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Impacts of organophosphate pesticide, sumithion on water quality and benthic invertebrates in aquaculture ponds

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ABSTRACT

This experiment was carried out to evaluate the effect of an organophosphate pesticide, sumithion on water and sediment quality and benthic invertebrates in aquaculture ponds for 120 days. Three treatments were tried in duplicate: no sumithion (control), weekly application of 1.0 mg/L sumithion (Low dose treatment) and 2.0 mg/L sumithion (High dose treatment). Among the different water quality parameters, transparency, NO_3–N and PO_4–P concentrations were significantly ($p < 0.05$) decreased in sumithion high dose and low dose, compared to control. The pH, organic matter (%), available phosphorus (mg/L) and total nitrogen (%) of bottom-sediment also did not vary significantly ($p < 0.05$) among the treatments. Seven genera of benthic invertebrates belonging to Chironomidae, Oligochaeta and Mollusca were identified over the experimental period. The abundances of benthic invertebrates (number per m^2) were significantly ($p < 0.05$) decreased in both groups treated with summation, compared to control without pesticide. The findings suggest that sumithion had adverse effect on abundance of benthic invertebrates that might have also negative impact on culture animals in aquaculture ponds.

1. Introduction

Pesticide usage in Bangladesh started from mid 1950s and gained momentum in late 1960s with the introduction of green revolution through the use of high yielding variety (HYV) rice in the country (Rahman, 2004). Pesticides have been promoted and increased in Bangladesh to intensification in crop production for overly growing population. Farmers have been receiving technical supports and considerable subsidies from the government over the years (Rasul and Thapa, 2003). The application of pesticides may lead to the contamination of the aquatic environment through several ways including spray drift, runoff and leaching (Van den Brink, 2013). Contamination of water by pesticides, either directly or indirectly can lead to fish kills or reduced fish productivity in the natural waters. Pesticides can directly affects fish through alteration in normal behavior (Satyavardhan, 2013; Ullah et al., 2014; Rani and Kumaraguru, 2014), physiological function (changes in hematological parameters), and histo-architectural changes in liver, kidney, intestine etc. (Saeedi et al., 2012; Salam et al., 2015; Sharmin et al., 2015). Pesticides indirectly affect the aquatic ecosystem by interrupting the aquatic food chain resulting in the loss/shift in abundance of natural species (Parveen and Faisal, 2002). It can also make the fish more susceptible to predators by decreasing habitat suitability and changing their behavior as well, which is a direct effect as a consequence of indirect effect (Prashanth et al., 2011; Gill and Raine, 2014). Results have shown that these indirect effects can be sometimes more vital than the direct ones (Murthy et al., 2013).

Benthic invertebrates are very important component of the aquatic food chain providing about 60% of total natural food items for bottom-feeding fish in aquaculture ponds (Ali et al., 1987). They also play an important role in sediment-water interactions through their burrowing and feeding activities. They re-suspend the ponds bottom and help in the exchange of nutrients, dissolved gases and other materials between sediments and overlying water.

In Bangladesh, more than 300 types of pesticides are used for crop protection in agriculture (Habib et al., 1984). Among them, sumithion, the *O*, *O* dimethyl *O*-(3-methyl-4-nitrophenyl) is important one which falls under the organophosphate group. It is effective to control wide range of important insects and certain other arthropod pests in the paddy fields. It is also used in larval

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rearing fish pond to control tiger bug. Since sumithion is widely used for crop protection and for eradication of aquatic insects in aqua-ponds, it is very important to know the extent of damage made by this chemical to fish and other aquatic life. Aquaculture plays an important role to reduce protein deficiency, generating employment, reducing poverty and earning foreign exchange. Bangladesh ranked fourth in world aquaculture production contributing 1.72 million metric tons in 2012 (FAO, 2014) of which more than 80% come from extensive/semi-intensive aquaculture ponds. Most of the fish production are based on natural productivity of aquaculture ponds. Therefore, application of pesticides are likely to degradation of pond ecosystem, which in turn, reduce the fish production in aquaculture ponds.

The present experiment is designed to determine the effects of a widely used pesticide, sumithion, on the water quality and benthic invertebrates in aquaculture ponds in absence of fish.

2. Materials and methods

2.1. Experimental design and pond preparation

This study was conducted in six earthen ponds (60 m^2 each) situated in the field laboratory of the Faculty of Fisheries, Bangladesh Agricultural University, Mymenshingh, Bangladesh for a period of 120 days between February and June, 2014. The ponds were equal in size and similar in shape, depth, basin conformation, bottom type and exposed to sunlight. The water depth was maintained to a maximum of 1.5 m using water supply/drainage facilities. Three treatments were tried in duplicate: ponds without sumithion (Control), with sumithion at a weekly dose of 1.0 mg/L (Low dose) and with sumithion at 2.0 mg/L (High dose). The ponds were assigned randomly to different treatments.

2.2. Measurements of water quality parameters

Various physicochemical parameters of water, such as temperature (°C), transparency (cm), dissolved oxygen (mg/L), pH, total alkalinity (mg/L), PO_4–P (mg/L) and NO_3–N (mg/L) were measured fortnightly during February to June, 2014 following the standard methods (APHA, 2012). Water temperature, transparency, dissolved oxygen (DO) and water pH were determined in situ using a digital thermometer, Secchi disk, DO meter (Model DO5509, Lutron) and portable pH meter (Model number-RI 02895, HANNA Instruments Co.), respectively. Total alkalinity was measured by titrimetric method using phenolphthalein and 0.0227 NaOH titrant (Model number-HI3811, HANNA Instruments Co.). Nitrate-nitrogen was determined by nitrate test kit (Model number-MI3874, HANNA Instruments Co.) and phosphate phosphorus was detected by phosphate test kit (Model number-MI3833, HANNA Instruments Co.).

2.3. Measurement of sediment quality parameters

The pond sediment (bottom-soil) was collected by an Ekman dredge. Chemical properties of pond sediment such as pH, available phosphorus (mg/L), total nitrogen (%) and organic matter (%) were determined fortnightly using standard methods (Sattar and Rahman, 1987).

2.4. Study of benthic invertebrates

Benthic samples were collected at around 11.00 a.m. fortnightly from all the experimental ponds using an Ekman dredge (bottom area 15 cm × 15 cm). Collected samples with benthic invertebrates and bottom mud were washed and filtered properly with pond water. At first, samples were sieved through a 0.2 mm mesh-screen net for the separation of benthic invertebrates and large particles from mud and water. Then the benthic invertebrates remained on the screen net were collected using a fine forcep and kept into small plastic bottles containing 5% formalin for preservation. The small plastic bottles were marked properly with a marker pen and taken to the laboratory for enumeration and taxonomic identification.

The samples were kept in laboratory for 48 h for hardening. The preserved organisms were then transferred to a Petri dish and washed with tap water to remove the remaining washable detritus and mud. The samples were then cleaned with distilled water and benthic invertebrates were separated from each using sorting needle and fine forcep. Finally, benthic fauna were sorted into major taxonomic groups using a magnifying glass (65 mm, Optical Instrument Co.) and low power microscope (magnification: 10 × 2.5) wherever necessary. Then all available organisms were counted and identified up to genera according to Wetzel and Lickens (1983).

The following formula was applied to determine the abundance/density (number of organisms per m^2).

$$\begin{aligned} \text{Abundance/density(no.per m}^2) &= \text{number of organisms} \\ &\times \text{area of bottom-mud collected by Ekman dredge} \times 44.44 \\ &= \text{number} \times 225 \times 44.44 \end{aligned}$$

where, area of open mouth of Ekman dredge = 225 cm^2.

2.5. Data analysis

Data were analyzed by repeated measures analysis of variance (ANOVA) with "treatment" as main factor and "sampling date" as repeated factor followed by Tukey's post hoc comparison to assess the differences among the different sampling dates and different treatments. Statistical significance was set at $p < 0.05$. Statistical analyses were performed using SPSS Version 14.0 for Windows (SPSS Inc., Chicago, IL). Values were presented as means ± standard deviation (SD).

Table 1
Water quality parameters (Means ± SD) during the study period.

Parameters	Treatments		
	Control	Low dose	High dose
Water temperature (°C)	29.15 ± 2.80	29.20 ± 2.63	29.16 ± 2.64
Transparency (cm)	18.26 ± 5.83^a	23.63 ± 3.59^b	27.26 ± 5.94^c
pH	8.42 ± 0.29	8.28 ± 0.28	8.29 ± 0.16
Dissolved oxygen (mg/L)	3.50 ± 0.95	3.52 ± 1.10	3.56 ± 1.00
Total alkalinity (mg/L)	113.16 ± 14.58	107.52 ± 13.85	110.14 ± 14.29
Nitrate-nitrogen (mg/L)	3.52 ± 1.04^a	2.97 ± 1.22^b	2.81 ± 1.43^b
Phosphate-phosphorous (mg/L)	2.42 ± 0.50^a	1.76 ± 0.49^b	1.56 ± 0.36^b

Values with different superscript letters indicate significant difference ($p < 0.05$).