DISCUSSION PAPER

SCIENTIFIC RESEARCH ON ENVIRONMENTAL TOXICOLOGY IN SOUTH-EAST ASIA: A VIEW OF ITS POSITION IN THE INTERNATIONAL ARENA

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ABSTRACT
Environmental toxicology in South-East Asia, like other areas of the world, receives increasing attention and shows significant growth. This paper reviews three questions which are more or less specific to the area: (1) the participation of South-East Asian (SEA) scientists in international networks and scientific journals, (2) the environmental problems specific for the region, and (3) the use of indigenous species for toxicity testing. Based on a survey in seven journals, it can tentatively be concluded that SEA scientists are under-represented in the international general journals on environmental toxicology. Their works are mostly focused on studies that rely on well established methods, ie. single species toxicity test and spatial distribution of toxicants. A great variation in the number of articles published from different countries is also observed. Confronted with the various kinds of environmental problems, many of which need immediate solution, environmental toxicology is expected to play a more concrete role, either through fundamental research or applied research. To be able to contribute to the environmental problems solving of the region, and to increase the contribution to the scientific knowledge, SEA Scientists have to utilise the comparative advantage of the region, ie. its ecological richness.

Key words: environmental toxicology, South-East Asia, scientific research

INTRODUCTION
Environmental toxicology receives increasing attention in the South-East Asian region. This situation is not different from other places in the world, but the conditions under which the science develops in South-East Asia (SEA) are different from elsewhere. As a science, there is no reason why environmental toxicology should be different only due to geographic distinction. In this age of electronic communication, hardly any barriers exist that prohibit the dissemination of scientific information. Experience teaches, however, that exchange of information is limited.

Independent activities already exist in each country of the region, both in courses and research programmes. Unfortunately, in terms of scientific networks, environmental toxicologists in SEA have limited forums to interact with their colleagues from the same region. Until recently, no society or scientific journal on environmental toxicology has been established in the region (note: only very recently an embryo of the Asia-Pacific branch of SETAC has been formed).

The lack of a network could lead to a loss of the opportunity to address regional issues in a coordinated manner. Moreover, the lack of scientific communication between environmental toxicologists in the region may lead to absence of peer review, repetition and duplication of efforts.

On one hand, environmental toxicology has to face various pollution problems that need immediate solutions, but on the other hand this scientific discipline is still young. This leads to a substantial gap between the development of environmental toxicology (as with other environmental sciences) and the environmental problems resulting from the rapidly increasing

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economic activities. This gap will certainly contribute to shaping the scientific orientation of institutes that work in the region.

Research programmes on environmental toxicology, presently existing in SEA, cover a wide area of interests and approaches. To be able to contribute better to the solution of environmental problems in the region as well as to the advancement of knowledge, research programmes adapted to the SEA context are needed. Scientists working in this region should explore the region's advantages, such as ecosystem richness, to develop research programmes that can answer both needs.

This paper aims to review three issues that we consider as critical for present day's environmental toxicology in South-East Asia: (1) the participation of SEA scientists in international networks, (2) environmental problems needing immediate solution, and (3) the direction of research including the need for using indigenous species and ecosystems.

INTERNATIONAL PARTICIPATION

Development of environmental toxicology in SEA deserves credit for its rapid acquisition of knowledge developed in more advanced regions. Environmental toxicology, which has been experiencing a rapid development only in the past two decades, has been recognised by scientists in SEA shortly after its inception in the US and Europe. In Indonesia, for example, the pioneering introduction of this field can be traced back to the early 70s (Djuangsih 1993).

In the last few years, interest in environmental toxicology has been growing in SEA. Most likely, this trend will be maintained in the years to come. To date, environmental toxicology has been introduced in many curricula, either in under-graduate or post-graduate courses. Moreover, research programmes in environmental toxicology have also been implemented in many SEA institutes and universities.

The presence of international organisations, such as NETTLAP (Network of Environmental Training at Tertiary Level in Asia Pacific), an educational unit of UNEP, is of considerable importance for the region. NETTLAP has organised several workshops and symposia on environmental education and training at the tertiary level, which also cover environmental toxicology (Hay and Thom 1993). Access to NETTLAP is facilitated by the appointment of a focal point for each member country.

Although research activities in this field have spread over the countries of SEA, a network of scientists working in this field hardly exists. Even at a national level, a network often does not exist. In some cases, however, scientific meetings have been organised at the national level (see eg. Soemardi and Notosoedarmo 1987).

Initiatives, such as a conference on environmental toxicology in SEA at Salatiga, Indonesia in 1992, have proven to be a good forum to identify the activities and potentials for networking at the regional level (Widianarko *et al.* 1994). A continuation of such activities with a regular frequency appears to be difficult to realise. The lack of a network may put the progress of the science at risk, because achievements obtained by one researcher will not directly benefit a colleague working at another place.

To obtain an indication of the present international participation of SEA environmental toxicologists, a survey in seven relevant international journals has been conducted: *Aquatic Toxicology*, *Environmental Toxicology and Chemistry*, *Environmental Pollution*, *Archives of Environmental Contamination and Toxicology*, *Chemosphere*, *Ecotoxicology and Environmental Safety* and *Bulletin of Environmental Contamination and Toxicology*. These journals were selected because they cover a range of environmental aspects and cover a range of impact ratings. All volumes appearing in the years 1993 through 1995 were screened for the affiliation of the first author, and articles reporting on work conducted in SEA countries were classified regarding the topic of research.

During 1993 to 1995, contribution of SEA scientists in these journals amounted to 36 out of 4154 articles, or about 0.8%. Results of the survey are shown in Tables 1, 2 and 3. With only one exception (*Bulletin of Environmental Contamination and Toxicology*), the contribution of SEA scientists in all of the journals was below 1%. The level of contribution is not correlated with the impact ratings of the journals, although most South East Asian contributions may be found in the *Bulletin of Environmental Contamination and Toxicology* which has the lowest impact rating among the journals covered in this study.

In the three years from 1993 to 1995, the contribution of SEA scientists to these journals has addressed a wide variety of areas, which can be categorised into nine areas, ie. (1) spatial distribution of toxicants (Abdullah *et al.* 1994; Mat and Maah 1994; Maah *et al.* 1994; Prudente *et al.* 1994; Tan and Vijayaletchumy 1994; Din 1995; Maah *et al.* 1995; Tan 1995); (2) toxicity studies (Curvin-Aralar and Aralar 1993; Din and Abu 1993; Vogt

Table 1. *Number of articles by authors from South East Asia, India, Japan, China and other Asian countries in seven international journals with different impact rates (ISI, 1993) during 1993-1995. The figures between brackets express the percentages in terms of the total number of articles published by the journals.*

JOURNAL	Impact Rate	South East Asia	India	Japan	China	Other Asian Countries	TOTAL
Aquatic Toxicology	**1.564**	**1** (0.56)	**1** (0.56)	**0** (0.00)	**0** (0.00)	**2** (1.12)	**179**
Environmental Toxicology and Chemistry	**1.553**	**1** (0.23)	**1** (0.23)	**5** (1.15)	**1** (0.23)	**4** (0.92)	**435**
Environmental Pollution	**1.302**	**4** (0.50)	**25** (3.10)	**20** (2.48)	**7** (0.87)	**10** (1.24)	**806**
Archives of Environmental Contamination and Toxicology	**1.252**	**2** (0.44)	**2** (0.44)	**24** (5.28)	**1** (0.22)	**4** (0.88)	**456**
Chemosphere	**0.877**	**7** (0.59)	**16** (1.35)	**96** (8.09)	**17** (1.43)	**23** (1.94)	**1187**
Ecotoxicology and Environmental Safety	**0.870**	**0** (0.00)	**13** (5.22)	**2** (0.80)	**0** (0.00)	**3** (1.20)	**249**
Bulletin of Environmental Contamination and Toxicology	**0.580**	**21** (2.49)	**109** (12.94)	**49** (5.82)	**11** (1.31)	**30** (3.56)	**842**

Table 2. *South East Asian articles in seven international journals (1993-1995): breakdown by country and area of interest.*

AREA OF INTEREST	COUNTRY					TOTAL
	Malaysia	Philippines	Singapore	Indonesia	Thailand	
Spatial Distribution of Toxicants	7	1	0	0	0	8
Toxicity Studies (Single Species)	3	3	1	1	1	9
Environmental Health (Human Toxicology)	2	0	1	0	0	3
Biodegradation	2	0	0	0	0	2
Microbial Toxicology	2	0	0	0	0	2
Toxicants in Foodstuffs (Food Safety)	2	0	0	0	0	2
Waste Treatment (Remediation)	1	1	0	0	0	2
Field Toxicity Studies	0	1	0	0	1	2
Atmospheric Pollution	2	0	0	3	1	6
	21 (58.3%)	6 (16.7%)	2 (5.6%)	4 (11.1%)	3 (8.3%)	36 (100%)

Table 3. *Chemical substances and ecosystem types in South East Asian articles in seven international journals*

SUBSTANCE	TYPE OF ECOSYSTEM				TOTAL
	Urban/Industry	Freshwater	Coastal/Marine	Terrestrial/Agricultural	
Heavy Metals	4	4	7	0	15 (41.7%)
Pesticides	0	1	0	6	7 (19.4%)
Non-pesticide Organic Pollutants	3	4	1	0	8 (22.2%)
Atmospheric Gases	0	0	3	3	6 (16.7%)
	7 (19.4%)	9 (25.0%)	11 (30.6%)	9 (25.0%)	36 (100%)

and Quinitio 1994; Curvin-Aralar and Aralar 1995; Kim Oanh and Bengtsson 1995; Law 1995; Low and Sin 1995; Shazili 1995; Vink *et al.* 1995); (3) environmental health (Mokhtar *et al.* 1994; Ong *et al.* 1993; Surif and Chai 1995); (4) biodegradation (Sahid and Wei 1993; Sahid and Teoh 1994); (5) microbial toxicology (Sahid and Zaabar 1993; Sahid and Yap 1994); (6) toxicants in food (Ibrahim 1993; Mat 1994); (7) waste treatment (Low *et al.* 1995; Millamena 1994); (8) field toxicity studies (Calumpang *et al.* 1995; Kim-Oanh *et al.* 1995); and (9) atmospheric pollution (Eong 1993; Murdiyarso 1993; Snidvongs 1993; Soepadmo 1993; Soegiarto 1993; Husin *et al.* 1995).

From the research areas listed above it can be seen that the environmental toxicological works in SEA are mostly concentrated on studies that rely on well established methods, ie. toxicity studies (single species) and spatial distribution of toxicants. It should be noted that a reasonable number of articles on atmospheric pollution are listed in Table 2, but these are mostly review papers derived from a conference which was published as a special edition of the journal, *Chemosphere*.

In terms of substances and types of ecosystem, SEA scientists have mostly studied heavy metals (41.7%) and coastal/marine ecosystems (30.6%). In Table 3, it can be seen that heavy metal studies are followed by those on non-pesticide organic pollutants (22.2%), pesticides (19.4%) and atmospheric gases (16.7%). Among the types of ecosystems studied, both freshwater and terrestrial/agricultural ecosystems received a reasonable attention (ie. 25%). The least studied ecosystem was the urban/industry ecosystem (19.4%).

Because this survey was limited to only seven journals, the results are, of course, by no means free from sampling bias. For example, pesticide studies in paddy field ecosystems seem to be under-represented, although this area of research is one of the most elaborated topics in the region (see Abdullah *et al.* 1997), as is illustrated by publications in other journals from a research group at the University of the Philippines (Tejada *et al.* 1993; Varca and Magallona 1994; Bajet and Tejada 1995). This may indicate that SEA scientists tend to publish in specialised and local journals, rather than to publish in general international journals.

In terms of the number of articles published there is a great variation between countries (Table 2). Most of the contributions come from Malaysia (58.3%), followed respectively by the Philippines (16.7%), Indonesia (11.1%), Thailand (8.3%) and Singapore (5.6%). It is not the aim of this paper to compare the progress between countries in the region, since the present survey is limited to seven journals and three years. But, at least, we can indicate that there is a difference in the involvement of scientists of each country in the international development of this field.

Overall, the participation of South East Asian scientists in the international arena of environmental toxicology must be considered as small. A possible explanation for this limited participation is that some works are not widely published. Some good results may be found in Masters and PhD theses at local universities. Since there is no obligation for PhD students in the region to publish their works in international scientific journals, the impetus for a wider dissemination is often absent. Other means of publication, such as national/regional scientific journals, conference proceedings, consultancy reports and interim publications, have also contributed to the limited participation of SEA in international journals.

ENVIRONMENTAL PROBLEMS NEEDING SOLUTION

The accelerating industrial and agricultural development coupled with the rapidly increasing populations in South East Asian countries during recent years exerts considerable pressure on ecosystems. Agricultural and industrial development is associated with an increasing use of toxic substances in SEA (Lacher and Goldstein 1997). As to pesticides, for example, more than 90% of the global end-user market in pesticides for rice production is located in Asia (Mabbet 1991 cited by Abdullah *et al.* 1997). The combination of three factors: agriculture, industry and population, has exposed SEA ecosystems to a diverse range of contaminants from industry and agriculture, and to a high degree of urban expansion (or landscape transformation).

Expansion of the industrial sectors has resulted in an ever increasing generation of hazardous wastes. Most industries with a major contribution to the region's economy, such as textile, pulp and metal finishing industries, have discharged and continue to discharge a considerable quantity of hazardous waste (Kim Oanh and Bengtsson 1995; Kusnoputranto 1993; Goeltenboth 1994; Ismail *et al.* 1994; Sarmani and Madjid 1994). It was estimated that in JABOTABEK (Jakarta and its satellite cities, Indonesia) 2 000 000 tons of industrial waste was produced in 1990, 2 250 000 tons in 1995, and 2 500 000 tons will be produced in the year 2000. Approximately 50% of this amount is considered as hazardous waste, which needs specific handling and treatments (Kusnoputranto 1993). In Peninsular Malaysia, 220 000 m^3 of toxic and hazardous waste is produced annually, of which approximately 44% can be attributed to the metal finishing industries (Din 1995). Studies on these industrial pollutants have shown that significant impacts on receiving ecosystems (Goeltenboth 1994; Ismail *et al.* 1994; Mena 1993) and human environmental safety were evident (Kusnoputranto 1993; Sarmani and Madjid 1994).

Another aspect related to economic development is the increase of living standards. Consumption patterns of the people in SEA are changing rapidly. This triggers the presence of previously unknown environmental pollution problems, such as exposure to volatile organic solvents in correction fluids and other modern consumer materials (see eg. Ong *et al.* 1993).

With intensive agricultural practices in SEA, an extensive use of agrochemicals cannot be avoided. In 1985, the pesticide market for the ASEAN countries was about US$ 498 million (Magallona 1994). During 1980 to 1985, Indonesia and the Philippines posted the highest growth rates in pesticide usage, ie. 30% and 16%, respectively. The use of pesticides in SEA is mostly associated with rice production (Magallona 1994).

Three environmental issues related to pesticides identified in SEA are residues, human poisoning and the ecological impacts of these compounds. Studies on pesticide residues in SEA can be found as early as 1971 (Gorbach *et al.* 1971). This classical investigation is rather exceptional, since the researchers were from the company that produced the pesticide. They investigated the residue of Thiodan in an aquatic ecosystem, following an extensive campaign of treatment on rice fields, in East Java, Indonesia. Pesticide poisoning due to acute occupational exposure is a latent problem of large magnitude in SEA (see eg. Tantiyaswasdakul 1993). This problem results from malpractice in pesticide handling and application.

Overuse of pesticides in rice fields has led to the development of resistance and pest resurgence. In 1986, following a massive devastation of rice crop in Indonesia by the brown planthopper, a presidential decree was issued to ban 57 of the 61 most commonly used pesticides (Sunoko 1993). This was the first time that pesticides have been banned for ecological reasons rather than to protect human health (Christopher 1988). This presidential decree included the adoption of integrated pest management (IPM), which has resulted in a marked reduction in pesticide use in Indonesia (Sunoko 1993). In terms of the total number of formulations and active ingredients, the country has to face more new chemicals (Tjahjadi 1993). This, of course, will only increase the pressure on the environment.

Since the 1980s, SEA has been experiencing a more rapid environmental transformation than any other Third World region in the humid tropics, surpassed perhaps only by Brazil (Low and Balamurugan 1991). The major element of this transformation is the conversion of forest to agricultural land, and from agricultural land to urban area as well. One of the most important driving forces behind this transformation is the rapid growth of the population.

It is estimated that by the year 2000, there will be at least 15 cities of over 1 million people in SEA. Three of the largest cities, Bangkok, Jakarta and Manila are expecting to grow into megacities, each consisting of over 10 million inhabitants (Low and Balamurugan 1991). These major cities hold the keys to economic development of the countries. All major economic activities, whether commercial, financial or industrial, are expected to be located in these cities and their immediate hinterlands. Unless waste treatment facilities grow at the same rate, a marked increase of environmental stress may be expected in the vicinities of these megacities.

Occurrence of heavy metals in the surface water in SEA has been reported by several authors (see eg. Low and Balamurugan 1991; Anonymous 1993a; Djuangsih 1993; Djuangsih and Salim 1994; Anonymous 1994). Over-concentration of industries in the suburb areas of the cities is the major contributor to this problem. The lead (Pb) concentration in surface water in two major cities, Jakarta and Surabaya, was reported to be up to 25- and 17-fold of the WHO threshold level respectively (Anonymous 1993a). A recent study revealed that lead content of vegetables grown in the urban area of Jakarta and irrigated with urban surface water is far beyond the WHO's standard (Anonymous 1994).

A study on water pollution in the Citarum River basin, West Java, gives an excellent example of industrial discharge combined with agricultural and domestic wastes in the upstream area which has put the catchment area at risk (Djuangsih 1993; Djuangsih and Salim 1994). A study at the Laguna Lake basin, the Philippines, revealed similar evidence of combined contamination (Mena 1993).

Transportation also contributes to the urban pollution problems. Population growth in the major cities of SEA has been accompanied by a marked increase in the number of vehicles in the area. It is reported that of the 700 000 vehicles in the Metro Manila in 1993, 75% are petrol fuelled and 25% are diesel fuelled (Anonymous 1993b). Gasoline vehicles, fuelled by leaded gas and not equipped with pollution control facilities, emit significant quantities of lead, carbon monoxide, nitrogen oxides and hydrocarbons. An observed impact of this sort of emission is the occurrence of heavy metal residues in vegetables cultivated adjacent to highways (Luwihana 1994).

Another environmental problem induced by the urban expansion is the discharge of domestic and human waste. Although this waste may contain some potentially toxic components, its main problem is that dumpsites serve as food and breeding grounds for disease vectors. Furthermore, the process of poorly planned human settlement in urban areas of SEA, especially in coastal areas, involves a potential for ecological disturbances to coastal ecosystem (Navarro 1995).

Confronted with the various kinds of environmental problems, the knowledge of environmental toxicology, and also environmental sciences in general, should be of significant importance. Unfortunately, although the availability of accurate and up-to-date data is critical for the success of the environmental management regime, there is no comprehensive environmental database in SEA. According to a recent study (Allen 1993), data problems exist with respect to both quantity and quality. It is often the case that environmental information is presented without a proper context. With regard to this lack of data, environmental toxicologists in SEA are challenged to generate data relevant to environmental impact assessments.

FUTURE DIRECTIONS OF RESEARCH

In view of the region's environmental problems and the desire of South-East Asia's scientists to contribute more to the international scientific community, environmental toxicologists in the region are faced with a dilemma: should they direct their efforts to novel and fundamental research, which will be contributing to the general advancement of knowledge, or to applied research, which exploits the available knowledge and techniques developed elsewhere, to tackle the local, national or regional problems?

As mentioned in the previous section, the current emphasis of environmental toxicological research in SEA seems to be on single species toxicity studies and on spatial distribution of toxicants. In terms of data generation and description of the present environmental status, these approaches may be useful. But that will not be the case if we want to proceed to the more fundamental aim of environmental toxicology, ie. the protection of ecosystem sustainability under toxicant threats.

A relevant question is whether the generation of locally relevant data, upon which environmental policy in SEA can base decisions concerning questions of immediate urgency, should follow the approaches developed in European and North American countries, or should move towards development of its own "niche".

In the case of pesticides, an argument often heard is that if a product has been registered for use under European or North American laws, an evaluation of the environmental risks has already been made and additional data on species indigenous to tropical countries would be redundant. Some of the species used in toxicity testing in Europe and North America actually originate from the tropics (eg. Tilapia). Therefore one may argue that it is not necessary for each country in SEA to test the same chemical with its own species. Several countries in SEA have implemented pesticides registration procedures based on these considerations.

However, for particular ecosystems, it can be misleading to rely only on toxicity data derived from "generic" species (see eg. Cao 1993; Widianarko 1993). There is presently insufficient scientific information that would support the claim that indigenous tropical species have the same range of sensitivities as temperate species. To avoid both false positives and false negatives in the evaluation of toxicants in the tropics, testing under tropical conditions, using indigenous species in addition to data already available from temperate regions, is advisable. There are some important arguments that support the use indigenous species in testing of chemicals, particularly pesticides, ie:

(1) Even if a product has been registered in Europe and North America, the information required on ecotoxicity is often very limited. For the aquatic environment the information usually does not go further than acute toxicity to *Daphnia* and fish, and inhibition of algal growth. For soil, the data are even more limited. It can be argued that the basis for risk assessment can be improved greatly by extending the range of test species and undertaking tests using regionally relevant test conditions;

(2) It is probable that there are tropical species that are more sensitive to pesticides than species from temperate countries, given the great biodiversity of animal and plant groups in the tropics. When it is assumed that sensitivities of species follow an approximately bell-shaped statistical distribution, with

very sensitive and very tolerant species being relatively rare, the likelihood of finding a very sensitive species increases with the total number of species in the community (Kooijman 1987);

(3) The same taxonomic group may have a different spatial distribution in the tropical ecosystems compared to temperate ecosystems. Groups of animals that would not be exposed to pesticides in temperate ecosystems may be exposed in tropical ecosystems if their niches are different; and

(4) The conditions under which organisms are exposed to environmental chemicals are often totally different between tropical and temperate ecosystems. The physico-chemical environment, including temperature, humidity and seasonal changes, influences both the fate of a chemical, its bioavailability, and the sensitivity of the organisms.

Regarding possible competitive advantages of South East Asia in environmental toxicology, scientists from this region may wish to explore the wealth of tropical ecosystems, which can be expected to react to toxicants differently from those of other climatic regimes. Rainfall, temperature, sunlight, and microorganisms in a tropical ecosystem provide different degrees of pesticide degradation and loss (Magallona 1989). So, degradation of agrochemicals will be one prospective area of study. Taking into account this phenomenon, we can develop methods which are contextual, in the sense that answers relevant to questions of the tropical ecosystem are addressed, and at the same time a contribution is made to general existing knowledge (see eg. Widianarko and Van Straalen 1996).

Another prospective research topic for SEA is field toxicity studies in species-rich communities. These types of studies can contribute to the development of knowledge on the flux of toxicants in complex ecosystems. Fundamental knowledge on the functioning of food chains and community effects of chemicals is the subject of recent scientific debates. Intricate interactions of species have been studied for many years, but only recently have the overall food-web structures of communities been thought to result from the interaction process in a more or less predictable way (Pim *et al.* 1991). The resilience of communities and therefore their ability to recover from toxicant exposure is tightly related to food-web structure. Tropical and temperate systems may have different food web topologies and consequently differ in their response to toxicants (Van der Valk 1995).

Community approaches can be applied to the study of effects in different types of ecosystems that are typical for the SEA region, such as rice field ecosystems, urban ecosystems, rain forest ecosystems, dry land (rain-fed) agroecosystems, etc (see eg. Calumpang *et al.* 1995; Vink 1994). Recently Cohen *et al.* (1994) demonstrated promising results from application of a food-web approach to assess pesticide impacts in rice field ecosystems in the Philippines.

CONCLUDING REMARKS

As with their colleagues in other regions, environmental toxicologists in SEA have to direct their work towards two objectives, namely to provide reliable answers to the environmental problems of the region, and to increase their contribution to the scientific knowledge. To be able to accomplish these objectives simultaneously, they have to utilise the comparative advantage of the region, ie. its ecological richness.

Over-emphasis on single species toxicity studies and spatial distribution of toxicants, will potentially result in inefficient use of resources. The application of such limited data is often difficult, because ecological complexity is not taken into account. When SEA scientists study the species-rich communities available to them, there is a great prospect for the development of regionally focused environmental toxicology.

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