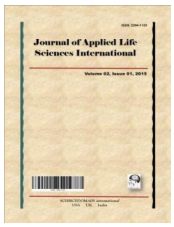

Journal of Applied Life Sciences International
10(3): 1-17, 2017; Article no.JALSI.31436
ISSN: 2394-1103

SCIENCEDOMAIN *international*
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Water Pollution in a Riparian Community: The Case of River Athi in Makueni County, Kenya

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JALSI/2017/31436
Editor(s):
(1) Vasil Simeonov, Laboratory of Chemometrics and Environmetrics, University of Sofia "St. Kliment Okhridski", Bulgaria.
Reviewers:
(1) Rajaram Pandurang Dhok, Shardabai Pawar College, Savitribai Phule Pune University, India.
(2) Suheyla Yerel Kandemir, Bilecik Seyh Edebali University, Turkey.
(3) Bechan Sharma, University of Allahabad, Allahabad, UP, India.
Complete Peer review History: http://www.sciencedomain.org/review-history/17789

Original Research Article

Received 5th January 2017
Accepted 3rd February 2017
Published 10th February 2017

ABSTRACT

The aim of this study was to determine the effects of water pollution on riparian community along River Athi in Makueni County. Specific objectives included; documenting the causes of pollution of the River Athi in Kathonzweni sub County, to access and establish the health effects resulting from the pollution of the River Athi in Kathonzweni district and finally to document measures/interventions put in place by the government and residents in the study area to control the pollution of the River Athi. Data was collected using a sample of 51 households on five villages living along the River Athi 5 kilometer distance from the River was studied. Structured questionnaires, observation, and interviews were employed and the collected data was analyzed using SPSS model and presented using tables. It was clear from the results that up-stream pollution from industries and sewage was the highest River polluter having Iiani village (93%), Kikome village (62.5%), Mumbeeni village (60%), Kyase village (50%) and Kwanyaa village (33.3%) (Chi-square(X^2)=1.7186). Results on the uses of River water within the five villages revealed that seven water uses including watering crops, washing, drinking, fishing, cooking, bathing, and brick making. Across the five villages, malaria was the commonest illness reported in

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liani village (46.7%), Kyase village (37.5%), Kwanyaa village (22.2%) and the lowest being Mumbeeni village (20%) (X^2=0.0035).According to the results, contact with River water was the common cause of most illnesses with Kwanyaa village (55.6%) having the highest percentage of illness caused by contact with River water. The study revealed that the residents' measures to control pollution were three that is observation of 30 m riparian reserve by farmers and developers, no disposal of refuse and pesticide cans in the River and not washing near the River by the residents. This study can provide a basis for designing water policies aimed at rural livelihood security improvement within the County and also globally.

Keywords: Water pollution; Riparian community; river; Makueni.

1. INTRODUCTION

Worldwide, pollution of Rivers and streams has become one of the most crucial environmental problems of the 20th century. Although some kinds of water pollution can occur through Natural processes, it is mostly as a result of human activities [1]. All biological organisms depend on water to carry out complex biochemical processes which aid in the sustenance of life on earth. Over 70 per cent of the earth's surface materials consists of water and apart from the air man breathes, water is one of the most important elements to man. Early civilizations flourished along the Rivers Nile, Tigris and Euphrates in ancient Mesopotamia, Indus in India, and Huang He in China due to their location near water sources [2]. Though water covers about 70 percent of the earth's surface, only 2.53 percent is fresh water while the remaining is salt water [3]. The World Water Council also records that of the 3 percent of fresh water, only 0.3 percent is found in Rivers and lakes, the rest being frozen [4]. This suggests that man has a relatively low amount of fresh water resources with which he can carry out his activities. Unfortunately, man's influence has begun to degrade the fresh water resource available for his development. According to [3] some 2 million tons of waste per day are disposed off within receiving waters, including industrial wastes and chemicals, human waste and agricultural wastes such as fertilizers, pesticides and pesticide residues. According to [5] the fertilizer industry effluents might significantly influence the neurotransmission system and protein turnover in the non-target organisms after exposure even at very low concentrations.

Rivers are potential sources for freshwater and some flow through major cities and towns of the world. Examples of notable Rivers include the Nile of Egypt, Indus of India, Rhine of Germany, Thames of London, Potomac of Washington DC (USA) and the Zambezi of Central Africa. [3] Indicates that 48 percent of the world's population lives in towns and cities and by 2030, this figure is likely to rise to about 60 percent. Over the last years, in many African countries a considerable population growth has taken place, accompanied by a steep increase in urbanization, industrial and agricultural land use. This has entailed a tremendous increase in discharge of a wide diversity of pollutants to receiving water bodies and has caused undesirable effects on the different components of the aquatic environment and on fisheries [6]. As a result, there is growing appreciation that nationally, regionally, and globally, the management and utilization of natural resources need to be improved and that the amount of waste and pollution generated by human activity need to be reduced on a large scale.

According to [7] increase in population, urbanization, industrialization and agriculture practices have aggravated the situation of River pollution. Industries are the major sources of pollution in all environments. Based on the type of industry, various levels of pollutants can be discharged into the environment directly or indirectly through public sewer lines. Wastewater from industries includes employees' sanitary waste, process wastes from manufacturing, wash waters and relatively uncontaminated water from heating and cooling operations [8]. High levels of pollutants in River water systems causes an increase in biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), total suspended solids (TSS), toxic metals such as cadmium(Cd), chromium(Cr), nickel(Ni) and lead(Pb) and fecal coliform and hence make such water unsuitable for drinking, irrigation and aquatic life. Industrial wastewaters range from high biochemical oxygen demand (BOD) to biodegradable wastes such as those from human sewage, pulp and paper industries, slaughter houses, tanneries and chemical industry. Others include those from plating shops

and textiles, which may be toxic and require on-site physiochemical pre-treatment before discharge into municipal sewage system [9].

Organic pollution of inland water systems in Africa, in contrast to the situation in developed countries of the world, is often the result of extreme poverty and economic and social under-development. Immediate vicinity and those who use the water body downstream. [10], indicate that "River pollution from city based industries and untreated sewage can lead to serious health problems in settlements downstream". Many Rivers in Kenya lose their quality after they have passed through cities due to a number of human and industrial activities that contribute to their pollution. Settlements downstream that depend heavily on River water for domestic activities are forced to look for more expensive alternatives where such communities are not fitted with pipe borne water. According to [11] concentration of pathogens in the water present a greater health risk to people using River water for drinking, bathing, irrigation of crops eaten raw, fishing, and recreational activities [12,13]. The Nairobi River for instance, traverses Nairobi, a city with population over 3 million, and flows along a number of informal settlements such as Mathare, Korogocho, and Dandora that are inhabited by poor people with young children. It receives effluent discharged from the city sewage treatment plants, before emptying its water into River Athi that runs for over 400 km to the Indian Ocean. Wastewater generated by inhabitants of megacities contaminates Rivers traversing them [14]. Yet, human pathogen content of Nairobi River is unknown. The combined waters of Nairobi and River Athis are extensively used by an estimated 4 million people, for drinking, and agricultural irrigation downstream.

Most Rivers around the globe and in Africa receive effluent discharged from the city sewage treatment plants, before emptying its water into Rivers down-stream. River Athi in Kenya that runs for over 400 km to the Indian Ocean with a basin area of 70,000 km^2, rises at 1º42'S as it enters the Indian Ocean as Galana River. It is the second longest River in Kenya and the waters are useful for irrigation, drinking and fisheries. The River and its tributaries flow through major towns, national parks, industrial, agricultural and residential areas. Wastewater generated by inhabitants of cities contaminates Rivers traversing them [14]. Yet, human pathogen content of Nairobi River which is one of the tributaries is unknown. The combined waters of Nairobi and River Athi are extensively used by an estimated 4 million people, for drinking, and agricultural irrigation downstream.

The indestructible nature and long term toxic effects of heavy metals including lead (Pb), nickel (Ni), manganese (Mn), zinc (Zn), cadmium (Cd) and chromium (Cr) to man as a result of consumption of organisms obtained from polluted Rivers has raised scientific and environmental concerns [15]. Weathering of soils and rocks and a variety of anthropogenic activities are two independent factors that result into the presence of heavy metals in water hence creating a societal health risk in Rivers that are otherwise useful for domestic purposes as is of the case of River Athi in Kenya. Kathonzweni district covers an area of 941.79 KM^2 with household population of 15,004 and a human population of 79,890 [16].

A total of over 30,861 people live along the River line stretch of 51.06 KM. This is half the total district population who live within the 5 KM distance from the River line. This population is believed to access the River Athi Water as their main source of domestic water. The effects of pollution in this River are felt by the population in Kathonzweni district which is at downstream of River Athi. The people in this area are more vulnerable to the effect of water pollution as there is no any other water source. The question of what causes the pollution of the River Athi and its effect on the health of residents living along the River in Kathonzweni Sub County need to be studied and determined.

The rationale for this study emanates from this recognition, and therefore seeks to incorporate pollution control measures in the River water to ensure health living of the local residents of the affected zones. The aim of the study was to establish the causes of River Athi water pollution and document the health effects on residents of the Kathonzweni Sub-County. It therefore set out to: (1) document out the causes of the pollution of the River Athi in Kathonzweni Sub-County, (2) establish the health effects resulting from the pollution of the River Athi in Kathonzweni district and, (3) find and document measures/ interventions put in place by the government and residents in the study area to control the pollution of the River Athi.

2. METHODOLOGY

2.1 Study Area

The study was done linearly along River Athi within a distance of five kilometers from the River

line. Given the average 4 -5 km distance to water points in Kenya it was assumed that communities within this area had an access to this water for their domestic use. The study area covered eight sub-locations namely; Katithi, Ivinganzia, Kanthuni, Yekanga, Yinthungu, Kithuki, Mwania and Kitise.

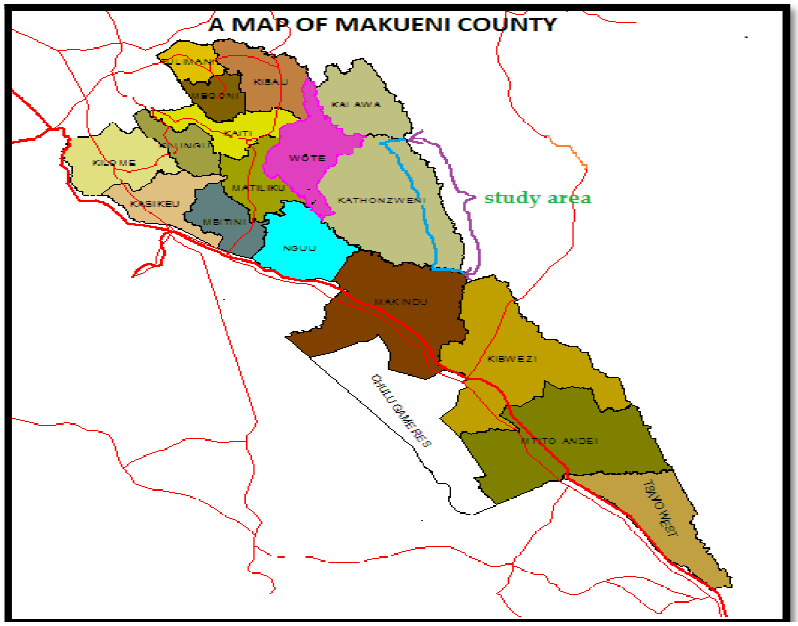

Fig. 1. Location of study area in Makueni County

Fig. 2. Google Earth map of the study site showing sampling of study centers

Fig. 3. Google map of spatial human activities in study area

2.2 Data Collection and Empirical Specification

Research methodology involved use of questionnaires administered to households sampled randomly in the study area. Systematic random sampling method was applied to study the households. Three Health institutions bordering the River line. More over questionnaires were administered to focused group discussions of villagers within the study area. Chemical laboratory analysis of River Athi water from the study area was carried. Lastly, intensive interview with key informants i.e. provincial administration and community health workers, public health officers, water officers and water service providers was carried out.

Within the study area, proportional numbers of households were systematically, randomly selected from each of the randomly selected village along the River Athi. The selected villages for study were Mumbeeni, Kyase and Kikome while Kwanyaa village was used as a control point. Data captured was recorded and subjected to statistical test and validation before reporting. The study area had 514 total households from the five villages randomly selected. The selected villages were; Mumbeeni village with 84 households, Iiani Village with 128 households, Kyase village with 122 households Kikome Village with 88 households and Kwanyaa village with 92 household. The total population of study area was 514 households and the sample size was 51 household based on 10% rule [17].

The study area formed a stretch along River Athi from the boundary of Kathonzweni Sub County with Mbooni at Thwake River confluence to Kibwezi west Sub County at Kikuu River confluence with a 5 Km width along the River. Sample size comprised of proportional number of households per named village those were picked systematically randomly from the villages. The sampling frame comprised of 514 households.

Water was collected from River Athi and taken for detailed chemical laboratory analysis from government laboratory to determine levels of pollution and contamination with heavy metals. This formed an informed decision on possible effects of contamination and pollution. The sampling was done during the dry season. Water found polluted and not fit for domestic use formed basis for further study on its health effects on the people leaving along the River line. Further study was carried to establish the effects of the water on the people randomly sampled from the five villages that bounder the River Athi.

Three health centres namely Mavindini, Iiani and Kitise were sampled for health incidences survey as they fall within the five (5) kilometer zone. The survey in health centres determined frequency of water hygiene related diseases. Public health officers who have the awareness responsibility on sanitation were interviewed. One major water service provider namely Kitise - Athi water supply CBO was engaged to in-depth discussion to highlight institutional intervention in awareness and water treatment before supply to

households. NEMA officers in the county were also interviewed to know if they were aware and extent of their intervention to curb the pollution pattern of the River. The data was subjected to SPPS test to try the hypothesis drawn within the villages.

3. RESULTS

3.1 Causes of the Pollution of the River Athi in Kathonzweni Sub-County

Results obtained on the level of education revealed that primary, secondary and university were the major education institutions attended by the household heads; having some of them not schooled. Iiani village (37.5%) had the highest number of residents who attended primary level of education and never accessed education (12.5%). Kikome village (20.8%) had the least in primary level education but the highest in secondary level of education (12.5%). Mumbeeni village (8.3%) and Iiani village (4.2%) were the only villages with residents going for university level of education (Table 1).

An investigation of the main sources of water in the study sites showed three water sources including River, rain water and shallow well. Across the five villages River dominated as the major source of water having Iiani village (54.2%), Mumbeeni village (41.7%), Kyase village (29.2%) then Kikome village and Kwanyaa both at (33.3%). ($P<0.05$ i.e. $X^2=0.0170$). Rain water was commonly used in Iiani village (8.3%) and Kyase village (4.2%). It was revealed that Iiani village (3%) also had shallow well as source of water (Table 2).

In the study area, households practiced several ways of refuse disposal which included: open space dumping, burning, compositing, burying and dumping. Burning was the commonest method of disposal in the study site; with Kikome village having (62.5%), Mumbeeni village (60%) and the least was Kyase village (25%) ($X^2=5.8497$). Open space dumping was the second major method of refuse disposal with Kwanyaa village (44.4%), Iiani village (40%), Kyase village (37.5%) and the least was Mumbeeni village (30%) ($X^2=2.0484$). The results showed that refuse compositing was highly used in Kyase village and Kikome village both at (25%) and lowly practiced in Mumbeeni village (10%). Refuse burying was only practiced in Kikome village (12.5%). Results showed that some households dumped refuse into the River; with Kyase village (12.5%), Kwanyaa village (11.1%) and Iiani village (6.7%) (Table 3).

Results obtained on common causes of River pollution in the study sites revealed that up-stream pollution from industries and sewage and dispose from agricultural chemicals were the commonest causes of River pollution. It was revealed that up-stream pollution from industries and sewage was the highest River polluter having Iiani village (93%), Kikome village (62.5%), Mumbeeni village (60%), Kyase village (50%) and Kwanyaa village (33.3%) ($X^2=1.7186$). Dispose from agricultural chemicals was the second cause of River pollution with Kyase village (37.5%), Mumbeeni village (30%), Kikome village (25%), Kwanyaa village (22.2%) and Iiani village (6.7%) (Table 4).

Table 1. Level of education of the residents living in the selected study site (%)

Level of education	Villages					X^2
	Mumbeeni village	Iiani village	Kyase village	Kikome village	Kwanyaa village	
Primary	29.2	37.5	25.0	20.8	25.0	0.2123
Secondary	4.2	8.3	4.2	12.5	8.3	0.1706
University/college	8.3	4.2	0	0	0	0.00019
Never schooled	0	12.5	4.2	0	4.2	5.2194

Table 2. Main sources of water in the selected study site (%)

Main sources of water	Villages					X^2
	Mumbeeni village	Iiani village	Kyase village	Kikome village	Kwanyaa village	
River	41.7	54.2	29.2	33.3	33.3	0.0170
Rain water	0	8.3	4.2	0	4.2	0.0059
Shallow well	0	3	0	0	0	0.0174

Table 3. Ways of disposing refuse in the selected study site (%)

Ways of disposing refuse	Villages					X^2
	Mumbeeni village	liani village	Kyase village	Kikome village	Kwanyaa village	
Open space dumping	30.0	40.0	37.5	0	44.4	2.0484
Burning	60.0	40.0	25.0	62.5	33.3	5.8497
Composited	10.0	13.3	25.0	25.0	11.1	0.0097
Buried	0	0	0	12.5	0	3.661
Dumped into or near the River	0	6.7	12.5	0	11.1	0.0001

Table 4. Common causes of river pollution in selected areas of study site (%)

Common causes of river pollution	Villages					X^2
	Mumbeeni village	liani village	Kyase village	Kikome village	Kwanyaa village	
Up-stream pollution from industries and sewage	60.0	93.3	50.0	62.5	33.3	1.7186
Dispose from agricultural chemicals	30.0	6.7	37.5	25.0	22.2	0.0003

3.2 Health Effects Resulting from the Pollution of the River Athi in Kathonzweni District

An investigation of uses of River water within the five Villages revealed seven water uses which included watering crops, washing, drinking, fishing, cooking, bathing, and brick making (Table 5). The results showed that both Mumbeeni village and liani village (100%) used water for drinking while Kwanyaa village (66.7%) highly used the River water for drinking compared to Kikome Village (87.5%) which used the River water for watering crops and cooking. More-over in Kyase village the River water was commonly used for cooking (50%). Results showed that that Kikome village (12.5%), Mumbeeni village (10%) and Kyase village (4.2%) (X^2=6.0811) were using the River water for making bricks. The households also used the River water for fishing mostly in Kyase and Kikome villages both with (25%) and the least was in liani village and Mumbeeni village both with (20%) respondents. Across the five villages cooking was one of the common water use and had the greatest percentage compared to the rest of uses with; Mumbeeni village (90%), Kikome village (87.5%), liani village (86.7%), Kikome village (66.7%) and Kyase village (50%) (X^2=0.0033). The results revealed that water use for bathing was highest in Mumbeeni village (60%) and least in liani village (6.7%).

It was revealed from the results that the study area community suffered seven common illnesses which included amoeba, malaria, diarrhea, cholera, fever, typhoid and coughing. Across the five villages malaria was the major suffered illness with liani village (46.7%), Kyase and Kikome villages both with (37.5%) and Kwanyaa village (22.2%) and the lowest being Mumbeeni village (20%) (X^2=0.0035). The highly suffered illness in Mumbeeni village was diarrhea (40%), In liani village malaria (46.7%), while Kyase and Kikome both reported malaria at (37.5%).Kwanyaa village typhoid (44.4%). Overall Amoeba (25%) was only experienced in Kikome village, Cholera (12.5%) was also only revealed in Kyase village and lastly the residents in Kikome village (12.5%) and Kwanyaa village (11.1%) were only infected with cough. The results showed that fever was commonly experienced in Kyase village and Kikome village both with (12.5%) respondents (Table 6).

Results obtained on causes of the above illnesses revealed five major causes which included poor sanitation in neighborhood, presence of mosquitoes, poor personal hygiene, contact with River water and climate change. According to the results contact with River water was the commonest cause of most illnesses having Kwanyaa village (55.6%) being the highest percentage, followed by Mumbeeni village and Kyase villages both with (50%) liani village (40%) and last was Kikome village (25%) (X^2=0.0102). The second major cause of illness

in study sites was presence of mosquito; Mumbeeni village (20%), liani village (20%), Kyase village (25%), Kikome village (25%) and Kwanyaa village both with (22.2%) (X^2=0.8919. The results showed that poor sanitation in neighborhood highly affected Mumbeeni village (20%) and liani village (6.7%). Moreover climate change led to illness in Kikome village (12.5%) and Kyase village (1%) (Table 7).

3.3 Measures/Interventions put in Place by the Government and Residents in the Study Area to Control the Pollution of the River Athi

The results obtained revealed that the households had three measures to control pollution i.e. adherence to 30 m riparian reserve by farmers and developers (Physical planning act cap 286 1996, water act 2002), no disposal of refuse and pesticide cans in the River and residents had decided not to wash near the River. Results showed that only households of both Kikome village (25%) and liani village (6.7%) had imposed the rule of not disposing refuse and pesticide cans in the River (X^2=3.3049). Observation of 30 m riparian reserve measure by farmers and developers was only captured in Kikome village (12.5%). The last measure in the study sites was not to wash near the River which was practiced by the residents of Kyase village (12.5%) (Table 8).

The study also investigated the government measures to control pollution in the study sites and found four common measures which were as follows; carrying Environmental Impact Assessment (EIA), ensuring no disposal of refuse and pesticide cans into the River and lastly ensuring no disposing of dead animals into water. According to the results all these governmental measures only were revealed across Kyase Village (12.5%) (Table 9).

Results obtained on the recommendations and solutions to water pollution included to arrest offenders, to educate residents on the need to protect the River, provision of enough drainage systems, community sensitization on pollution control measures, provision of clean water by the County government, the government to enact regulation to control River pollution, fencing along the River banks, construction of dams, digging terrace to control surface run off and construction of latrines by every household. Among all these recommendations, education of residents on the need to protect the River

Table 5. Uses of river water in selected areas of study site (%)

Uses of river water	Villages %					X^2
	Mumbeeni village	liani village	Kyase village	Kikome village	Kwanyaa village	
Watering crops	60.0	6.7	12.5	87.5	44.4	3.2275
Washing	40	86.7	12.5	37.7	33.3	1.7255
Drinking	100.0	100.0	12.5	25	66.7	5.7027
Fishing	20	20.0	25.0	25.0	22.2	0.8915
Cooking	90.0	86.7	50.0	87.5	66.7	0.0033
Bathing	60.0	6.7	37.5	12.5	22.2	1.3748
Brick making	10	0	4.2	12.5	0	6.0811

Table 6. Common illnesses in the community within the selected study site (%)

Common illness in community	Villages %					X^2
	Mumbeeni village	liani village	Kyase village	Kikome village	Kwanyaa village	
Amoeba	0	0	0	25.0	0	9.8366
Malaria	20.0	46.7	37.5	37.5	22.2	0.0035
Diarrhea	40.0	26.7	12.5	0	0	8.7897
Cholera	0	0	12.5	0	0	3.6109
Fever	10.0	6.7	12.5	12.5	11.1	0.7025
Typhoid	30.0	20.0	12.5	12.5	44.4	3.5613
Coughing	0	0	0	12.5	11.1	3.4846

Table 7. Causes of illnesses in the selected study site (%)

Causes of illness	Villages %					X^2
	Mumbeeni village	liani village	Kyase village	Kikome village	Kwanyaa village	
Poor sanitation in neighborhood	20.0	6.7	1	0	0	9.4493
Presence of mosquitoes	20.0	20.0	25.0	25.0	22.2	0.8919
Poor personal hygiene	3	6.7	12.5	12.5	0	0.0012
Contact with River water	50.0	40.0	50.0	25.0	55.6	0.0102
Climate change	0	0	1	12.5	0	7.7889

Table 8. Residents measures to control river pollution in selected study site (%)

Residents measures to control pollution	Villages %					X^2
	Mumbeeni village	liani village	Kyase village	Kikome village	Kwanyaa village	
Number of refuse and pesticide cans in the River	0	6.7	0	25	0	3.3049
Adherence to 30 m riparian reserve by farmers and developers	0	0	0	12.5	0	3.6109
Number of residents washing in or near River	0	0	12.5	0	0	3.6109

Table 9. Governments measures to control river pollution in selected areas of study site

Governments measures to control pollution	Villages %					X^2
	Mumbeeni village	liani village	Kyase village	Kikome village	Kwanyaa village	
No disposal of refuse and pesticide cans in the River	0	0	12.5	0	0	3.6109
Carrying EIA before building structures	0	0	12.5	0	0	3.6109
No River pollution	0	0	12.5	0	0	3.6109
No disposing of dead animals into water	0	0	12.5	0	0	3.6109

was the commonest across the five villages the highest being in Kikome village (87.5%), liani village (80%), Mumbeeni village (60%), Kikome village (55.6%) and lastly Kyase village (25%) (X^2=7.8632). Apart from educating the resident's Mumbeeni village recommended for community sensitization on pollution control (60%) compared to liani village which further recommended on arresting offenders (30%). Moreover, Kyase village considered provision of enough drainage systems, Community sensitization on pollution control measures and that all households should have latrines all at (37.5%) respondents. Kikome village recommended for arrest of offenders (37.5%). Kwanyaa village respondents recommended for provision of enough drainage systems, community sensitization on pollution control measures and provision of clean water by the county government (44.4%). Lastly the lowest recommendations across the five villages included fencing along the River banks (10%) only captured in Mumbeeni village, construction of dams recommended in liani village (6.7%), while Kyase village and Kikome village both recommended at (12.5%). Kwanyaa village only (11.1%) respondents recommended for construction of dams as a control measure to pollution (X^2=0.00968). Digging terraces to control surface run off was only captured in Kyase village and Kikome village both at (12.5%). Household having latrine was only recommended in Kyase village by (37.5%) (Table 10).

Table 10. Recommendations and solutions to water pollution in selected study site (%)

Solutions to water pollution	Villages					X^2
	Mumbeeni village	liani village	Kyase village	Kikome village	Kwanyaa village	
Arrest offenders	30.0	33.3	12.5	37.5	11.1	7.63848E-05
Educate residents on the need to protect the River	60.0	80.0	25.0	87.5	55.6	7.86328E-08
Provision of enough drainage systems	10.0	26.7	37.5	12.5	44.4	5.40438E-07
Community sensitization on pollution control measures	60	20	37.5	12.5	44.4	2.02506E-08
Provision of clean water by the county government	10	20	12.5	25	44.4	9.72676E-07
The government to enact regulations to control River pollution	20	20	25	12.5	0	6.29318E-05
Fencing along the River banks	10	0	0	0	0	4.32842E-08
Construction of dams	0	6.7	12.5	12.5	11.11	0.00968
Dig terraces to control surface run off	0	0	12.5	12.5	0	1.4208E-07
All households should have latrines	0	0	37.5	0	0	2.04E-31

4. DISCUSSION

4.1 Causes of the Pollution of the River Athi in Kathonzweni Sub-County

The study area had majority of household heads who had attended primary level of education (X^2=0.2123) most probably due to lack of financial capital and availability of higher education institutions. liani village had the highest number of residents who had attended primary level of education (37%) and also most of its household heads were not schooled (12.5%) this may be attributed to high commercial farming along the River and school absence when sick. Kikome village (20.8%) had the least number of households attended primary level of education but the highest in secondary level of education. This could be attributed less effect of pollution brought about by pollution control measures imposed by government officers working in the area. Mumbeeni village (8.3%) and liani village (4.2%) where the only villages with residents going for university level of education; this could commonly be caused by high presence of transiting governmental institution such as secondary schools and also commercial farming in the villages to offer opportunities for learning and most time available to those learning free from being sick. An investigation of the main sources of water in the study sites showed three water sources including River, rain water and shallow well. Across the five villages River dominated as the main source of water (X^2=0.0170). This is in agreement with [3] which found out that Rivers are potential sources for fresh-water and also the [5] which recorded that of the 3% of fresh water, only 0.3% is found in Rivers and lakes. Rain water was commonly used in liani village (8.3%) and Kyase village (4.2%). It was revealed that liani village (3%) also had shallow well as source of water this could be attributed to high income within the area coming from commercial farming and also high water table as well as some household looking for other sources of water on knowledge that River Athi water is polluted hence need to look for alternative water source (Table 2).

According to [18] anthropogenic factors such as agricultural development, population growth, urbanization and industrialization as well as market policy failures have been identified as the root causes of water pollution. In the study area, households practiced several ways of refuse disposal which included: Open space dumping, burning, compositing, burying and dumping. Burning was the commonest method of disposal

in the study site; Kikome village (62%), Mumbeeni village (60%) and the least was in Kyase village (25%) this could be attributed to a cheap method of refuse disposal and ignorance to enforce regulations against poor refuse disposal. This would subsequently allow wastes be washed into the river for the case of surface run off. This is in agreement with [19] who noted that the laws prohibiting the indiscriminate dumping of refuse or pollution of Rivers exist but the enforcement of these laws proves difficult. Open space dumping was the second major method of refuse disposal having Kwanyaa village (44.4%), Iiani village (40%), Kyase village (37.5%) and the least was Mumbeeni village (30%); this could have been caused by uncontrolled solid waste disposal in the study site by either residents, governments institutions or the County government officers in charge of environment. The results showed that refuse compositing was highly used in both Kyase village and Kikome village (25%) but lowly practiced in Mumbeeni village (10%). This could commonly be attributed to production of manure for farming and for sell and also knowledge that composting can be used as method of good waste disposal to avoid river pollution. Refuse burying was only practiced in Kikome Village (12.5%); mostly because of presence of Non-governmental Organizations (NGOs) and Community Based Organizations (CBOs) which sensitized the community to bury the waste to avoid it getting into river hence polluting it. Study revealed that some households dumped refuse into the River commonly in Kyase village (12.5%); a phenomenon which could be influenced by lack of exposure/education in that Village (Table 3). According to [20] in Kumasi many people attribute the increasing water pollution In the Kumasi metropolis to the failure to collect, treat and dispose of waste water efficiently. This showed that the community was also contributing to polluting river Athi water.

According to [8] increase in population, urbanization, industrialization and agriculture practices have aggravated the situation of River pollution. Results obtained on common causes of River pollution water in the study sites revealed that up-stream pollution from industries and sewage and dispose from agricultural chemicals were the commonest causes of River pollution. According to [3], some 2 million tons of waste per day are disposed off within receiving waters, including industrial wastes and chemicals, human waste and agricultural wastes such as fertilizers, pesticides and pesticide residues. It was revealed that up-stream pollution from industries and sewage (X^2=1.7186) was the highest River polluter this may have been attributed to negligence by industrial owners towards treatment of industrial waste and sewage from up-stream. Dispose from agricultural chemicals was the second cause of River pollution (Kyase village 37.5%, Mumbeeni village 30%, Kikome village 25%, Kwanyaa village 22.2% then Iiani village 6.7%) which could be due to low education level on containing agricultural waste by the local human resource being used in agricultural practices for example chemical and fertilizer application. Although some kinds of water pollution can occur through Natural processes, it is mostly as a result of human activities [1] (Table 4).

4.2 Health Effects Resulting from the Pollution of the River Athi in Kathonzweni District

An investigation of uses of River water within the five villages revealed seven land water uses including watering crops, washing, drinking, fishing, cooking, bathing, and brick making This was noted by [21] report which revealed that; adequate water supply promotes good health and improves the prospects of new livelihood activities which are otherwise denied and are a key step out of poverty (Table 5). The results showed that both Mumbeeni village (100%), and Iiani village (100%) user River water for drinking mostly due to their proximity to the River or most common because this was the only main source of water and Kwanyaa village only (87.5%) highly used the River water for drinking mostly probably because most households had this water pumped to them by water service providers. In Kikome village (87.5%) which used the River water for watering crops and cooking respectively. More-over in Kyase village the River water was commonly used for cooking. This is because a significant number of households were convinced that cooking will kill the pathogens in water hence less harm from the polluted River Athi water. The study revealed that Kikome village (12.5%), Mumbeeni village (10%) and Kyase village (4.2%) were using the River water for making bricks used in house building which could have led to cheap house construction hence proper resource utilization and reduced poverty. The households also used the River water for fishing mostly in both Kyase and Kikome villages (25%). This could have highly lead to link of pollutants from the River to residents within the study area as it is the main

source of meat for the residents hence causing disease in the households. This is in agreement with [6] who noted that the fertilizer industry effluents might significantly influence the neurotransmission system and protein turnover in the non-target organisms after exposure even at very low concentrations. Further, the data suggested that the fish ache could be used as a potential biochemical marker for fertilizer industry effluent pollution in aquatic systems.

Across the five villages cooking was one of the common water use and had the greatest percentage (Mumbeeni village at 90%, Kikome village at 87.5%, Iiani village at 86.7%, Kwanyaa village at 66.7% and Kyase village at 50%) as compared to the rest of uses most probably because in every household cooking should take place every day unless there is no access to a source of food.

It was revealed by study results that within the study area community suffered seven common illnesses which included amoeba, malaria, diarrhea, cholera, fever, typhoid and coughing. Across the five villages malaria was the commonest illness with Iiani village having the highest percentage (46%) which could be attributed to presence of mosquitoes in the study site. According to [11] concentration of pathogens in the water present a greater health risk to people using River water for drinking, bathing, irrigation of crops eaten raw, fishing, and recreational activities. The highly suffered illness in Mumbeeni village (46.7%) was diarrhea which is also a clinical symptom of amoeba or typhoid both of which are resultant of water pollution; supported by a report from a chemical analysis of water undertaken by government chemists done on 25th March 2015 Nairobi (Appendix I). The quality of freshwater at any point on a landscape reflects the combined effects of many processes along water pathways and both quantity and quality of water are affected by human activity on all spatial scales [22].

In overall, Amoeba was only experienced in Kikome village (25%) this may be attributed to low use of latrines for defecation, Cholera was also only revealed in Kyase village (12.5%) which could also be mostly caused by lack of latrine use by the households in study site and beyond in the upstream. [10], indicate that “River pollution from city based industries and untreated sewage can lead to serious health problems in settlements downstream” [10]. Lastly the residents in Kikome village (12.5%) and Kwanyaa village (11.1%) were only infected of cough. The results showed that fever was commonly experienced in both Kyase and Kikome villages both at (12.5%) since this villages commonly experienced high attack by malaria. Persons who use polluted water are in danger of contracting water-borne, water-hygiene, and water-contact or water-habitat vector diseases [23] (Table 6).

Five major causes of illness included poor sanitation in neighborhood, presence of mosquitoes, poor personal hygiene, contact with River water and climate change were revealed. According to the results, contact with River water was the common cause of most illnesses having Kwanyaa village (55.6%) with the highest percentage. This could be attributed to awareness by different stakeholders that the river water is polluted and those in contact are highly affected. This is followed by Mumbeeni village and Kyase village both with (50%) respondents. Iiani village (40%) this could be attributed to limited sources of water hence no other option on the source of water; and lastly Kikome village (25%) may be because some of the households used shallow wells as source of water (Table 2). According to [11] concentration of pathogens in the water present a greater health risk to people using River water for drinking, bathing, irrigation of crops eaten raw, fishing, and recreational activities.

The second major cause of illness in Mumbeeni village (20%) was presence of mosquito together with poor sanitation in neighborhood. Persons who use polluted water are in danger of contracting water-borne, water-hygiene, and water-contact or water-habitat vector diseases [23]. It was clear that poor sanitation in neighborhood highly affected Mumbeeni village (20%) and Iiani village (6.7%) this could be attributed to their closeness to the source of pollution i.e. upstream pollution from industries and sewage as they are immediate recipients of the River water as it leaves the industrialized towns and Nairobi city. Moreover climate change led to illness in Kikome village (12.5%) and Kyase villages (1%). This was attributed to the people belief and perception on climate change based on their continued stay along the river on how climate had changed over (time. Table 7) this could also have been caused by lack of mitigation measures to climate change by the households.

4.3 Measures/Interventions put in Place by the Government and Residents in the Study Area to Control the Pollution of the River Athi

Hayakawa et al. [24] Confirmed that Agriculture in some settings across the earth requires the use of inorganic fertilizers and the application of pesticides. The application of such chemicals leads to the release of toxins as Nitrogen (N) and Phosphorus (P). These toxins leach into soils to contaminate underground water and also lead to the eutrophication of water systems. The results revealed that only households of Kikome village (25%) and Iiani village (6.7%) had imposed the rule of not disposing refuse and pesticide cans in the River. This could commonly be attributed to most of them attending secondary school level as compared to those in other Villages. Observation of 30m riparian reserve measure by farmers and developers was only captured in Kikome village (12.5%) which could have been due to fact that most households practicing farming hence experienced the highest impacts from agriculture practice near the River. The last measure in the study sites was not to wash near the River by only the residents of Kyase village(12.5%) where most impacts of pollution was experienced and that the residents could highly be using the water for domestic use. It was also clear that within the study area there were water service provider institutions that is Matheani-Kithuki water supply and Athiani-Kitise water supply; both institutions supplied water to connected households and markets. They also had measures to control River pollution which included sensitization of community to avoid River bank cultivation, use of non-poisonous agro-chemicals, building public toilets at their water supply outlets, prevent community from fetching water using donkey in the River. This is believed as the reason behind the increased awareness in Kyase village as compared to others (Appendix II).

The study also moved deeper to investigate the government measures to control pollution in the study sites and found four common measures which were as follows: carrying Environmental Impact Assessment (EIA), ensuring no disposal of refuse and pesticide cans into the River and lastly ensuring no disposing of dead animals into water. According to the results all these governmental measures were revealed across Kyase village mostly because in this village there were government officers who were working in Ministry of environment and were involved in programmes in the area hence enforcing the law. The study also found that National Environmental Management Authority (NEMA) and Water Resources Management Authority (WARMA) which are government institution were involved in conservation of River water by giving stop orders to offenders of River pollution and prosecuting people disposing effluent into the River Athi (Appendix III).

Results obtained on the recommendations and solutions to River water pollution included to arrest offenders who break the set regulations by National Environmental Management Act (NEMA), on treating water before disposal a same phenomenon revealed by [20] who noted that many people in Kumasi attribute the increasing water pollution due to failure in treating and disposing of waste water efficiently. In addition, government institutions like hospitals and learning institutions contribute to water pollution, making the prosecution of individuals in both private and public institutions a farce. The other measures included educating residents on the need to protect the River water, provision of enough drainage systems, community sensitization on pollution control measures, provision of clean water by the County government, the government to enact regulation to control River pollution, fencing along the River banks, construction of dams, digging terrace to control surface run off and construction of latrines by every household. Among all these recommendations, education of residents on the need to protect the River was the commonest across the five villages (Kikome village 87.5%, Iiani village 80%, Mumbeeni village 60%, Kwanyaa village 55.6% and Kyase village 25%) this was sought to build the knowhow on protection of water sources including the entire River ecosystem. Apart from educating the residents, Mumbeeni village (60%) recommended for community sensitization on pollution control compared to Iiani (30%). This is because it experienced most health effects of the River pollution. It further recommended for arresting the offenders mostly because the community in this Village highly used the water for drinking hence caring for their health. Moreover Kyase village (37.5%) recommended for provision of enough drainage systems since according to the results this Village had the highest number of diseases suffered across the five Villages and believed that drainage systems will control River pollution. Kwanyaa village (44.4%) also recommended for provision of enough drainage systems, community

sensitization on pollution control measures and provision of clean water by the county government. Lastly, the lowest recommendations across the five villages included fencing (10%) along the River banks only captured in Mumbeeni village. This could be due to high cost of fencing as this method is seen as a capital and labour intensive across the study site. Digging terraces to control surface run off (12.5%) was captured both in Kyase village and Kikome villages a pollution control method which could have been gained from experience of community based groups (CBOs). Household to have latrine was only recommended in Kyase village (37.5%) where presence of cholera disease among the households was only reported revealing an observation also confirmed by [25] who commented that in many areas in less developed countries, toilets, latrines or proper drains are non-existent or have broken down; wastes are disposed of near or in the same River, lakes or wells used for drinking and food preparation.

5. CONCLUSION

From the results obtained in this study it can be concluded that;

- Overall, the common cause of River pollution was up-stream pollution from industries and sewage; and also from the local commercial agricultural activities and practices along the River.
- Across the five villages, malaria was the major suffered illness followed by Diarrhoea, typhoid and cholera.
- The residents' and governmental water pollution control measures were lowly involved in control of water pollution in the study area and where practiced, its enforcement was weak.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

Appendix I. Selected household socio-economic characteristics

Sub location	Sampling site	Sample size	Male	Female	Total	Households	Area KM^2	Population density
Ivinganzia			1353	1517	2870	553	34.85	82.35
Kanthuni	Iianiani	13	1407	1646	3053	557	43.34	70.44
Katithi	Mumbeeni	8	1364	1540	2904	576	38.93	74.59
Yekanga			1419	1483	2902	523	34.93	83.09
Yinthungi	Kyase	12	1460	1629	3089	584	40.52	76.23
Kithuki	Kikome	9	2750	2991	5741	1064	82.85	69.29
Mwania	Kwanyaa	9	1569	1670	3239	599	62.87	51.52
Total		**51**	**11,322**	**12,476**	**23,798**	**4,456**	**338.29**	**70.35**

River length under study = 51.06 KM
With distance under study from the Riverine 5KM
Arithmetical study area of 514 total households in (5 51.06) = 255.30 KM^2*

Appendix II. Water service provider (institution) in the study sites

Name of water service provider (institution)	Role of the institution	Control measure to river pollution by the institution
Matheani-Kithuki earth water supply	-Supply of water to connected households and markets	-Sensitization of community to avoid River bank cultivation. -Use of non-poisonous agro-chemicals -Building public toilets at their water supply outlets -Prevent community from to fetching using donkey in the River.
Athiani-Kitise water supply	Supply of water to connected households and markets	Sensitization of community to avoid River bank cultivation. -Use of non-poisonous agro-chemicals -Building public toilets at their water supply outlets

Appendix III. Government institution involved in conservation of water in study sites

Government institution involved in conservation of water	Policy/act governing the institution activity	Enforcements to control pollution	Practical intervention to River water pollution	Reasons preventing optimal service delivery
National Environmental Management Authority (NEMA)	EMCA 1997 with 2015 amendments	Giving stop orders to offenders of River pollution	1. Partnering with other relevant government agencies to enforce and clean the River from solid waste (Plastic bags)	Few technical officers
		Prosecute people disposing effluent into the River Athi	2. Annual public sensitization forums	Little annual budgetary allocation
water resources management authority (WARMA)	Water resources management act and water policy 2012.	No enforcement unit but liaise with NEMA for enforcement	Sensitizing community through water resource users association (WRUA)	Financial constrains

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/17789