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Physical-Chemical and Bacterial Contamination Levels in Mzinga River Catchments of the Southern Dar es Salaam City, Tanzania: Public Health Implications

Josephat Alexander Saria

Department of Environmental Studies, Faculty of Science, Technology and Environmental Studies, The Open University of Tanzania, Dar es Salaam, Tanzania

Email Address:
josephat.saria@out.ac.tz

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Abstract: Water is an appreciated natural resource for the survival of all living organisms. Management of the quality of this precious resource is therefore of special importance. In this study Mzinga River and its tributaries water samples were collected at a weekly interval from 2nd November 2014 to 6th December 2014 and analyzed for physicochemical and bacteriological evaluation of pollutants. Total and faecal bacteria were analyzed using membrane techniques while physical chemical parameters were analyzed using specified standard methods. The water pH was found to range from 6.09±0.08 to 7.05±0.06 which is slightly acidic though it is within the acceptable WHO limits of 6.5-8.5. The mean values of ammonium and phosphate varied between 4.50±0.03 mg/l to 6.50±0.04 and 7.18±0.27 to 9.70±0.12 respectively. Both of these are higher than Tanzania acceptable limits (2mg/l and 5mg/l respectively). The mean result of the analysis of the water samples for total coliform ranges from 14.17±4.06 CFU/100ml to 486.80±102.32 CFU/100ml, while faecal coliform ranges from 2.78±1.03 CFU/100ml to 120.36±4.50 CFU/100ml. The bacteriological contamination was due to the fact that Mzinga river is passing through a populated urban area thereby more exposed to direct sewage disposal and incoming industrial effluents. These results implicate the probability of people around these areas being prone to water-borne infections such as diarrhea or cholera.

Keywords: Cholera, Faecal Coliform, Mzinga, Phosphate, BOD_5

1. Introduction

Cholera outbreak in Dar es Salaam region started in mid-August 2015. As of early September 2015, the cumulative number of cholera cases in the affected areas was more than 900 cases including 13 deaths. Cholera is a bacterial intestinal infection caused by *Vibrio cholerae*, transmitted through contaminated food and water [1]. The major features of pathogenesis of cholera are well established. Infection due to *V. cholera* begins with the ingestion of contaminated water or food. It occurs repeatedly in many African countries, mainly due to poor hygiene. It has a short incubation period, from one to five days, with the main symptom being diarrhoea that quickly leads to severe dehydration and death if untreated. From 1970, *V. cholera O1 El Tor* has gradually spread to most of the continent with case-fatality rates between 4% and 12%. From 1991 to 1996, the number of cases remained high and ranged between 70,000 and 160,000 [2]. This was the largest proportion of all reported cholera cases in 1994, and 42% of all cholera deaths reported globally that year, were in Africa [3].

Most vibrio species are everywhere in estuarine and marine environments and are also found in fresh water provided that there is a certain minimal level of group one element ions [4]. The cholera *vibrio*, however, was long considered to be an exception, in that it was believed not to be an environmental organism but associated with water only as a result of sewage contamination [5]. Due to that, it has been established that water is important in the transmission of cholera. Water from public supplies, toilets, sewage etc was implicated in the previous pandemics. In the present pandemic, properly treated public water supplies, shallow or deep well water supply, river water supply which are used by majority of Dar es Salaam residents, are not generally considered to be a risk factor [6]. However, serious epidemics of cholera continue to occur in areas where water treatment is poor or sporadic or no treatment at all. Many of the sources that are thought to contribute to the epidemiology of diseases associated with raw fruits and vegetables are impacted by ecological conditions that affect survival or growth of pathogenic microorganisms [7]. These sources include raw manure, inorganic amendments, irrigation water and dust [8-10]. The microbial quality of vegetables grown with wastewater is highly alarming [9]. In most of African countries one of the techniques used to kill microbes from vegetables is thermal but for fear of denaturation of beneficial nutrients during heating vegetables are served and consumed raw [10].

In Tanzania, sources of irrigation water are shallow wells, streams and rivers where, large amounts of untreated wastewater are discharged into urban drainage systems and other natural waterways, rivers receive waste from tanneries and textile industries, abattoirs, urban water storm and agricultural runoffs from farming communities along its course [6, 11].

River water is the most important and multi-usage component in the outskirts of a cities like Dar es Salaam, where there is no public water supply. It is basically used for drinking, irrigation, fishery and energy production [5, 6, 12]. Although water is a natural resource for sustaining life and environment that we always have, the chemical composition of surface or subsurface water is one of the prime factors on which the suitability of water for domestic, industrial or agricultural purpose depends on its quality [13]. In another study [14], explained different sources of surface water degradation that over the past few decades, the ever-growing population, urbanization, industrialization and unskilled utilization of water resources have led to degradation of water quality and reduction in per capita availability in various developing countries. Like other developing countries of the world, Tanzania is also facing critical water shortage and pollution. Dar es Salaam City receives its water supply from the Ruvu and Kizinga rivers with three water treatment plants, namely, Upper Ruvu, Lower Ruvu and Mtoni, which have a total installed capacity of 605,000m^3/day [15,16]. Mzinga River is one among four major rivers available in watershed in the region including Mpiji River, which forms the northern boundary of Dar es Salaam, Msimbazi River flows to the north of the city centre and together with Kizinga River, water from these two flows into the harbor area of the city.

Since the city experiences massive population pressure, there is progressive deterioration of water quality due to an increase in domestic, agricultural activities and effluent discharges especially besides the urban rivers. Almost all the freshwater bodies are being polluted by expanding human population and in consequence, industrialization, intensive agricultural practices and discharge of massive amount of waste water etc. which result in deterioration of water quality [17].

Mzinga river water originates from springs in the highland of Msongola. The River has many tributaries but the main ones to be studied are Binguni, Mianzini and Toangoma. Studies on fresh water quality of urban rivers have been conducted by various researchers [18, 19]. However, no inclusive work has been done so far to explore the physico-chemical and microbiological characteristics on the water quality of Mzinga river and its tributaries all together. Water quality depletion of Mzinga river is due to improper waste disposal from agro-industrial wastes and environmental degradation consequential to deforestation of river catchments [18].

To avoid any health hazard as the result of consumption of contaminated water, physicochemical analysis of water is unavoidable. Therefore in this study of assessment of the variation of physicochemical parameters of water in Mzinga river from its source to the consumer level is undertaken. The results obtained will be compared to documented Tanzanian standards for water quality and World Health Organization standards, and will be used to provide useful information about the quality of water in Mzinga area.

2. Material and Methods

2.1. Study Area

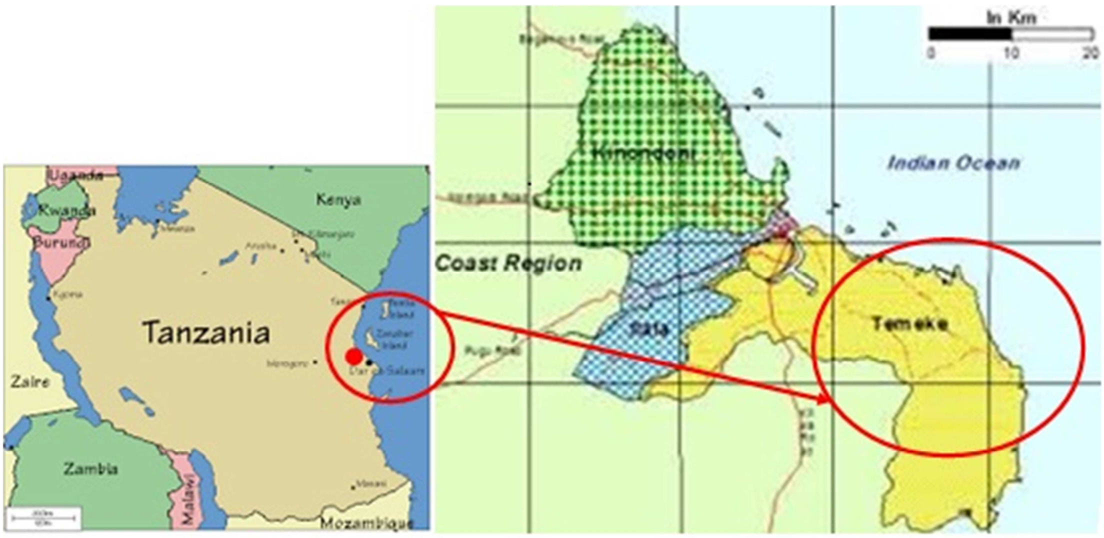

Figure 1. *Map of Tanzania Showing Sampling Site.*

Mzinga river is among urban rivers located in Dar es Salaam. It is located in southern part of Dar es Salaam crossing Charambe ward, in southern part is nearby Mbagala Rangi tatu, eastern part of Mbagala kuu and Western part of Tandika. Approximately 18 km stretch of Mzinga river flows from west to east in the centre of the city and serves as a source of water for agricultural and domestic activities. Together with Kizinga River, they are originated from Pugu Kisarawe hills and consist of sandy sediments. The rivers flow to the north-east direction to Indian ocean. Mzinga has a total length of 10 km and a catchment of 41 km^2 (Figure 1).

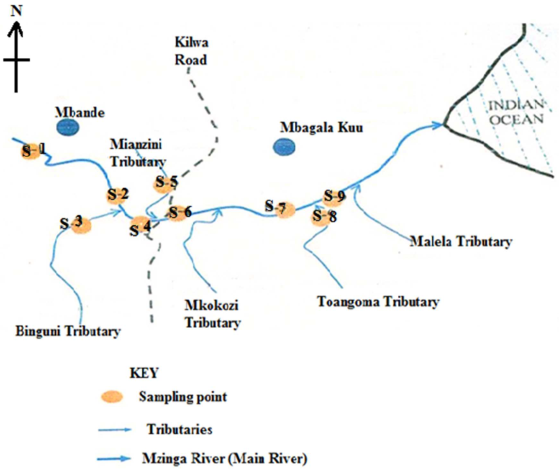

Figure 2. *Mzinga River with its Tributaries.*

Water sampling was done by grab sampling technique, making sure each tributary was sampled in every visit. The monitoring was done at the weekly interval from 2nd November 2014 to 6th December 2014. The sampling time was in the morning and stored in 0.5L sampling bottles. Sampling was done in the morning so that analysis of the samples can be done in the laboratories the same day and to avoid recreational and other farming activities on the river.

Table 1. *Sampling Points.*

Sampling point	Name/ Location	Considerations for selection
S-1	Mbande	Agricultural activities and blocked cross-bridge are present
S-2	20m from Binguni tributary	Human settlements
S-3	Binguni tributary	Entrance of Binguni tributary
S-4	Along Mzinga River	Agricultural activities and human settlements
S-5	Mianzini tributary	Entrance of Mianzini tributary
S-6	Along Mzinga River	Near Car wash
S-7	15m from mianzini tributary	Human settlements
S-8	Tuangoma tributary	Entrance of Toangoma tributary
S-9	Along Mzinga River	Agricultural activities and human settlements

2.2. Physicalchemical Analysis

Parameters such as pH, temperature and DO were analyzed in-situ by using HACH instrument (Sension 15b). Other parameters like Phosphate, Ammonia and BOD were analyzed in the laboratory as per standard methods of water and wastewater examinations [20]. Triplicate in nine (9) sampling points were considered from all tributaries in study area (Fig. 2).

Samples were collected using 500 ml sterile bottles tied on a graduated yard stick so as to sample at about 30 cm depth. Collected samples were immediately transferred to a cool box containing ice packs until the time of filtration, which never exceed 6 hours after collection [20, 21]. Environmental parameter (pH), were measured *in situ* at each station using a multi-parameter water quality checker (HoribaU-10, Japan).

2.3. Microbiological Analysis

Total and faecal bacteria were analysed using membrane techniques as described in American Health Public Association [21], whereby 100 ml of undiluted and diluted (1 - 10 times) water sample were filtered through 0.45 µm pore size membrane filters. The filters were transferred to two selective media where FC was grown on m-FC broth and TC was grown on m-Endo broth. Plates for Faecal coliform (FC) bacteria were incubated at 44.5 ± 0.5 C° for 24 hrs. FC colonies appeared blue while plates for total coliform (TC) bacteria incubated at 37 ± 0.5 C° for 24 hours were reddish in color.

3. Results and Discussion

3.1. Physical Chemical Parameters

The pH is the indicator of acidic or alkaline condition of water status. According to Tanzania Standard permissible limit for drinking purpose ranges from 6.5-8.5 [2, 3]. Analysis of samples in nine sampling sites (Figure 1 & 2), range from 6.09±0.08 to 7.05±0.06 which is slightly acidic. The variation of pH is due to the fluctuation of discharges from the domestic sewage waste.

This shows that water samples have amounts of effluent and impure urban waters hang extremely from amount of free CO_2 in water, organic acids and humic acids which originated from agricultural activities closer to sampling points. Also other sources may be from polluted industrial effluents in which they are directed to Mzinga river and hence increases the concentration of SO_2, NO_2 etc. For evaluation of water quality is very important confirmation of presence of materials which are created from decomposition of wastes of animal and plant origin. Nitrogen and phosphorus compounds are contributed from fertilizers used in agricultural fields near the river region which seep into the ground water. This reason is comparable with several reports made in literature for contamination of ground water may be due to the seepage of agricultural chemicals, domestic sewage and animal waste [6]. In the present study mean values of ammonium and phosphate varied between 4.50±0.03mg/l and 6.50±0.04, 7.18±0.27 mg/l and 9.70±0.12

respectively. For ammonium, the highest detected value is three times higher than permissible Tanzanian limit for drinking water while for PO_4^{3-} is about twice higher than recommended value [22]. The presence of higher vegetation decomposed in water is possible reason for higher level of nutrients. Similar findings were also found by in another study [23], suggested that sources of nutrients like nitrate, salinity, phosphate and silicate were in ponds with macrophytes, while phosphorus content was higher due to the presence of microcystic bloom.

Table 2. *Mean Concentrations of Physical-Chemical Parameters and Bacterial Concentrations from all Sampling Sites.*

Parameter	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9
NH_4^+(mg/l)	6.50±0.03	5.25±0.28	5.52±0.03	6.25±0.03	5.75±0.01	5.50±0.04	6.25±0.19	4.50±0.03	6.50±0.04
pH	6.13±0.07	6.69±0.05	6.09±0.08	6.48±0.01	7.05±0.06	6.94±0.03	6.68±0.03	6.67±0.06	6.56±0.05
PO_4^{3-}(mg/l)	8.50±0.04	7.18±0.27	7.27±0.05	9.20±0.15	7.61±0.17	7.29±0.19	9.15±0.20	7.31±0.18	9.70±0.12
BOD5(mg/l)	85.50±2.04	86.01±0.63	107.10±3.19	89.30±0.42	110.30±1.03	89.20±0.41	90.30±5.70	90.80±1.17	85.20±0.63
DO (mg/l)	4.86±0.06	4.68±0.09	3.78±0.04	4.32±0.05	3.43±0.05	4.32±0.05	4.33±0.02	4.33±0.04	4.85±0.06
TC (CFU/100mL)	14.17±4.06	226.33±2.06	83.63±12.32	486.80±102.32	76.80±24.31	118.80±45.67	217±27.21	162.36±5.79	220.80±28.03
FC (CFU/100mL)	8.31±4.90	24.36±21.43	16.39±8.73	73.44±1.23	7.29±5.74	2.78±1.03	120.36±4.50	81.34±21.73	108.04±47.39

Dissolved oxygen (DO) is a very crucial parameter for the survival of aquatic organisms and is used to evaluate the degree of freshness of water/river. The dissolved oxygen (DO), which acts as an indicator of the oxygen status of the water body fluctuated between 3.43±0.05 mg/l and 4.86±0.06 mg/l in the river stretch under study. Large depletion of DO is indicative of the presence of considerable amount of bio-degradable organic matter in the river water [8]. The minimum level of DO 3.43±0.05 mg/l was found in S-5 the entrance of Mianzini tributary which received municipal sewage and domestic waste water.

The BOD_5 is referred as amount of used oxygen for biochemical decomposition of organic matter in water. BOD_5 is used for determination of relative demand of oxygen for effluents and discard waters because ir is an indicator of pollution level of waters. In this study, BOD_5 values varied from 85.20±0.63mg/l to 110.30±1.03mg/l. These values are extremely higher than Tanzanian and WHO standards limits of 6.0mg/l and 5.0 mg/l respectively [3, 22]. It has been established before [24] that if the amount of decomposing organic material is too high, it means BOD_5 is also high (Table 3).

Table 3. *Status of Water Sample in Terms of BOD_5.*

BOD Level (mg/l)	Status of the Sample
1-2	Clean water with little organic waste
3-5	Moderate clean with some organic waste
6- 9	A lot of organic materials and bacteria
> 10	Very poor water quality. Large amount of organic material in water

From Table 2, all water from the nine points' is highly contaminated and unfit for human consumption. Generally, from analyzed samples (Figure 3) when BOD_5 levels are high, the level of DO is small. This is because the demand for oxygen by the bacteria is high and they consuming oxygen from the that dissolved in the water (Table 3). If there is no organic waste present in the water, there won't be as many bacteria present to decompose it and thus the BOD_5 will tend to be lower and the DO level will tend to be higher.

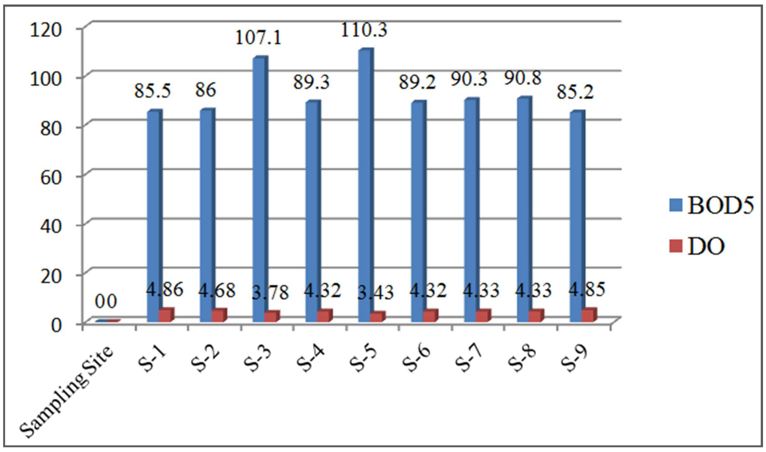

Figure 3. *Comparison of levels of BOD_5 and DO from Sampling Sites.*

3.2. Bacterialogical Contamination

From the health point of view, the most important characteristic of good quality water is obviously an absence of pathogenic organisms [19]. By convention, water contamination is considered to be the introduction or release into water organisms or toxic substances that render it unfit for human consumption [25]. Meanwhile, water bodies polluted by fecal discharge from man and other animals may transport a variety of human pathogens. The presence of faecal coliform bacteria indicates that your water is contaminated with faeces or sewage, and it has the potential to cause diseases like cholera. Both WHO and Tanzanian standards suggest zero bacteria values in drinking water.

The mean result of the analysis of the water samples ranges from 14.17±4.06 CFU/100ml to 486.80±102.32 CFU/100ml for total coliform, while faecal coliform ranges from 2.78±1.03 CFU/100ml to 120.36±4.50 CFU/100ml. The detection of high number of bacteria was due to the fact that Mzinga river passes through a populated urban area thereby more exposed to direct sewage disposal and incoming industrial effluents as was reported before [18]. It is evident that several human activities, (Table 1) could also result into further contamination including the use of on-site latrines which was observed along the river. Other human activities such as direct bathing are known to contribute to the high amounts of faecal indicator bacteria loads in the near shore waters [26]. Another possible source of contamination identified by other researchers at Mzinga river is the direct defecation in the mangrove forest in this site as also reported by [18].

Human diseases can occur due to consumption of crops that have been irrigated with polluted water. Crops that are eaten raw (*e.g.*, celery, lettuce, tomatoes, peppers) are especially dangerous for the transmission of disease-causing organisms. Because some bacteria will desiccate (or dry-out) and die from prolonged exposure to air, the risk for illness can be decreased by delaying the harvest and consumption of crops [3].

Several studies throughout the world have demonstrated a very close relation between the consumption of fruits and vegetables irrigated with raw wastewater or polluted river water and many food borne diseases like gastroenteritis, cholera, chemical toxicity etc [8, 27]. River water used in irrigation is largely considered an inevitable option to compensate water shortages in developing countries especially Tanzania. It was observed during sampling that the irrigation of vegetables especially African spinach (*Amaranth sp*.), Chinese cabbage (*Brassica chinensis*), Cowpea leaves (*Vigna unguiculata*), Leafy cabbage (*Brassica rapa*), Lettuce (*Lactuca sativa*) and Pumpkin leaves (*Moschata cucurbita*). All nine samples from sampling site met the international standards for the guideline limit for faecal coliform bacteria in unrestricted irrigation of crops likely to be eaten raw where the levels of faecal coliform counts observed were lower than 200 CFU/100 ml recommended for irrigation of vegetable [2]. Hence these waters are not suitable for human consumption but can be used for irrigation of vegetable and salad crops without prior treatment.

4. Conclusion and Recommendation

The results suggest that sources of contamination are due to the influence of environmental factors. Generally the bacteriological indicators in the studied waters along the coast of Tanzania were extremely higher than the acceptable standards according to WHO and TBS indicating high risk situation for consumption hence be a good source of cholera. Further studies and monitoring programs are recommended to substantiate the current results. It is recommended that the government enforce strict rules and legislation on adequate treatment of wastewater and effluents before discharge to the environment. Proper washing and disinfection of vegetables before consumption is strongly advised.

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