Occurrence and Fate of Pesticides in the River Water Systems of Borneo Island: A Study in the Malaysia and Indonesia Sections

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1. Purpose of the Study

The objective of this research was to monitor the occurrence and and spatial distribution of pesticides (specifically organophosphates (OPPs), neonicotinoids (NNIs), and pyrethroids (PYRs)) in some river Borneo Island. This research focus on three rivers in Sarawak states, Malaysia and East Kalimantan, Indonesia: Miri, Baram, and Mahakam River. These rivers were selected due to its importance to human activities such as industries, agriculture, and mining. Moreover, they are particularly susceptible to river water contamination as a result of agricultural practices, including oil palm plantation in particular. The base rationale for this river-selection choice is a mixture of environmental, agricultural, and socio-economic factors.

2. Methodology

2.1. Sampling Location and Storage.

This research focus on three rivers in Sarawak states, Malaysia and East Kalimantan, Indonesia: Miri, Baram, and Mahakam River. Water samples was collected from various locations along these rivers to monitor the occurrence and spatial distribution of OPPs, NNIs, and PYRs.

2.2. Water Sample Collection and Storage.

Water samples were collected in amber glass bottles to avoid contamination that might alter the integrity of the sample. The samples were transported to the laboratory under cold conditions to maintain the chemical composition of the samples until analysis. The samples were then subjected to extraction using liquid-liquid extraction method and analysis carried out using GCMS and HPLCMS.

2.3. Sampling location.

The sample was collected from three rivers as described in Table 1. As a major river in the Borneo Island, economically and ecologically important, Miri River, Baram River, and Mahakam draws its water upstream from a prominent area [1-3]. Apart from agriculture, which forms a major part of the economic activities in this region, the surrounding areas have been developed with large oil palm plantations. The proximity of these plantations to the river poses a high risk of agricultural runoff into the river system. It may contain pesticides that need monitoring due to the effect it might have on the quality of water and aquatic life as well as public health where their survival depends on agriculture around the river basin. However, there is a major risk to water quality in the river which runs through pesticide use in the plantation area. The overall impact wherein agricultural field runoff would bring along with it pesticide residue to affect aquatic life and communities dependent on the river. A study on pesticide contamination in the these rivers would ensure not only ecological integrity but also ensure the welfare of the local population.

Table 1. The characteristic of sampling location

River Name	Location (Range)	Number of Points	Description of Sampling Points
Miri River	4°23'57.5"N 113°59'06.8"E to 4°27'52.2"N 114°00'49.0"E	7	Commercial, hotel, fish market, residential Miri oil port, golf yard, dockyard industry, plastic industry, national reserve, agricultural farm, oil palm plantation,
Baram River	4°32'36.8"N 114°09'21.9"E to 4°35'04.5"N 113°59'08.0"E	7	Maritime industry, shipyard industry, plywood industry, sawmill, palm oil plantation, concrete industry, metal industry
Mahakam River	0°30'54.0"S 117°09'09.8"E to 0°35'35.6"S 117°04'37.6"E	7	Inter-island port, industries (shipyard, plywood, petroleum tank, dockyard, cement, coconut oil), commercial, mall, residential, wood plantation

2.4. Sample treatment and instrumental analysis

Surface water was collected from the river using a water sampler at approximately 5 L and stored in a glass jar until it was transported to the laboratory. In the laboratory, water samples were filtered through filter paper to remove any particulate matter. Liquid-liquid extraction (LLE) was applied to extract 5 L of water samples. Briefly, 1 L of filtered water with 100 mL of hexane was added to the funnel and shaken for 2 min. The hexane layer was collected in a round flask, the water samples were re-extracted twice with hexane, and hexane was combined. Subsequently, a water sample was extracted using a procedure similar to that for hexane with another solvent, such as dichloromethane, ethyl acetate, and methanol. In the case of methanol, the extraction was conducted only once as the final extraction and evaporated directly without separation because it did not separate well. Evaporation was conducted using a rotary evaporator until 3 or 5 mL of extract was added. Anhydrous sodium sulfate (Na_2SO_4) was added to the concentrated extract to remove residual water. The extract was cleaned using a preconditioned silica gel chromatography column with hexane and eluted with hexane, dichloromethane (DCM), and methanol. All eluents were combined and evaporated, and the solvent was exchanged with acetonitrile. Subsequently, the solution was evaporated to 2 mL and transferred to a 1 mL vial for LC-MS/MS analysis. The remaining eluent solvent was exchanged with DCM, concentrated to 0.5 mL, 200 μL internal standard pesticides were added, and the mixture was filled with DCM to a volume of 1 mL. Transfer to GC vials for GC-MS/MS analysis.

3. Results

This study examines the presence and concentration levels of various pesticides and insecticides in the waters of the Miri, Mahakam, and Baram rivers in Borneo (Table 2). The study analyzed Oxadiargyl+NH4, Thiacloprid, Thiamethoxam, Chlorpyrifos, Cyphenothrin, Diazinon, Dichlorvos, and Iprodione in Miri, Mahakam, and Baram Rivers, with concentrations measured in parts per trillion (ppt). Oxadiargyl+NH4 showed moderate variability in the Miri River (0.08–0.24 ppt, mean 0.15 ppt, SD 0.07 ppt) but was more consistent in the Mahakam River (0.07–0.13 ppt) and highly stable in the Baram River (0.07–0.10 ppt). Thiacloprid levels fluctuated widely in the Miri River (0.07–1.52 ppt), remained constant in Mahakam (0.05 ppt, no SD), and were below detection in Baram. Thiamethoxam was undetectable in the Miri and Baram Rivers, while Mahakam recorded low levels (ND–0.22 ppt, mean 0.22 ppt). Chlorpyrifos concentrations were stable in the Miri River (0.22–

0.34 ppt) but below detection limits in Mahakam and Baram, indicating negligible presence. These findings highlight significant variability in chemical distributions, with the Mahakam and Baram Rivers generally exhibiting more stable and lower pesticide concentrations compared to the Miri River.

Table 2. Pesticide detected in Miri river, Baram river, and Mahakam river.

Compounds detected	Miri (ppt)			Mahakam (ppt)			Baram (ppt)		
	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD
Oxadiargyl+NH4	0.08-0.24	0.15	0.07	0.07-0.13	0.1	0.02	0.07-0.10	0.09	0.01
Thiacloprid	0.07-1.52	0.79	1.03	0.05	0.05	-	LOD	-	-
Thiamethoxam	LOQ	-	-	ND-0.22	0.22	-	LOQ	-	-
Chlorpyriphos	0.22-0.34	0.28	0.08	LOQ	-	-	LOQ	-	-
Cyphenothrin（Ⅰ,Ⅱ,Ⅲ）	2.0-12.10	7.42	3.76	4.51-13.41	7.12	3.75	3.44-11.44	7.53	2.59
Diazinon	0.18-1.27	0.37	0.44	0.17-0.20	0.18	0.01	ND-0.21	0.19	0.01
Dichlorvos	0.66-15.13	2.89	5.4	0.73-1.03	0.79	0.19	0.71-0.93	0.84	0.07
Iprodione	ND-0.33	0.32	0.01	ND-0.35	0.34	0.02	ND-0.32	0.32	-

The study examined phenothrin, diazinon, dichlorvos, and iprodione concentrations across Miri, Mahakam, and Baram Rivers, revealing significant variability in some cases. Phenothrin levels were highest in the Mahakam River (4.51–13.41 ppt, mean 7.12 ppt) and lowest variability in Baram River (mean 7.53 ppt, SD 2.59 ppt). Diazinon showed moderate variability in Miri River (0.18–1.27 ppt, mean 0.37 ppt), with much lower, stable concentrations in Mahakam (mean 0.18 ppt) and Baram Rivers (mean 0.19 ppt). Dichlorvos concentrations varied significantly in Miri River (0.66–15.13 ppt, mean 2.89 ppt), while Mahakam and Baram Rivers had low, stable levels (mean 0.79 and 0.84 ppt, respectively). Iprodione levels were consistently low and stable across all rivers, with mean concentrations around 0.32–0.34 ppt. These findings highlight both spatial and chemical differences in pesticide distributions, with variability influenced by local environmental factors.

The data amasses a broad spectrum of pesticide and insecticide levels in the Miri, Mahakam and Baram Rivers. It can be noticed that Cyphenothrin displayed the highest heterogeneity and presence across all the three rivers meaning there is widespread application or discharge in the region. Conversely, some of the locations have Thiamethoxam and Chlorpyriphos at extremely low or undetected levels. This indeed stresses the need for continued surveillance as well as regulatory restrictions on the usage of the chemicals during the agricultural processes as they have far-reaching effects on the environment and human health merely by being present even in small concentration levels. The concentration levels among the rivers may also point to the localization of farming methods, industries and laws/rules controlling the usage of farming chemicals.

Addressing the presence of pesticide and insecticide residues in the Miri, Mahakam, and Baram rivers presents several future challenges. Key among these is the need for comprehensive monitoring programs to detect and quantify a wide range of chemicals accurately. Understanding the ecotoxicological impacts on aquatic life and ecosystems necessitates long-term studies to assess chronic and acute toxicity [4], given the significant variability observed in compounds like Cyphenothrin. Human health risks from contaminated water sources highlight the importance of conducting thorough risk assessments, considering bioaccumulation and potential health effects [5]. Developing stringent regulatory frameworks and promoting sustainable agricultural practices are essential. Policymakers need to update regulations based on scientific evidence and ensure compliance through effective enforcement mechanisms. Public awareness and education are vital for encouraging sustainable practices and reducing reliance on chemical pesticides.

Reference

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