Macroinvertebrates as Bioindicators of Point Source Pollution of Sambul River, Kenya.

Article · December 2018

3 authors:

Rono Kipchumba Ali
Moi University
19 PUBLICATIONS **68** CITATIONS
SEE PROFILE

Mugatsia Tsingalia
Moi University
26 PUBLICATIONS **236** CITATIONS
SEE PROFILE

Paul Wanjala Muyoma
Bomet University College
15 PUBLICATIONS **8** CITATIONS
SEE PROFILE

MACROINVERTEBRATES AS BIOINDICATORS OF POINT SOURCE POLLUTION OF SAMBUL RIVER, KENYA

A. RONO[1*], H. TSINGALIA[1], J. MAKATIANI[1] AND P. WANJALA[1]

[1]Department of Biological Sciences, Moi University, Kenya.
(alikipchumba@yahoo.com/ mugatsi2005@gmail.com / jkmakatiani@gmail.com/ *piwanjala@gmail.com*)

AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration between all authors. Author AR designed the study, wrote the protocol and interpreted the data. Authors AR, HT and JM anchored the field study, gathered the initial data. Authors AR, HT and JM performed preliminary data analysis. Authors AR and PW managed the literature searches and produced the initial draft. All authors read and approved the final manuscript.

How to Cite

Rono, A., Tsingalia, H., Makatiani, J., & Wanjala, P. (2018). Macroinvertebrates as Bioindicators of Point Source Pollution of Sambul River, Kenya. *Journal of Global Ecology and Environment,* 8(3), 112-123. Retrieved from http://www.ikprress.org/index.php/JOGEE/article/view/4371

ABSTRACT

Water pollution is a major global concern which calls for regular evaluation of levels of contamination of water bodies. It has been suggested that water borne infections account for over 14,000 people daily in the world. Point source pollution can be defined as contaminants from a single identifiable source. The major environmental concern by the residents around Sambul River is pollution of waters of Sambul River by effluent from Moi University sewage treatment plant (STP). Sambul River is the main source of water for both domestic and agricultural use among residents of Sambul area. This study focused on analysis of efficacy of the (sewage treatment plant) using macro-invertebrates as bio-indicators of contamination of waters of Sambul River. Purposive sampling design was used to select three sampling points; downstream of Sambul River where bio-treated sewage has mixed with waters of Sambul River, at point of effluent discharge to the river and upstream (control) of Sambul River where the river water does not mix with STP effluent. Triplicate water samples were collected at each sampling point bi-weekly and transported to the Laboratory for analysis. Sampling was done from May to August 2015. The impact of bio-treated effluent on the abundance of aquatic macro invertebrates at Sambul River was evaluated using Shannon- Wiener diversity index. The findings revealed that treated effluent had no significant effect on the aquatic macro invertebrate abundance at the receiving river, as demonstrated by Shannon-Wiener diversity index (H). H-values were; upstream (H=2.504), wetland (H=2.4096) and downstream (H=2.371). High H-value indicates less number of species diversity while a lower value of H indicates a higher diversity of macro-invertebrates. Higher biodiversity is an indicator that the effluent from the STP is treated to recommended standard as required by National Environmental Management Authority (NEMA). The findings of this research are important to demonstrate to concerned parties, including the public and the government; NEMA that the effluent from Moi University STP is treated to expectation. This will return confidence to the public on consumption of water from Sambul River.

Key words: Effluent, Point source pollution, Bio-indicators, Macro-invertebrates, Shannon-Wiener index

1. INTRODUCTION

Adequate treatment of wastewater prevents possible harm to the environment and public health. In Kenya, sewage is generated by residential, institutional, commercial and industrial establishments. In many cities, the industrial waste and street drains from rain water enters the sewerage system. Sewage is a major carrier of microbial pathogens and chemical toxins (Yapo et al, 2014). The safe treatment of sewage is thus crucial to the health of any community. Physical, chemical and biological treatment methods have been incorporated in most of the treatment plants (Omoto, 2006). The application of chitinous products in treatment of wastewater has gained prominence in recent years (Gregorio & Pierre-Marrie, 2008). Sewage treatment process involves multiple steps of sanitization. The treatment process aims to reduce or remove organic matter, solids, microbes, nutrients, and other various forms of contaminants from wastewater (Naidoo & Olaniran, 2013). Consequently, each sewage treatment plant has to obtain a permit with a list of allowed range of physicochemical and biological parameters. In Kenya, wastewater discharge permits are issued by the Water Resources Management Authority (WRMA) and the National Environmental Management Authority (NEMA).

1.1. Justification of the study

Universities are important to the economy of Kenya as a source of knowledge and employment to the rapid growing population. However, these institutions are suspects to discharging of untreated effluent that may pollute water bodies. There was a public outcry raising concern on the quality of effluent from Moi University STP being released into Sambul River. Consequently, it was important to determine the efficiency of Moi University sewage treatment plant. This study used macro-invertebrates to evaluate levels on contamination of Sambul River by effluents from Moi University STP. Aquatic macro-invertebrates as bio-indicators have the advantage that they are capable of integrating all the biological effects of the mix of contaminants in effluents. This could be difficult to predict by measuring physicochemical concentrations in the abiotic environment alone that is administered by Water Resource Management Authority (WARMA). The major environmental concern of the Moi University sewage treatment plant is the contamination of the effluent receiving Sambul River. The treatment plant has a design capacity of 3,200 m^3/day and wastewater undergoes biological treatment in stabilization ponds. The receiving Sambul River was suspected to be contaminated through nutrient loading which was likely to lead to eutrophication and algal blooms. Algal blooms result in bad taste and odour as a consequent of organic decomposition. The effects could cause serious damage to aquatic life in the river. Negative effects on macro-invertebrates and other aquatic biodiversity through creation of oxygen sags and a potential for bio-accumulation through food chains can occur leading to cases of contaminated aquatic food and micro-biological contamination of water (Vijay, Sardar, Dhage, Kelkar, & Gupta, 2010). The results of the study will offer data on the effectiveness of sewage treatment plant in removing pollutants from its effluent and consequently suggest effective effluent treatment options in order to conform to environmentally acceptable methods of treating sewage discharges that enter the country’s aquatic systems.

2. MATERIALS AND METHODS

2.1. Study Area

The study was conducted at Moi University main campus, situated in Uasin Gishu County, Kenya. The study area is described by latitude 0^{o} 06′N to 0^{o} 08′N and longitude 5^{o} 08′E to 35^{o} 10′E at an elevation above 2000 m above sea level (Figure 1). Eldoret area experiences two wet seasons: the short rains from October to November and the long rains from March to June. These rains support the moisture in the ground for much of the year and these favours farming activities in the area. On average, Moi University receives 1,200 and 2,000 mm of rainfall per annum and has loam and clay soil types. This climatic condition is conducive for maize and livestock production. Daily temperatures range from 12 to 25°C.

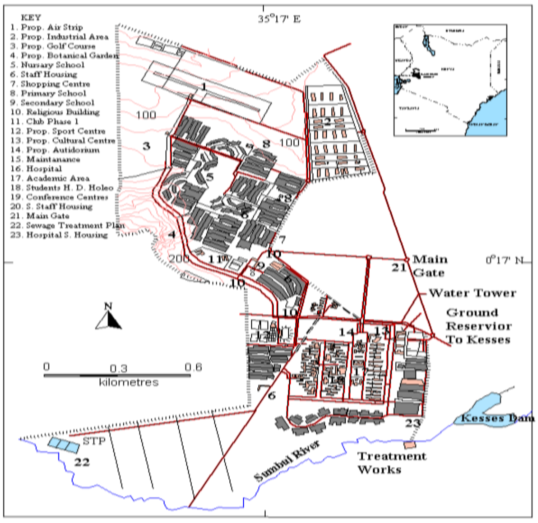

Figure 1: Moi University plan (by Kanda, Geographic information systems laboratory, Moi University, 2015).

2.2. Selection of sampling points

Sampling points were selected using a purposive design. Three sampling points (Figure 2) were selected and they comprised of the following; sampling point 1 (SP1), which is the point of the wetland where the effluent joins the Sambul River, sampling point 2 (SP2), which is at downstream of Sambul River where biologically treated effluent is mixed with waters from the Sambul River and sampling point 3 (SP3) which is upstream of Sambul River a point before the Sambul River water mixes with effluent from the sewage treatment plant. This point served as a control, reflecting the most naturally preserved conditions of river ecosystem without the influence of the sewage effluent. All sampling points were selected 100 m apart from each other.

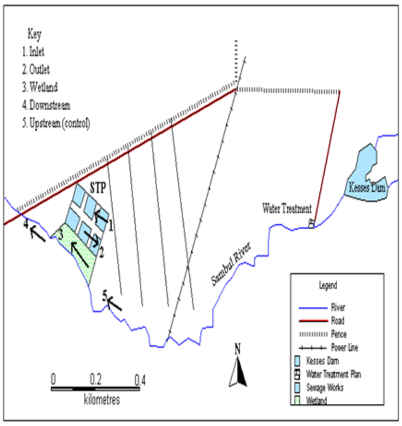

Figure 2: Sampled points at the Moi University sewage treatment plant and Sambul River (by Kanda, GIS lab, Moi University, 2015)

2.3 Sampling techniques and procedures

Manual- grab sampling technique was used to collect wastewater samples at each of the three (SP1- SP3) sampling points. Samples were collected bi- weekly 2015 between 0900 and 1500 hours from May to June, (wet season) and from July to August 2015 (dry season). Samples were collected by placing a D-frame (Merrit & Cummins, 1996) aquatic net (500 µm) and scooping mud with a core-sampler from a 0.25 m^2 transect placed immediately upstream of the net. The mud samples were scooped from up to a depth of 15 cm and placed in a plastic container. Any dislodged organisms trapped in the D-frame net were emptied into plastic containers and immediately killed using 2% formalin. Different life stages (larvae/nymph, pupae and adult) of aquatic macroinvertebrates were collected depending on the taxa encountered. All debris was removed from the samples after picking all attached organisms. The macroinvertebrate samples were then sieved through a 500 µm mesh sieve in the field to separate the substrate and the benthic fauna (Sutherland, 1997). The sieve retained some organisms which were then preserved in 4% formalin and identified up to the family level using a standard identification key (Macan, 1977; APHA, 1998) in the laboratory.

2.4 Shannon-Weiner diversity index

The diversity indices of aquatic macro-invertebrate community samples were determined as indicators of water quality. Community composition and relative abundance of families also were analysed. The Shannon-Weiner diversity index was used in the form described by the equation as follows:

$$H = -\sum \mathrm{Pi}\ (\ln \mathrm{Pi}) \quad \text{...... Equation (1)}$$

Where:

H = Shannon-Weiner diversity index.
ln = Natural logarithm
Pi = Proportional abundance of a given family (i).

The proportional abundance (Pi) was calculated as follows:

$$\mathrm{Pi} = \frac{\mathrm{ni}}{\mathrm{N}} \quad \text{...........Equation (2)}$$

and abundance in the sampling points (upstream, wetland and downstream) are summarized in Tables 1, 2 and 3 respectively. At the sampling points, a total of 14 macroinvertebrate families in 12 orders were identified from a total of 5,365 individuals collected. A total of 1,928 macroinvertebrates was collected at the upstream (control) point while 1,721 and 1,716 were collected from wetland and downstream sampled points, respectively. The derived Shannon-Weiner diversity index (H) value for upstream (control), wetland and downstream indicate that in terms of aquatic macroinvertebrate populations, upstream had the highest value (H=2.504,) followed by downstream (H=2.409) while wetland had the lowest (H=2.371) (Tables 1, 2 and 3). The highest H value was identified at the upstream (control) implying that macroinvertebrate diversity at upstream was higher than that of wetland and downstream. However, downstream sample point showed higher macroinvertebrate diversity than wetland point. In addition, upstream (control) had a total of 14 macroinvertebrate families which was higher than that of wetland and downstream with 13 and 11 respectively (Tables 1, 2 and 3).

Where:

ni = the number of individuals of a given family.
N = the total number of individuals of all families in the sample.

Historically, the Shannon-Weiner diversity index has been used to measure the effects of habitat quality such as effects of pollution effluents on biodiversity. It is a measure of the likelihood that the next individual was the same family as the previous sample. It combines two quantifiable measures, namely: the family richness S (the number of families in the community) and abundance N (total number of individuals in the sample).

3. RESULTS AND ANALYSIS

3.1 Abundance of macro-invertebrates

The aquatic macro-invertebrate composition The relative abundance of EPT (Ephemeroptera, Plecoptera and Tricoptera) at upstream (control) sampled point were 5.91, 8.77 and 7.05% respectively. Downstream showed a relative abundance of 5.35, 8.54 and 6.68% and wetland had 3.96, 6.18 and 10.90% respectively for EPT. Families of Coleoptera, Diptera, Gastropoda, Chilopoda and Hirudinea were equally represented in the sampled points (Table 4).

The family Gammaridae showed a relative abundance of 5.08% at the upstream (control) sampled point while it was absent at wetland and downstream. Similarly, family Lumbricidae had a relative abundance of 0.07% and 1.34% at the upstream (control) and downstream sampled points, but was absent at wetland sampled point Hygrobatidae family was absent at wetland sampled point but had a relative abundance of 1.35% and 0.01% at the upstream (control) and downstream sampled points (Table 4).

Table 1: Shannon -Weiner diversity index of macroinvertebrate families at the upstream study site of Sambul River

Phylum	Class	Order	Family	number of individuals (n)	n/N	(pi)	Pi^2	ln pi	pi ln pi
Arthropoda	Insecta	Ephimeroptera	Baetidae	114	114/1928	0.059	0.0035	−2.830	−0.167
		Plecoptera	Nemouridae	169	169/1928	0.088	0.0077	−2.430	−0.214
		Trichoptera	Hydropsychidae	136	136/1928	0.071	0.0050	−2.645	−0.188
		Odonata	Gomphidae	189	189/1928	0.098	0.0096	−2.323	−0.228
		Coleoptera	Helodidae	267	267/1928	0.138	0.0190	−1.981	−0.273
		Diptera	Chironomidae	110	110/1928	0.057	0.0032	−2.865	−0.163
			Tibulidae	126	126/1928	0.065	0.0042	−2.733	−0.178
			Simulidae	213	213/1928	0.110	0.0121	−2.207	−0.243
	Crustacea	Amphipoda	Gammaridae	98	98/1928	0.051	0.0026	−2.976	−0.152
	Malacostraca	Decapoda	Hygrobatidae	26	26/1928	0.013	0.0002	−2.674	−0.056
Mollusca	Gastropoda	Basommatophora	Limnaeidae	133	133/1928	0.069	0.0048	−4.343	−0.185
Annelida	Oligochaeta	Enchytraeida	Lumbricidae	13	13/1928	0.007	0.0001	−4.962	−0.035
	Clitellata	Hirudinea	Erpobdellidae	189	189/1928	0.098	0.0096	−2.323	−0.228
Platyhelminthes	Turbellaria	Planaria	Planariidae	145	145/1928	0.075	0.0056	−2.590	−0.194

S (number of families) = 14, N (total number of individuals) = 1928, Σ (sum) of - Σpi ln pi= -2.504, H= 2.504

Table 2: Shannon - Weiner diversity index of macroinvertebrate families at the wetland study site of Sambul River

Phylum	Class	Order	Family	number of individuals (n)	n/N	Pi	Pi^2	ln pi	pi ln pi
Arthropoda	Insecta	Ephimeroptera	Baetidae	92	92/1721	0.0535	0.0029	-2.9281	-0.1567
		Plecoptera	Nemouridae	147	147/1721	0.0854	0.0073	-2.4604	-0.2101
		Trichoptera	Hydropsychidae	115	115/1721	0.0668	0.0045	-2.7061	-0.1808
		Odonata	Gomphidae	167	167/1721	0.0970	0.0094	-2.3330	-0.2263
		Coleoptera	Helodidae	155	155/1721	0.0901	0.0081	-2.4068	-0.2169
		Diptera	Chironomidae	216	216/1721	0.1255	0.0158	-2.0754	-0.2605
			Tibulidae	134	134/1721	0.0779	0.0061	-2.5523	-0.1988
			Simulidae	221	221/1721	0.1284	0.0165	-2.0526	-0.2636
Mollusca	Gastropoda	Basommatophora	Limnaeidae	145	145/1721	0.0843	0.0071	-2.4734	-0.2085
Annelida	Clitellata	Hirudinea	Erpobdellidae	173	173/1721	0.1005	0.0101	-2.2976	-0.2309
platyhelminthes	Turbellaria	Planaria	Planariidae	156	156/1721	0.0906	0.0082	-2.4013	-0.2176

S (number of families) = 11, N (total number of individuals) = 1721, Σ (sum) of - Σ pi ln pi= -2.371, H= 2.371

Table 3: Shannon - Weiner diversity index of macroinvertebrate families at the downstream study site of Sambul River

S (number of families) = 13, N (total number of individuals) = 1716, Σ (sum) of - Σ pi ln pi= -2.4096, H = 2.409

Phylum	Class	Order	Family	number of individuals (n)	n/N	Pi	Pi^2	ln pi	pi ln pi
Arthropoda	Insecta	Ephimeroptera	Baetidae	68	68/1716	0.0396	0.0016	-3.2289	-0.1279
		Plecoptera	Nemouridae	106	106/1716	0.0618	0.0038	-2.7839	-0.1720
		Trichoptera	Hydropsychidae	187	187/1716	0.1090	0.0119	-2.2164	-0.2416
		Odonata	Gomphidae	155	155/1716	0.0903	0.0082	-2.4046	-0.2171
		Coleoptera	Helodidae	137	137/1716	0.0798	0.0064	-2.5282	-0.2018
		Diptera	Chironomidae	197	197/1716	0.1148	0.0132	-2.1646	-0.2485
			Tibulidae	160	160/1716	0.0932	0.0087	-2.3730	-0.2212
			Simulidae	186	186/1716	0.1084	0.0117	-2.2219	-0.2409
	Malocostraca	Decapoda	Hygrobatidae	9	9/1716	0.0052	0.0000	-5.2591	-0.0273
Mollusca	Gastropoda	Basommatophora	Limnaeidae	129	129/1716	0.0752	0.0057	-2.5876	-0.1946
Annelida	Oligochaeta	Enchytraeida	Lumbricidae	23	23/1716	0.0134	0.0002	-4.3125	-0.0578
	Clitellata	Hirudinea	Erpobdellidae	243	243/1716	0.1416	0.0200	-1.9547	-0.2768
Platyhelminthes	Turbellaria	Planaria	Planariidae	116	116/1716	0.0676	0.0046	-2.6941	-0.1821

Table 4: Composition and relative abundance (%) of the macroinvertebrate families in the upstream, wetland and downstream study sites of Sambul River.

Order	Family	Upstream= (control)	Relative abundance (%)	Wetland	Relative abundance (%)	Downstream	Relative abundance (%)
Ephimeroptera	Baetidae	114	5.91	92	5.35	68	3.96
Plecoptera	Nemouridae	169	8.77	147	8.54	106	6.18
Trichoptera	Hydropsychidae	136	7.05	115	6.68	187	10.90
Odonata	Gomphidae	189	9.80	167	9.70	155	9.03
Coleoptera	Helodidae	267	13.85	155	9.01	137	7.98
Diptera	Chironomidae	110	5.71	216	12.55	197	11.48
	Tipulidae	126	6.54	134	7.79	160	9.32
	Simulidae	213	11.05	221	12.84	186	10.84
Amphipoda	Gammaridae	98	5.08	-	-	-	-
Basommatophora	Limnaeidae	133	6.90	145	8.43	129	7.52
Oligochaeta	Lumbricidae	13	0.07	-	-	23	1.34
Hirudinea	Erpobdellidae	189	9.80	173	10.05	243	14.16
Planaria	Planariidae	145	7.52	156	9.06	116	6.76
Decapoda	Hygrobatidae	26	1.35	-	-	9	0.01
	Total (N)	**1928**		**1721**		**1716**	

n = Number of individuals in a family, N = Total number of individuals in all families.

4. DISCUSSION

The selected water quality parameters of the receiving Sambul River at upstream and downstream were not significantly different. This implies that the effluent discharged from the Moi University sewage treatment plant (MUSTP) had insignificant impact on water quality parameters of the receiving Sambul River. Consequently, MUSTP had insignificant impact on the aquatic macroinvertebrate community that inhabit Sambul River. The aquatic macroinvertebrate composition and abundance at the upstream (control site), wetland and downstream sampled points showed no significant differences. The derived Shannon-Weiner diversity index (H) value for upstream (control), wetland and downstream indicate that in terms of aquatic macroinvertebrate diversity, upstream had the highest diversity followed by downstream and wetland had the least (H) value.

The abundance of EPT (Ephemeroptera, Plecoptera and Tricoptera), that are highly sensitive to pollution (intolerant), were not significantly different at upstream, downstream and wetland sampled points. The study finding agrees with Barbour, Gerritsen, Snyder, & Stribling (1999) in that the families of Coleoptera, Diptera, Gastropoda and Chilopoda that are moderately tolerant to pollution were equally represented in the sampled points while families of Hirudinea represented taxa highly tolerant to pollution.

This study established no decrease of taxa richness and dominance by tolerant taxa downstream that would translate into low community diversity. This agrees with the study hypothesis that there are no significant changes in the abundance of aquatic macroinvertebrate at the receiving Sambul River that may be attributed to the effect of discharged treated effluent. Downstream, however, slight recovery in taxa richness was found and this could be attributed to effect of river dilution and self-cleansing. Lack of induced nutrient enrichment downstream from the effluent explains the fact that there was no concomitantly increase in productivity of the Sambul River waters downstream.

Several studies maintain that numerically macroinvertebrates increase under moderate nutrient enrichment and decrease under high nutrient inputs (Landman, Van Den Heuvel & Ling, 2005). Sambul River was considered undisturbed while downstream and wetland sampled points were considered to be disturbed.

5. CONCLUSION AND RECOMMENDATION

Based on the results reported and discussed in the preceding section, the following conclusions are drawn. The study confirms that Moi University sewage treatment plant is efficient in the treatment of wastewater as indicated by Shannon-Weiner index on abundance and diversity of macro invertebrates. The effluent discharged into Sambul River had no effect on macroinvertebrate abundance and diversity. This further confirms the efficacy of Moi University sewage treatment plant. Upstream results indicate that there might be another source of pollution, before the point source of discharge of effluent into Sambul River. This study recommends further exploration by research on other sources of pollution including household domestic wastes and farm waste materials that maybe washed into the river by water surface runoff.

REFERENCES

Andrew, D.E., Lenore, S.C., & Arnold, E.G. (1995). Standard Methods for the Examination of Water and Wastewater. 19th Edition.

Barbour, M.T., Gerritsen, J., Snyder, B.D., & Stribling, J.B. (1999). Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish. 2nd Edition. Technical Report No. EPA 841-B-99-002. Office of Water, U.S. environmental Protection Agency.

Gregorio, C., & Pierre-Marrie, M. (2008). Application of chitosan, a natural amino polysaccharide, for dye removal from aqueous solutions by adsorption processes using batch studies. *Progress in Polymer Science, 33*: 4.

Landman, M.J., Van Den Heuvel, M.R., & Ling, N. (2005). Relative sensitivities of common freshwater fish and invertebrates to acute hypoxia. New Zealand Journal of Marine and Freshwater Research, 39: 1061–1067.

Macan, T.T. (1977). A key to British Fresh and Brakish water Gastropods. Freshwater Biologicak Association. 100 pp.

Merrit, R. W., & Cummins, K. W. (1996). *An introduction to the aquatic insects of North America,* 3rd edition. Dubuque: Kendall-Hunt, IOWA.

Naidoo, S., & Olaniran, A. (2013). Treated wastewater effluent as a source of microbial pollution of surface water resources. *Int J. Environ. Res. Public Health, 11*(1): 249-270.

Omoto, E. (2006). A study of Nairobi wastewater treatment efficiency and effluent quality for safe discharge and possible beneficial uses. *MSc thesis, University of Nairobi:* 5-50.

Vijay, R., Sardar, K., Dhage, S., Kelkar, S., & Gupta, A. (2010). Hydrodynamic assessment of sewage impact on water quality of Malad Creek, Mumbai. *India. Environmental Monitoring Assessment, 165*: 559-571.

Yapo, R.I., Koné, B., Bonfoh, B., Cissé, G., Zinsstag, J., & Nguyen-Viet, H. (2014). Quantitative microbial risk assessment related to urban wastewater and lagoon water reuse in Abidjan, Côte d'Ivoire. J Water Health 2014; 12 (2):301.