Impacts of Dairy Effluent on Quality of the Kipsonoi River, Bureti Sub County, Bomet County, Kenya

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Abstract
About 17 million Kenyans have inadequate access to clean water, and this is causing fears of water borne diseases. This is a footprint consequential of contaminants introduced through human activities . Dairy farming is pivotal in food security efforts in kenya. However, dairy processing plants are known to be serious environmental pollutters and health risks. The impacts of effluents from a milk processing plant on the characteristics of Kipsonoi Riv The effluents caused profound changes in the levels of some of the physico-chemical and biological indicators. The levels of iron (0.57-0.70mgl-1), nitrate-nitrogen (10.9-17.7 mgl-1), and biological oxygen demand (BOD) (48.0- 52.5mgl-1), were above the World Health Organization (WHO) safety levels for health and the ecology of the area. The relatively slight increase in the levels of pH, dissolved solids, alkalinity, nitrate, chloride, sodium, potassium, calcium, zinc and manganese at the discharge point were quickly diluted further downstream. It is apparent that the river has an efficient self-purification system. The few parameters compared with NEMA-Kenya and WHO guidelines, only five exceed the former and five exceed the latter.

Keywords: Dairy faming**,** effluent, industrial pollution, water quality, river water, Kipsonoi River, milk processing plant, guidelines

Introduction

Background of the Study

Population growth, urbanisation and increased per capita milk consumption are main reasons for recent increasing milk demand in Africa(Ndambi &Hemme,2008). In Kenya, per capita milk consumption was estimated at 19kg in rural areas and 125kg in urban areas and the processing sector handles about 80% in the formal sector(FAO, 2011), Milk processing plants discharge effluents containing organic matter, and inorganic into water receiving bodies. These discharges affect the waters' BOD, COD, Dissolved solids, Suspended , chlorides, grease and oilNitrogen, phosphate sulphate, temperature, color, PH, (Bharati $ Shetee Shinkar, 2013; Kolev Slavov,2017; Raghunath&punnagalarasi, 2016).

Industrial development in the developing countries has grown rapidly due to the national policies that are tailored to speed-up the industrialization process. For instance, Kenya plans to be industrialized by the year 2030 as stipulated in the sustainable development goals which implies further industrialization process. However, the impacts of such policies on water bodies are likely to be negative if appropriate mitigation measures are not integrated into the policies of sustainable development. It is evident that industrial development will benefit from new policies and new regulations for managing the environment, especially in the enforcements of these regulations in environmental conservation of water, energy and waste disposal.

In Kenya, the increasing industrial development has increased water pollution in the last decade. Organic, inorganic and microbial matter are increasingly polluting, both ground and surface water resources (Republic of Kenya, 2004). Wastewater from industries are characterized by high biological oxygen demand (BOD), the level of oxygen needed for biotic breakdown of soluble biological matter under normal state at a respective temperature and time (Nzomo, 2005). It is used to understand the contamination amounts in aquatic ecosystems (Ngodhe, 2014) when affluent BOD and the sewage BOD and the biological amounts are examined on the unit (Ntiba *et al.*, 2001).

The Objective of the Study

The study aimed at highlighting the pollution impacts of a dairy processing plant on the Kipsonoi River

Significance of the Study

The study sought to evaluate the impacts of agro-industry on the quality of the Kipsonoi river, Bureti Sub County, Kenya. The critical parameters in the study were microbiological contamination levels, physicochemical parameters and levels of the cations and anions in water. The results are expected to assist in ensuring that significant ecological, environmental and economic contributions of Kipsonoi River in the East African Community are safeguarded and how to protect it from pollution by designing affordable methods of purification at industrial level.

Study Area

The Kipsonoi River is a tributary of the Sondu River, which drains into the Lake Victoria. It is located in Sotik area of Bureti Sub County which lies between the latitudes 35^0E and 36^0E and the longitudes 0^0S and 1^0S. It also stands at an altitude of about 1824m above the sea level with a gentle slope towards the northwest. The area receives an annual average rainfall of about 1377mm old, 1983), which is well distributed throughout the year except for the dry season - February to early March.

The study area covered a distance of about 10km of the Kipsonoi river; stretching from the south where the Kipsonoi river is joined byb the Sisei river to the north where itb is joined by the Chebonge river.

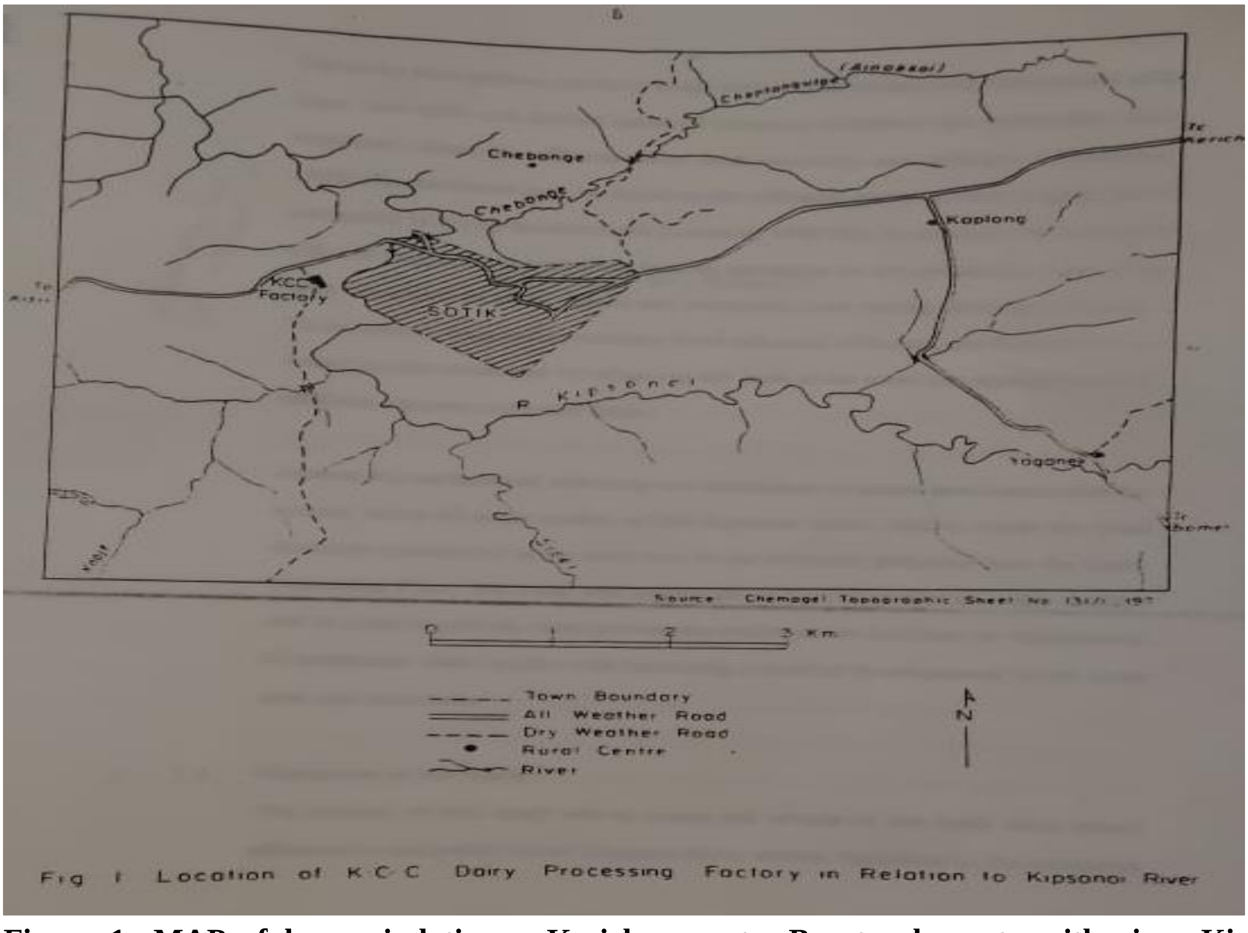

Figure 1: MAP of kenya indating Kericho county, Buret subcounty with river Kipsonoi including sampling points.

Sotik subcounty soils are developed from intermediate igneous rocks. The eastern side has well-drained, deep and dark red friable clay soil, while those of the western part are further sub-divided according to the terrain (Independent Electoral and Boundaries Commission, 2012). On the plain are poorly drained deep and dark grey firm cracking clay underlying top soil, while the slopes have well drained, moderately deep and dark-red firm clay loams. These soils support extensive agricultural activities, which include crop cultivation and dairy farming. The study area also has an urban centre, which among other things provides ready market for some of the agricultural products. The 10 kilometres stretch of the Kipsonoi River covered in the study was characterized by absence of natural vegetation, bare watershed, scattered exotic trees such as cypress, wattle and eucalyptus along some sections of the river and cultivation in some parts which extended to the banks of the river. Sotik Kenya Co-operative Creameries (K.C.C) is situated at about 200 meters from the Kipsonoi River. The milk processing plant empties its effluent directly into the river.

The threats to water quality in the study area generally stems from agro-chemicals, organic matter (decomposing in water), soil erosion and car acid sprays. The Kipsonoi River, which is the focus of this study, traverses the vicinity of the milk processing plant (Sotik Kenya Co-operative Creameries), which at the time of this study was the only milk processing plant in the area. It is the source of industrial water as well as the disposal site for the effluents of the processing plant. The effluents which result from washings and spillages contain heat from the cooling process and chemical substances as well as additives and cleansing agents that may reduce the quality of water. This study attempted to assess the effects of the effluents from the Sotik dairy processing plant on the quality of the Kipsonoi River waters. Treatment of effluents reduce variously components of the dairy effluent substantially (Swati et al(2014).

Materials and methods

This study involved primary data analysis on the influence of a dairy processing plant on the water quality of the Kipsonoi River, in comparison with the World Health Organization and Kenya's Environmental Management and Coordination Act 1999, Regulations of 2006 (Ref EMCA, 1999). This section outlines water sampling method, laboratory analysis and water quality Index(WQI) estimation.

Water Sampling

Six sampling stations: K_1, K_2, K_3, K_4, K_5 and K_6 stretching from south to north were set up on the Kipsonoi River. Stations K_1 and K_2 were located 2 km and 0.5 km respectively upstream area from the point of discharge (Station K_3), while stations K_4, K_5 and K_6 were located at 0.5km, 2km and 5 km in that sequence downstream of the discharge point. These stations were generally placed at domestic water points and where there was turbulent flow of the water to make the samples as well mixed as possible.

Four water samples were collected in 500ml plastic bottles from each station twice a month for a period of four months (from March - June). While it was preferable to carry out water sampling daily and even on weekly basis, the long distance (over 400km) between the study area and the laboratories where analyses were done coupled with unavailability of quick means of transport were quite limiting. However, efforts were made to achieve uniformity of the results obtained by sampling from morning to early afternoon (Starting at 9.00 a.m to 1.00 p.m) during the study period. The dry months were March to April and wet months were in May – June.

Laboratory Analyse

Parameters of sampled water analysed were; Suspended Solids, Dissolved Solids, Total Alkalinity, Hardness, Nitrite-Nitrogen, Nitrate-Nitrogen, Phosphate-Phosphorous, Chloride, Fluoride, Sulphate, Calcium Carbonate (Total Alkalinity *(*TA) and Hardness (HA)), Calcium, Magnesium, Aluminium, Sodium, Potassium, Manganese, Iron, Biological Oxygen Demand, pH, Electrical Conductivity and Temperature. The physicochemical parameters were measured using aqua read meter while aquagenx test kit was employed for the bacteriological analysis. Na^+, K^+, Ca^{2+}, Mg^{2+}, HCO_3^-, Cl^- and SO_4^{2-} were analyzed using atomic absorption spectroscopy and colorimetry. Potentiometric PH measure was carried out on site by use of calibrated PH meter. A turbidimeter was used in situ (Nephelometer). On site analysis of EC/temperature was done using conductivity by the use of a conductivity meter. TDS was determined using the gravimetric method as stipulated in recommended procedures for analysis of water and waste water (Adong, 2001). TDS for 12 samples of water was determined by use of gravimetric method as indicated by Adong (2001). DO was analyzed using DO-meter probe in the aquaread meter. BOD was analyzed using BOD OxiTop meter (WTW™ 208211) according to Yuan et al., 2001. Bacteriological analysis involved presumptive, confirmatory and completed tests.

Estimation of Water Quality Index

The three parameters (Suspended Solids, Nitrogen Nitrates, and Biological Oxygen Demand (BOD) that exceeded the Kenyan water regulations standards (NEMA, 2006) were further analysed for Water quality index (WQI)at at pre-effluent discharge points , effluent discharge, and post discharge points using mean of the parameter.

The WQI is calculated using the formula by Tehera et al, (2016) as follows:

Qi = (Ci/Si)X100;

Qi= quality rating scale, Ci= Concentration of parameter I, Si= Standard values- these are usually country specific.

Results

Variation in water parameters

The results of water analyses for the six sampling stations established on the Kipsonoi River are presented in figures 1 to 4 The discharged effluents altered the water quality of the Kipsonoi River. They contributed to the increase of measured values of some parameters and decrease of others. The values of Dissolved Solids (Figure 1), alkalinity, Nitrite-nitrogen, Chloride (Figure 2), and Sodium values (Figure 3) were higher downstream as compared to the upstream. The acidity of effluent caused reduction in Fluoride values (Figure 2). Fluorides are removed in the water as hydrogen fluoride (HF) molecules by hydrogen ions (H+) of the acidic effluents.

It is noted that all the parameters had high concentrations at the discharge point. Among the physical characteristics, the greatest influence was on conductivity, followed by that of dissolved solids (Fig. 1). For the nutrient based parameters, the greatest influence was on the Calcium Carbonate (TA) followed by nitrates, sulphate, and Carbonate (HA) in that order (Fig. 2).

In regards to metal concentration, sodium and calcium were highest (Fig. 3). BOD was about six times at the discharge point compared with the concentrations before and after (Fig. 4**).** Does the river have the capacity to self clean? The values of almost all the parameters measured for the sampling stations upstream to the effluent discharge points compares fairly well, with those for the downstream stations. This indicates that the purification processes in the river are adequate to restore the river to its original status after receiving the effluent from the Sotik Milk Processing Plant. However, it is important to note that if more milk processing plants are established in the area, and similarly discharge their effluents into the river, the capacity of the river to self clean might be strained and the river will be adversely impacted on by the pollution due to their cumulative effects.

The comparisons of seasonal variations of the measured parameters show that most parameters recorded lower values during the rainy period than the dry period (Table1). This is an indication of the effects of dilution by the rain water. The slightly higher water temperature at station K_3 was due to the warm effluents. The pH remained fairly constant in all the stations but at K_3 it was observed to be much lower during the rainy season.

The electrical conductivity values further remained stable downstream despite increased concentration of the dissolved solids during the rains (May and June). This could have been due to non-conduction by some of the dissolved solids, particularly the organic matter. The suspended solids were unaffected downstream but the increase during the rains could be attributed to terrestrial run off. The higher nitrite-nitrogen values during the rains and the slightly higher Nitrate levels at the downstream stations (K_4, K_5 and K_6), during the same period, suggested high nitrogenous compound reaching the river from terrestrial run-off. The lower fluoride level reached during the rains could partly be due to deposition with increased load of suspended solids, and partly due to dilution by increased discharge into the river. The increased values of calcium, sodium and potassium downstream could be attributed to their increased concentrations in the effluents. Geological factors were also noted to contribute to the higher values of these metals in the wet periods. Magnesium values ranged from 0.8 and 4.19mgl^{-1}, during the entire study period, probably due to the trapping of some magnesium by the clay soils of the study area or precipitated as carbonate or silicate in the river. The iron concentrations were lower downstream due possibly to adsorption in the increased load of suspended solids.
An analysis of variance on iron, sodium and potassium were significantly different between the stations. Aluminium fell below detectable level in both rainy and dry periods. BOD values were lower during the rainy seasons than the dry season probably due to the dilution effects of the rain water.

Does the effluent discharged conform to the NEMA-Kenya and WHO water quality Standards? Comparisons of the parameters f the effluents discharged into the Kipsonoi River with the recently (2006) published Kenya's Environmental Management and Coordination Act Regulations(nema, (NEMA, 2006) and the World Health Organization's water quality standards indicates that some elements exceeded the acceptable limits while others are within the acceptable/permissible limits provided by either one or both guidelines (Table 2). Potential Hydrogen (PH) exceeded the acceptable limits of provided by the two guidelines by 0.1. Suspended Solids, Nitrogen Nitrates, and Biological Oxygen Demand (BOD) exceeded the NEMA's acceptable limits by factors, 9, 18 and 19 respectively. Iron (Fe) values fell within NEMA's acceptable limits, but exceeded WHO's by a factor of 9.4. The rest of the parameters are either within the acceptable limits of one or of both guidelines or there are no standards provided for them.

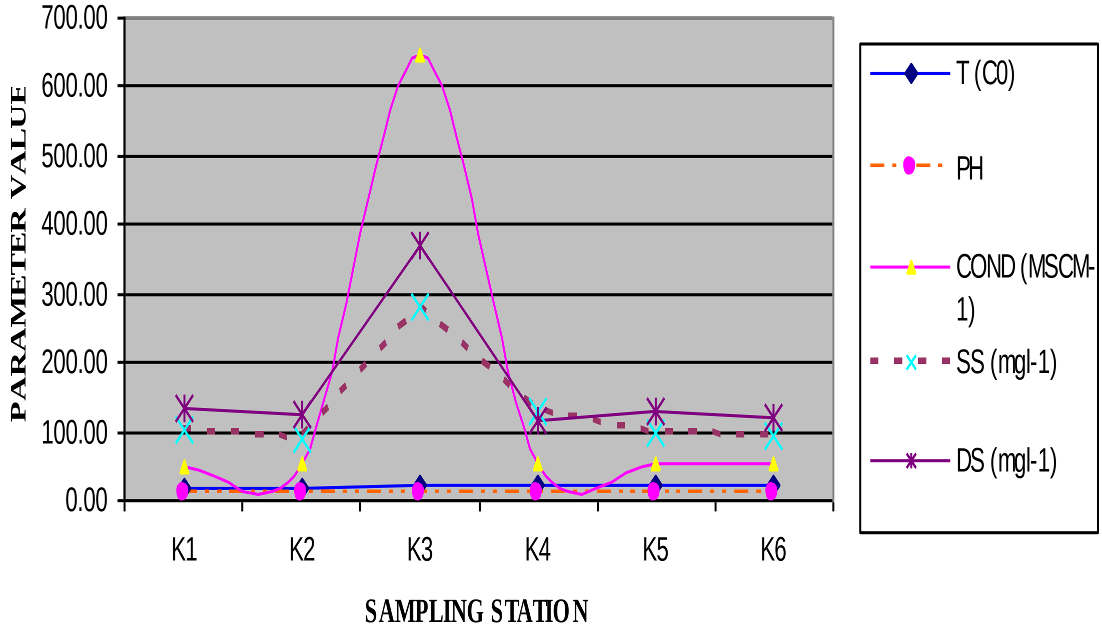

Figure 2: Variation in physical characteristics across the sampling stations

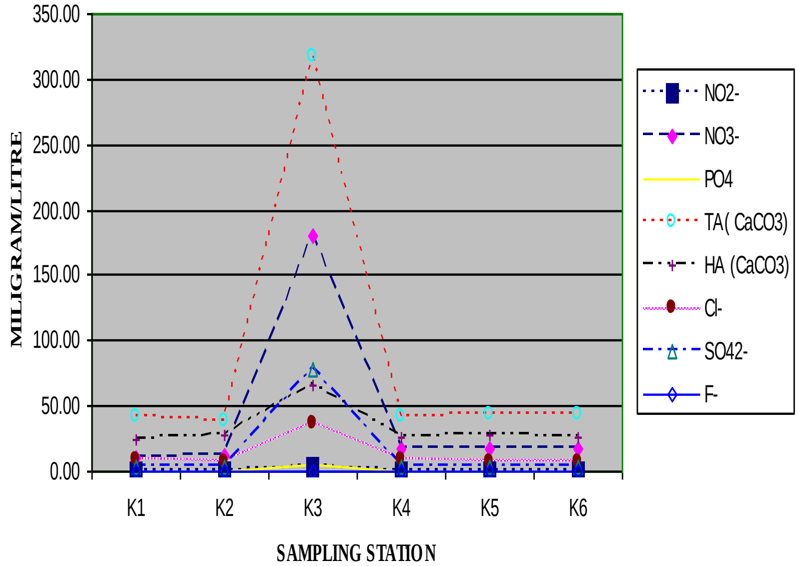

Figure 3: Variation of nutrients across the sampling stations

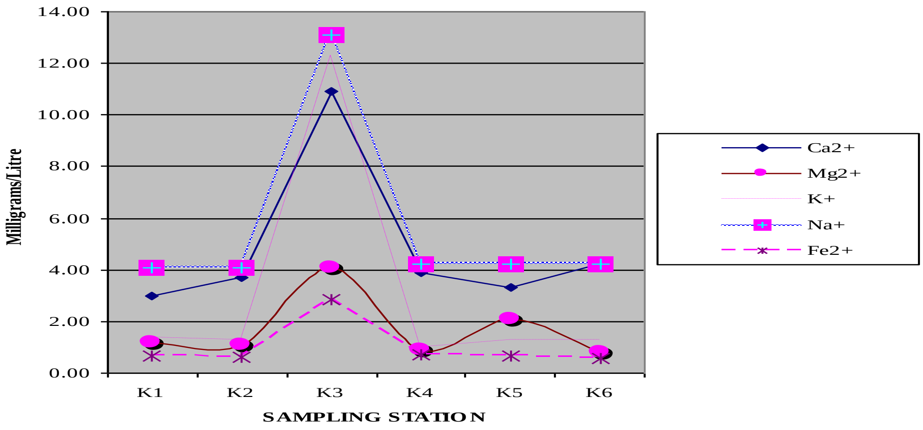

Figure 4:. Variation in selected metals across the sampling stations

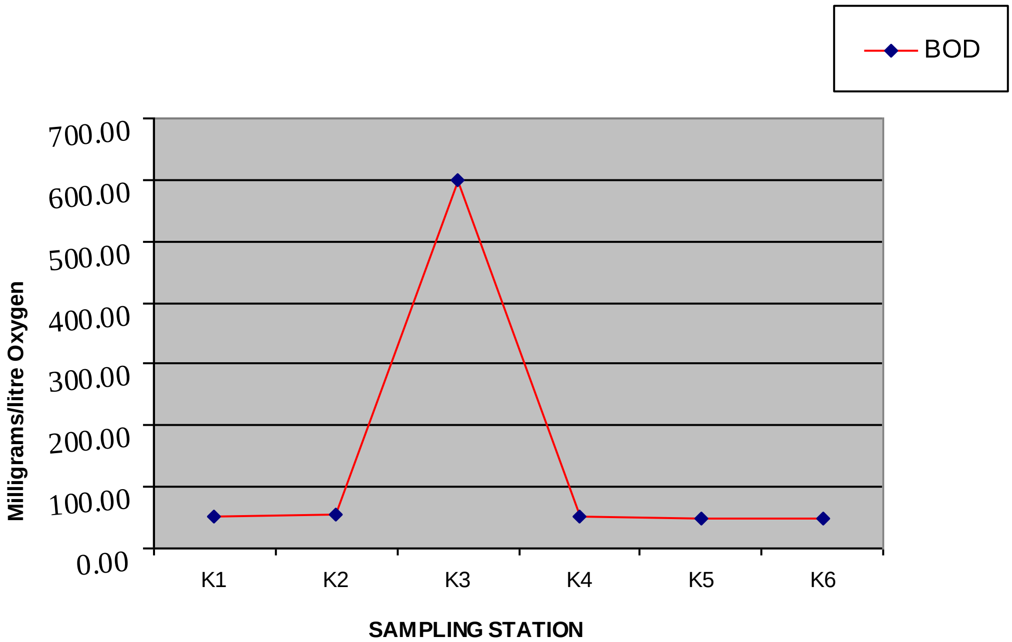

Figure 5: Variation in BOD across the Sampling Stations

Estimation of Water Quality Index

The Kenya Water Quality standards outlines water quality for various uses, namely; domestic and agriculture(NEMA, 2006/legal notice 121). The three parameters (Suspended Solids, Nitrogen Nitrates, and Biological Oxygen Demand (BOD) in this study exceeded these Kenyan water regulations standards.

Table 1: Water Quality Index for Parameters that Exceeded Kenya Water Standards

Parameter	NEMA Domestic Water Quality Standads	Pre-Discharge Concentration (WQI)	Effluent Concentration (WQI)	Post Discharge Concentration (WQI)	Average parameter WQI
Suspended Solids	30mg/l				
Nitrogen Nitrates	10mg/l				
Biological Oxygen Demand(BOD)	30mg/l				

Discussions

Pollution of the Kipsonoi River waters poses wide-ranging implications for the environment and human health. The Parameters **(**Nitrogen Nitrates, Biological Oxygen Demand and iron) that exceeded the WHO's and Kenyan Environmental Management and Coordination Act, 1999 Regulations recommended levels for drinking water pose potential negative impacts to health and environment. WHO (2004) stipulates the maximum admissible level at 200 mg/L. Higher sodium ion (Na+) concentration brings hypertension, congenital illnesses, kidney complications and nervous problems (Todd, 2009). Nitrate-nitrogens, however, are not hazardous to human beings, but their secondary products, nitrites and nitroamines, can cause serious illnesses in both human beings and livestock.

Consumption of water contaminated with Nitrite cause *infantile Methaemoglobinaemia* disease or what is often called blue baby disease, a blood disorder-affecting babies. Massive consumption of salt can dangerously accelerate chronic congestive heart failures (Wilson & Pyatt, 2007). The effects vary between adults and children due to the immaturity of infant kidneys (Adong, 2001). Children with chronic gastrointestinal illnesses can undergo fluid loss, causing dehydration and excessive amounts of sodium in the plasma (hypernatremia); permanent damage to the brain is typical in such conditions (Oyoo *et al.,* 2010). This occurs when nitrite causes conversion of haemoglobin, the carrier of oxygen in the blood, to methaemoglobin, which cannot transport oxygen. The nitroamines are carcinogens and have been suspected of inducing gastro-intestinal cancer in humans.

Ecologically, nitrates contribute to eutrophication of water bodies, a phenomenon that has resulted in disruption of ecological balance in the aquatic ecosystems. Nitrogen and Phosphorus emission on surface freshwaters speeds up eutrophication, causes excessive blooming of algae and blooming of algae and flourishing of fluvial weeds, resultantly from nutrients from agriculture (Machiwa, 2013). The massive fertilizer effluents also destabilize the biomass of phytoplankton and water transparency and translucency changing the water quality (Rajendran *et al.*, 2006). A glaring example of the consequence of eutrophication in Kenya is the prolific spread and growth of an aquatic weed, the water hyacinth, in the Lake Victoria. The weed has been reported to have caused far reaching environmental implications- disappearance of some fish species, emergence and prevalence of disease-causing vectors, reduction in income from the sale of fish, impediment to marine transport, fishing and water collection among others.

It has also been noted that high levels of iron in water cause staining of fabrics and ceramic materials during washing, and iron concentration greater than $1mgl^{-1}$ imparts bitter taste to drinking water. High BOD loading means more microbial activity, which in turn means the presence of more organic wastes. These organic wastes will deplete the water of the dissolved oxygen resulting in anoxic condition that is unfavourable for the survival of aquatic organisms, such as fish. Anoxic condition has been reported to progressively increase in the Lake Victoria, which is the drainage basin of the Kipsonoi River including other rivers. Contributions of this condition by the Kipsonoi River is undebateable. During 1960-1961, this condition was observed in the deepest part of the Lake Victoria. Heckey (1993) reported it at 45 meters, while Njuru (2001) reported the same condition at 30 meters level. Given that the mean depth is 40 meters, Mogaka *et al*. (2003) noted that about 50% of the lake's volume is uninhabitable to both commercial and endemic fish species for part of the year. Though no statistics exists that can be linked to anoxic conditions, Mogaka *et al.* (2003) claims that significant loss of income from the sale of Nile Perch fish is expected with the progressive increase in anoxic condition.

Conclusions

The physical properties (TDS, temperature, DO, turbidity, salinity, electrical conductivity (EC) and PH of the water samples were determined. The release of the dairy effluents into the Kipsonoi River induced profound changes in the levels of all the physico-chemical indicators. In addition, there was a dramatic increase in levels of the parameters, but the desirable limits of some parameters according to NEMA-Kenya and WHO guidelines were not exceeded, except at discharge points. The water at this pollution zone was still of acceptable quality in terms of all the parameters, with exceptions of iron, nitrate-nitrogen, manganese and BOD. The relatively slight increase in the levels of pH, dissolved solids, alkalinity, nitrate, chloride, sodium, potassium, calcium, zinc and manganese in the downstream section of the Kipsonoi River were possible impacts associated with the disposal of the dairy industrial effluents. The rest of the parameters were quickly diluted or depleted as the river water flowed downstream. Some parameters were elevated in specific sampling sites while for others it was the reverse. The water samples in all the sampling sites were heavily polluted with the coliforms. These levels significantly decreased after filtration using the activated carbon ceramic filter. Pollutants levels after filtration reported here are considerably lower than those in earlier studies. The findings indicate that the fabricated ceramic filter is effective in reducing various physical and chemical parameters and bacteria that undermine the water quality.

However, there was an efficient self-purification in the Kipsonoi River. The effluents reaching the river were quickly diluted and purified so that upstream and down stream values were similar for some of the quality parameters. Chemically, the Kipsonoi River waters reflect, to some extent the interaction of well- leached soils with rainwater. Soil leaching and run off from agricultural lands appeared to contribute to increase in mineral content and nitrates in the river respectively.

Recommendations

Analysis showed that industrial discharge greatly chanhed the parameters of Kipsonoi River. Public health interventions to improve its standard is required. It is crucial to continue monitoring the quality of water of the River to assess the trends in pollution using microbiological and physiochemical features as indicated by the behaviours in the River. The quality of the River water should be protected, its integrity vigorously enforced and where absent more effective ones should be introduced. The Sotik Kenya Co-operative Creameries (K.C.C) dairy plant should treat its effluents to ensure that they conform to the Environmental Management Coordination Act, 199 regulations of 2006 for water quality and waste management standards.

Taking the case study of the Kipsonoi River as an example of how effluents discharged from milk processing plants affect river water quality, NEMA and relevant lead agencies need to enforce regulations on effluent discharges nationally (Environmental Management and Coordination- Waste Management Regulations, 2006.

Since pollution of the Kipsonoi River does not solely come from the milk processing plant only because but also from other sources (both point and not point), the Kenya National Environment

Management Authority (NEMA), need to facilitate co-ordination of the collaborative, sectoral environmental conservation measures along the Kipsonoi River. There should be regular follow-up studies on the Kipsonoi River to monitor water quality in relation to human activities and effluent to this vital river.

Recommendations for Further Study

In order to conserve and protect the Kipsonoi River and improve on its environmental management by the dairy plant, this study proposes the following recommendations:

1. To collect data that can lay a foundation for a broad public health response, social and health records should be included in this study in addition to physiochemical and biological data revealed in this study.
2. There is a need to also collect economic and social data incorporating origins and other methodologies of purification of water for domestic purposes and latrine types available.
3. It is vital to take note of the opinions of likely origins of water pollution within the study areas and data on ways of environmental management and conservation.

Appendices

Table 2: Comparisons of variation of mean values of physico-chemical parameters for the dry season (March- April 1993) and the rainy season (May and June 1993)

Parameter	Sampling Station												Remarks
	K_1		K_2		K_3		K_4		K_5		K_6		
	D	R	D	R	D	R	D	R	D	R	D	R	
T (^{0}C)	20.00	19.25	20.25	19.25	22.00	21.00	21.50	20.00	21.50	19.50	21.00	19.50	*
PH	7.50	7.15	7.55	7.10	7.15	6.40	7.60	7.10	7.60	7.30	7.45	7.30	*
COND ($MSCM^{-1}$)	51.10	47.00	52.55	52.15	731.50	565.50	53.65	50.25	54.40	50.35	52.95	49.90	*
SS (mgl^{-1})	127.90	79.80	103.5	77.05	213.25	346.85	131.90	128.55	122.35	69.70	108.75	76.55	**
DS (mgl^{-1})	96.00	171.00	73.00	178.50	289.50	450.50	96.50	136.50	114.50	142.00	104.00	133.50	***
NO_2^- (mgl^{-1})	0.05	0.20	0.08	0.23	3.90	1.60	0.07	0.22	0.05	0.22	0.07	0.21	***
NO_3^- (mgl^{-1})	10.40	11.35	10.45	12.70	23.45	338.45	14.90	20.55	16.15	19.00	16.65	16.85	*
PO_4 (mgl^{-1})	0.02	0.12	0.05	0.14	6.66	3.73	0.05	0.19	0.05	0.14	0.05	0.06	***
TA (mgl^{-1} $CaCO_3$)	36.00	46.60	33.00	42.00	4850	147.90	36.00	48.10	36.00	51.10	33.00	54.15	***
HA (mgl^{-1} $CaCO_3$)	28.00	22.00	30.00	25.00	57.00	74.00	27.00	26.00	30.00	25.00	26.00	25.00	*
Cl^- (mgl^{-1})	5.20	12.35	5.20	8.30	52.00	20.75	6.35	11.65	4.10	9.50	5.60	9.65	***
SO_4^{2-} (mgl^{-1})	1.80	3.70	2.30	3.30	113.50	41.55	2.80	2.60	2.60	2.60	2.10	3.40	*
F^- (mgl^{-1})	0.95	0.27	0.81	0.25	1.28	0.38	0.53	0.25	0.81	0.13	0.53	0.09	*
Ca^{2+}(mgl^{-1})	2.80	2.65	3.40	4.05	12.60	9.00	3.10	4.60	2.50	4.20	2.80	4.85	*

$Mg^{2+}(mgl^{-1})$	1.75	0.80	1.55	0.55	6.20	3.55	1.40	0.35	2.10	0.95	1.10	0.10	*
$K^{+}(mgl^{-1})$	0.75	2.00	0.75	1.90	12.00	12.50	0.40	2.10	0.75	1.85	0.60	1.90	*
$Na^{+}(mgl^{-1})$	3.50	4.75	3.50	4.75	12.25	14.00	2.95	5.50	3.60	4.75	3.05	5.35	*
$Fe^{2+}(mgl^{-1})$	0.60	0.80	0.50	0.80	4.70	0.95	0.55	0.85	0.60	0.75	0.55	0.60	*
BOD (mgl^{-1}) O_2	67.35	34.75	69.25	37.75	618.50	577.50	69.20	34.25	64.40	31.75	68.70	34.00	**
$Al^{+3}(mgl^{-1})$	Trace Amounts												

***Key: D** = Dry Season; **R** = Rainy Season,* =Variation relatively similar; ** = Significant variation – rainy season values lower than dry season values, *** = Significant variation – rainy season values higher than dry season values*

Table 3: Comparison Between the Measured Values of the Effluent Parameters with the Kenya's Environmental Management Coordination Guidelines (NEMA) and the World Health Organization (WHO) Guidelines

Parameter	Measured value at Discharge Point	Environmental Management Coordination Regulation Guidelines (NEMA)	World Health Organization (WHO) Guideline Value	Remarks
T (^{0}C)	21	**+/-3**	*****	
PH	6.4	6.5-8.5	6.5-8.5	Exceeded the acceptable limits
COND $(MSCM^{-1})$	648.5±256.6			
SS (mgl^{-1})	280.1±176	30 mg/l	**	Exceeded the NEMA's acceptable limits
DS (mgl^{-1})	370.1±113.8	1200 mg/l	1000 mg/l	Within the acceptable limits
NO_2^- (mgl^{-1})	1.6	3 mg/l	**	Within NEMA's acceptable limits
NO_3^- (mgl^{-1})	181.0±275.4	10 mg/l	**	Exceeded NEMA's acceptable limits
PO_4 (mgl^{-1})	5.19±2.65	**	**	
TA $(mgl^{-1}$ $CaCO_3)$	316.3±174.6	**	**	
HA $(mgl^{-1}$ $CaCO_3)$	316.3±174.6	**	< 500 mg/l	Within the WHO acceptable limits
Cl^- (mgl^{-1})	36.4±15.7	250 mg/l	250 mg/l	
SO_4^{2-} (mgl^{-1})	77.5±38.5	**	400 mg/l	Within the WHO acceptable limits
F^- (mgl^{-1})	0.83±0.54	1.5 mg/l	**	Within NEMA's acceptable limits
$Ca^{2+}(mgl^{-1})$	10.9±3.9	**	*	
$Mg^{2+}(mgl^{-1})$	4.1±2.6	**	*	
$K^{+}(mgl^{-1})$	12.5	**	**	
$Na^{+}(mgl^{-1})$	13.1±5.1	**	200 mg/l	Within the WHO acceptable limits
$Fe^{2+}(mgl^{-1})$	2.83±1.92	10 mg/l (dissolved)	<0.3 mg/l	Within the NEMA's acceptable limits but exceeded WHO's acceptable limits
BOD (mgl-1) O_2	598±101.8	30 mg/l		Exceeded the NEMA's acceptable limits
$Al^{+3}(mgl^{-1})$ Trace	Trace Amounts	**	0.2 mg/l	Within the WHO's acceptable limits

***Key** * =No guidelines values provided, ** = No guidelines values available at the time of the study*

Source: Republic of Kenya (2006) and WHO. (1984)

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