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Evaluation Of The Efficiency Of Wastewater Stabilization System Using Macro-Invertebrates Community And Pollution Tollerance Index

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***Abstract:** In this study, macro-invertebrates community was used to establish the pollution tolerance index of four wastewater stabilization ponds at University of Eldoret in Kenya. The stabilization ponds have not been expanded since the inception of the university despite the ever rising population of students and staff. As such this study was set to evaluate the efficiency of the wastewater stabilization ponds in wastewater restoration by the use of bioindicators. Since chemical analysis is expensive and hazardous to human health, index of benthic integrity that uses macro-invertebrates communities was used in the study. Macro-invertebrates were sampled from one identified site of each of the four wastewater stabilization ponds monthly for a period of six months. Macro-invertebrates samples were placed in plastic containers and preserved in 70 % alcohol, which were taken to the laboratory for identification. Five orders comprising thirteen Families were collected during the study period. The abundance by percentage occurrence was Diptera (59%), Hemiptera (38%), Coleoptera (1.5%) Ephemeroptera, (1%), and Isopoda (0.5%). The number of taxa increased from pond 1 to pond 4. Pond 1 was least diversified with seven families while pond 4 was most diverse pond with 10 families. Pond 2 had eight families while pond 3 had nine families. The heterogeneity indices revealed high values of diversity and evenness in the stabilization ponds except in pond 1; (0.4255) and (0.3826) respectively, while in the contrary dominance was highest in pond 1 (0.7546). Results for Pollution tolerance index value showered poor water quality with range of values from 7.7 to 11 an indication of inefficiency of the wastewater stabilization system.*

***Keywords:** Wastewater, stabilization ponds, macro-invertebrates, pollution tolerance index and efficiency.*

I. INTRODUCTION

The development and application of bioindicators has been in use since 1960s (Hilsenhoff, 1988). Bioindicators are developed for ecosystem health assessment, for human effects and interventions, human health assessment, and for evaluating sustainability (Burger, 2006). Bioindicators are recommended for water quality assessment as they are less costly and environmentally friendly biomonitoring tool (Aura *et al.*, 2010). Biomonitoring of ecosystems require the use of bioindicators that are biologically and methodologically user friendly, and can effectively be used to provide early warnings (Burger, 2006). Focus is now being directed towards aquatic organisms, which are used as ecological indicators (bioindicators) of water quality (Wenn, 2008). Among the most commonly used bioindicators for assessing water quality status include macro-invertebrate communities. Macro-invertebrates are commonly used to monitor the health status of different watersheds (Holt, 2010). Unlike chemical analysis that gives snapshot status, macro-invertebrates provide cumulative effects of long term status of watersheds (Andem *et al*., 2015). Macro-invertebrates populations have families

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with differential responses to pollution and thus their relative abundance is used to infer the nature, load and severity of polution (Wenn, 2008). Macro-invertebrates possess hallmark traits making them ideal biological monitoring tool for assessment of aquatic ecosystems' integrity (Carignan, 2002 and Holt 2010).

Indices of biotic integrity (IBI) have been developed from macro-invertebrates assemblage for assessment of aquatic ecosystems' health (Orwa *et al.*, 2013). (IBI) are of different versions developed for different regions and for varying ecosystems. Benthic-index (B-IBI) and pollution tolerance index (PTI) are the most commonly used indices in assessment of aquatic ecosystems. (B-IBI) is used in assessment of samples from deep regions of streams and rivers (Kerans and Karr, 1994), while PTI is used in sampling from riffles and other shallow areas to detect moderate to severe stream quality degradation (Mark *et al*., 1997). PTI is useful in developing an information data base and the concept of developing tolerance ranges of organisms (Mark *et al.*, 1997). The PTI groups macro-invertebrates into three categories on the basis of pollution; sensitive, moderately sensitive, and tolerant groups (Mark *et al*., 1997). These groups are assigned numerical values depending on their pollution tolerance values. For wastewater, a PTI value greater than 23 is considered as excellent condition, a PTI of 17-22 indicates that the water quality is good; a PTI between 11 and16 indicates fair water quality while water with PTI below 10 is considered as poor quality. Currently the United States Environmental Protection Agency uses PTI to determine quality of water using macro-invertebrates (Idroos and Manage 2012). Macro-invertebrates that are used to calculate the PTI include aquatic worms, backswimmers, water boatman, riffle bettles, scud, leech, blackfly, midge larvae and snails that lack gills (Mark *et al*., 1997). Large numbers of these types of organisms normally, in absence of sensitive and somewhat sensitive organisms to pollution indicates poor water quality that is organically polluted (Burger, 2006). Some of these organisms i.e., aquatic midge and blood worms are adapted to polluted water as they have haemoglobin that enhances the efficiency of oxygen extraction from water and allows them exist in hypoxic environments (Welch 1992). Presence of pollution-tolerant macro-invertebrates only is an indication of poor water quality. Macro-invertebrates also possess certain advantages as indicators for water quality health compared to other bioindicators. The advantages include, group diversity that make it possible for some members to respond to pollution; long life span that allow the observation of temporal changes in communities due to pollution (Wenn, 2008). In addition, macro-invertebrates are cost effective monitoring tool that can be used for regular assessment of ecological integrity of aquatic ecosystems (Orwa *et al.*, 2012).

II. METHODOLOGY

STUDY AREA

The study was carried out at the University of Eldoret Sewage treatment plant. The university is located in the highlands of Uasin Gishu County, 9 kilometers north of Eldoret Town and at latitude $1^{O}30$'N and $0^{O}05$'S and longitude $34^{O}15$'W and $35^{O}45$'E. It lies at an altitude of approximately 2000m above sea level. The effluent from the treatment plant drains into major wetland, the Marula Swamp before draining to Marula River which is a major source for domestic water to the surrounding communities. The area experiences an average annual rainfall of 1000 mm and average temperatures of 24^{0}C during the day and 10^{0}C at night.

MACRO-INVERTEBRATES ANALYSIS AND PTI DETERMINATION

Macro-invertebrates sampling was done using a scoop net (0.5mm mesh size). The macro-invertebrates samples collected were fixed in 10% formalin solution in a sample collection container, hand sorted in a white plastic tray, placed into vials and preserved in 70% alcohol and transported to the laboratory for identification. Macro-invertebrates were identified to order and family taxonomic unit using identification key by IFM, 2006, and Aquatic invertebrates Identification Guide by Walker, 2006. Pollution tolerance indices (PTI) were determined to evaluate the wastewater quality status of the stabilization ponds to ascertain if the ponds were effective in wastewater restoration. The indices were computed by utilizing methods used by (Olomukoro and Dirisu 2013). The PTI for the ponds were determined by assigning the organisms' abundance codes. The codes were assigned depending on the number of organisms sampled for each family per sampling site of the stabilization ponds. The codes assigned were R(rare)= 1 – 9 organisms; C(common)= 10 – 99 organisms and D(dominant) = 100 or more organisms. The code numbers for each site sampled were added together and multiplied by standard multiplication factor for each code. The multiplication factors assigned for the codes were; 1.2 for R (rare), 1.1 for C (common) and 1.0 for D (dominant) (Andem *et al.,* 2015) since the macro-invertebrates under study were pollution tolerant. Multiplication factors of 2 and 3 are assigned for facultative or somewhat tolerant and pollution sensitive groups respectively (Andem *et al.*, 2015). The PTI value for each pond was arrived at by adding the products of each letter code and its respective multiplication factor.

DATA ANALYSIS

Data storage and management was done using Microsoft Excel spreadsheet for windows 2007. Macro-invertebrates were identified at order and family taxonomic units. Macro-invertebrates were counted to determine order and family abundance for the treatment ponds. Community indices i.e., Shannon-weiner diversity, evenness and dominance were determined by using Minitab^{TM}Version 14.0 for windows.

III. RESULTS

MACRO-INVERTEBRATES ABUNDANCE AND DIVERSITY OF THE SEWAGE TREATMENT PONDS

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A total of 6506 macro-invertebrates were collected from the sewage treatment ponds. Five orders and thirteen Families were identified as shown on (Table 1). Diptera was the most abundant and diverse taxon. The order had 3845 macro-invertebrates belonging to five families. Diptera accounted for 59% of macro-invertebrates collected from the ponds. Hemiptera was ranked the second abundant and diverse taxon and had 2486 macro-invertebrates belonging to four families. Hemiptera accounted for 38% of macro-invertebrates collected from the ponds. Coleoptera had 95 macro-invertebrates belonging to two families. The order accounted for 1.5% of the total macro-invertebrates collected from the ponds. Ephemeroptera had 52 macro-invertebrates of the family Caenidae that accounted for 1% of the macro-invertebrates sampled from the ponds. Isopoda was the least abundant taxon, with 32 macro-invertebrates of Jarinidae, which accounted for 0.5% of the total macro-invertebrates. Pond 1 was least diversified with seven families while pond 4 was the most diverse pond with 10 families. Pond 2 had eight families while pond 3 had nine families. Chironomidae dominated ponds 1, 2 and 3 while Corixidae dominated pond 4. The abundance of Chironomidae decreased while that of Corixidae increased from pond 1 to pond 4.

Order	Family	Pond 1	Pond 2	Pond 3	Pond 4
Coleoptera	Dytiscadae	0	6	35	50
	Grynidae	0	0	3	1
Diptera	Ceratopogonidae	1	0	0	0
	Chironomidae	1534	846	686	489
	Cullicidae	0	8	4	0
	Ephyridridae	187	47	1	30
	Stratiomydae	15	0	0	0
Ephemeroptera	Caenidae	0	0	3	49
Hemiptera	Corixidae	280	338	353	719
	Hydrometridae	0	0	0	7
	Notonectidae	3	282	84	19
	Pleidae	0	36	292	76
Isopoda	Jarinidae	3	4	0	25

Table 1: Macro-invertebrate family abundance and diversity for the ponds

Fig 1 shows clearly the decreasing and increasing trends of orders Diptera and Hemiptera respectively from pond 1 to pond 4. An increasing trend is also observed for order Coleoptera in pond 2 to 4. Ephemeroptera and Isopoda had few organisms for their trends to be observed on fig 1.

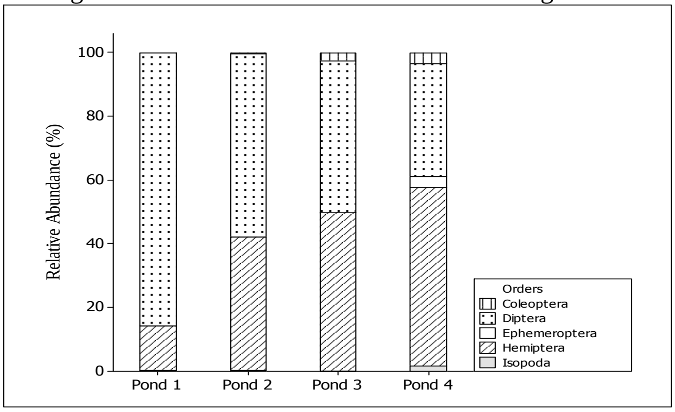

Figure 1: Percentage relative order abundance of macro-invertebrates per stabilization pond

Dominance was highest in pond 1 (0.7546) as shown on figure 2. Ponds 2, 3 and 4 had very close dominance values of (0.4919), (0.4856) and (0.4694) respectively.

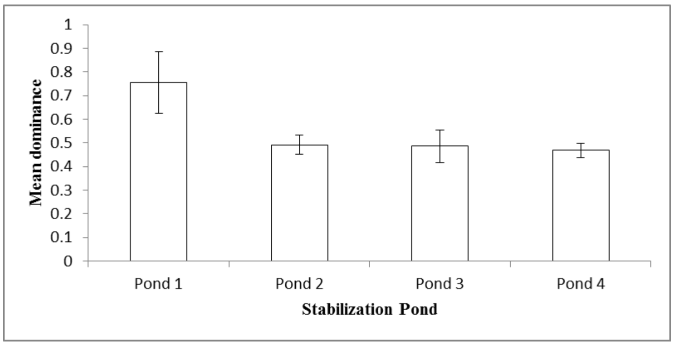

Figure 2: Mean dominance of macro-invertebrates per wastewater stabilization ponds

Diversity was least in pond 1with mean value of (0.4255) while in ponds 2, 3 and 4 was (0.744), (0.7809) and (0.8192) respectively as shown on figure 3. Evenness was also least in pond 1(0.3826) and highest in pond 4 (0.7278) while pond 2 and 3 had mean values of (0.4209) and (0.5672) respectively.

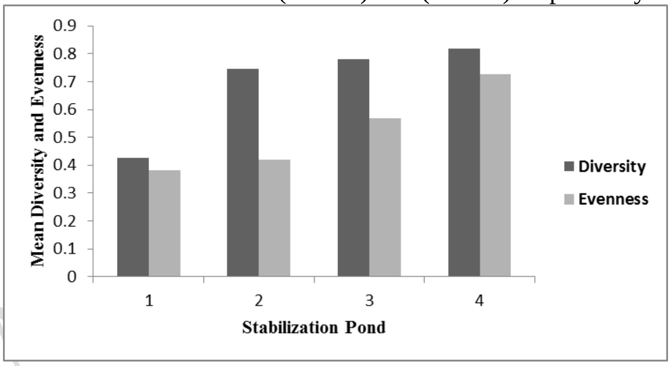

Figure 3: Mean diversity and evenness of macro-invertebrates per wastewater stabilization ponds

Table 2 shows pollution tolerance index (PTI) values of the four sewage treatment ponds. The pollution tolerance index (PTI) values of the ponds ranged between 7.7 and 11. Pond 1, 2 and 3 had similar value in terms of PTI rating. The (PTI) values for ponds 1, 2 and 3 indicated poor water quality status while that of pond 4 indicated fair water quality status.

Pond	PTI	Status
1	7.7	Poor
2	8.8	Poor
3	10	Poor
4	11	Fair

Table 2: Pollution tolerance index (PTI) rating for wastewater status of the ponds

IV. DISCUSSION

MACRO-INVERTEBRATES ABUNDANCE AND DIVERSITY

Macro-invertebrates have been used over time to determine water quality status of aquatic ecosystems (Hilsenhoff, 1988) including wastewater stabilization systems. Macro-invertebrates are useful in understanding well ecological health of aquatic ecosystem (Olomukoro and Dirisu 2013) and provide a continuous record of environmental degradation (Vertessy and Rissman 2000). Macro-invertebrates are widely used as indicators because they are an ideal biological monitoring tool in that; they are relatively easily sampled and usually occur in great diversity and numbers (Davey, 1980). Macro-invertebrates also have short life cycles, with several life stages (i.e. egg, larvae, pupae and adult) that may be studied in a short period of time (Vertessy and Rissman 2000). The results of the study indicate Diptera and Hemiptera dominated the sewage treatment ponds in abundance and taxa diversity. The high abundance of Diptera in polluted environment is attributed by the fact that most species belonging to the order are highly tolerant to pollution (Harding *et al.*, 1999). The high density of Dipterans especially Chironomidae in the first three ponds was an indication of relatively highly polluted water compared to pond 4. Chironomidae being the most tolerant to pollution family is found in large numbers at highly degraded and polluted sites (Buss *et al.*, 2002). High nutrients and reduced DO levels in the first three ponds favored Chironomidae compared to other families. Chironomidae had enhanced red pigmentation suggesting that the wastewater had reduced oxygen levels (Welch 1992). Chironomidae appeared red because they synthesis hemoglobin to enhance oxygen absorption at low tensions (Buss *et al.*, 2002). As the concentration of nutrients decreased, the abundance of Chironomidae decreased in the ponds as shown on table 1.

Hemiptera was the second most abundant and diverse taxon after Diptera. The observed increase of Hemiptera may have been attributed by the decreasing nutrient concentration in the sewage treatment ponds. For the five families that were collected belonging to Hemiptera, Corixidae was the dorminant family. Corixidae which belong to aquatic bugs showed increasing trend in the treatment ponds. The increasing trend is attributed by the fact that most aquatic bugs have adaptation that enable them survive in polluted aquatic ecosystem (Harding *et al.*, 1999). In polluted environment, aquatic bugs do not depend on dissolved oxygen in water but obtain their oxygen directly from air (Chadde, 2009). Most families of Coleoptera and Ephemeroptera are sensitive and moderate sensitive to pollution respectively except few families such as Dytiscadae and Grynidae for Coleoptera and Caenidae for Ephemeroptera (Andem 2015). As such Coleoptera, Ephemeroptera and Isopoda were poorly represented in the stabilization ponds due to polluted status of wastewater in the ponds. The orders accounted for less than 5% of all macro-invertebrates that were collected from the sewage treatment ponds. The low percentage of Coleoptera, Ephemeroptera and Isopoda may have been attributed to similar water quality status of the first three treatment ponds which were rated poor. This explains the low representation of the three orders in ponds 1, 2 and 3.

The trends observed for dominance and diversity indicates pond 1 varied highly from ponds 2, 3 and 4, which had values with small variations between them. The small variations observed for dominance and diversity for ponds 2, 3 and 4 was attributed to similar status of wastewater in the three ponds. The similar wastewater status of ponds 2, 3 and 4 is an indication that the ponds did not have major impact in wastewater restoration compared to pond 1 hence the high variation between pond 1 and the three ponds.

POLLUTION TOLERANCE INDEX

Pollution tolerance index is used to evaluate the overall health of aquatic environment through the use of macro-invertebrates abundance and diversity (Andem 2015). In this study, pollution tolerance index was used to assess the status of wastewater in the stabilization ponds. The pollution tolerance index results obtained from the study rated the wastewater of the treatment ponds as poor. The poor rating obtained is an indication that the treatment ponds are inefficient in the restoration process. The poor rating may have resulted from large volume of wastewater getting into the treatment ponds than what they are designed to hold. The large volume of wastewater reduces the retention time of wastewater in the ponds hence affecting negatively the ponds performance. The poor rating of the treatment ponds also results due to lack of proper management practices. If sludge is left to accumulate over a long period of time, the efficiency of treatment ponds in wastewater restoration is reduced. According to (Quiroga 2004), performance of sewage treatment ponds is enhanced by disposing accumulated sludge every two to three years. Better pollution tolerance index would have been obtained for the sewage treatment ponds if the ponds were efficient and effective in wastewater restoration.

V. CONCLUSION AND RECOMMENDATION

The results obtained from the study indicated inefficiency of the wastewater stabilization system in wastewater restoration. Therefore the university needs to expand the sewerage system. The expansion will enable the system to increase its capacity making it more efficient in wastewater restoration.

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REFERENCES

[1] Andem, A. B., Esenowo, I. K. and Bassey, D. O. (2015). Application of Biotic Indices and Pollution Tolerance Index in Assessing Macro-invertebrates Assemblage of Ediba River, Cross River State, Nigeria J Environ Anal Toxicol S 7: 007. Doi 10.4172/2161-0525.S7-007

[2] Aura, C. M., Raburu P. O. and Herrman, J. (2010). Bioassesment of the water Quality of River Kipkaren, Nzoia River Basin, Kenya. http://41.215.122.106:80/dspace/handle/0/367

[3] Burger, J. (2006). Bioindicators: Types, Development, and Use in Ecological Assessment and Research. Environmental Bioindicators (2006) Volume: 1, Issue: 1, Pages: 22-39 ISSN: 15555275

[4] Buss, D. F., Silveira M. P., Nessimian. J. L. and Dorville, L.F.M. (2002). Influence of water chemistry and environmental degradation on macro-invertebrates assemblages in a river basin in south-east Brazil. Hydrobilogia 481: 125-136.

[5] Carignan, V. and Villard, M.C. (2002). Selecting indicator species to monitor ecological integrity: A review. Environmental Monitoring and Assessment 78, 45–54

[6] Chadde, J. S. (2009). Macro-invertebrates as Bioindicators of Stream Health. Western U.P. Centre for Science, Mathematics & Environmental Educ. 105 Dillman Hall, Michigan Technological University, 1400 Townshed Dr., Houghton, MI 49931 Tel: (906) 487-3341 or Email:jchadde@mtu.edu

[7] Davey, G.W. (1980). The Use of Biological Parameters for The Assessment of Water Quality- A Literature Review. E.P.A. Publication 99. Victorian Government Printer, Melbourne.

[8] Hardings, J. S., Young R. G., Hayes, J. W., Shearer K. A. and Stark J. D. (1999). Changes in agricultural intensity and river health along a river continuum. Freshwater Biology 42: 345-357.

[9] Hilsenhoff, W. L. (1988). Rapid Field Assessment of Organic Pollution with a Family-Level Biotic Index. Journal of the North American Benthological Society

[10] Holt, E. A. and Miller, S. W. (2010). Bioindicators: Using Organisms to Measure Environmental Impacts. (Department of Watershed Sciences, Utah State University) © 2010 Nature Education Knowledge 3(10):8

[11] Idroos, F. S. and Manage, P.M. (2012). Aquatic Life Health Quality Assessment of the Bolgoda Canal and Waga Stream with respect to Selected Physicochemical Parameters and Bioindicator: Journal of Tropical Forest and Environment Vol. 2, No 02 (2012) 13-16

[12] IFM. (2006). Aquatic Ecology. Department of Biology, Linkoping University, Sweden. 14-58pp

[13] Kerans, B. L. and Karr J. R. (1994). A Benthic Index of Biotic Integrity (B-IBI) for rivers of the Tenness Valley.Ecological Applications. 4(4): 768-785.

[14] Mark K, Mitchell M. K., and Stapp, W. B. (1997). Adapted from Volunteer Stream Monitoring: A Methods Manual, United States Environmental Protection Agency, Office of Water, Document no 841-B-97-003 pg 123-127

[15] Olomukoro, O. J. and Dirisu, A. (2013). Macro-invertebrate Community and Pollution Tolerance Index in Edion and Omodo Rivers in Derived Savannah Wetlands in Southern Nigeria. Department of Animal and Environmental Biology, Faculty of Life Science, University of Benin, Benin City, P. M. B. 1154, Nigeria.

[16] Orwa, P. O., Raburu, P. O., Kikpkemboi J., Rangoei, P., Okeyo-Owour, J. B. and Omari S. (2013). Use of Macro-invertebrate Assemblage to assess the Ecological Integrity of Nyando Wetlands, Kenya. Journal of Ecology and the Natural Environment.ISSN 2006-9847. 2013 Academic Jounals http://www.academicjournals.org/JENE

[17] Orwa, P. O., Raburu P O., Njiru J. and Okeyo-Owour, B. J. (2012). Human Influence on Macro-invertebrates Community Structure within Nyando Wetlands, Kenya. International journal of aquatic science ISSN: 2008-8019 Vol 3, No 2, 2012.

[18] Quiroga, F. J. T., (2004). Waste Stabilization Ponds for Wastewater Treatment, Anaerobic Pond 23 - 4

[19] Vertessy, D. and Rissman J. (2000). Monitoring The Impact of Wastewater Treatment Plant Effluent on The Water Quality and Biological Communities of Receiving Environments. 63rd Annual Water Industry Engineers and Operators' Conference Civic Centre-Warrnambool 6 and 7 September, 2000

[20] Welch, E.B. (1992). Ecological Effects of Wastewater River. Chapman and Hall Publishers, London. 35pp.

[21] Wenn, C. L., (2008). Do Fresh Water Macro-invertebrates Reflect Water Quality ImprovementsFollowing the Removal of Point Source of Pollution from Spen Beck, West Yorkshire? School of Earth and Environment, Vol 3, 369-406, University of Leeds, W. Yorkshire LS2 9JT Tel: 01133436461 ISSN: 1744-2893 (online)