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Widespread contamination by persistent toxic substances in Vietnam and their implications on environmental quality and human health

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Abstract—Vietnam is a developing country located in the central part of the Southeast Asian tropical region. The country comprises the Red River and Mekong River Delta, inhabiting more than 30 million people, which is one of the most populous areas in the world. These deltas have become one of the most productive agricultural regions in Southeast Asia. Agrochemicals have been used extensively in the past and until very recently for agricultural purposes and malaria eradication program. The present paper provides a comprehensive overview of the environmental distribution, patterns and trends of contamination of toxic substances including persistent organochlorines (OCs) and endocrine active compounds (EACs) in different environmental compartments from Vietnam. Monitoring data reported during the 1990s demonstrated widespread and elevated contamination of DDTs in air, water, sediments and soils from in Vietnam. Recent studies in frame of the Asia-Pacific Mussel Watch Program have also revealed that fish, mussels and resident birds from Vietnam contained higher concentrations of DDTs as compared to other countries in region, suggesting the role of Vietnamese environment as a significant emission source of DDT in the Southeast Asian region. Subsequent surveys on coastal lines from north and middle part of Vietnam likewise demonstrated that contamination of some endocrine active compounds such as alkylphenols and phthalates are ubiquitous. In particular, relatively high concentrations of bis-phenol A were found in some locations in Red River delta, comparable or higher than those reported for several locations in developed nations in Western Europe and North America. A case study on seasonal variation of alkylphenols and phthalates in surface water of river delta and estuary of north and central Vietnam indicated the differences in distribution of these compounds between dry and rainy seasons. Higher concentrations of alkylphenols and phthalates were found in dry season in estuary; while the contrasting pattern was observed in the river delta, showing elevated residues in rainy season. This result suggests the different behavior of alkylphenols and phthalates in river delta and in coastal environment. The temperature dependence in tropical ecosystem and the influence of the specific local sources may be reasons for the observed results in the seasonal variations. To our knowledge, this is the first extensive study on the widespread contamination of EACs in Vietnam. Regarding the trends of contamination by OCs, preliminary survey conducted in Red River delta water and sediments indicated a rapid decline trend in water and a slow decrease in sediments during 1995–2001.

From ecotoxicological and human health perspectives, concentrations of bis-phenol A and di(2-ethylhexyl)phthalates in surface water from some locations in Vietnam exceeded the guideline values for Ecotoxicological Effects and the Environmental Risk Limit, respectively, suggesting potential for toxic implications on aquatic wildlife. Human exposure to persistent organic pollutants indicated that DDT residues levels in human breast milk from both Hanoi and Hochiminh city were among the highest values reported for Asian developing countries as well as developed nations. Daily intakes estimating based on the exposure through sea-foods indicates that intakes of DDTs by Vietnamese populations were among the highest rank in Asia-Pacific countries, suggesting potential risk for human exposure to elevated DDT pollution. Future studies should be focused on the time trends of POPs and EACs in biota of Vietnam with view of predicting the future trend of contamination and to reveal new clues for understanding possible toxic impacts on aquatic organisms.

Key words: persistent organochlorine, environmental quality, human health, Vietnam

Introduction

Global contamination and toxic effects of persistent or-

ganic pollutants (POPs) has been an emerging environmental issue and has received considerable attention during the past decades. Although the extent of contamination by POPs has been predominant in industrialized nations, an increasing

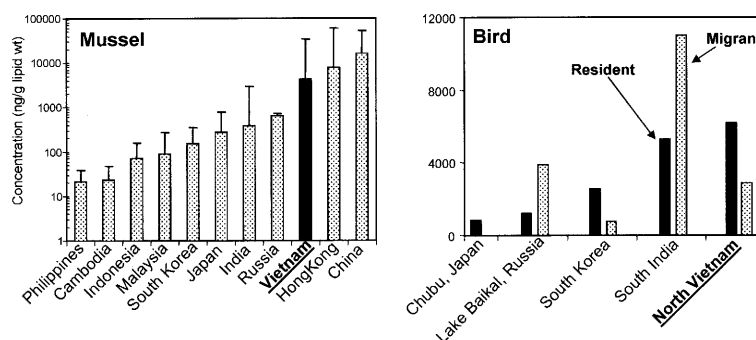


Fig. 1. Comparison of DDT residue levels in mussels and birds from Vietnam and other countries in Asia-Pacific region. Data cited from Monirith et al. 2003, Minh et al. 2002.

number of recent investigations highlighted the role of Asia-Pacific as a potential source of emission for POPs, particularly to pristine areas such as the Arctic and the Antarctic (e.g. see review by Tanabe et al. 1994, Tanabe 2002).

Vietnam is a developing country located in the central part of the Southeast Asian tropical region. The country comprises the Red River and Mekong River Delta, inhabiting more than 30 million people, which is one of the most densely populated areas in the world. These two deltas have become one of the most productive agricultural regions in the Southeast Asia. Agrochemicals have been used extensively in the past and until very recently for agricultural purposes and malaria eradication program. During the recent decade, in the context of the Asia-Pacific Mussels Watch Program and the JSPS Core University Program, extensive studies on the contamination, fate and human health implications of POPs in Vietnam has been conducted. This paper review of the results of the monitoring surveys in Vietnam, an agriculture-based country located at the center of the South East Asian region. The extent of contamination, fate and human health implications of POPs and EDCs in Vietnam are discussed.

Widespread contamination in different environmental compartments

On the basis of Asia-Pacific Mussel Watch Program conducted in 1990s, widespread and relatively high contamination of DDTs in various environmental compartments such as air, water, sediment and soils and also fish from both north and south Vietnam were reported (Thao et al. 1993, Iwata et al. 1994, Kannan et al. 1995). This result suggests the widespread usage of DDTs in Vietnam in the past for both agricultural purposes and malaria control. In addition, relatively higher concentrations of PCBs were observed in municipal wastewater from Hochiminh City, Vietnam (Iwata et al. 1994). Interestingly, survey during 1989–1993 showed that Vietnamese fish also contained higher PCB residues as compared to fish from other Asian countries. The high PCB contamination in Vietnam observed during survey in early 1990s could be derived from both the electrical equipments imported from industrialized nations like former Soviet Union

and Australia and the army weapons extensively used in Indochina War during 1961–71.

Interestingly, monitoring studies in recent years (1997–2003) have continued to show elevated contamination of DDTs in different environmental media. For example, one of the recent data in the Mussel Watch Program showed that DDT residue concentrations in mussels from Vietnam are among the highest reported for the countries surveyed in South East Asian region (Monirith et al. 2000, 2003) (Fig. 1). Resident birds collected from Red river delta estuary, North Vietnam, contained elevated concentrations of DDTs (Minh et al. 2002). DDT residue levels in resident birds from North Vietnam were also higher than those in other countries in the region (Fig. 1). It is worthy to note that though the recent amounts of DDTs used in Vietnam were lower than those of other countries in the region, the extent of DDT contamination in environmental samples in Vietnam is higher. This observation suggests that the application of DDTs in Vietnam has continued until very recently, resulting in elevated contamination of these compounds in different species occupying low to high trophic levels in food chain.

As far as the EDCs contamination are concerned, extensive investigations have been made to examine distribution of alkylphenols and phthalates in Red River delta and Huong River delta, the two largest rivers in the north and middle Vietnam. Again, alkylphenolic compounds have been detected at almost all sampling locations examined, supporting the concept of ubiquitous contamination of EDCs in both river delta and estuary ecosystems.

In particular, relatively high concentrations of bis-phenol A were observed in surface water collected from Red River delta, which were comparable, and in higher at some sites, than those reported in industrialized nations in western Europe and North America, suggesting the presence of significant source of this compound in the Red River delta.

Implications for environmental quality and human health

Widespread contamination by OC insecticides, particularly DDTs in different environmental samples of Vietnam

has been apparent as indicated in the survey in early 1990s. Estuarine sediments collected from various locations from the northern to southern part of the country, contained relatively high concentrations of DDTs (Iwata et al. 1994). The Environment Canada has recently updated the sediment quality guidelines for protection of the aquatic life. The Interim Fresh water Sediment Quality Guidelines (ISQGs) and the Probable Effect Levels (PELs) for *p,p'*-DDE are 1.42 and 6.75 ng/g dry wt, respectively, while these values for *p,p'*-DDT are 1.19 and 4.77 ng/g dry wt (Canadian Environmental Quality Guideline 2002). Among the 18 locations examined throughout Vietnam, about half of the sediment samples contained *p,p'*-DDE and *p,p'*-DDT greater than the ISQG values. Several samples collected from the municipal sewage canal contained elevated levels of DDTs, far beyond the probable effect levels (PELs). Similarly, residue concentrations of DDTs in soils collected from some locations from north, middle and south Vietnam (Thao et al. 1993) approached or exceeded the guideline level of 700 ng/g dry wt proposed by Environment Canada and the level of 1000 ng/g dry wt recommended by Japanese Government. Given these facts, it is important to note that the magnitude of contamination by DDTs in Vietnam is of concern and warrant further studies. From the environmental health and global contamination point of view, the role of Vietnam as potential source of DDTs for other countries in the region as well as in higher latitudes should be considered as the priority research focus in future.

In a recent survey examined endocrine active compounds in surface water along various locations in Vietnam, elevated levels of bis-phenol A were found in several sites in the Red River delta. The maximum concentrations in Balat estuary and in the river delta were 1200 and 1300 ng/l, respectively. These levels were exceeding the predicted no-effective concentration ($PNEC_{water}$) of 1000 ng/L (United States and European Standard) (Fig. 3). The magnitude of contamination by DDTs and bis-phenol A in Vietnam has been of concern and deserves continued monitoring studies.

In the perspective of human health implication, surveys conducted in early 1990s on OCs in foodstuffs provided useful information regarding the dietary intake of these compounds by Vietnamese population (Kannan et al. 1992). Interestingly, the estimated average daily intakes based on the exposure through foodstuff to PCBs in Vietnam were higher than India, Thailand and comparable to those reported for developed nations like USA and Germany. Particularly, average daily intake of DDTs by Vietnamese was estimated to be 19 $\mu\text{g}/\text{person}/\text{day}$; and this value was the highest as compared to the countries in the region and in developed nations (Kannan et al. 1992). Although the data used for estimation has been reported a decade before, this fact clearly suggests elevated exposure to DDTs and PCBs by Vietnamese population and that the usage of DDTs has been extensive during

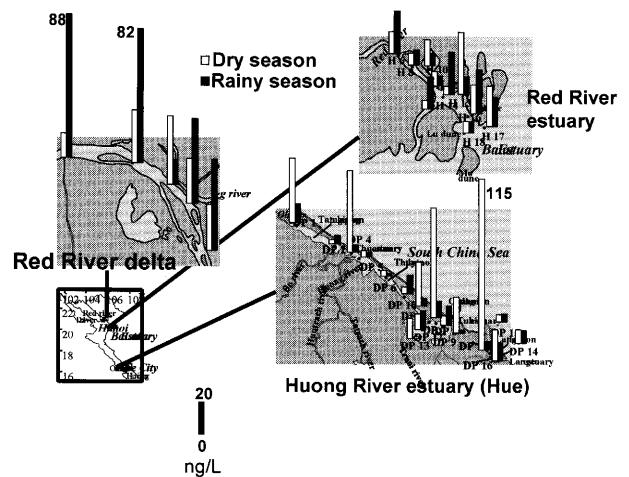


Fig. 2. Distribution of alkylphenols (ng/L) in water from the two biggest rivers in north and middle Vietnam: Red River and Huong River.

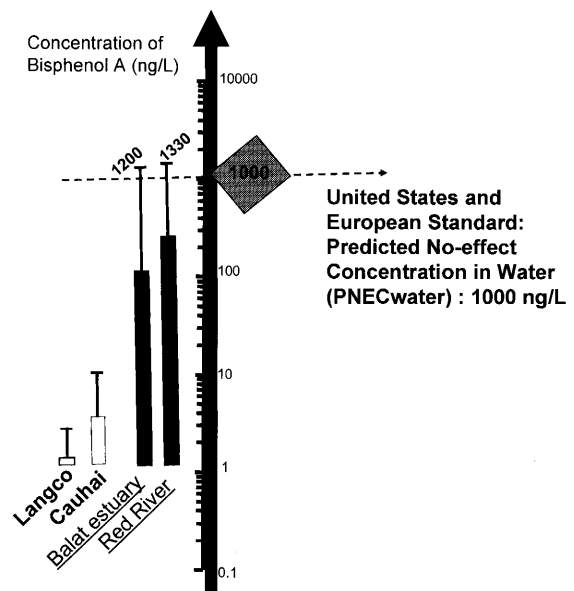


Fig. 3. Magnitude of contamination of bis-phenol A in surface water from river delta and estuary of north and middle areas in Vietnam in comparison with the guideline value for ecotoxicological effects [United States and European Standard: Predicted No-effect Concentration in Water– $PNEC_{water}$ (1000 ng/L)].

the past 10 year.

Surveys in the framework of recent Asia-Pacific Mussel Watch Program indicated that dietary intake of DDTs and PCBs from fish in Vietnam were higher than those in Cambodia and Thailand, but still lower than those in industrialized nations such as Australia, Japan and Hong Kong (Monirith et al. 2000). On the basis of the recent data of average seafood consumption reported by Food and Agriculture Organization of the United Nations, the average daily intake of PCBs and DDTs from seafood for different countries in Asia-Pacific region were estimated (Monirith et al. 2003) (Table 1). Interestingly, results again showed that intakes of

Table 1. Estimated daily intakes of PCBs and DDTs from seafoods in countries in Asia-Pacific region.

Country	Seafood consumption (g/person/day)	Intake of PCBs (ng/person/day)	Intake of DDTs (ng/person/day)
Cambodia	54.2	40	18
China	68.5	170	16440
Hong Kong	68.5	250	8200
India	12.3	47	52
Indonesia	53.4	69	53
Japan	173	5200	610
South Korea	140	520	490
Malaysia	158	160	220
Phillipines	81.1	460	32
Thailand	78.6	240	440
Vietnam	51.8	72	2100
Russia	53.2	3400	640

Intakes of PCBs and DDTs were estimated based on the mean concentrations in mussels reported by Monirith et al., 2002 and 2003.

Seafood consumption data cited from WHO (2000).

(<http://apps.fao.org/lim500/wrap.pl?FoodBalanceSheet&Domain=FoodBalanceSheet>)

DDTs by Vietnamese population were apparently higher than those reported in other countries examined (Table 1).

Tolerable daily intake by breast fed children

A recent study extensively examined persistent organochlorines (OCs) in human breast milk from Hanoi and Hochiminh city, the two largest cities in Vietnam showed interesting results (Minh et al. 2004). Similar to those observed in environmental samples, breast milk of mothers living in suburb of Hanoi and Hochiminh city contained elevated levels of DDTs, which were among the highest levels reported for Asian developing countries as well as developed nations (Minh et al. 2004). In order to assess the risk for breast-fed infants due to OC exposure via breast milk, daily intake of OCs by infants was calculated based on the assumption that the average milk consumption of a 5 kg infant is 700 g/day (Oostdam et al. 1999). The mean values of daily intake of OCs were estimated by using the following equation:

$$DI = \frac{C_{\text{milk}} \times 700 \text{g} \times C_{\text{lipid}}}{5}$$

where DI is daily intake ($\mu\text{g}/\text{kg}$ body wt./day); C_{milk} : concentration of the chemical in milk ($\mu\text{g}/\text{g}$ lipid wt); C_{lipid} : lipid content in milk (%).

The estimated daily intakes are shown in Fig. 4. It was recognized that although intake of DDTs by most infants is below the guideline proposed by Health Canada (Oostdam et al. 1999) in average, intake by some individuals is close to or exceeds this guideline. This fact may raise greater concerns on infant health because children are highly susceptible to effects from environmental contaminants.

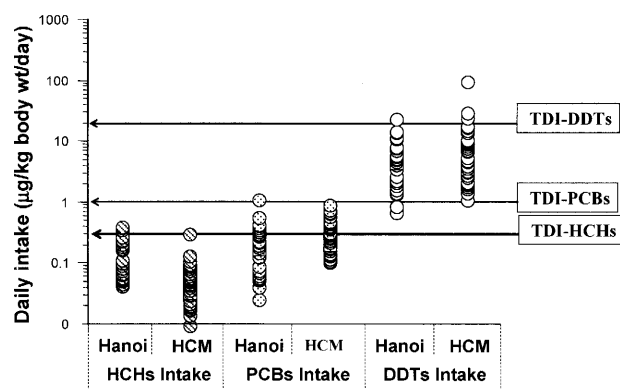


Fig. 4. Estimated daily intake ($\mu\text{g}/\text{kg}$ body wt/day) of HCHs, PCBs and DDTs by breast-fed children living near dumping sites in suburb areas of Hanoi and Hochiminh city, Vietnam in comparison with the Tolerable Daily Intake (TDI) proposed by Health Canada.

Conclusions and Recommendations

Multi-media monitoring studies conducted during the last decade on POPs in Asia-Pacific region including Vietnam has elucidated that contamination by OC insecticides, particularly DDTs, has been apparent. As a consequence, high degree of exposure of general populations to DDTs via foodstuff, particularly fish and other seafood has been of concern over the last many years. In addition, a certain group of people living near the dumping sites of municipal wastes are exposed to elevated concentrations of organochlorine insecticides and PCBs. Particularly, the first children are exposed at greater levels of contaminants via breast milk and thus are at higher risk. It is important to note that despite the decrease in global contamination by POPs in the future; developing countries in Asia-Pacific region may continue to be

a potential source for certain contaminants such as DDTs. Temporal trend studies are therefore needed for developing countries. Possible toxic effects on human health and wildlife should also be thoroughly investigated.

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