Mosquito development and biological control in a macrophyte-based wastewater treatment plant

I.M. Kengne Noumsi*, A. Akoa*, R. Atangana Eteme*, J. Nya*, P. Ngniado*, T. Fonkou and F. Brissaud*****

*Wastewater Research Unit, Faculty of Science, University of Yaounde I, P.O. Box: 8404 Yaounde, Cameroon (E-mail: *ives_kengne@yahoo.fr*)

**Faculty of Science, University of Dschang, P.O. Box: 67 Dschang, Cameroon (E-mail: *tfonkou@yahoo.fr*)

***Hydrosciences, University of Montpellier II, 34095 Montpellier Cedex 05, France (E-mail: *brissaud@msem.univ-montp2.fr*)

Water Science & Technology **Vol 51 No 12 pp 201–204** © IWA Publishing 2005

Abstract A one-year study of the proliferation of mosquito in a *Pistia stratiotes*-based waste stabilization ponds in Cameroon revealed that *Mansonia* and *Culex* were the main breeding genera with about 55% and 42% of the total imagoes respectively. Though the ponds represent a favorable breeding ground for mosquitoes, only 0.02% of captured imagoes was *Anopheles gambiae*, suggesting that this wastewater treatment plant does not significantly contribute to the development of the malaria vector in the area. *Gambusia* sp. introduced to control mosquito population in the ponds acclimatized relatively well in most of the ponds (B3–B7) and their feeding rate without any diet ranged from 15.0 to 50.2 larvae/day for a single fish.

Keywords Biological control; *Gambusia* sp.; macrophyte lagoons; mosquito; wastewater treatment

Introduction

Many advantages plead in favor of waste stabilization ponds (WSP) technology in developing countries which lack capital and qualified manpower to run sophisticated systems: i) its simplicity of construction and operation, ii) low operation and maintenance costs and iii) capability to withstand excess organic and hydraulic loads. Furthermore, most developing countries have a warm tropical and subtropical climate that allows high biological activity year-round, which means high efficiency of the system (Denny, 1997; Kivaisi, 2001). Unfortunately, large water bodies covered by macrophytes may represent a favorable breeding ground for mosquitoes, thus providing nuisance pests and or disease vectors to the nearby communities (Dill, 1989; Russell, 1999). Methods to control mosquito breeding at acceptable level include periodic spraying of insecticides (expensive and sometimes ecologically dangerous), periodic macrophyte harvesting and/or the use of mosquito predators such as larvivorous fishes (Charudattan, 1987; Eldridge and Martin, 1987).

This work was undertaken in order to seek how to minimize the proliferation of such disease vectors or nuisance pests in a *Pistia stratiotes*-based treatment plant devoted to treat approximately 45 m^3/day of domestic sewage from the Biyem-Assi (Yaounde) residential quarter. The first step of the investigation aimed at assessing the biodiversity of mosquitoes breeding in this plant. The second step focused on the biological control of mosquitoes with *Gambusia* sp.

Methods

This work was carried out in a 0.1 ha WSP system comprising a decantation–digestion pond (B0) followed by a series of 7 rectangular ponds vegetated mainly with the floating macrophyte *Pistia stratiotes.* Details of its construction and operation are given in Kengne Noumsi (2000).

Biodiversity of the culicids was assessed five times a month from November 1997 to October 1998 taking into account immature and adult mosquito stages breeding in all the macrophyte ponds (B1–B7). Concomitantly, the following physicochemical characteristics of water were measured at the outlet of each pond: pH, temperature, conductivity, dissolved oxygen, BOD_5, SS and turbidity.

Immature free living mosquitoes were sampled by randomly dipping at 5 stations in each lagoon with a 250 mL dipper while, for attached ones, 5 macrophyte roots were washed in a white basin by gently swirling them in water to release the mosquito larva and nymphs. Adult mosquitoes were trapped using a $0.25\,m^2$ trap derived from the model proposed by Aubin *et al.* (1973). In each pond, 3 traps were randomly located and inspected after 24 hours. Identification was done according to the immature mosquito determination keys of the Ethiopian region (Hopkins, 1952) and the adult mosquito key of the Ethiopian region (Edwards, 1941).

Prior to the assessment of their feeding rate, 50 *Gambusia* sp. fishes were allowed for a week to acclimatize to the rough conditions of the different macrophyte ponds. In each pond (except B1 which had an excess of sludge), 50 individuals ($25 \leq$ size ≤ 45 mm) collected in the surrounding natural wetlands were introduced in a $0.4\,m \times 0.4\,m \times 0.4\,m$ wooden box wrapped in a net. After this period, 5 fishes without any diet and 300 mosquito larvae at 3 to 4th stage belonging both to the genus *Culex* and *Mansonia* (most frequent species in the plant) were introduced in aquariums containing 3.5 L of water and their number evaluated after 24 hours. Mosquito fish and water were from each pond where the fish had survived. The feeding capacity of *Gambusia* was evaluated using this formula: $Nle = Ni - (Nlp + Nn)$, with Nle the number of mosquito larvae eaten, Ni the number of mosquito larvae introduced ($Ni = 300$ larvae), Nlp the number of mosquito larvae present in the aquarium after 24 hours and Nn the number of nymphes.

Results and discussion

A total of 17,568 adult mosquitoes were captured during the investigation period among which 54.8 and 41.9% belonged respectively to the genus *Mansonia* and *Culex* (Table 1). Identification of species both at the immature and mature stages indicated that most of the *Culex* belonged to *C. quinquefasciatus, C. decens* and *C. tigripes,* while for *Mansonia* it was both *M. africana* and *M. uniformis.* About 3% of captured imagoes were *Coquillettidia* (especially *C. metallica*), *Ficalbia* and *Anopheles*. Though not found at adult stage, a few *Aedes* larvae were found in ponds B1 and B2 only during the month of December 1997. Taking into consideration the whole plant, approximately 43 mosquitoes emerged on an

Table 1 Biodiversity of adult mosquitoes in the plant

Immature stage characteristics	Genus	Number of imagoes captured during the whole period of study			% with respect to the total number of imagoes
		Male	Female	Total	
Living attached to *Pistia stratiotes* roots	*Mansonia*	3,969	5,654	9,623	54.78
	Coquillettidia	94	107	201	1.14
	Ficalbia	46	57	103	0.59
Free living	*Culex*	3,839	3,529	7,368	41.94
	Anopheles	0	3	3	0.02
	Aedes	0	0	0	0
	Unidentified *	–	–	270	1.53
	Total	7,948	9,350	17,568	100

*Parts essential for identification were lost during collection.

average basis per m^2/day. Luckily, bearing in mind the endemic malaria situation of the region (Manga *et al.*, 1992), this plant can be considered as not favoring the development of the malaria vector, since only 0.02% of the total capture was *Anopheles gambiae*.

The larvivorous fishes acclimatized relatively well in the latest ponds (B5–B7) since no death was encountered during the one week period of study (Table 2). On the contrary, a stabilization of the death rate was observed the 3rd and 4th day in ponds B3 and B4 (respectively 35 and 46 fishes alive). In pond B2, no fish survived after the 2nd day.

The death rate of fishes could be due to the rough conditions of the milieu (Table 3). In pond B2 for example, the low level of dissolved oxygen (0.8 mg/L) and the high level of SS (149 mg/L) certainly hampered the survival of fishes. The increase of their acclimatization could be due to the progressive improvement of the water quality. In pond B5 where no death was encountered despite a still high NH_4 content, the level of D.O increased up to 4 mg/L, while SS dropped to 64 mg/L. These conditions, though remaining difficult, seemed to permit their survival.

The feeding rate of *Gambusia* ranged from 15.0 to 50.2 larvae/day for a single fish (Table 4). The highest average rate was recorded in aquarium receiving water from pond B6 (39.4 larvae/day) and the lowest in water from pond B4 (27.4 larvae/day). However, analysis of variance of Kruskal–Wallis revealed no significant difference between the ponds ($H = 5.71$, $df = 4$, $p = 0.223$). The statistical insignificance of the number of larvae consumed between the various pounds could be explained by the fact that once acclimatized, fishes were no longer influenced by the water quality. The average number of mosquito larvae consumed for all the ponds was estimated at approximately 31 larvae/fish/day. This could be attributed to the fact that no fish was submitted to a diet prior to the experiment.

Table 2 Number of fishes alive in the various ponds in function of time ($n = 5$)

	Number of fishes alive (mean ± SEM)					
	B2	B3	B4	B5	B6	B7
Day 1	9 ± 6	41 ± 3	47 ± 2	50 ± 0	50 ± 0	50 ± 0
Day 2	0 ± 0	36 ± 4	47 ± 2	50 ± 0	50 ± 0	50 ± 0
Day 3	0 ± 0	35 ± 4	47 ± 2	50 ± 0	50 ± 0	50 ± 0
Day 4	0 ± 0	35 ± 4	46 ± 2	50 ± 0	50 ± 0	50 ± 0
Day 5	0 ± 0	35 ± 4	46 ± 2	50 ± 0	50 ± 0	50 ± 0
Day 6	0 ± 0	35 ± 4	46 ± 2	50 ± 0	50 ± 0	50 ± 0
Day 7	0 ± 0	35 ± 4	46 ± 2	50 ± 0	50 ± 0	50 ± 0
% survival after one week	0	70	92	100	100	100

Table 3 Physicochemical characteristics of the wastewater in the ponds

Ponds	Physicochemical properties of wastewater (mean ± SEM)						
	pH	Temperature (°C)	Conductivity (μS/cm)	D.O (mg/L)	BOD_5 (mg/L)	SS (mg/l)	N-NH_4^+ (mg/L)
B1	7.07 ± 0.04	26.4 ± 0.2	1,292 ± 26	0.3 ± 0.0	308 ± 12	277 ± 13	89.2 ± 4.6
B2	7.12 ± 0.04	26.6 ± 0.2	1,258 ± 27	0.8 ± 0.1	212 ± 13	149 ± 9	85.6 ± 4.7
B3	7.18 ± 0.03	26.7 ± 0.2	1,215 ± 22	1.7 ± 0.2	173 ± 10	103 ± 7	79.1 ± 3.6
B4	7.22 ± 0.04	26.7 ± 0.2	1,147 ± 23	2.2 ± 0.2	173 ± 9	70 ± 13	71.4 ± 3.7
B5	7.26 ± 0.04	26.8 ± 0.2	1,094 ± 22	3.6 ± 0.3	135 ± 8	64 ± 4	65.4 ± 3.2
B6	7.30 ± 0.04	26.7 ± 0.2	1,045 ± 23	4.4 ± 0.2	101 ± 7	45 ± 3	60.2 ± 3.3
B7	7.63 ± 0.06	26.7 ± 0.3	903 ± 28	9.6 ± 2.0	83 ± 2	30.1 ± 2	52.3 ± 3.2

Table 4 Mean number of mosquito larvae eaten by a single fish in 24 hours ($n = 5$)

Origin of water	Number of larvae eaten/day	
	Mean	Minimum – Maximum
B3	30.3	18.2–50.2
B4	27.9	15.0–45.0
B5	29.4	15.4–39.6
B6	39.4	24.0–47.2
B7	25.9	16.0–35.4

Conclusion

As any other standing pool, this *Pistia*-based treatment plant represents a favorable breeding ground for mosquitoes. However, it can be considered as not favoring the development of the malaria vector, since *Anopheles gambiae* was found only accidentally and in small number. These results highlight the dilemma of sanitary engineers and local public health authorities that have to treat water at low-cost while reducing the nuisance pest.

Successful trials of the acclimatization of *Gambusia* in most of the treatment ponds and their feeding rate without any diet lower than 25 mosquito larvae/day are viewed as very promising. *Gambusia* are present in streams and marshes of Yaounde, and could be domesticated for biological control of mosquitoes in such treatment plants.

Acknowledgements

This work was supported by the International Foundation for Science, IFS (grant n° 1580/3F) and the French Ministry of Foreign Affairs (Programme CAMPUS, grant n° 94 016 400).

References

Aubin, A., Bourassa, J.P. and Pellisier, M. (1973). An effective emergence trap for the capture of mosquitoes. *Mosquito News*, **33**(2), 250–252.

Charudattan, R. (1987). Impact of pathogens on aquatic plants used in water treatment and resource recovery systems. In *Aquatic Plants for Wastewater Treatment and Resource Recovery*, Reddy, K.R. and Smith, W.H. (eds.), Magnolia Publishing Inc., Orlando, Florida, pp. 795–803.

Denny, P. (1997). Implementation of constructed wetlands in developing countries. *Wat. Sci. Tech.*, **35**(5), 27–34.

Dill, C.H. (1989). Wastewater wetland: User friendly mosquito habitats. In *Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and agricultural*, Hammer, D.A. (ed.), Lewis Publishers, Chelsea, MI, pp. 665–668.

Edwards, F.W. (1941). *Clé des Culicinae adultes de la région éthiopienne*, ORSTOM, Paris.

Eldridge, B.F. and Martin C.V. (1987). Mosquito problems in sewage treatment plants using aquatic macrophytes in California. In *Proceed. & Papers of the 55th Ann. Conf. of the California Mosquito and Vector Control Association*, pp. 87–91.

Hopkins, G.H.E. (1952). *Mosquitoes of the Ethiopian Region. Part 1: Larval bionomics of mosquitoes and taxonomy of culicine larvae*, Brit. Mus. Nat. Hist. 2nd edn., London.

Kengne Noumsi I.M (2000). *Evaluation d'une station d'épuration des eaux usées domestiques par lagunage à macrophytes à Yaoundé: Performances épuratoires, développement et biocontrôle des Diptères Culicidae*. Thèse Doctorat 3e Cycle, Univ. Yaoundé I, Cameroon.

Kivaisi, A.K. (2001). The potential for constructed wetland for wastewater treatment and reuse in developing countries. *A review. Ecol. Eng.*, **16**, 545–560.

Manga, L., Robert, V., Messi, J., Desfontaine, M. and Carnavale, P. (1992). Le paludisme urbain à Yaoundé Cameroun: Etude entomologique de deux quartiers centraux. *Mem. Soc. R. Belge Ent.*, **35**, 155–162.

Russell, R.C. (1999). Constructed wetlands and mosquitoes: Health hazards and management options – An Australian perspective. *Ecol. Eng.*, **12**, 107–124.