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IMPACTS OF WATER POLLUTION ON NAIROBI RIVER, KENYA A CRITICAL LITERATURE REVIEW

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ABSTRACT

Purpose: This study aimed at evaluating the impact of water pollution and bacteria on physio-chemical parameters, macroinvertebrates and algae in Nairobi River.

Methodology: The paper used a desk study review methodology where relevant empirical literature was reviewed to identify main themes and to extract knowledge gaps.

Conclusion: Pollution increases in the river as one moves down from Ondiri Swamp to Ruai and comprises mainly of solid wastes, raw sewage and industrial wastes. There is adequate evidence of fecal pollution in Nairobi River with levels far exceeding limits set by KBS (1996). This means that the river water is a health hazard and is not fit for human and animal consumption as well as for other domestic and industrial uses.

Recommendations*:* Sustainable use and conservation of freshwater resources, water pollution control and prevention and institutional capacity building. Continuous monitoring and assessment of different pollution trends occurring within the river system should be carried out.

Keywords: *Pollution, alga, ecosystem*

1.0 INTRODUCTION

1.1 Background of the Study

Natural processes have influenced the physical and biological characteristics of water and the quality of water varies from place to place, from season to season within the year, with the climate, and with the types of rocks and soil through which the water moves or infiltrates. Natural water quality may be altered by wind or stream transported sediments, nutrient loads, temperature, soil bacteria, and evaporation. Water quality is also influenced by human activities resulting in pollution. Clearing of forests and cultivation practices along riverbanks increase the rate of bank erosion that results in more violent fluctuations in flow-rates of rivers and increased sediment loads (Day, 2015)

One-third of the world's population is currently living under moderate or severe water stress. 1.3 billion people lack access to an adequate supply of safe water and 25 million people die each year from diseases caused by unsafe drinking water and lack of water for sanitation and hygiene more than half of these being young children (UNEP 2020, Macharia, 2015). With the finite freshwater resources on the one hand and an increasing demand on the other, the need to protect and manage water resources properly has never been greater than it is now.

There is no doubt that during the present century, the most serious pollution is the direct result of human' activities. As soon as industries, factories, manufacturing plants residential areas, commercial enterprises, and unplanned settlements like slums became common, the problem of disposal of domestic, industrial and commercial waste increased. Sewage treatment plants and septic tanks could no longer cater for the increasing amount of municipal and industrial sewage (Cronje, 2021).

Dump sites were created next to river systems and direct disposal of untreated sewage into river water began to take place. This was followed by outbreaks of water related diseases like diarrhea, typhoid, ascaris, cholera, scabies, trachoma and bilharzia. Aquatic assemblages of species such as phytoplankton, macro-algae, macrophytes, zooplankton, macroinvertebrates, amphibians, fish, crabs and mollusks began facing serious problems for their survival and existence (Humphrey, 2019).

Thermal water pollution involves the introduction of heat energy into water bodies from industrial cooling towers. It increases productivity thereby reducing the oxygen content in the water. Silt from agricultural land is another form of physical pollution that inhibits light penetration and reduces the number of organisms which survive below the surface of the water (King, 2015).

Lack of effective pollution control compromises the quality of water, posing potential health hazards, increasing treatment and maintenance costs, and damaging inland, estuarine and coastal aquatic' ecosystems. Water pollution exacerbates water scarcity because it limits the use by, or imposes a higher cost for treatment on downstream users (Shaffer, 2015).

1.2 Statement of the Problem

In the early part of the twentieth century, Nairobi River had pristine waters, which were clean and potable at source. Anthropogenic impacts began to be felt from the 1960s, and greatly increased from the 1970s through to the 1990s. This was due to population increase, urbanization, industrial growth, increase in agriculture hence use of agrochemicals, degradation of natural vegetation cover, growth of large informal settlements along the river and the poor maintenance of the municipal sewage disposal system and treatment of sewage.

Most of the slums in Nairobi including, Majengo, Pumwani, Shauri-Moyo, Mathare, Kariobangi, Mangoini, Mukuru-Kayaba and Lunga-Lunga are located on the banks of Nairobi River. The tributaries that traverse the slum areas include Mathare, Gitathuru and Ngong Rivers (Thorn, 2015). The slum dwellers discharge raw sewage, garbage and other solid wastes directly into the river. They are also known to defecate in plastic bags ("flying toilets") which they throw into the river due to lack of proper toilet facilities. Squatters and homesteads along the river valleys use the sewage laden sections of the river for irrigation thus increasing the risk of contamination (Webb, 2019)

Unplanned human settlement coupled with the unmonitored side effects of industrialization, has put enormous pressure on Nairobi River. Untreated industrial effluent, raw sewage and liquid and solid waste have turned the once clear waters into a dangerous sludge and in some places totally blocked by the everyday rubbish discarded by households and industry.

Most municipal sewerage plants within Nairobi discharge partially treated and untreated wastewater into Nairobi River posing significant health hazards and localized eutrophication. Pit

latrines and septic tanks located in recharge zones constitute a risk of groundwater contamination. Tanneries, dairy processing factories, breweries, slaughterhouses, petrol stations, garages, food kiosks and other service industries typically do not have properly functioning wastewater treatment plants. Their effluents contribute significant organic loads, heavy metals and other toxic substances to receiving waters (Ministry of Water Resources, 2018).

There is inadequate pollution control and enforcement measures and weak institutional capacity to monitor water quality and effluent discharges from industries and sewerage works. There is a general lack of awareness of the impacts of pollution and a general disregard of the needs and rights of other water users. There is therefore need to monitor water quality and provide data for water pollution control and planning purposes (Hearne, 2016).

1.3 Significance of the Study

There is need to examine the chemical and bacteriological status of Nairobi River to ascertain if the river maintains the required degree of purity, to discover the extent of any variations which occur and to determine the effect of heavy rainfall or of long-continued drought on the river system. This is often associated with investigations to ascertain the effect of purification taking place during the flow downstream attributable to dilution. Nairobi River has acquired a color, taste and odor that is a nuisance to scenic beauty and environmental integrity and the root cause of this phenomenon needs to be investigated (Rukwaro, 2021).

Results obtained will be helpful in implementation of the national policy on biodiversity conservation, pollution control, sustainable development and improvement of the knowledge of microbial functioning as well as form a basis for future comparative studies of other African urban river systems. Information collected during the study will be useful to the Ministry of Environment and Mineral Resources, Ministry of Nairobi Metropolitan Development, National Environment Management Authority and the United Nations Environment Program among other organizations in the country involved in the work of environmental protection and conservation. This study aimed at evaluating the impact of water pollution and bacteria on physio-chemical parameters, macroinvertebrates and algae in Nairobi River

1.4 Objectives of the Study

This study will establish the current status of some pysico-chemical parameters in Nairobi River. The study will also investigate the presence of pathogenic bacteria and the effects of pollution on macroinvertebrates and algal species in the river.

2.0 LITERATURE REVIEW

2.1 Introduction

Environmental challenges currently facing the developed and developing countries are not merely natural or biophysical but hu-man beings are instrumental in the contemporary environmental changes (Hearne, 2016).. Almost every human activity affects the biophysical environment in some way often destroying the existing equilibrium or accelerating natural rates of change. The accelerating changes to environment are being driven by growth in the human population, the increasing level of anthropogenic resource consumption and changes in technology and socio-political organization.

It is now well established that there is a close relationship between human population growth, poverty and environmental degradation. Poverty drives ecological degradation when desperate people overexploit their resource base, sacrificing the future to salvage the present. Ecological degeneration, in turn, perpetuates poverty, as degraded ecosystems offer diminishing yields to their poor inhabitants. A self-feeding downward spiral of economic deprivation and ecological degradation takes hold (Lenton, 2016).

The widespread scarcity, gradual destruction and aggravated pollution of freshwater resources in many regions of the world, especially the developing countries, along with the progressive encroachment of incompatible activities, demand integrated water resources planning and management (Lenton, 2016). Such integration must not only cover all types of interrelated freshwater bodies, including both surface water and groundwater, but also consider water quantity and quality aspects.

More than 1.2 billion people have no access to safe drinking water. Twice as many people do not have adequate waste water disposal facilities. According to the estimates of the World Health Organization (WHO), 80% of all diseases and an annual total of approximately 25 million premature deaths in the developing countries are caused by contaminated water (WHO, 2010). Water shortages also lead to the danger of distribution of conflicts and political confrontation.

Today, 26 countries are already affected by acute water shortages. The United Nations Food and Agriculture Organization (FAO) expects 70 countries to suffer from water shortages by 2050 and yet well over 70% of the earth's surface is covered by water. The total volume of water on the planet is estimated to be in the region of 1.4 billion cubic kilometers. However, 97.4% of this total is saltwater, and thus is only of limited use to humans (Clarke, 2015).

A large part of the remaining 2.6% is permanently stored in glaciers, icebergs and deep, rock strata. This leaves just 1% for direct use (Benn, 2015). Nonetheless, in purely arithmetic terms there is still more than enough fresh water available for household use, irrigation schemes, electricity generation, industrial purposes, and the maintenance of ecosystems. The problem lies in its very uneven distribution

2.2 Pollution of the Nairobi River

Water resources in Kenya are threatened due to increased encroachment of human population on the catchment areas and the associated increase in socio-economic activities that are supposed to create wealth but end up creating poverty instead. The rapid build-up of anthropogenically generated pollutants and corresponding loss of biodiversity in inland freshwater bodies suggest that the past and the present rates of development are not sustainable in a biophysical environmental sense (Whitmee, 2015).

The City of Nairobi has experienced rapid industrialization and growth in population during the last 100 years. This rapid growth has not been matched by development of infrastructure to deal with waste disposal. Since 1902, solid wastes, effluents from streams, yellow soap industries and raw sewage began to enter the Nairobi River. As a result, problems have arisen with regard to garbage, human and industrial waste disposal leading to pollution of the water resources (Kwitonda, 2015).

In many cities of the world, a river is considered an asset, which provides open spaces and recreational opportunities. It is also a welcome variation to the urban landscape of concrete and tarmac. However, this is not the case in Nairobi. Rapid growth of population combined with urban and industrial expansion has put enormous pressure on the Nairobi River. Untreated industrial effluent, raw sewage and industrial wastes have turned the once clear waters into a dangerous

sludge, in some places totally blocked by the everyday rubbish discarded by households and industries (UNEP, 2020)

Accelerated pollution of the river has destroyed the aquatic system and continues to cause serious health problems for thousands of people, particularly within the informal settlements. Water-related diseases such as typhoid, malaria, amoebiasis and diarrhea are prevalent in communities living along the river. Lack of availability of fresh water and functional sanitation facilities coupled with low levels of environmental awareness and lack of policy and law enforcement has left Nairobi residents with a deplorable situation impacting adversely on all who live, or indeed visit the city (UNEP, 2020). Despite its ecological, hydrological and economic importance, Nairobi River is facing a lot of environmental problems. The lives of the local inhabitants are threatened as they rely on this source of water for domestic and other uses.

Despite the extensive work devoted towards water pollution analysis and control in rivers and streams, there is still no clear understanding of the pollution that has already occurred in these ecosystems. This justifies the need for further research to establish baseline data from which future changes can be evaluated, through investigating the effects of water pollution on bacteria, macro invertebrates and algae as an integrated whole, a vital and functional component of the aquatic ecosystem. The current study aims to identify the effects of pollution on some organisms present in Nairobi River and will be of use in establishing the nature of pollution and the cause of undesirable tastes, odors and slime growths.

2.3 Empirical review

Karanja (2018), conducted a study on the factors influencing water service provision in Kenya: a case of Nairobi City water and sewage company. The study investigated factors that influence water service provision in Nairobi County. The purpose of this study was to investigate the underlying factors that influence water service provision in Kenya, Nairobi County. The objectives of the study were to determine how water sources influence water service provision in Nairobi County, to establish how water management influence water service provision in Nairobi County, to determine how the existing water supply infrastructure influences water service provision in Nairobi County. The research design used was descriptive survey research design. The target population was the staff working in Technical Directorate and specifically those in production and

distribution departments. A sample size of 267 staff members from the company was selected. The study used stratified random sampling techniques due to the nature of the population studied. The two departments have a population of 877 staff. To achieve the objectives, the study used primary data in the form of questionnaires, and secondary data from literatures, articles, books and internet sources. The collected data was analyzed using package for social science. The study established that there are various sources of water in the Nairobi County including dams, rainwater, boreholes, runoff the river, weir intakes and springs. However, water treated at the production plants is sufficient to only 68% of the customers in the Nairobi County. The results of the study showed that there are various sources of water in the Nairobi County including dams, rainwater, boreholes, runoff the river, weir intakes and springs. However, water treated at the production plants is sufficient to only 68% of the customers in the Nairobi County. The study found that increase in water sources, efficient water management and improved water supply infrastructure would lead to increase in water services provision while good environmental conditions have a positive relationship with water services provision.

Bonareri (2017) conducted a study on the effects of human activities on water quality of Rupingazi River, Embu County, Kenya. Quality of water in rivers and lakes depends on physical, chemical and biological properties. The aim of this study was to assess the effects of human activities on water quality of river Rupingazi and its major tributaries that transverse parts of Embu County in Kenya. The study objectives were to determine whether there was variation in the selected physicochemical parameters of water; find out the major human activities carried out by the community adjacent to the river and their effects on the quality of water of river Rupingazi and its tributaries. Standard laboratory methods and in-situ measurements were used to obtain data for water sampled from 12 purposely chosen points along the Rupingazi River. Laboratory and field data were statistically analyzed ($p<0.05$) by primarily applying Analysis of Variance (ANOVA), t-test and regression analysis. Results are displayed in tables and graphs. The results of the study showed that there is significant seasonal variation between some parameters for wet and dry seasons. Temperature and pH were significantly higher in dry season recording 22.97±0.20C and 8.16±0.04 respectively ($n=36$, $p<0.05$). Turbidity, DO, TSS and nitrates were all significantly higher in wet season. Recorded results were Turbidity 98.59±13.34NTU; DO 6.64±0.31mg/L; TSS

103.33±12.43mg/L; Nitrates 12.16±1.88mg/L (n=36, p< 0.05). There was no noted significant variation in EC and TDS for both seasons (n=36, p>0.05). A semi-structured questionnaire was administered to 144 randomly selected household heads (HHH) of whom 52.77% were men and 47.23% were women to obtain data on human activities in the study area. Primary level of education was identified as the highest level attained by 50.5%, with subsistence farming as the main source of income. On average farm size owned per house hold (HH) was 1.08 acres.

Ouma (2015), conducted a study on the physical chemical and bacteriological quality of water from five rural catchment areas of Lake Victoria basin in Kenya. Dumping of urban, industrial and agricultural wastewater has impacted negatively on the water quality of Lake Victoria. The aim of this study was to determine the effects of seasonal variation on the physical, chemical and microbial quality of water from five rural catchment areas of Lake Victoria. A total of 180 samples were collected during the dry and wet seasons. Color, pH, temperature, electrical conductivity (EC), dissolved oxygen (DO), turbidity and chloride were determined using portable meters. Total dissolved solids (TDS) and total suspended solids (TSS) were determined by gravimetry. Zinc, aluminum, iron, mercury and lead were analyzed using flame atomic absorption spectrophotometer. BOD, nitrates, phosphate, ammonia and bacteriological analysis were enumerated using standard assays. Color, chloride, TSS, TDS, zinc, mercury and nitrates were all below the maximum permissible limit. While the following parameters were above the maximum permissible limit: EC (420-753 µS/cm), turbidity (279-554 NTU), BOD (170-330 mg/L), phosphate (0.18-1.22 mg/L) and lead (0.08-0.90 mg/L); temperature (26-27 oC) in dry season; pH (8.9) in Dunga in wet season; aluminum in dry season (0.32-0.62) and in Dunga (0.46 mg/L) and Usoma (0.34 mg/L) in wet season; ammonia in dry season (0.54-0.72 mg/L) and at Luanda Rombo in wet season (0.70 mg/L). Apart from Luanda Rombo (5.3 mg/L) and Usoma (5.5 mg/L) the DO values (3.1-4.7 mg/L) were below the minimum permissible limit. Coliforms ranged between 10-18 MPN/100 ml. Pathogenic bacteria isolated were Escherichea coli (69.6%), Salmonella spp (18.5%), Shigella spp (6.5%) and Vibrio cholerae (5.4%). The results of the study showed that most parameters were above permissible limits and pollutants levels were higher than in previous studies, suggesting a continuation with contamination. Water was more polluted in catchment areas closer to urban areas. Seasonal variations showed that pH, color, turbidity, TSS, BOD, phosphate,

nitrates and coliforms were significantly high ($p < 0.001$) in the wet season. In the dry season temperature, EC, TDS, heavy metals, chloride and ammonia were significantly high ($p < 0.001$). High level of pollutants in wet season is due to storm water run offs carrying a higher load of contaminants while in dry season it is likely due to the increased solubility of ions as a consequence of the elevated water temperature and low pH

2.4 Research Gaps

A knowledge gap occurs when desired research findings provide a different perspective on the issue discussed. For instance, Bonareri (2017) conducted a study on the effects of human activities on water quality of Rupingazi River, Embu County, Kenya. The aim of this study was to assess the effects of human activities on water quality of river Rupingazi and its major tributaries that transverse parts of Embu County in Kenya. Standard laboratory methods and in-situ measurements were used to obtain data for water sampled from 12 purposely chosen points along the Rupingazi River. Laboratory and field data were statistically analyzed ($p<0.05$) by primarily applying Analysis of Variance (ANOVA), t-test and regression analysis. Results are displayed in tables and graphs. The results of the study showed that there is significant seasonal variation between some parameters for wet and dry seasons. On the other hand, our current study focused on the impacts of water pollution on Nairobi River Kenya.

In addition to that, a methodological gap can be identified from the research. For example, Karanja (2018) who conducted a study on the factors influencing water service provision in Kenya: a case of Nairobi City water and sewage company. The purpose of this study was to investigate the underlying factors that influence water service provision in Kenya, Nairobi County. The study employed a descriptive research design. A sample size of 267 staff members from the company was selected. The study used stratified random sampling techniques due to the nature of the population studied. The two departments have a population of 877 staff. The results of the study showed that there are various sources of water in the Nairobi County including dams, rainwater, boreholes, runoff the river, weir intakes and springs. However, water treated at the production plants is sufficient to only 68% of the customers in the Nairobi County. The study found that increase in water sources, efficient water management and improved water supply infrastructure would lead to increase in water services provision while good environmental conditions have a

positive relationship with water services provision. Our current study adopted s desk study review methodology where relevant empirical literature was reviewed to identify main themes.

3.0 METHODOLOGY

The study adopted a desktop literature review method (desk study). This involved an in-depth review of studies related to the impacts of water pollution on Nairobi River. Three sorting stages were implemented on the subject under study in order to determine the viability of the subject for research. This is the first stage that comprised the initial identification of all articles that were based on the impacts of water pollution on Nairobi River. The search was done generally by searching the articles in the article title, abstract, keywords. A second search involved fully available publications on the subject of the impacts of water pollution on Nairobi River. The third step involved the selection of fully accessible publications. Reduction of the literature to only fully accessible publications yielded specificity and allowed the researcher to focus on the articles that related to the impacts of water pollution on Nairobi River which was split into top key words. After an in- depth search into the top key words (pollution, alga, ecosystem), the researcher arrived at 3 articles that were suitable for analysis.

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4.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

This study focused on the impact of water pollution on bacteria, macro invertebrates and algae in Nairobi River. Sampling was done at Ondiri Swamp, Naivasha Road Bridge, Museum Hill Bridge, Kamukunji Bridge, MwikilNjiru Bridge and Ruai. The major sources of pollution of Nairobi River include raw sewage, industrial liquid waste discharges, solid waste, urban run-off and soil erosion arising mainly from anthropogenic activities (UoN UNEP, 2020).

Nairobi River harbors both environmental and enteric bacteria. Environmental bacteria are part of the normal biota of water, soils and plants. Although some may be opportunistic pathogens, their presence in Nairobi River is expected (Mongare- Bundambula, 2015). However, the presence of enteric bacteria such as the coliform organisms, E Coli and Streptococcus faecalis is a serious indication of contamination caused by human and animal excreta and urine. The levels of these pathogens in water increased with increase in pollution with Ruai, Mwiki and Kamukunji Bridges recording the highest colony counts. Kamukunji Bridge is characterized by open sewers that discharge raw sewage into the river while the Nairobi City Council Sewerage Treatment Plant releases its waters directly into the River at Ruai.

Algal communities along Nairobi River increased with increase in pollution from Ondiri Swamp to Ruai and this was due to the fact that most of the organisms observed in all stations belonged to the category of polluted water algae. Ironically, no clean water algae were found at Ondiri Swamp while filter clogging algae were only present at Naivasha Road Bridge. Kamukunji Bridge had no taste and odor algae while Ruai had no plankton and other surface algae found there. Oxygen levels, toxic chemicals, nutrients and habitat quality affect availability of benthos and algae in any aquatic ecosystem. This array of factors makes it hard to determine whether an organism is an indicator of a rich or poor ecosystem quality. A bioindicator of poor water quality in a flowing water ecosystem can be an indicator of favorable conditions in wetland ecosystems.

During the wet season, bacterial colonies in stagnant water increased due to the total dissolved solids in the river. The variation of bacterial colonies in flowing water was influenced most by the turbidity of the water. Algal diversity was determined by five physicochemical parameters namely: turbidity, air temperature, total phosphates (TP), nitrates and biochemical oxygen demand (BOD). During the dry season, bacterial colonies in stagnant water varied due to BOD in the river water. Algal diversity was determined by two physicochemical parameters namely: BOD and nitrate concentrations. The diversity of macro invertebrates differed greatly with Ondiri Swamp and Museum Hill Bridge exhibiting communities with different species of organisms. Pollution tended to reduce the number of species in a community by eliminating organisms that are sensitive to changes in water quality. This was the case in Naivasha Road, Kamukunji, Mwiki Bridges and Ruai sampling stations.

In view of the present results, it is concluded that field investigations coupled with laboratory analysis of samples obtained from the six sampling stations confirmed gross pollution of the Nairobi River. Pollution increases in the river as one moves down from Ondiri Swamp to Ruai and comprises mainly of solid wastes, raw sewage and industrial wastes. There is adequate evidence of fecal pollution in Nairobi River with levels far exceeding limits set by KBS (1996). This means that the river water is a health hazard and is not fit for human and animal consumption as well as for other domestic and industrial uses. Several benthic communities were encountered in the river with most lying in the category of pollutant tolerant benthos. The same thing applied to the algal communities with majority falling under the category of polluted water algae.

4.2 Recommendation

Sustainable use and conservation of freshwater resources, water pollution control and prevention and institutional capacity building. Cleaner production mechanisms and sewage treatment plants should be introduced in industries discharging effluents into Nairobi River. Awareness creation among local residents living and farming along the river bed needs to be emphasized and promoted. Improvement of infrastructural and social amenities such as provision of clean tap water, toilets and pit latrines located at adequate distances away from the river bed, storm water, household drains and ditches to direct waste waters into appropriate sewage channels and proper garbage disposal sites located far away from the river should be undertaken especially in slum areas. Utilization of modem disposal methods like waste reduction and recycling practices at the household and industrial level should be encouraged and promoted.

Continuous monitoring and assessment of different pollution trends occurring within the river system should be carried out. Engineered solutions, such as flow weirs and channeling technologies should be incorporated in order to increase flow conditions, especially on stagnant portions of the river to enhance self-purification and oxygen dissolution. Use should be made of biotechnological methods such as microbial bio monitors to assess water quality status. The Ministry of Environment and Natural Resources (MENR) and the National Environmental Management Authority (NEMA) should be strengthened to ensure that they fully enforce existing legislation on water pollution and administer stiff fines and penalties to individual offenders and institutions whose activities result in pollution of the river.

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