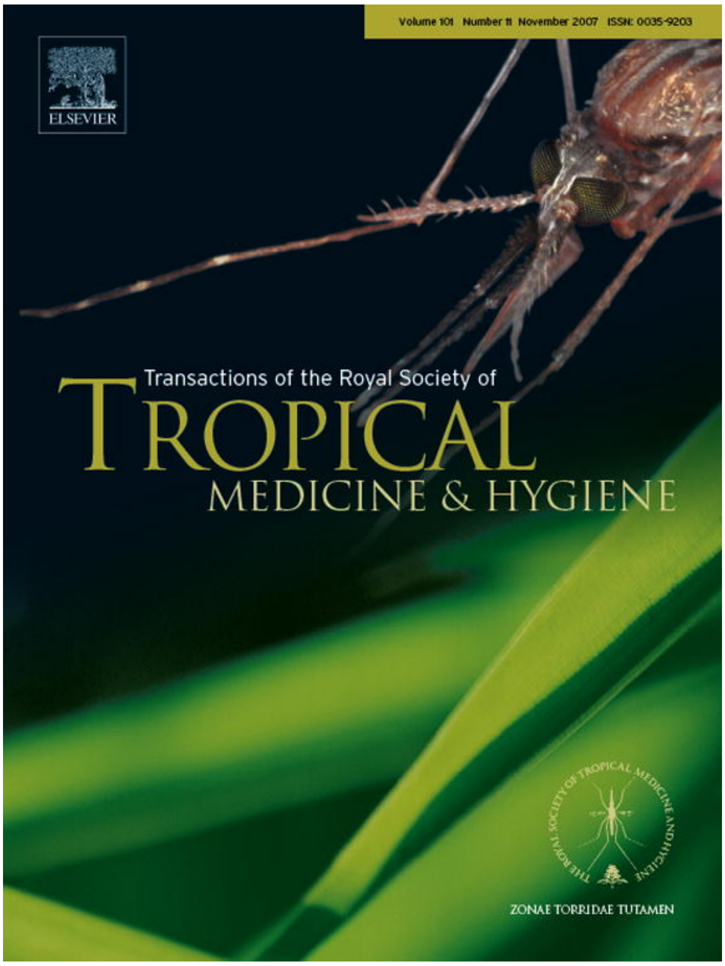
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Simple intervention to reduce mosquito breeding in waste stabilisation ponds

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Summary Waste stabilisation ponds (WSP) are the preferred method for treatment of urban wastewater in low-income countries but, especially in arid regions, the pond systems can be important breeding sites for mosquitoes of medical importance. In a WSP system in Faisalabad, Pakistan, we assessed the impact of simple environmental interventions on mosquito occurrence and abundance. Reducing the amount of floating matter in the ponds, eliminating emergent vegetation and repairing cracks in the cement structure reduced the number of mosquito-positive samples in the intervention ponds to almost zero, whereas the control ponds had a significant number of positive samples. This suggests that a combination of simple low-cost interventions is a feasible environmental management strategy for vector control in WSP systems that are located in areas where medically important mosquitoes may breed in the shallow ponds.

1. Introduction

Waste stabilisation ponds (WSP) are considered the most appropriate way to treat the increasing flows of urban wastewater in tropical and subtropical regions of the world. WSPs provide significant environmental and health benefits by preventing surface water pollution but, especially in arid regions, the large, shallow and perennial basins can provide breeding opportunities for locally important vectors of human disease. One of the few studies on this subject focused on a system of WSPs outside the city of Faisalabad, Pakistan. The study found that the WSP accommodated a substantial number of *Anopheles* and *Culex* mosquito species, especially *A. subpictus*, *C. quinquefasciatus* and *C. tritaeniorhynchus*, and thereby increased the potential for

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the occurrence of vector-borne diseases among the urban population (Mukhtar et al., 2006). Some of the potential vectors of disease were found to be associated with emergent vegetation and floating matter along the edges of the ponds. It was therefore proposed that regular removal of emergent grass along the margins of the ponds and improved pond maintenance was likely to reduce mosquito production. This paper reports the findings of a 6-month intervention study assessing the effect of vegetation removal and improved pond maintenance on immature mosquito abundance in Faisalabad, Pakistan.

2. Materials and methods

2.1. Waste stabilisation ponds

The WSP system under study was located in a densely populated periurban area of Faisalabad (population >2 million) and received primarily domestic wastewater. It consisted of two parallel sets of six ponds, with each set consisting of three anaerobic ponds, two facultative ponds and one maturation pond. The anaerobic ponds were 150 m long, 200 m wide and 3.5 m deep and were designed for anaerobic digestion of untreated wastewater. The facultative ponds received wastewater from the anaerobic ponds and removed organic matter through a combination of aerobic and anaerobic processes. Facultative ponds were designed to be oxygen-rich as their function was pathogen removal. Both facultative and maturation ponds were 500 m long, 250 m wide and 1.5 m deep. The ponds in each series were connected through open concrete channels. Prior to the intervention, owing to poor maintenance of the system, the cemented slanting walls of the ponds, particularly around the anaerobic ponds, had broken at different points. This led to the emergence of dense vegetation along the pond margins. Removal of the grids at the inflow to the anaerobic ponds had allowed for large pieces of floating solid waste, including tree branches, plastic bags and empty bottles, to enter the anaerobic ponds. However, in the facultative and maturation ponds only grass at a few points and occasionally floating waste along the margins were visible.

2.2. Intervention

The intervention was implemented in one set of anaerobic, facultative and maturation ponds whilst the other identical set of ponds served as a control. As a first intervention, the grid in the drain providing water to the intervention series of ponds immediately before the water entered the anaerobic ponds was reinstalled to reduce the inflow of floating waste. In the six intervention ponds, all floating matter was removed at the start of the study and, because of the reinstalled grid, did not reappear in the ponds. A labourer was hired to clean the grid, to remove any emergent grass and was provided with cement to fix cracks along the edges of the ponds as they emerged. A technician from the local utility supervised the work during his normal daily inspections. Members of the research team confirmed that no emergent vegetation was seen at any part of the intervention ponds throughout the study period. The operational cost of the intervention piloted in the study amounted to approximately US$13 per month including manpower and cement.

2.3. Larval collections

From 16 March to 31 August 2004, mosquito larvae were collected fortnightly from intervention and control ponds. The samples were collected using a standard 350 ml aluminium dipper with a 1 m handle (Herrel et al., 2001). From each pond, six well dispersed samples were collected from different points along the margin. A sample represented 30 dips taken within a 5 m^2 area. For the control ponds, the percentage area of pond margin covered by vegetation was calculated at the start of the study to decide on the number of samples to be taken from sites with and without vegetation. On each collection date, three (of six) samples were collected from emergent vegetation in the anaerobic ponds but only one sample (of six) was collected from emergent vegetation in the facultative and maturation ponds (Mukhtar et al., 2006).

2.4. Mosquito identification

Collected larvae were preserved in vials containing 70% isopropyl or alcohol for later identification. The third and fourth instar larvae were identified, whilst early instars and damaged larvae were only counted, noted and discarded. Pupae were not counted or recorded. For further information on the identification of mosquitoes, see Mukhtar et al. (2006). Samples were classified as positive or negative for each of the mosquito species.

3. Results

A total of 936 samples (28 080 dips) was taken from intervention and control ponds combined. The overall abundance both of *Culex* and *Anopheles* mosquitoes was greatest in the anaerobic ponds, followed by the facultative ponds and least in the maturation ponds (Table 1). However, for *A. culicifacies* and *A. stephensi*, the trend appeared to be different. Overall, seven different mosquito species were found (four *Culex* and three *Anopheles* species), with *C. quinquefasciatus* being the most abundant.

In the intervention ponds the percentage of samples positive was reduced to zero for *Anopheles* and almost zero for *Culex*, whereas in the control ponds 19.2% of samples were positive for *Anopheles* and 34.0% for *Culex* (Table 1). In the control ponds, the sampling gave a very heterogeneous result, with 65% of the samples being negative; all positive samples were found in habitats with vegetation. Owing to the magnitude of the observed differences between intervention and control ponds, no statistical analyses were performed.

4. Discussion

The mosquitoes found in the particular habitats surveyed in this study included confirmed vectors of malaria, Japanese encephalitis and West Nile virus in Pakistan or in the Indo-Pakistan subcontinent (Herrel et al., 2001; Peiris and

Table 1 Percentage of samples positive (% +ve) and arithmetic mean (AM) number of larvae per sample for *Culex* and *Anopheles* mosquitoes in the control and intervention waste stabilisation ponds in Faisalabad, Pakistan

Species (total No. collected)	Anaerobic ponds				Facultative ponds				Maturation ponds				All ponds			
	Control (n = 234)[a]		Intervention (n = 234)		Control (n = 156)		Intervention (n = 156)		Control (n = 78)		Intervention (n = 78)		Control (n = 468)		Intervention (n = 468)	
	% +ve	AM	% +ve	AM	% +ve	AM	% +ve	AM	% +ve	AM	% +ve	AM	% +ve	AM	%	AM
A. stephensi (3984)	0.4	0.2	–	–	9.6	16	–	–	7.7	18	–	–	4.7	9	–	–
A. subpictus (16 909)	27.0	64	–	–	6.4	8	–	–	5.1	9	–	–	16.5	36	–	–
A. culicifacies (936)	–	–	–	–	4.5	3	–	–	5.1	6	–	–	2.4	2	–	–
Total *Anopheles* (21 829)	27.4	65	–	–	12.8	26	–	–	7.7	34	–	–	19.2	47	–	–
C. quinquefasciatus (164 476)	51.2	687	–	–	7.1	23	–	–	2.6	0.6	–	–	28.4	351	–	–
C. tritaeniorhynchus (70 258)	24.8	119	–	–	16.0	185	–	–	10.3	172	–	–	19.4	150	–	–
C. pipiens (29 866)	35.0	121	–	–	1.3	3	0.6	0.2	1.3	14	–	–	18.4	64	0.2	0.1
C. pseudovishnui (12 793)	1.2	39	–	–	11.5	15	–	–	9.0	16	–	–	6.0	27	–	–
Total *Culex* (277 393)	51.7	966	–	–	19.2	227	0.6	0.2	10.3	204	–	–	34.0	593	0.2	0.1
Total mosquitoes (299 222)	52.2	1031	–	–	19.9	253	0.6	0.2	11.5	237	–	–	34.6	639	0.2	0.1

[a] No. of samples in parentheses.

Amerasinghe, 1994). Simple maintenance and management measures focusing on eliminating emergent vegetation and removing floating matter eliminated mosquito breeding from the WSPs. In the control ponds, where the interventions were not implemented, the relative importance of the different pond types and species preferences were entirely comparable with a previous survey in the same system (Mukhtar et al., 2006).

Based upon the findings, it must be recommended that vegetation management and maintenance of the concrete structures and waste inflow to WSPs be improved in areas with a risk of mosquito-borne diseases or where there is a mosquito nuisance. Similar interventions have been proposed by Agunwamba (2001) following his observations of the WSP systems outside Nsukka, Nigeria, where regular dredging of the ponds was also called for. Kengne Noumsi et al. (2005) have proposed the introduction of larvivorous fish in WSPs to control mosquito populations further.

Environmental management is receiving renewed attention as a method for control of vector-borne diseases such as malaria (Keiser et al., 2005); however, there is a need for more evidence that specific interventions in specific areas are effective and can contribute to overall disease control. The intervention presented in this paper may provide such a case, contributing to a reduced risk of disease transmission in a specific ecosystem.

Authors' contributions: FK and WvdH developed the study protocol; MM and JHJE assisted in the study design and oversaw data collection; MM identified the collected larvae; JHJE and FK carried out data entry and analysis and drafted the manuscript; all authors participated in interpretation of the data, critically reviewed subsequent drafts and read and approved the final manuscript. JHJE and FK are guarantors of the paper.

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Conflicts of interest: None declared.

Ethical approval: Not required.

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