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Ecological risk assessment of pesticide residues in Taihu Lake wetland, China

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ABSTRACT

As a major ecosystem type, wetland provides invaluable ecological services. Environmental pollution, especially pesticides pollution should be paid more attention to keep wetlands healthy. Based on the risk quotient method, coupled with a probabilistic risk assessment model, this paper proposed a methodology suitable for ecological risk assessment of pesticide residues for wetland ecosystems. As an important industrializing and ecologically vulnerable area in China, the Taihu Lake wetland was chosen for the case study. The risks of eight pesticides in Taihu Lake wetland were assessed, as single substances and in mixtures. The assessment indicates that risks of the representative species are not significant. In general, the herbicide is found to be more toxic for algae, whereas insecticides pose more risks to zooplankton, insect and fish. For each pesticide in the wetland, the ecological risk it poses is acceptable. But the combined ecological risk posed by mixture can harm more than 10% of species of the wetland ecosystem, mainly dominated by dichlorvos, dimethoate and malathion contributions. These results imply that pesticide residues have been posing pressures on the ecosystem of the Taihu Lake wetland. It is recommended that proper countermeasures should be implemented to reduce the risks.

1. Introduction

Wetland is one of the three major ecosystem types on the earth, and provides irreplaceable ecological services for the ecosystem and human society. But over time, more than half of the wetlands disappear after years of being drained, dredged, filled, leveled, and flooded (Zedler and Kercher, 2005). With rapid urbanization and industrialization, wetland degradation and loss have been identified in many countries, both developed and developing (Tiner, 1984; Holland et al., 1995; Dahl, 2000; Ralph, 2003; Zedler and Kercher, 2005). However, since the last half of the 20th century, the preservation of wetlands attracts more and more attention as their value to society has become more fully understood (Stevens et al., 1995; Dahl and Allord, 1999; Woodward and Wui, 2001). Studies of wetland protection are emerging. Yet the literature focuses mainly on the functioning of constructed wetlands, ecological water demands and vegetation development (Spieles, 2005; Chen et al., 2009; Cui et al., 2009). In fact, with rapid social and economic development, contamination of wetlands from chemicals has become an urgent problem worldwide. Due to agricultural use and industrial production, pesticide residues in wetlands have caused potential risk to the ecosystem. Organisms can easily bioaccumulate, biomagnify or biotransfer certain pesticides to concentrations high enough to injure the ecosystem potentially, especially through the transmission process in the food chain. But the attention that is paid to environment pollution and the subsequent ecological risk in wetlands is not enough.

It is critical important for environmental managers and decision-makers to understand the ecological risk posed by pesticide contamination to the wetland ecosystem. Information on site-specific ecological risk assessment of pesticide contamination is of great importance for resource agencies and environmental managers to identify and prioritize keystones for wetland protection. According to this need, in this paper, we intend to build a procedure for ecological risk assessment of pesticide contamination, and apply it to a wetland in Taihu Lake area in China for risk analysis and management.

2. Materials and methods

2.1. Study area and environmental samples

Taihu Lake, the third largest freshwater lake in China, is located in the southern end of Yangtze River Delta, and covers approximately 2425 km^2. With an average water depth of 1.89 m, a maximum depth of 3.34 m and a volume of 51.5×10^8 m^3, Taihu Lake is an important wetland serving as a water supply for industry, agricultural irrigation, recreation, transportation and biodiversity preservation. However, with the rapid economic growth since the late 1970s, water and soil pollution from industry, agriculture, and

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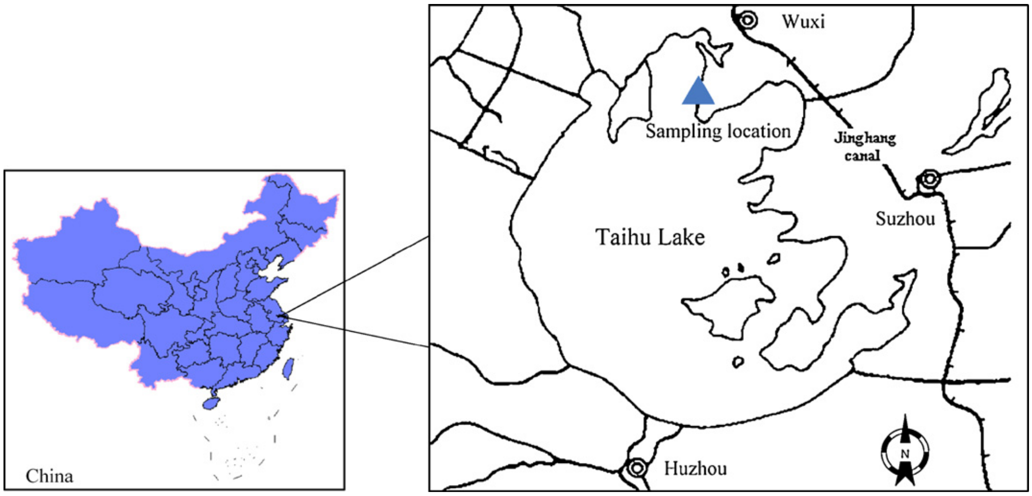

Fig. 1. Taihu Lake and the location of sampling sites.

urban waste has been increasing significantly in the area. In May, 2007, an estimated 4 million people in Wuxi, an industrial city located along the lake, were deprived of drinking water for nearly a week, as a carpet of algae scum or agglomerate of biological origin made local lake water unusable (Guo, 2007; Yang et al., 2008).

China is a large producer and consumer of pesticides. Pesticides like HCH and DDT were widely used from the 1950s until their uses were banned in 1983 (Li et al., 1999,2001; Qiu et al., 2004; Wang et al., 2005). The agriculture in the Taihu Lake wetland area is highly productive. Large amounts of pesticides were used in this area in the past (Li et al., 1999). Studies also showed that concentrations of pesticides in Taihu Lake area were still measurable or even high in most water, soil and organism samples (Wang et al., 2003; Feng et al., 2003; Bian et al., 2009). But intense scientific research efforts were mostly on the origin and distribution of the pesticide residues in Taihu Lake, to a lesser degree on ecological risk they posed to the ecosystem potentially. There is a growing urgency to assess the ecological risk in Taihu Lake wetland area rather than to simply monitor the environmental concentration.

The environmental concentration data of pesticide residues were collected from the open literature (Ta et al., 2006). Sampling sites are located in the northeast of Taihu Lake area, which is the drinking water source of Wuxi city and a heavily polluted area. The environmental quality and ecological status of this wetland, a key ecosystem that Wuxi will construct and protect, attracts high concern. Water samples drawn at 0.5 m under the surface were collected from 10 different sampling sites in the northeastern Taihu Lake wetland. Fig. 1 shows the location of Taihu Lake and the sampling sites. Within a one year period, the water samples were collected three times, during the normal season (November 2003), the dry season (January 2004) and the rainy season (August 2004). 14 different kinds of organic pesticides and their metabolites were analyzed in this literature. Due to the availability of related toxicant data, 8 kinds of pesticides were selected for further study. The environmental concentration data for pesticide residues in different water seasons are presented in Table 1.

2.2. Ecological risk assessment

Ecological risk assessment is a process that evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors (USEPA, 1992). In environmental protection, it is used as an increasingly important tool for investigating the nature and magnitude of ecological impacts, and for assisting decision-making by environmental managers (Lipton et al., 1993; Slater and Jones, 1999). In recent years, risk assessment procedures have become well developed and documented (USEPA, 1998). Specific methods often used range from simple risk quotient calculation to probabilistic risk assessment (USEPA, 1998; Solomon and Sibley, 2002).

2.2.1. Risk quotient method

The risk quotient (RQ) model has been developed in an effort to quantify the risk of specific species exposures to chemicals with the surrounding natural environment. RQ is the quotient of measured or estimated environmental concentration (exposure) divided by a toxicant reference values (TRV). It is a single-value estimate for screening-level risk assessment at early stage (Van Beelen and Doelman, 1997; Newsted et al., 2002; Hela et al., 2005), and the RQ of a single pesticide *i* was calculated using:

$$RQ_i = \frac{\text{exposure}}{\text{toxicity}} = \frac{MEC_i}{TRV_i} = \frac{MEC_i}{LC_{50}\ \text{or}\ EC_{50}} \quad (1)$$

where MEC_i is the measured environmental concentration of pesticide *i*, and TRV_i is the toxic reference value (LC_{50} – half lethal concentration for the 50% of the population of the tested species or EC_{50} – effect concentration for the 50% of the population of the tested species) of pesticide *i*.

For a mixture of *n* kinds of pesticides, the risk quotient of the mixture (RQ_m) was calculated as the addition of RQ_i for mixture

Table 1
Concentration (ng/L) of pesticide residues in water of Taihu Lake (Ta et al., 2006).

	Atrazine	DDT	Dichlorvos	Dimethoate	Lindane	Malathion	Methy-parathion	Parathion
November 2003	252	0.17	31.0	232	1.74	5.32	0	1.18
January 2004	277	3.07	35.1	168	3.17	24.70	0	3.20
August 2004	132	0	95.1	638	1.02	4.66	12.30	2.13
Total mean value	217	1.06	51.6	346	1.98	11.60	4.12	2.17