

The Value of the Freshwater Snail Dip Scoop Sampling Method in Macroinvertebrates Bioassessment of Sugar Mill Wastewater Pollution in Mbandjock, Cameroon

Innocent Takougang^{1*}, Phillipe Barbazan², Paul B. Tchounwou³ and Emmanuel Noumi⁴

¹Department of Public Health, Faculty of Medicine and Biomedical Sciences, University of Yaounde I, P.O. Box 1364, Cameroon

²Centre Pasteur du Cameroon, P.O. Box 1274 Yaounde, Cameroon

³NIH-RCMI Center for Environmental Health, College of Science, Engineering and Technology, Jackson State University, Jackson, MS 39217, USA

⁴Department of Biological Sciences, Higher Teachers Training College, University of Yaounde I, P.O. Box 47 Yaounde, Cameroon

*Correspondence to Dr. Innocent Takougang. E-mail: itakougang@yahoo.com

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Abstract: Macroinvertebrates identification and enumeration may be used as a simple and affordable alternative to chemical analysis in water pollution monitoring. However, the ecological responses of various taxa to pollution are poorly known in resources-limited tropical countries. While freshwater macroinvertebrates have been used in the assessment of water quality in Europe and the Americas, investigations in Africa have mainly focused on snail hosts of human parasites. There is a need for sampling methods that can be used to assess both snails and other macroinvertebrates. The present study was designed to evaluate the usefulness of the freshwater snail dip scoop method in the study of macroinvertebrates for the assessment of the SOSUCAM sugar mill effluents pollution. Standard snail dip scoop samples were collected upstream and downstream of the factory effluent inputs, on the Mokona and Mengoala rivers. The analysis of the macroinvertebrate communities revealed the absence of *Ephemeroptera* and *Trichoptera*, and the thriving of *Syrphidae* in the sections of the rivers under high effluent load. The Shannon & Weaver diversity index was lower in these areas. The dip scoop sampling protocol was found to be a useful method for macroinvertebrates collection. Hence, this method is recommended as a simple, cost-effective and efficient tool for the bio-assessment of freshwater pollution in developing countries with limited research resources.

Keywords: bioassessment, snail dip scoop method, macroinvertebrates, sugar mill pollution, surface water quality, Cameroon

Introduction

In order to stimulate industrial development and economic growth, many African countries have relaxed their anti-pollution regulation where it existed and environmental laws are rarely a constraint [1]. The consequence is industrial pollution problems. The detection of agro industrial pollution is urgent in Africa to insure the protection of water resources against organic, inorganic pollutants and pesticides which are released in

freshwater ecosystems [2]. Methods for the detection of water pollution are chemical and biological. Chemical analyses do not detect punctual pollutions, are costly and not sustainable for third world countries. Several organisms are used as water quality indicators. These include bacteria, ciliates, diatoms and macroinvertebrates. Macroinvertebrates are potential markers of water pollution as some members are sensitive to different levels of pollution [3–4]. The abundance of these organisms, their wide distribution, the ease with which they are

identified, and their sedentarity have contributed to their utilization in water pollution assessment [5]. Most reports of the use of macroinvertebrates in freshwater pollution monitoring are from Europe, North America and Asia [6-7]. These data are rare in Africa which is biogeographically different [8-9]. Studies of freshwater organisms for public health purposes have mainly focused on medically important snails. The development of sampling technique which can bring both molluscs and others macroinvertebrates is necessary in the biological evaluation of freshwater pollution [10]. The present work was aimed to evaluate the usefulness of the dip scoop sampling method for the study of macroinvertebrates in the detection of pollution by sugar mill wastes in a tropical environment.

Materials and Methods

Study Areas

Mbandjock is located 110 kilometres from Yaounde, the capital city of Cameroon, on the Yaounde-Nanga Eboko-Bertoua road. The climate is of the transitional tropical and equatorial type with four seasons. The long dry season goes from mid-October to mid-April, the small rainy season from mid-April to June, the small dry season from July to August, and the long rainy season from August to the mid-October.

Mokona and Mengoala rivers border the Mbandjock town and receive waste waters from the sugar mill SOSUCAM (Sugar Producing Company) before joining river Sanaga (Fig. 1). The SOSUCAM factory is in activity from mid-November to mid-June. During the activity phase of the factory, effluents are loaded with residual water coming from the manufacture of sugar (fermented organic materials, chemicals additives, fat, etc.). When the factory is non functional, the effluents contain low organic matters and detergent used in cleaning the machines [11].

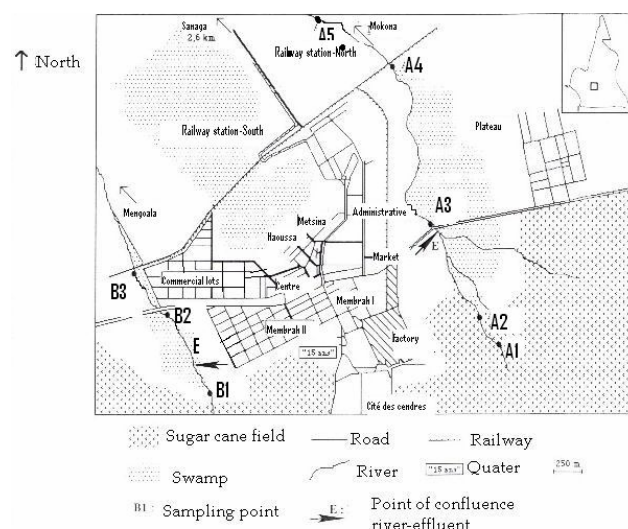


Figure 1: Location of sampling points on Rivers Mokona (A1-A5) and Mengoala (B1-B3) in Mbandjock, Cameroon

Selection of Sampling Sites

The choice of sampling sites was based on the accessibility and the location of the confluence sites between the effluents and the rivers. Five sampling sites were selected on the river Mokona (A1 to A5) and three on Mengoala (B1 to B3). Sites A1, A2 and B1 were situated upstream; A4, A5, B2 and B3 downstream of the sites of confluence. As the course of the effluent was modified during the study period, site A3 was downstream during the first sampling episode (P1) and upstream in the second sampling (P2). Sites A1 and A2 were situated upstream at approximately 1500 m and 1400 m respectively from the site of confluence, while A3, A4 and A5 were situated downstream at 50 m, 1600 m and 1900 m respectively. On Mengoala river, B1 was at 400 m upstream, while B2 and B3 were downstream at 750 m and 1250 m from the confluence site.

Study Method

The length of the study area measures 3450 m for Mokona and 1650 m for Mengoala. At each of the sampling sites, water velocity was determined using a floating object, a measuring tape and a stop clock. The collection of macroinvertebrates was carried out in calm water sites using a dip scoop [10]. Two sampling periods were identified, one in September 1991, rainy season, factory not functional (P1), and another in April 1992, dry season, factory in activity (P2). At each of the collection sites, ten scoops (0.5 mm mesh) were collected around the submerged substrates. The content of each scoop was transferred to a 5 L bucket provided with a lid, washed and fixed in 10 % formaldehyde. The samples were carried to the laboratory where macroinvertebrates were identified according to standard protocol, and counted [12].

The Shannon & Weaver diversity (H) index was determined for each sampling site. The statistical significance of the macroinvertebrate population was assessed by comparing faunal composition and the diversity index, the source of variation being the location of the sampling site in comparison to effluent-rivers confluence and the operational status of factory activity.

Results

The Mokona river is larger (mean width= 10 m) than Mengoala river (mean width= 4.5 m). The periaquatic flora is represented mainly by *Pennisetum purpureum*, which was found at all study sites (Table 1). The velocity of effluents on Mengoala was smaller than that of Mokona (Table 2).

Spatial Variation of the Fauna

During the first sampling period (P1), *Trichoptera* were present at A1 and A2, and *Decapoda* were found at A1 and A5 (Table 3). The number of taxa upstream at P1 did

not differ significantly to that obtained downstream of either Mokona or Mengoala rivers ($P > 0.05$). On the Mengoala river, *Plecoptera* and *Plannipenna* were found at B3 (P1). *Basommatophora* and *Odonata* were present at B1 and B3 at P1, but not at P2 (Table 4).

Table 1: Aquatic and periaquatic plants of Mokona (A1-A5) and Mengoala (B1-B3) rivers in Mbandjock, Cameroon (September 1991 and April 1992)

Taxa	Sampling Points							
	Mokona				Mengoala			
	A1	A2	A3	A4	A5	B1	B2	B3
Poaceae			x	x				
<i>Panicum brevifolium</i> linn.								
<i>Panicum calvum</i> stapf								
<i>Echinochloa pyramidalis</i> hitchc	x	x	x	x			x	x
<i>Paspalum conjugatum</i> Berg.				x				
<i>Acroceras amplexens</i> stapf				x		x	x	x
<i>Sorghum</i> sp.	x	x	x	x		x	x	x
<i>Pennisetum purpureum</i> schumach.	x	x	x	x	x	x	x	x
Commelinaceae								
<i>Aneilema beniniense</i> kunth			x		x	x		
Basalminaceae								
<i>Impatiens irvingii</i> Hook. F. ex Oliv.			x					
Cyperaceae								
<i>Rhynchospora corymbosa</i> britcon	x		x	x	x	x		
<i>Scleria verrucosa</i> willd.						x		
Polygonaceae								
<i>Polygonum limbatum</i> Meisn	x		x					
Onagraceae								
<i>Ludwigia abyssinica</i> A. rich.				x				
Mimosaceae <i>Mimosa pudica</i>				x				
Hydrocaritaceae <i>Ottelia ulvifolia</i> walp.			x	x				

x: Species present.

B1, A1, A2: Sampling point upstream of the point of confluence.

B3, A4, A5: Sampling point downstream of the point of confluence.

Table 2: Water velocity (in m³/s) of Mokona, Mengoala rivers and the effluents of the SOSUCAM sugar factory in Mbandjock, Cameroon (P1: September 1991; P2: April 1992).

Sampling sites		Rivers	
		Mokona	Mengoala
Upstream	P1	0,47	0,16
	P2	0,39	0,13
Effluent	P1	0,03	0,01
	P2	0,06	0,0013
Downstream	P1	0,35	0,15
	P2	*	*

* Data not collected

The velocity was measured at A2 point (upstream) and at A5 point (downstream) for Mokona river, B1 (upstream) and B2 (downstream) for Mengoala river.

Temporal Variation of the Fauna

At sites A1 and A2, the number of taxa did not differ significantly between P1 and P2 ($p = 0.14$). Trichoptera represented 21.77 % of the population at A2 (Fig. 2). Chironomidae dominated the population of Diptera (Fig. 3). At A3 when the factory was not operational (P1), Diptera represented 45.17 % of the macroinvertebrate population (Fig. 2). The sample collected during the period of activity (P2) showed no significant alteration ($p = 0.08$). At site A4 when the factory was not operational (P1), Diptera were less numerous and represented by Chironomidae only. During the activity period, Syrphidae thrived and a regression of Chironomidae was noted (Fig. 3). A significant reduction in the number of taxa was observed compared to A2 ($P < 0.05$).

A proliferation of Culicidae (*Diptera*) was observed at site A5 (P2), where they represented 65% of the population. Ephemeroptera, Sphlounuridae, Heptageniidae, Caenidae and Heteroptera which were present at P1, were absent. *Diptera syrphidae* were sampled on the effluents at both P1 and P2 (Table 3).

On the Mengoala river at B1, Ephemeroptera *Baetidae* and *Diptera Chiromidae* constituted the essential of the population at sampling periods P1 and P2 (Fig. 4). B2 was characterized at P2 by the dominance of *Diptera Syrphidae*. Similarly, *Syrphidae* represented 93.64 % of the population at site B3 when the factory was operational. *Chironomidae* and Ephemeroptera *Siphonuridae* which constituted the essential of the fauna at P1 were absent (Table 4).

Table 3: Macroinvertebrates count (per 10 dip scoops) in the Mokona (A1-A5) river in Mbandjock, Cameroon by factory activity status: P1-non operational (September 1991); P2- operational (April 1992)

Organisms (Families)	Development stage	A1		A2		Effluent		A3		A4		A5	
		P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
Diptera													
Syrphidae	Larvae					23	311				340		1
Chironomidae	Larvae	94	40	74	115			145	25	6		15	1
Ceratopogonidae	Larvae				10				1				
Chaoboridae	Larvae										2		
Culicidae	Larvae										8		90
Heteroptera													
Naucoridae	Adults							4		2		2	7
Corixidae	Adults	1						3		13		1	13
Nepidae	Adults	3						3					
Notonectidae	Adults									2		2	
Mesoveliidae	Adults	1	1		1			16		20		1	
Veliidae	Adults	3											
Gerridae	Adults	1		3	1			9	1	7		2	
Hydrometridae	Adults			1				1				2	
Pleidae	Adults							6					
Decapoda													
Atyidae	Adults	9	1									1	
Coleoptera													
Hydraenidae	Adults											1	
Hydrophilidae	Adults			1				1		1		5	
	Larvae							2		1		4	
Haliplidae	Adults							3	5	8	1		2
Gyrinidae	Larvae											2	
Lymnebiidae	larvae												2
Elmidae	Adults			1				6					1
	Larvae			3				1					
Dryopidae	Larvae	3	1										
Dytiscidae	Adults							3					7
Hygrobidae	larvae												1
Ephemeroptera													
Heptageniidae	Larvae	4										6	
Caenidae	Larvae											1	
Siphonuridae	Larvae	5						16				20	
Ephemeridae	Larvae	3						10					
Baetidae	Larvae	2	5	10	110				32	15			
Trichoptera													
Hydroptilidae	Larvae			24									
Ecnomidae	Larvae			3									
Phryganeidae	Larvae	5											
Trichoptera perlidae	Larvae							1					
Odonata													
Platycnemidae	Larvae	2	1					15		1			
Aeschimidae	Larvae			4				1	1			1	
Calopterygidae	Larvae											9	
Coenagrionidae	Larvae	5		2				12		1			
Libellulidae	Larvae	1								2			
Corduliidae	Larvae			2				11					

Table 3 (continued)

Table 5 (continued)														
Organisms (Families)	Development stage	A1		A2		Effluent		A3		A4		A5		
		P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	
Basommatophora														
Planorbidae					2			40		25			12	
								9						
Ferrissidae			2					3		2				
lymnaeaidae								6	1	1			1	
Lamellibranchiata														
Sphaeriidae								3						
Anneida														
Achaeta	Adults							3						
Oligocheata	Adults				3									2
								31						
Total number of individuals		143	53	124	246	28	311	321	08	106	353	78	138	
Total number of taxa		18	9	8	10	2	1	23	10	15	5	16	14	

P1: Factory non operational

P2: Factory operational

A1, A2: Sampling points upstream of point of confluence

A4, A5: Sampling points downstream

Point A3 was upstream at P1 and downstream at P2, as the course of the effluent was modified.

Table 4: Macroinvertebrates count (per 10 dip scoops) in the Mengoala (B1-B3) river in Mbandjock (Cameroon) by factory activity status: P1-non operational (September 1991); P2- operational (April 1992)

Oganism (Family)	Development stage	B 1		Effluent		B2		B3	
		P1	P2	P1	P2	P1	P2	P1	P2
Diptera									
Simuliidae	Nymphe	1					-		
Syrphidae	Larvae			494	507	-	73		320
Chironomidae	Larvae	29	150				-	25	
Ceratopogonidae	Larvae				76		-		1
Athericidae	Larvae				11		-		
Culicidae	Larvae					-	4		18
Sciomyzidae heteroptera	Larvae		2						
Herbride	Larvae		1						
Corixidae	Adults	1					-	13	11
Nepidae	Adults						-	1	
Notonectidae	Adults		1				-	6	
Mesoveliidae	Adults	1					-	1	3
Veliidae	Adults	1	2				-		
Gerridae	Adults		2				-	1	3
Hydrometridae	Adults		2				-		3
Naucoridae	Adults		4				-		
Decapoda									
Grapsidae	Adults						-	1	
Atyidae plannipenna	Adults	11	20				-		
Osmylidae	Larvae						-	1	
Coleoptera									
Hydrophilidae	Larvae	3	2			-	6		2
	Adults		2				-		1
Haliplidae	Adults						-	3	

Table 4 (continued)

Organism (Family)	Development stage	B1		Effluent		B2		B3	
		P1	P2	P1	P2	P1	P2	P1	P2
Lymnebiidae	Adults					-		2	
Gyrinidae	Adults	2				-		2	
Elmidae	Adults	3				-	1		
Dryopidae	Adults					-	2		
Plecoptera									
Perlidae	Larvae					-		1	
Ephemeroptera									
Siphonuridae	Larvae	9	8			-		349	
potamanthidae	Larvae	2				-			
Baetidae	Larvae		260			-			
Odonata									
Platycnemidae	Larvae	1				-		1	
Basommatophora									
lymnaeidae	Adults	2				-		1	
Planorbidae	Adults					-		5	
Total number of individuals		64	458	498	594	-	86	412	362
Total number of Taxa		12	13	1	3	-	5	16	9

P1: Factory non operational; P2: Factory operational; B1: Sampling points upstream of point of confluence

B2, B3: Sampling points downstream of point of confluence.

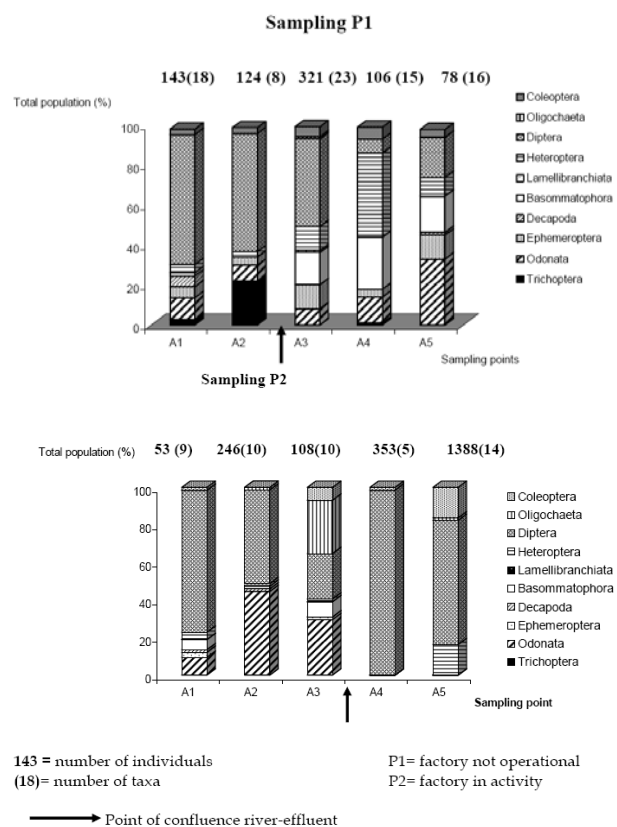
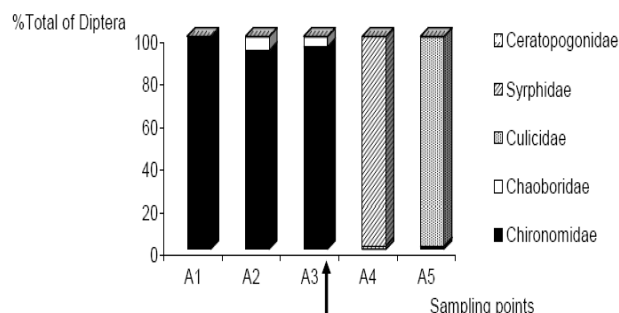


Figure 2: Effects of a sugar mill effluent on the longitudinal distribution of macroinvertebrates in the Mokona (A1-A5) River in Mbandjock (Cameroun)



143 = number of individuals
(18) = number of taxa

P1= factory not operational
P2= factory in activity

→ Point of confluence river-effluent

Figure 3: Effect of a sugar mill effluent on the longitudinal distribution of Diptera on the Mokona (A1-A5) river in Mbandjock, Cameroon.

Diversity Index

The diversity index for sites upstream from the site of confluence did not show any significant difference whether the factory was operational or not ($p = 0.24$). The variation in the diversity index became significant downstream from the site of confluence when the factory was operational.

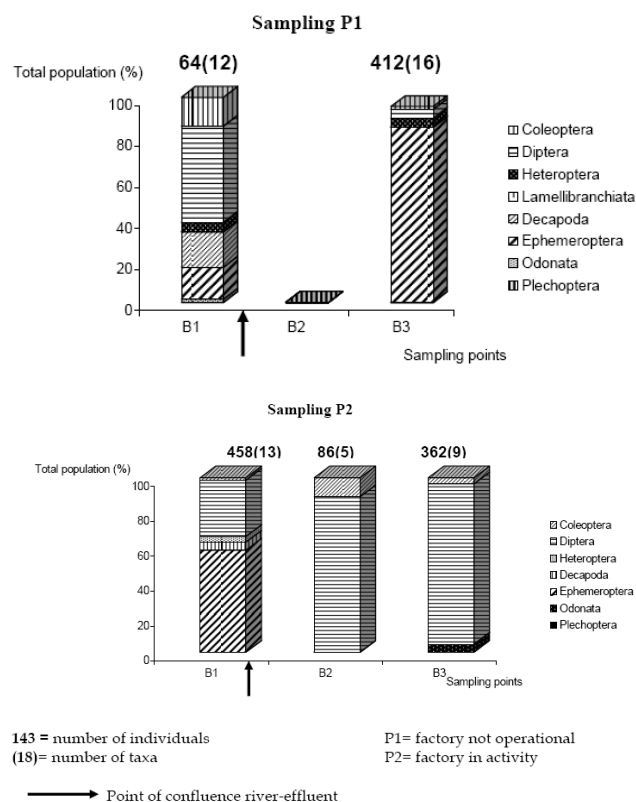


Figure 4: Effect of the Mbandjock sugar mill operational status on the longitudinal distribution of macroinvertebrates on the Mengoala (B1-B3) river

Discussion

A rich macroinvertebrates fauna was observed upstream and downstream of the Mokona and Mengoala rivers when the SOSUCAM sugar mill was not operational. Changes in the macroinvertebrate community and diversity became significant when the factory was operational. Concurrent investigation revealed that the period of activity was characterized by a heavy load of organic matter discharged into receiving rivers [12]. Under such conditions, only pollutant-tolerant saprophiles such as Diptera *Syrphidae* and Culicidae survive and thrive. The presence of Trichoptera Hydroptilidae and Ecnomidae upstream indicates that water of these areas have acceptable quality [13-14]. The deterioration of the water quality of these rivers is confirmed by the diversity index which decreased downstream when the factory is operational. The relatively low value of the diversity index at site A1 (P1) could be the consequence of water impoundment which was observed at this site. Downstream, the increased values of the diversity index illustrate a moderate organic pollution and auto-epuration. This reconstitution benefits from the combined action of some Diptera which degraded organic materials and the oxygenation by aquatic and periaquatic plants. The rapid recovery observed here is a characteristic of African streams which often harbour abundant flora [8].

In studies conducted in temperate zones (North America and Europe), organic industrial pollution leads to

enrichment of the aquatic fauna in Diptera Chironomidae, Chaoboridae, and in Oligochaeta Tubificidae [14-15]. In a river receiving the effluents of a corn factory, Foree [16] noted the absence of macroinvertebrates. Chuter [17], studying the pollution by effluents of dairy farming in a tropical environment, reported a proliferation of Tubificidae, Ancyliidae and Chironomidae. He noted that, effluents are harmful to Ephemeroptera, Ostracoda, Hydropsychida and Simuliidae. None of these studies noted the proliferation of Syrphidae, nor the presence of Culicidae observed in the present study. Methods of collecting aquatic macroinvertebrates for the evaluation of the pollution of current water use the Surber, the Petersen and Eckman dredge and artificial substrates [18]. These methods rarely collect snail hosts of human parasites. The modifications observed in the macro invertebrates population structure and the Shannon & Weaver diversity index (Figure 5) corroborate those of other authors [19-20]. The dip scoop which is the standard method for the collection of snail hosts of schistosomes could equally be used for the macroinvertebrates biomonitoring of freshwater industrial pollution in tropical environments. The method could be used by community-based workers with minimal training for macroinvertebrates identification in resource limited areas (21).

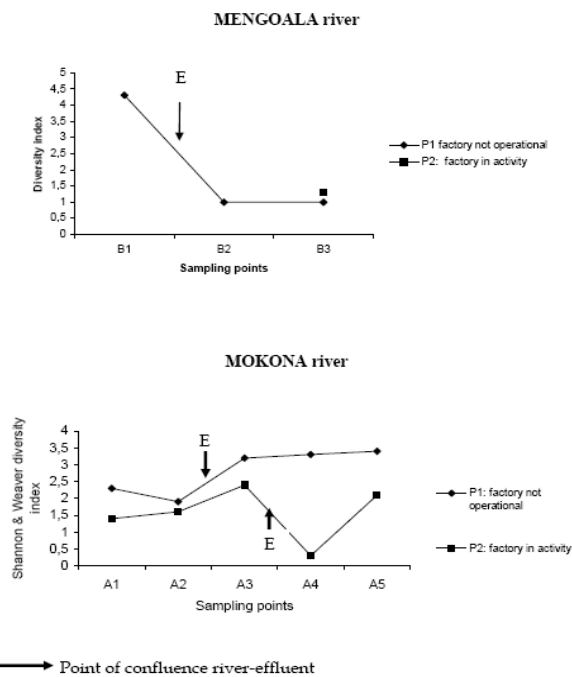


Figure 5: Effect of effluents of SOSUCAM sugar mill effluents on the Shannon & Weaver diversity index of macroinvertebrates in the Mengoala (B1-B3) and Mokona (A1-A5) rivers in Mbandjock, Cameroon.

Conclusion

The discharge of wastes from the sugar factory SOSUCAM into the Mokona and Mengoala rivers contributes to the deterioration of the biological quality of their waters. The pollution resulted in the reduction of the

number and diversity of taxa. Syrphidae were the main taxa found downstream of the sites of confluence. The standard dip scoop method which is used to sample freshwater snails can also be used for freshwater pollution biomonitoring in tropical environments with limited research resources. The value of Syrphidae as indicator of sugar mill effluent pollution requires further investigations.

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References

1. La Dou, J.: Transfert de technologie «à risque» vers les pays en développement. *Cahiers santé*, **1992**, 2, 153-160.
2. Yaméogo, L.; Resh, V. H.; Molyneux D. H.: Control of river blindness in West Africa: Case history of biodiversity in a disease control program. *Eco. Health*, **2004**, 1, 172-183.
3. Moor, J. W.: Diversity and indicator species as measures of water pollution in a sub arctic lake. *Hydrobiologia*, **1979**, 66 (1), 73-80.
4. Ramade, F.; Cosson, R.; Echaubard, M.; Le bras, S.; Moreteau, J. C.; Thybaud, E.: Détection de la pollution des eaux en milieu agricole. *Bull. Ecol*, **1984**, 15 (1), 21-37.
5. Metcalfe, J. L.: Biological water quality assessment of running status in Europe. *Environ. Pollu*, **1989**, 60, 101-139.
6. Resh V. H.: Use of freshwater benthic macroinvertebrates and rapid assessment procedures in developing and newly industrialized countries. In: Biological Assessment and criteria: Tools for water resources planning and decision-making. Davis, W. S., Simon, T. P. (Eds). Boca Raton, FL: Lewis Publishers, **1995**; pp. 161-177.
7. Solimini, A.G.; Gulia, P.; Monfrinoti, M.; Carchini, G.: Performance of different biotic indices and sampling methods in assessing water quality in the lowland stretch of the Tiber River. *Hydrobiologia*, **2000**, 423, 197-208.
8. Dejoux, C.: La pollution d'origine industrielle. In "la pollution des eaux continentales africaines". ORSTOM (Ed.) Paris, **1988**; pp. 289-330.
9. Yaméogo, L., Crosa, G., Sammon, Nabé, K., Tholley, D.; Calamari, D.: Long-term assessment of insecticide treatments in West Africa: Aquatic Entomofauna. *Chemosphere*, **2001**, 44, 1759-1773.
10. Brown, D. S.: Methods. In "Freshwater Snails of Africa and their Medical Importance". Taylor and Francis (Ed.), London, **1980**; pp. 435-450.
11. Tchounwou, P. B.; Lantum, D. M.; Monkiedje, A.; Takougang, I.; Barbazan P.: The urgent need for environmental sanitation and safe drinking water supply in Mbandjock, Cameroon. *Archives of Environmental Contamination and Toxicology*, **1997**, 33, 17-22.
12. Durand, J. R.: Lévêque, C. Faune et aquatique de l'Afrique soudano-sahélienne. Tomes I et II. ORSTOM (Ed). Paris, **1980** ; P. 873
13. Takougang, I.; Tchounwou, P. B.; Barbazan, P.: Impact des effluents d'un complexe agroindustriel sucrier sur la distribution des mollusques dulçaquicoles à Mbandjock (Cameroun). *Cahier Santé*, **1993**, 3(3), 178-182.
14. Sladeczek, V.: System of water quality from the biological point of view. *Arch. Hydrobiol*, **1973**, 7, 1-218.
15. Mattingly, R. L.; Cummins, K. W.; King, R. H.: The chironomid. *Hydrobiology*, **1981**, 77, 161- 165.
16. Anonymous: Les rivières de Haute-Normandie vues par les invertébrés. Direction Régionale de l'Environnement de Haute-Normandie, **1999**.
17. Foree, E. G.: Industrial wastes. Fermentation industries-pharmaceutical, corn and sugar. *J. wat. Poll. Cont. Fed.*, **1975**, 47(6), 1398-1402.
18. Chutter, F. M.: An empirical biotic index of the quality of water in South African streams and rivers. *Water Research*, **1972**, 6, 19-30.
19. APHA: Standard Methods for the examination of water and wastewater. 17th Edition. American Public Health Association, AWWA, WPGF, Washington DC, USA, **1990**,
20. Heister, R. D.: The biotic index as a measure of organic pollution in streams. *Amer. Biol. Teach.*, **1972**, 2, 79-83.
21. Fore, L. S.; Paulsen, K.; O'Laughlin, K.: Assessing the performance of volunteers in monitoring streams. *Freshwater Biology*, **2001**, 46(1), 109-123.