SURFACE WATER QUALITY IN KENYA'S URBAN ENVIRONMENT: A CASE STUDY OF GITHURAI, NAIROBI, KENYA

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Abstract
Safe, clean drinking water and sanitation facilities are key to economic development and public health in Kenya. Rapid urbanization and population growth mean worsening conditions for millions of Kenyans, especially the poorest. Sanitation is one of the greatest problems especially in the informal settlements where 60% of the people in the urban centers reside. In fact, 50% of all preventable illnesses in Kenya are water, sanitation and hygiene related. This study was done to establish the level of indicator water quality parameters, and establish water borne disease prevalence in Githurai and adjacent communities. Water samples were collected from 6 points distributed uniformly along Kiu River in Githurai. Using standard methods, the samples were analyzed for Dissolved Oxygen (DO), BOD, TSS and TDS in the JKUAT environmental laboratory. A survey was also done in Githurai, Kahawa Sukari and Kahawa Wendani to establish the prevalence of water borne diseases. Data was collected from local medical clinics and Ruiru District Public Health Office. Randomly selected individuals were also interviewed to establish the frequency of visits to health facilities**.** The study revealed that dissolved oxygen in surface water was between 1.5 and 8.5 mg/L while biochemical oxygen demand (BOD) was between 200 and 400 mg/L. This was much higher than NEMA standards for surface water which demand that the BOD of any effluents to be discharged into surface water should be less than 30 mg/L. Total suspended solids (TSS) varied from 900 to 950 mg/L. NEMA allows domestic water not to have TSS of more than 30 mg/L. Total dissolved solids (TDS) were in the range of 3000 to 9000 mg/L compared to a maximum of 1200 mg/L which is allowed by NEMA. Surface water in Githurai is highly polluted and poses public health risks. Some 30-40% of all patients visiting hospitals in the study area suffered from diarrheal diseases and the average resident in Githurai was treated for water borne diseases once every three months. Therefore, an urgent intervention is required to clean up Kiu River and stop further contamination of the river.

Key words: Sanitation, informal settlement, water quality, BOD, TSS, TDS

1.0 Introduction

Water is a scarce commodity in Nairobi, and the little that is available often gets polluted as a result of various human activities. Therefore, as is the case in many other cities in the world, Nairobi is experiencing a steady decline of available freshwater. This is because there is also a steady increase in population. Urban population often grows as a result rural-urban migration by people looking for better living standards (Grau and Alde, 2007). Populating urban areas reduces the land use pressure in fragile rural ecosystems, but results in environmental pollution when the production of human waste increases. Therefore, appropriate interventions are required to manage the wastewater, ensure public health protection, and guard against pollution of scarce water resources; and if possible reduce pressure on scarce freshwater resources (Bakir, 2000).

Githurai is a highly populated suburb of Nairobi City. It is located in the Northern outskirts of Kenya's Capital City. This area has experienced population increase without corresponding planning and infrastructure development. The rapid urban population growth is characterized by poor sanitation, environmentally related infections, as well as psychological and social illnesses (Choldin, 1978). Sanitation improvement usually results in reduced cases of water related diseases. By increasing sewerage coverage from 26% to 80% of the households, Brazil reduced diarrhea among children under the age of three, by 22% (Nelson and Murray, 2008).

Informal settlements accommodate 60% of Kenya's urban population (Antao, et al., 2007). Although Githurai is not classified as an informal settlement, it has characteristics of an informal settlement. It discharges wastewater without any form of treatment; industries in Githurai discharge effluents that do not comply with Kenya's standards for discharge into the environment; and the wastewater is allowed to either percolates into the ground where it contaminates groundwater or flows into the natural drainage system causing surface water pollution. Because of this contamination of water resources, water related diseases are common. Out of the common diseases found in developing countries, 70% of them are related to water and sanitation (Antao, et al., 2007). The purpose of this study was to assess the public health situation in Githurai, which is a suburb of Nairobi City. Specific objectives for this study included assessing Kiu River water quality relative to Kenya's water quality guidelines; and evaluating the prevalence of water related diseases in Githurai.

2.0 Materials and Methods

At the Municipal Council of Ruiru population, domestic water supply and sanitation data were obtained. During the wet season, October to December 2009, surface water quality measurement in Githurai was assessed by taking sample along the river, starting from the point where the river enters Githurai from Kiambu (Figure 1), to a point 1 km east of point where the river crosses Thika road. A survey was done in Githurai area to identify suitable and representative sampling points, at places which were accessible on foot. Sampling points 1-3 were located West of Thika Road, while sampling points 4-6 were located to the east of Thika Road. Using a GPS system the coordinates of sampling points were established.

Sampling was carried out at each point in the mid morning. Using sterilized sampling bottles, two samples were collected at each sampling point. This was to ensure that the data obtained was representative of the pollution level at the sampling station. Using standard methods, the water samples collected were analyzed for turbidity, pH, dissolved oxygen, ammonia, nitrates, phosphates, coliform count, and electrical conductivity. The pH and electrical conductivity (EC) were measured with the help of a combined EC and pH meter. An EC meter measures the electrical conductivity of the water. While clean water has a low EC, water that is contaminated with nutrients has relatively higher EC.

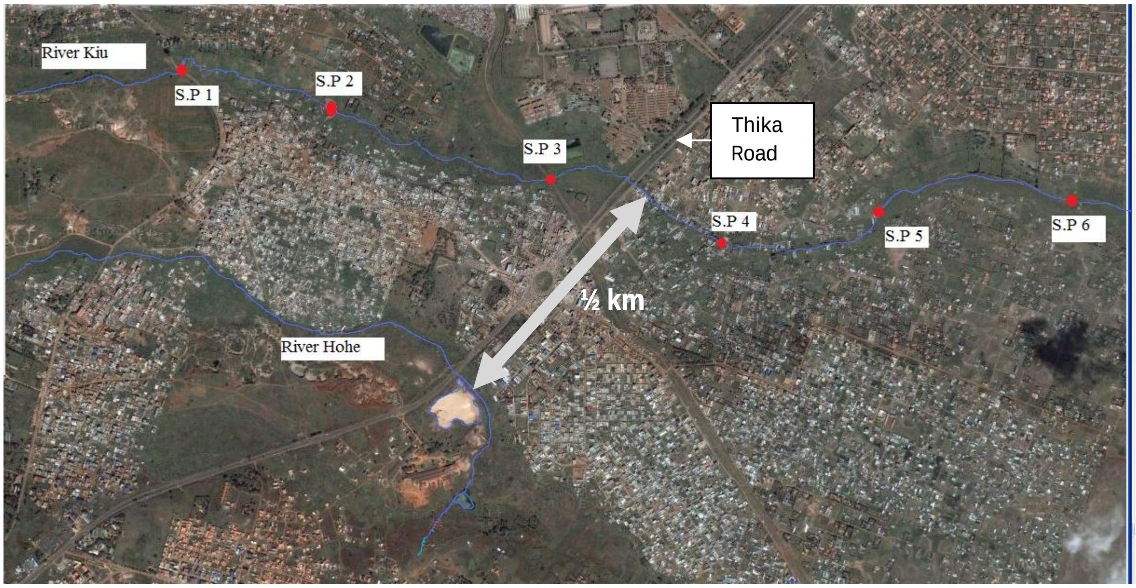

Figure 1: Aerial photograph of the project site

Total Suspended Solids (TSS) was determined by filtering 100ml of sample through a glass-fiber filter paper by the help of a suction pump. The weight of the evaporation dish plus filter was obtained. The trapped material (residue) was dried at a temperature of 180 ^oC in a porcelain dish for 24 hours. Cooling of the residue was done in dry desiccators, for 30 minutes. The obtained residue was weighed on an analytical balance and the results recorded.

Total Dissolved Solids (TDS) was determined by passing 100 ml of a sample through a filtering unit and drying of the filtrate done in the oven at 180 ^oC to dryness for 24 hours. Cooling in dry desiccators was done for 30minutes and the resulting residue was weighed on an analytical balance. The results were thus recorded.

Nutrients such as nitrogen and phosphorus, the 5 day Biological Oxygen Demand (BOD_5) and dissolved oxygen were measured using standard methods. By dipping the pH meter probe in half of 100ml of sample, stirring continued and steady pH reading obtained.

Nephelometric Method, using a turbidity meter, was used for the measurement of turbidity. The turbidity meter probe was dipped in half of 100 ml of sample, stirring continued and turbidity meter reading obtained in NTU units.

The electrical conductivity (EC) was determined by dipping the EC meter probe in half of 100ml of sample, string continued and steady EC reading obtained. A survey was done in Githurai, Kahawa Sukari and Kahawa Wendani to establish the prevalence of water borne diseases. Data was collected from local medical clinics and Ruiru District Public Health Office. Randomly selected individuals were also interviewed to establish how frequently they visited health facilities for treatment of diarrheal diseases**.**

3.0 Results and Discussion

The Kenya Water regulations state: "*Every person shall refrain from any act which directly or indirectly causes, or may cause immediate or subsequent water pollution… and No person shall throw or cause to flow into or near a water resource any liquid, solid or gaseous substance or deposit any such substance in or near it, as to cause pollution"* (Government of Kenya, 2006). In Githurai, this regulation is violated as is evidenced by the surface water quality.

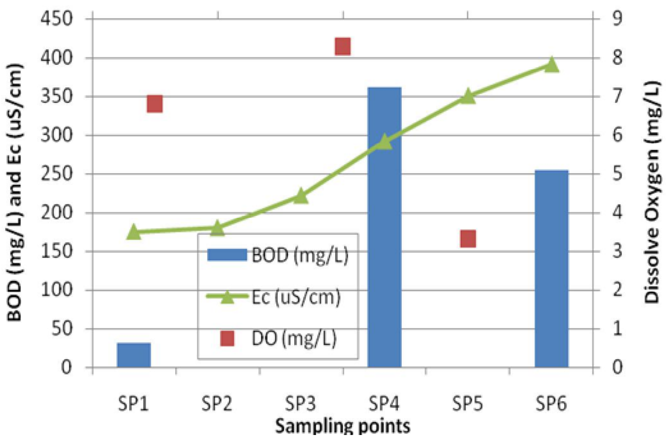

Figure 2: Pollution levels in Kiu River

3.1 Surface Water Pollution in Githurai

Water pollution is the contamination of water by undesirable foreign matter. One category of water pollutants is oxygen-demanding wastes; wastes that can be decomposed by oxygen-requiring bacteria. As the river entered Githurai, the concentration of dissolved oxygen was between 7 and 8.3 mg/L and as the final sampling point DO was about 3.3 mg/L. According WHO standards for drinking water resources, the minimum level of dissolved oxygen should be 4 mg/L. The reduced levels of dissolved oxygen (Figure 2) occurred probably as a result of increasing quantities of oxygen demanding wastes in the water. BOD_5 was about 30 mg/L as the water entered Githurai, 1 km West of Thika Road compared to more than 300 mg/L at SP6, 1 km East of Thika Road (Figure 2).

Increasing BOD indicated that there was an increase in organic substances as the river entered Githurai. This likely happened due to discharge of raw sewage into the river (Figure 2). These findings are similar to the data of Antao, et al, (2007) who found high pollutant levels in Ruiru River, a neighboring river with a similar environment. Pollution in surface water makes it a significant source of water-borne diseases.

Figure 3: Domestic wastewater flowing in open ditches which finally discharge into Kiu River

The average BOD at sampling point SP6 was 250 mg/L (Figure 2), and the streamflow was estimated as 100 L/s. It was also estimated that the distance from SP1 to SP6 was 2 km, and that the average width of the area contributing flow and pollution to the river was 2 km. Therefore the area contributing towards pollution of Kiu River up to SP6 was estimated as 400 ha. From census data obtained in the Ruiru District office, the population of Githurai is estimated as 100,000 people.

$$\text{DOD per day } \left(\frac{\text{Tonnes}}{\text{day}}\right) = 250\,\frac{mg}{L} * 100\,\frac{L}{s} * 3600 * 24\,\frac{s}{Day} * \frac{10^{-9}\,Tonne}{mg} \qquad \text{........... (1)}$$

$$Annual\ BOD\ (Tonnes) = BOD\ per\ day * 365 \qquad \text{........... (2)}$$

$$BOD\ production\ (Tonnes\ per\ ha) = \frac{Annual\ BOD\ (Tonnes)}{400\ ha} \qquad \text{........... (3)}$$

$$BOD\ production\ (Tonnes\ per\ capita) = \frac{Annual\ BOD\ (Tonnes)}{100{,}000\ persons} \qquad \text{........... (4)}$$

Using the formulas above, the annual BOD production per unit area in Githurai was calculated as 2.0 Tonnes/ha per year and BOD contribution per capita was 8 kg per year (Table 1). Lake Victoria, with an area of 4.87 million ha, a population of 1 million people, contributes 7510 Tonnes of BOD per year (Scheren et al., 2000). This works out to BOD production of 1.5×10^{-3} Tonnes/ha or 8 kg/capita/year. The high loading of BOD in the surface water of Githurai is probably because the area lacks a sewer system. Individual properties use septic tanks for wastewater treatment. Apparently these wastewater treatment systems have inadequate facilities to handle human waste from the large Githurai population. Most home owners end up discharging virtually untreated sewage into open ditches which finally discharge into Kiu River, thus becoming a source of contamination. According to the calculations done above, BOD production per unit area in densely populated urban areas such as Githurai was more than 1000 time more than it was estimated to be in a rural area. This is likely because untreated wastewater in Githurai was discharged into the surface Kiu River. Mohammed (2002) found that coastal waters in the vicinity of Dar es Salaam harbor were heavily polluted by wastewaters that are discharged into the ocean without any form of treatment. The same study found that surface water in Dar es Salaam received about 56 Tonnes/day of BOD.

Table 1: BOD production in Githurai compared to a rural area

Parameter	*Githurai*	*Rural area (Lake Victoria Basin)*
BOD production (Tonnes/ha/year)	2.0	0.0015
BOD production (kg/capita/year)	8	8

Failure to treat wastewater before discharge results in the pollution of surface water bodies. This is the case in Githurai, and necessary interventions are required to collect and treat wastewater before discharge into the environment.

3.2 Solids in the Surface Water of Githurai

Suspended and dissolved solids are pollutants that can find their way into surface water bodies. In Kiu River, suspended solids varied between 910 and 960 mg/L (Figure 4). The upper limit for effluent discharge into surface water bodies is 30 mg/L of suspended solids (Government of Kenya, 2006), which would allow the discharge of about 260 kg/day of solids. The TSS of 960 mg/L allows over 8,000 kg/day of solids. The City of Dar es Salaam has recorded pollution, in term of suspended solids, of up to 78,429 kg/day (Mohammed, 2002). Although the situation in Githurai is not as bad as in Dar es Salaam, the right interventions should be taken to avoid this pollution of surface water bodies.

The concentration of dissolved solid increased from upstream to downstream with the highest concentration being nearly 9,000 mg/L close to SP6 where the electrical conductivity was about 400 µm/cm (Figure 4 and Figure 2). Irrigation water should not have TDS of more than 1200 mg/L (Republic of Kenya, 2006). Therefore, Kiu River water seems is to be unacceptable for agricultural use.

Nutrients in water form another class of water pollutants, including water-soluble nitrates and phosphates that cause excessive growth of algae and other water plants, and deplete oxygen supply in water. In the presence of nutrients, certain aerobic bacteria become more active and deplete oxygen levels even further, so that only anaerobic bacteria can be active. This makes life in the water impossible for fish and other organisms. Nitrates in drinking water can harm the health of young children. As Kiu River runs along the populated parts of Githurai, the concentration of nutrients increases. The maximum concentration (about 2.9 mg/L of Total Nitrogen and 3 mg/L of Phosphorus) was reached near sampling point SP6 4 (Figure 5). NEMA has no guidelines for maximum levels of nutrients in effluent for discharge into surface water bodies. However, drinking water should not have more than 10 mg/L of Nitrates. The amount of nutrients in this case appears to be low, perhaps because the amount of agricultural and industrial activity is not sufficient to elevate nutrient levels in surface water.

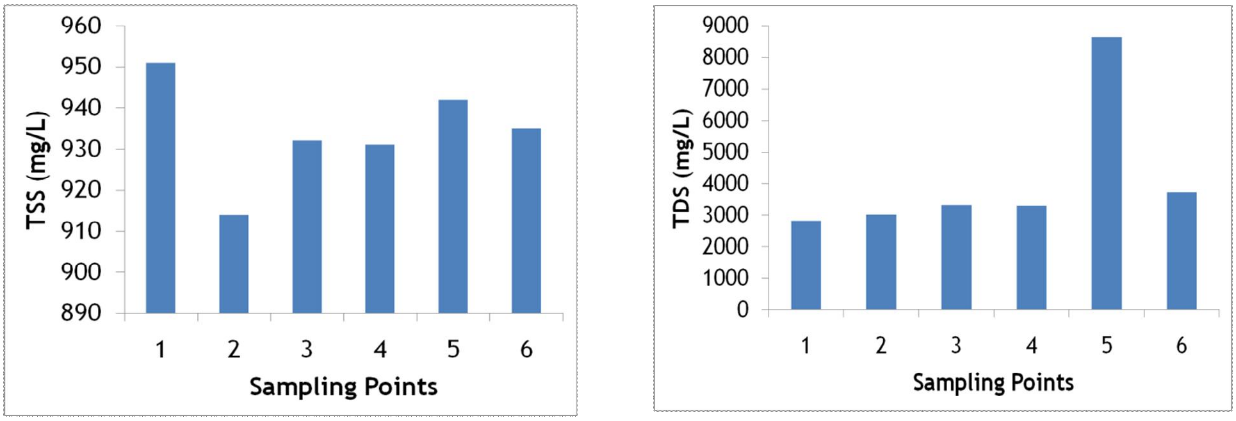

Figure 4: Dissolved and Suspended solids in Kiu River water

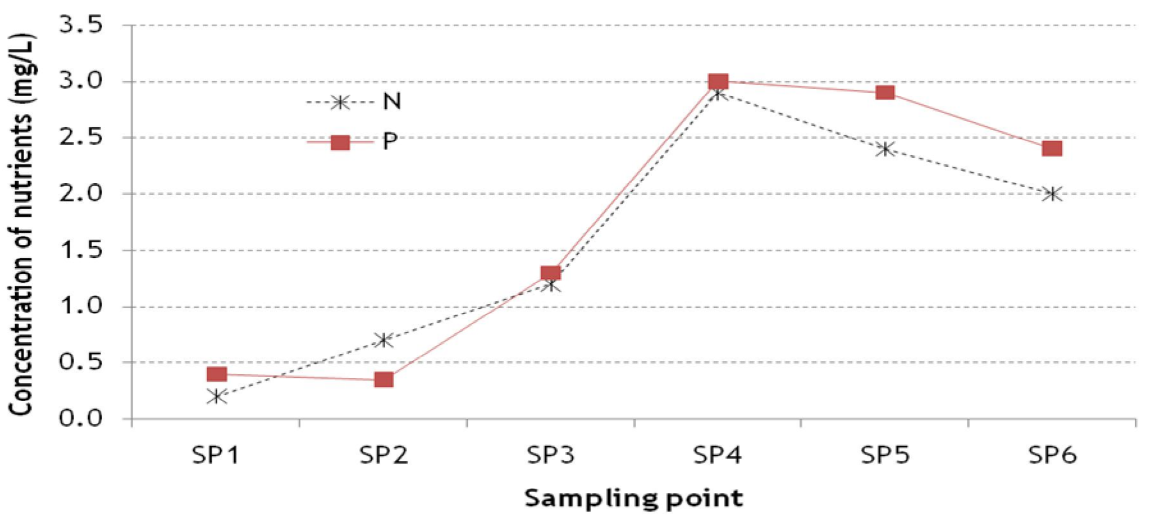

Figure 5: Nutrients in Kiu River water

During the study period, it was observed that solid waste was allowed to accumulate and release leachate with organic pollutants. This was particularly the case in the open air market and residential areas. What is more, solid waste was frequently dumped into surface drainage ditches, meaning that all fluids released from the solid waste ended up in Kiu River.

Wherever BOD concentration is high, disease-causing agents such as bacteria, viruses, protozoa and parasitic worms are likely to also be present. Coliform bacteria, indicating the presence of disease-causing agents were detected at all sampling points. According to NEMA, water to be used for the irrigation of restricted crops should have less than 1000 MPN/100 ml of coliform bacteria (Government of Kenya, 2006). In this study the population of coliform bacteria detected was $120x10^6$ MPN/100 ml of water. Therefore Kiu River water must be treated before being used for any purpose especially irrigation.

3.3 Water- Related Diseases in Githurai

Only 53% of low income residents in Ruiru District have access to treated drinking water (Antao, et al., 2007). This means that the low income population faces much higher public health risks than the rest of the population.

Many Githurai residents often complain of malaria, diarrhea and intestinal worms. These infections are mostly caused by ingesting contaminated water. Diarrhea is a leading cause of death in children. According to the Public Health Office in Ruiru District, where Githurai is located, in year 2010 the majority of cases with diarrheal diseases (typhoid, amoebiasis, etc) were between 30 and 40% of all the patients seeking medical care. Unlike diarrheal diseases, Malaria was highest during the wet months of the year and was lowest during May, June and July when it was relatively dry (Figure 6). Most likely, malaria was high during wet weather because of the enhanced breading of mosquitoes. However, because diarrheal diseases are connected with the state of cleanliness, their occurrence tended to be independent of weather conditions. Among poor families in Brazil, Sobel, et al., (2004), found childhood diarrheal morbidity in children aged 1–4 years to be a problem. They suggested that it was necessary to boil baby bottles and bottle nipples, and that care givers needed to observe hygienic preparation of fruit juices.

The rate of hospital visits because of water borne diarrheal diseases was most frequent in Githurai where on average person was treated once every 3 months (Figure 7). In Kahawa Sukari, which is a more affluent residential area, the average resident was treated for diarrheal diseases once every 3.5 year while in Kahawa Wendani the time interval between hospital visits was 2 years.
Infection with intestinal worms was less frequent. In Kahawa Sukari and Kahawa Wendani residents completed 5 years without worm infections. In Githurai these infections occurred once in 4 years. The rate of malaria occurrence was similar to that of diarrheal diseases. In Githurai people complained of Malaria once every 1.5 years while in Kahawa Sukari and Kahawa Wendani the complaints were reported once every 3.5 year and 2 years, respectively.

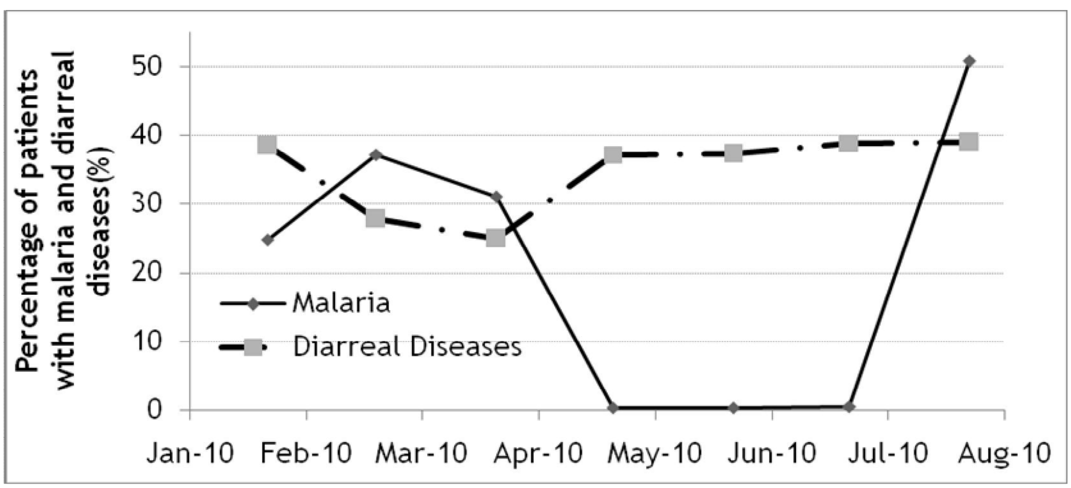

Figure 6: Water-related disease occurrence during the study period

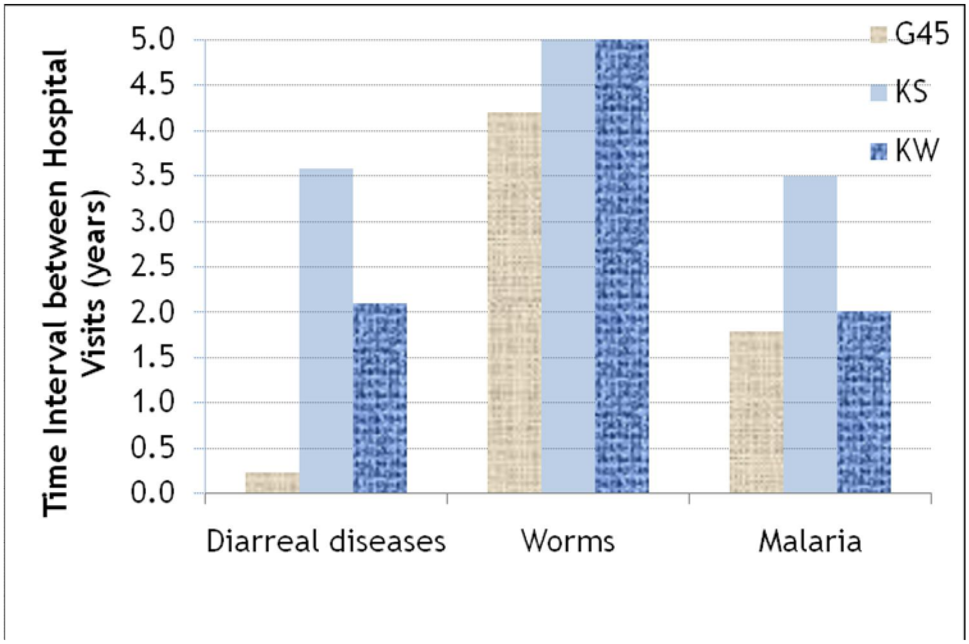

Figure 7: Time interval between hospital visits

4.0 Conclusions and Recommendations

(i) As Kiu River entered Githurai the BOD was 30 mg/L but before leaving the area, it had BOD of 300 mg/L, indicating that pollutants were injected into the river within Githurai.

(ii) BOD production in Githurai is about 8 kg/person/year, a figure which is comparable to the rate of BOD production in Lake Victoria region.

(iii) Kiu River water had over 1200 mg/L of TDS, and was therefore considered unacceptable for agricultural use.

(iv) Some 30-40% of all patients visiting hospitals in the study area suffered from diarrheal diseases.

(v) The average resident in Githurai gets treated for water borne diseases once every three months. Therefore, an urgent intervention is required to clean up Kiu River and stop further contamination of the river.

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