). Journal of Water and Health 10 (2): 262-270.

Exner, M. (2015). The discovery of the aetiology of cholera by Robert Koch 1883. In Bartram et al. (Eds.) Routledge Handbook of Water and Health. London and New York, Routledge, pp. 648-657.

Hiremath, S.C., Yadawe, M.S., Pujeri, U.S., Hiremath, D.M., Pujar, A.S. (2011). Physicochemical analysis of ground water in Municipal Area of Bijapur (Karnataka). Current World Environment 6: 265-269.

Olalemi, A. (2015). Bacteriophages as surrogates of viral pathogens: a novel tool for the shellfisheries industry. PhD Thesis. University of Brighton, Brighton, UK.

Olalemi, A., Baker-Austin, C., Ebdon, J., Taylor, H. (2016a). Bioaccumulation and `persistence of faecal bacterial and viral indicators in Mytilus edulis and Crassostrea `gigas. International Journal of Hygiene and Environmental Health 219(7): 592-598.

Olalemi, A., Purnell, S., Caplin, J., Ebdon, J., Taylor, H. (2016b). The application of phage-`based faecal pollution markers to predict the concentration of adenoviruses in mussels `(Mytilus edulis) and their overlying waters. Journal of Applied Microbiology 121: ` 1152-1162.

Patil, P.N., Sawant, D.V, Deshmukh, R.N. (2012). Physicochemical parameters for testing of water – A review. International Journal of Environmental Sciences 3(3): 1194-1207.

Pommepuy, M., Guillaud, J.F., Dupray, E., Derrien, A., Le Guyader, F., Cormier, M. (1992). Enteric bacteria survival factors. Water Science and Technology 25(12): 93-103.

Shittu, O.B., Olaotan, J.O., Amusa, T.S. (2008). Physicochemical and bacteriological analysis of water used for drinking and swimming purposes in Abeokuta, Nigeria. African Journal of Biomedical Research 2: 285-290.

Sobsey, M.D. (2016). Advances and innovation to achieve microbially safe and sustainable water: Detection, treatment, and risk management. National Water Research Institute 2016 Clarke Prize Lecture, Fountain Valley, California, USA.

WHO (2014). Preventing diarrhoea through better water, sanitation and hygiene: exposures and impacts in low- and middle- income countries. World Health Organization, Geneva (2014).

Wilkes, G.1., Brassard, J., Edge, T.A., Gannon, V., Jokinen, C.C., Jones, T,H., Neumann, N., Pintar, K.D., Ruecker, N., Schmidt, P.J., Sunohara, M., Topp, E., Lapen, D.R. (2013). Bacteria, viruses, and parasites in an intermittent stream protected from and exposed to pasturing cattle: Prevalence, densities, and quantitative microbial risk assessment. Water Research 47(16): 6244-6257.