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Water quality assessment using macroinvertebrates and physico-chemical parameters in the riverine system of Iligan City, Philippines

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Abstract. The water quality in the riverine systems (Mandulog and Iligan) of Iligan City decreases as it approaches the downstream. Canonical Correspondence Analysis (CCA) was used to determine which physico-chemical parameters would influence the assemblage of macroinvertebrates. Results revealed that Total Suspended Solids (TSS) affect the groups Plecoptera, Tricoptera, Diptera and Simuliidae while nitrate affects Plecoptera and Gomphidae. Principal Component Analysis (PCA) was used to determine which physico-chemical parameters describe the sampling sites. Out of the ten physico-chemical parameters that were determined, only the pH, silicate and nitrate showed significant correlation that describe the sampling sites. These results indicated that the sampling sites within the two rivers show similar chemical attributes.
Key Words: Water quality, macroinvertebrates, physico-chemical parameters.

Introduction. Macroinvertebrates or more simply "*benthos*" are organisms in the aquatic environment without a backbone that can be seen with the naked eye. These animals can be found on rocks, logs, sediment, debris and aquatic plants during some period in their life. The *benthos* include crustaceans such as crayfish, mollusks such as clams and snails, aquatic worms and the immature forms of aquatic insects such as stonefly and mayfly nymphs. Among the aquatic insects, Ephemeroptera, Plecoptera and Trichoptera (EPT), comprise rich assemblages in low and medium order stony cobble streams. These organisms are sensitive to environmental perturbations and therefore occur in clean and well-oxygenated waters. Therefore, EPT assemblages are frequently considered to be good indicators of water quality (Rosenberg & Resh 1993).

Aquatic macroinvertebrates are an important component of the freshwater communities and a link to the aquatic food chain (Waters 1995). Its species diversity is controlled by productivity, habitat heterogeneity and biotic interactions (Townsend 1989 as cited by Moretti & Callisto 2005). They are widely used as water quality bio-indicators due to their long life period (Marques & Barbosa 2001 as cited by Moretti & Callisto 2005) and they are also sensitive to changes in the ecosystem (Uyanik et al 2005). Moreover, they are serve as a tool to measure continuous and chronic effects of pollution, stream degradation from storm water runoff, point source discharges and are thus indicators of stream recovery (Yandora 1998). They can be collected very easily from most aquatic systems with inexpensive or homemade equipment.

Objectives of the Study:

1. To determine the assemblage of the macroinvertebrates;
2. To determine the physico-chemical parameters (pH, DO, temperature, conductivity, TSS, phosphate, nitrite, nitrate and silicate) of the river;

3. To calculate the water quality of the sampling sites in terms of Field Biotic Index (FBI) and Water Quality Index (WQI);
4. To compare the biota and physico-chemical parameters of the sampling sites according to season;
5. To compare FBI and WQI of the sampling sites according to seasons;
6. To determine which physico-chemical parameter describes the sampling sites.

Material and Method. Iligan City, Philippines is bounded on the north by the 3 municipalities of Misamis Oriental (namely Lugait, Manticao and Opol), on the south by the 3 municipalities of Lanao del Norte (Baloi, Linamon and Tagoloan) and the 2 municipalities of Lanao del Sur (Kapai and Tagoloan II), on the northeast by Cagayan de Oro City, on the east by the municipality of Talakag, Bukidnon; and on the west by Iligan Bay.

Iligan, which has many rivers that run through it, comes from the word ”ilig”, which means flow. There are two major rivers that are located in the heart of the city which are the subject of this study. Mandulog is a 50 km river whose headwaters come from the Kalatungan range in Bukidnon. The other river, Iligan River comes from Lanao del Sur.

Five sampling sites come from each of these rivers, the Mandulog and Iligan City rivers (Table 1; Figure 1 & 2). The dip-net, kick-net and handpicking methods were employed to collect macroinvertebrates from each of the sampling sites and the physico-chemical parameters were measured *in situ*.

Table 1

The sampling sites along the two rivers systems of Iligan City with its coordinates

No.	*Sampling Sites*	*GPS Coordinates*
1	Kabangahan	N 08°14.727′ E 124°22.236′
2	Caluda	N 08°14.996′ E 124°18.463′
3	Kapay	N 08°14.907′ E 124°18.459′
4	Bayug	N 08°15.097′ E 124°15.453′
5	Mandulog	N 08°15.152′ E 124°14.411′
6	Tambacan	N 08°13.659′ E 124°14.068′
7	Tubod	N 08°13.166′ E 124°14.527′
8	Abuno	N 08°10.556′ E 124°15.276′
9	Pindugangan	N 08°11.404′ E 124°15.827′
10	Tipanoy	N 08°11.745′ E 124°15.451

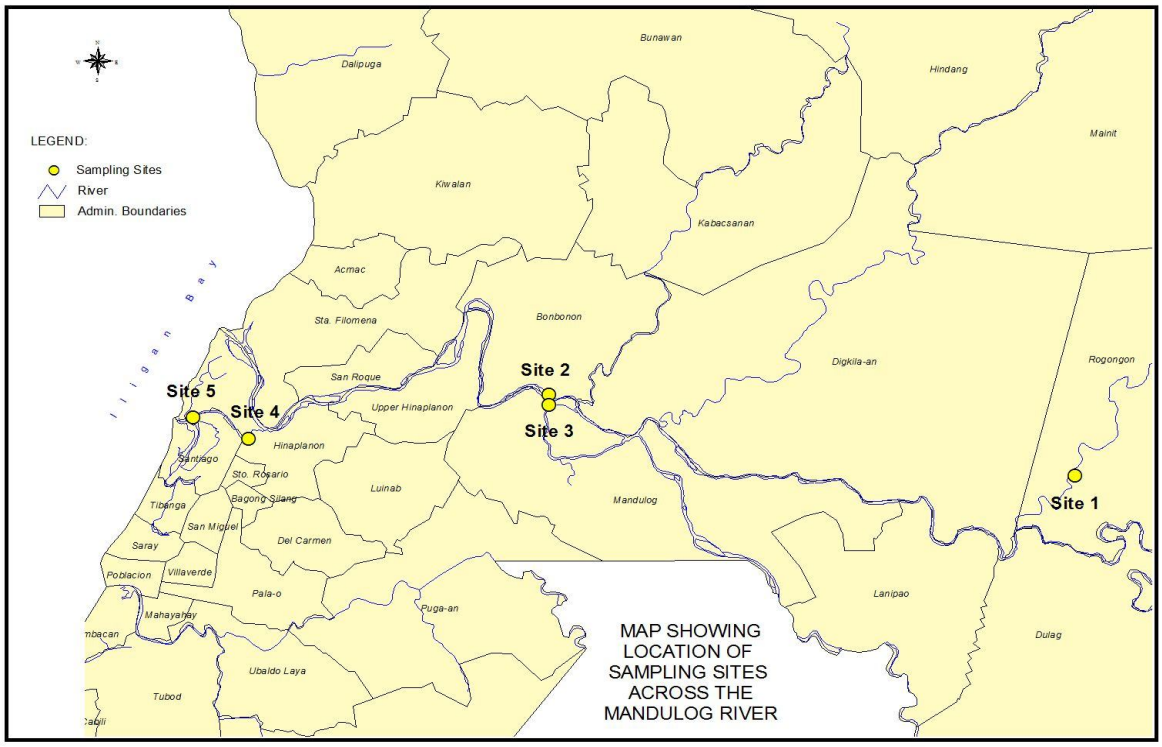

Figure 1. Map showing the sampling sites in Mandulog River, Iligan City.

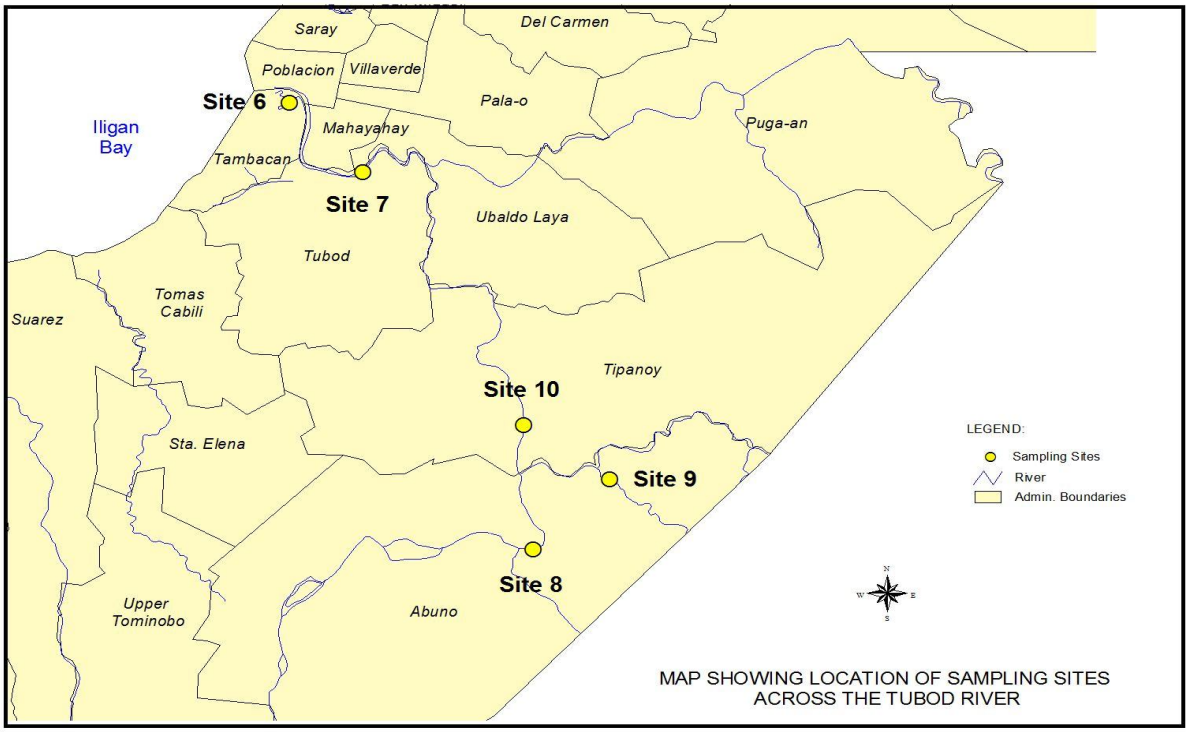

Figure 2. Map showing the sampling sites in Iligan (Tubod) River, Iligan City.

Results and Discussion. From the ten sampling sites included in this study, nine groups of macroinvertebrates and four families were found (Table 2). The number of macroinvertebrates varied for every sampling site and this could be explained by the different factors affecting the activity of the rivers. Ephemeroptera (mayflies) are the greatest number among all the macroinvertebrates in all sampling sites while

Megaloptera (dragonfly and damselfly nymphs) are the least in number. The insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies) and Tricoptera (caddiesflies) are collectively known as EPT which means that they are generally pollution-sensitive (Rosenberg & Resh 1993), they are also good indicators of water quality. They are thus good for evaluating the balance in the community. These groups are present in the Kabangahan, Caluda and Kapay sites.

Table 2

Comparison of macroinvertebrate counts according to seasons (wet and dry) using Kruskal-Wallis Test

Groups	*Data from Iligan Rivers n = 30*	*Data from Mandulog Rivers n = 30*	X^2
	Mean count	*Mean count*	
Ephemeroptera	24.10	10.07	1.51^{ns}
Tricoptera	0.30	4.07	1.01^{ns}
Coleoptera	0.27	0.40	0.10^{ns}
Hemiptera	4.37	1.40	1.55^{ns}
Mollusca	0.87	0.13	0.02^{ns}
Shrimp	0.47	1.97	0.05^{ns}
Diptera	3.50	2.67	3.18^{+}
Plecoptera	7.03	11.60	0.03^{ns}
Psephenidae	0.00	0.57	4.21*
Gomphidae	0.00	0.03	1.00^{ns}
Formicidae	0.17	0.00	1.00^{ns}
Simuliidae	3.13	0.90	0.04^{ns}
Megaloptera	0.23	0.00	1.00^{ns}

n= number of sampling sites; ns= not significant; + significant ($0.05<\alpha\leq0.10$); * significant ($0.01<\alpha\leq0.05$).

Among the macroinvertebrate groups whose mean count in both riverine systems showed significance both in the dry and wet seasons were Diptera (3.18) and Psephenidae (4.21) (Tables 2, 3, 4). Diptera are macroinvertebrates that are represented by chironomids. Swarms of adult midges (Chironomidae), for example, are conspicuous and troublesome; but the adult midge lives just long enough, usually less than a day, to mate and lay eggs. Thus, most of the life cycle happens under water of the larval stage that is wormlike in appearance; some have adapted to oxygen-poor situations (www.britannica.com).

In this study, it is noted that Diptera, namely Chironomidae had higher numbers during the dry season (Giumaraes et al 2009) in Tipanoy, Kabangahan, Abuno and Tubod sampling sites. The high presence of chironomids suggests potential pollution most probably because people use the rivers to carry out their daily chores such as washing, bathing effluent discharges (Agboola & Denloye 2011). The human impacts mostly due to deforestation, erosion, urban and industrial pollution (Beqiraj et al 2006). The high abundance of Diptera, particularly in Chironomidae found is affected by the variability of physical and chemical characters. In contrast, Trichoptera displayed more stable proportions to the emergences since it can tolerate a wide range of environmental conditions (Freitag 2005). Moreover, low macroinvertebrate counts were also observed during the summer months in the downstream area of the two rivers (Mandulog and Tambacan sampling sites). This could be attributed to the high values of phosphate and nitrogen ions. These results correspond with the study of Duran (2006) in the Behzat stream in Turkey. Macroinvertebrates have also been identified and the highest species number was recorded near tributaries due to the availability of food while the lowest are in the impacted areas where there are pollution discharges and gravel excavation (Beqiraj et al 2006).

Table 3
Comparison of macroinvertebrate counts during the dry season using Kruskal-Wallis Test

Groups	*Data from Iligan Rivers n = 15*	*Data from Mandulog Rivers n = 15*	X^2
	Mean count	*Mean count*	
Ephemeroptera	24.27	7.07	2.43^{ns}
Tricoptera	0.20	0.00	1.00^{ns}
Coleoptera	0.47	0.33	0.311^{ns}
Hemiptera	4.00	1.20	0.96^{ns}
Diptera	5.60	5.33	0.82^{ns}
Plecoptera	14.07	23.20	0.15^{ns}
Psephenidae	0.00	1.13	4.44*
Gomphidae	0.00	0.07	1.00^{ns}
Formicidae	0.33	0.00	1.00^{ns}
Simuliidae	6.27	1.80	0.18^{ns}
Megaloptera	0.47	0.00	1.00^{ns}

n= number of sampling sites; ns= not significant; + significant ($0.05<\alpha\leq 0.10$); * significant ($0.01 < \alpha \leq 0.05$).

Water penny are aquatic beetles under the family Psephenidae which are around 6 to 10 millimeters in length (Arnett et al 2002) where it showed significance at α=0.05 (Table 3). The presence of water penny larvae in an aquatic ecosystem can be used as a test for the quality of the water since it belongs to the sensitive category. These beetles cannot live in habitats where rocks acquire a thick layer of algae, fungi or inorganic sediment. Therefore, their presence along with other diverse phyla signifies good quality water.

Table 4
Comparison of macroinvertebrate counts during the wet season using Kruskal-Wallis Test

Groups	*Data from Iligan Rivers n = 15*	*Data from Mandulog Rivers n = 15*	X^2
	Mean count	*Mean count*	
Ephemeroptera	23.93	13.07	0.01^{ns}
Tricoptera	0.40	8.13	3.08^{+}
Coleoptera	0.13	0.47	0.01^{ns}
Hemiptera	4.73	1.60	0.81^{ns}
Mollusca	1.73	0.27	0.07^{ns}
Shrimp	0.93	3.93	0.02^{ns}
Diptera	1.40	0.00	5.74*

n= number of sampling sites; ns= not significant; + significant ($0.05<\alpha\leq 0.10$); * significant ($0.01<\alpha\leq 0.05$).

Macroinvertebrates are widely used as indicators of ecological condition because of their variety of responses to human disturbances. Their assemblage may also be affected by changes in water chemistry such as reduced dissolved oxygen levels (McKayy & King 2006) and by flow alteration caused by increased water temperatures (Rader & Belish 1999).

The FBI (Hilsenhoff 1987) is based on family level identification of stream arthropods including insects, amphipods and isopods. It is not as sensitive as species-based indices but it has an advantage for rapid stream assessment. The FBI is a quantitative measure that requires counting of individuals in each family. It is based on the scale of 10 and high values indicate high pollution intolerance while lower values indicate low pollution intolerance.

Table 5 shows the FBI (Hilsenhoff 1987) and WQI scores with its interpretations in the two major rivers in Iligan City. Water quality in Abuno sampling site shows excellence implies a no apparent organic pollution. On the other hand, Kabangahan, that Caluda, Kapay, Mandulog, Pindugangan and Tipanoy sampling sites have very good water quality indicative of possible slight organic pollution. Bayug and Tubod sampling sites however, have only good water quality indicating some organic pollution while the Tambacan site reveals a fairly significant organic pollution in all the sampling months.

Table 5

Field Biotic Index (Hilsenhoff 1987) mean readings in ten sampling sites in the two major rivers in Iligan City

Sampling sites	*FBI*			*WQI*		
	Wet	*Dry*	*Implication*	*Wet*	*Dry*	*Implication*
Kabangahan	3.8	3.2	Possible slight organic pollution	58	54	medium
Caluda	3.8	3.8	Possible slight organic pollution	62	57	medium
Kapay	4.3	2.5	Possible slight organic pollution	61	57	medium
Bayug	4.4	5.3	Some organic pollution	56	55	medium
Mandulog	4.5	4.3	Possible slight organic pollution	59	56	medium
Tambacan	6.1	5.6	Fairly significant organic pollution	61	57	medium
Tubod	6.3	3.5	Possible slight organic pollution	60	48	medium
Abuno	2.9	3.6	No apparent organic pollution	62	49	medium
Pindugangan	3.7	3.9	Possible slight organic pollution	61	54	medium
Tipanoy	4.8	4.0	Possible slight organic pollution	62	54	medium

The midstream and downstream portion where the other sampling sites are located are vulnerable to various urban impacts, such as erosion, release of domestic, industrial and agricultural effluents, and deforestation as well (Guimaraes et al 2009). The sampling sites that were most likely impacted were characterized by the presence of silted banks with little or no vegetation in the riverbanks, the presence of household wastes, agricultural wastes and constructions, among others. These observations in some sampling sites contribute to the reduction of the lotic system functioning like the maintenance of biological diversity (Brown 2007).

Based on WQI which uses the online calculator, all sampling sites fall within the medium category wherein seven out of nine physico-chemical factors were used such as pH, DO, temperature, TSS, TDS, PO4-P and NO3-N to calculate the WQI (Table 5). These results may be attributed to some of the non-point sources of pollution in the two areas. Thus, the number of areas in which the absence of pollution is possible is decreasing, making this a wake-up call for us to continually guard and protect the rivers.

Table 6 shows the comparison of FBI and WQI between the Iligan and Mandulog Rivers according to season. The results reveal that the two rivers show a significance with the WQI at -2.37 at $0.01<\alpha\leq0.05$ only during the dry season. Water quality along the two rivers is best identified when the physico-chemical parameters were used rather than the macroinvertebrate counts. This clearly conveys that the two rivers are polluted. It is during the dry season that most of the activities of the people living near the rivers are at a peak while during the wet season most of the water is washed out to the sea.

Table 6

Comparison of FBI and WQI between Iligan and Mandulog Rivers when grouped according to seasons using T- Test

Season	Index	Data from Iligan Rivers		Data from Mandulog Rivers		T value
		n	Mean	n	Mean	
Combined data of dry and wet seasons	FBI	30	4.12	30	3.86	0.68^{ns}
	WQI		56.70		57.57	-0.44^{ns}
Data from dry season	FBI	15	3.48	15	3.54	-0.10^{ns}
	WQI		52.27		55.80	-2.37*
Data from wet season	FBI	15	4.76	15	4.18	1.50^{ns}
	WQI		61.13		59.33	0.56^{ns}

FBI - Field Biotic Index; WQI - Water Quality Index; n= number of sampling sites; ns= not significant; * significant ($0.01<\alpha\leq0.05$).

Figure 3 shows the Canonical Correspondence Analysis (CCA) to determine which physico-chemical parameters would influence the assemblage of macroinvertebrates. Results reveal that Total Suspended Solids (TSS) affect the groups Plecoptera, Tricoptera, Diptera and Simuliidae while nitrate affects Plecoptera and Gomphidae (Table 7). Tricoptera and Plecoptera are organisms that are sensitive to the conditions of the waters such that any changes in the concentrations of the chemical components of the water, which would affect its assemblage. Organic pollution generally reduces invertebrate diversity dramatically, resulting in a community dominated by Chironomidae (Diptera) and Oligochaetes (Wright 1995). Phosphorus concentration would also affect variation in mcroinvertebrate communities (Pinel-Alloul et al 1996).

Table 7

Summary statistics of species response to the environmental variables that significantly describe the macroinvertebrate groups as represented by F value and beta coefficient generated from General Linear Models (GLM) derived from ordination using Canonical Correspondence Analysis (CCA)

Groups	TSS		Nitrate	
	F value	Beta coefficient	F value	Beta coefficient
Ephemeroptera	0.03^{ns}	-	0.42^{ns}	-
Tricoptera	5.33**	-3.74	0.19^{ns}	-
Coleoptera	0.07^{ns}	-	0.37^{ns}	-
Hemiptera	0.04^{ns}	-	1.80^{ns}	-
Mollusca	2.38^{ns}	-	0.02^{ns}	-
Shrimp	3.65^{+}	-2.21	0.16^{ns}	-
Diptera	10.36**	4.72	2.91^{+}	1.40
Plecoptera	15.83**	20.39	0.72^{ns}	-
Psephenidae	3.27^{+}	0.62	0.62^{ns}	-
Gomphidae	0.01^{ns}	-	25.52**	0.07
Formicidae	1.25^{ns}	-	0.16^{ns}	-
Simuliidae	10.63**	4.81	1.99^{ns}	-
Megaloptera	1.74^{ns}	-	0.10^{ns}	-

TSS - Total Suspended Solids; ns - not significant; + significant ($0.05<\alpha\leq0.10$); ** highly significant ($\alpha\leq0.01$).

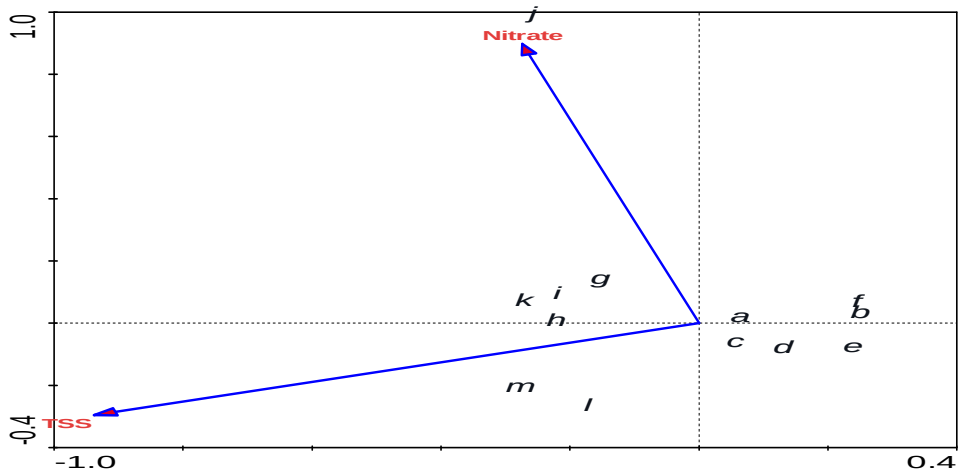

Figure 3. Ordination biplot of environmental variables and macroinvertebrate groups using Canonical Correspondence Analysis (CCA). In the graph are included the environmental variables which significantly describe the macroinvertebrate groups (a-Ephemeroptera, b-Trichoptera, c-Coleoptera, d-Hemiptera, e-Mollusca, f-Shrimp, g-Diptera, h-Plecoptera, i-Psephenidae, j-Gomphidae, k-Formidae, l-Simuliidae, m-Megaloptera) in Iligan and Mandulog Rivers.

Principal Component Analysis (PCA) was used to determine which physico-chemical parameters describe the sampling sites. Out of the ten physico-chemical parameters that were determined in this study, only the pH, silicate (Axis 1) and nitrate (axis 2) show significance (Figure 4 and Table 8). These results indicate that the sampling sites within the two rivers show similar chemical attributes.

The physico-chemical parameters are significant attributes of the river systems and its measurements would provide a status of the water quality. During the dry season, high values of the nitrite and silicate was recorded but nitrate showed lower values. The results would imply that the activities along the rivers contribute to its nutrient concentration (Guldin 1989). These activities include the washing of clothes, bathing, and planting of some crops along the riverbanks as well as sewage and manure.

Table 8

Summary statistics for the environmental variables that significantly contribute to axis 1 and axis 2 as represented by F value and beta coefficient generated from General Linear Models (GLM) derived from ordination using Principal Component Analysis (PCA)

Environmental variables	*Axis 1*		*Axis 2*	
	F value	*Beta coefficient*	*F value*	*Beta coefficient*
Nitrate	0.15^{ns}	-	561.37**	1.25
pH	6.42**	0.17	0.95^{ns}	-
Silicate	271.02**	-131.14	0.01^{ns}	-

ns-not significant; ** highly significant ($\alpha \leq 0.01$)

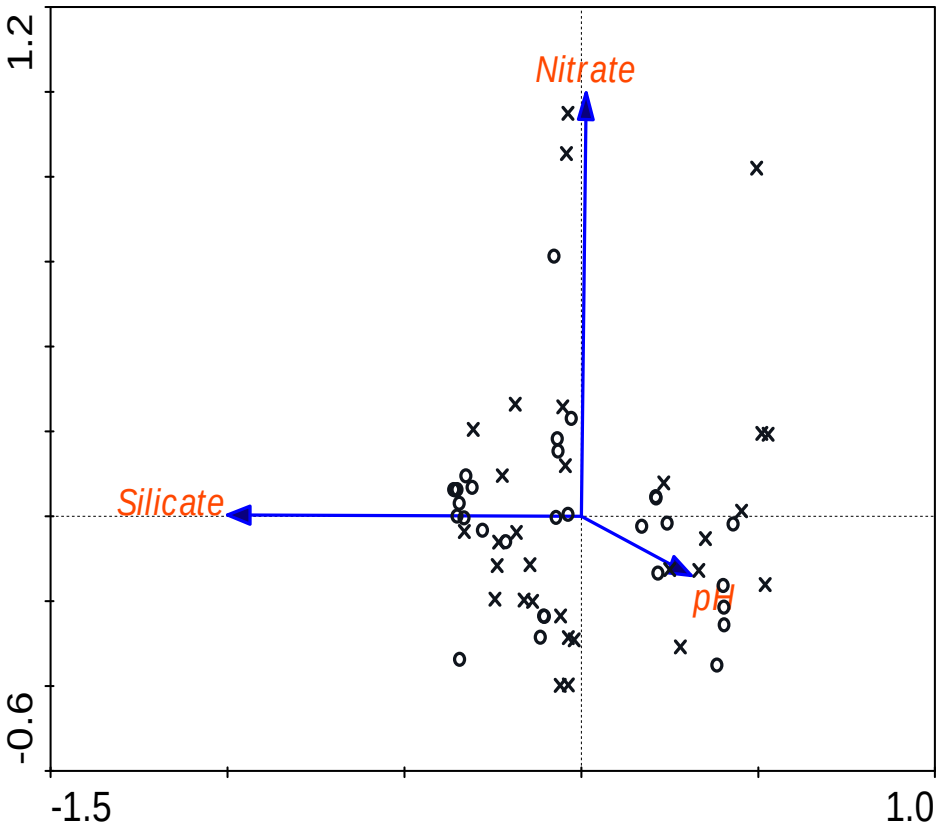

Figure 4. Ordination biplot of environmental variables and sampling sites using Principal Component Analysis (PCA).

Conclusions. It is therefore concluded in this study that water quality along the two rivers is most properly identified when the physico-chemical parameters is used together with the macroinvertebrate counts. It clearly conveys that the two rivers are polluted and pollution decreases as it approaches the downstream portions of the rivers. It is during the dry season that most of the activities of the people living near the rivers are at peak while during the wet most of the water are washed out going to the sea. The researchers would like to recommend that there should be a continuous monitoring of the riverine systems of Iligan City; information dissemination at the rivers location through seminars and symposia; a closed season for quarrying activities in the river that the present communities to be able to regenerate; tree planting activities along the riverbanks to minimize erosion that is being done by natural calamities like flooding.

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