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Review article

A review of human biomonitoring in selected Southeast Asian countries

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ABSTRACT

Rapid development and industrialization in Southeast (SE) Asia has led to environmental pollution, potentially exposing the general population to environmental contaminants.

Human biomonitoring (HBM), measurement of chemical and/or their metabolites in human tissues and fluids, is an important tool for assessing cumulative exposure to complex mixtures of chemicals and for monitoring chemical exposures in the general population.

While there are national HBM programs in several developed countries, there are no such national programs in most of the SE Asian countries. However, in recent years there has been progress in the field of HBM in many of the SE Asian countries.

In this review, we present recent HBM studies in five selected SE Asian countries: Bangladesh, Indonesia, Malaysia, Myanmar and Thailand. While there is extensive HBM research in several SE Asian countries, such as Thailand, in other countries HBM studies are limited and focus on traditional environmental pollutants (such as lead, arsenic and mercury). Further development of this field in SE Asia would be benefited by establishment of laboratory capacity, improving quality control and assurance, collaboration with international experts and consortiums, and sharing of protocols and training both for pre-analytical and analytical phases.

This review highlights the impressive progress in HBM research in selected SE Asian countries and provides recommendations for development of this field.

1. Background

Southeast (SE) Asia is highly populated and is considered as one of the fastest developing regions in the world, with increasing demand for electricity and fuels. In addition, many SE Asian countries underwent rapid industrialization, driven by foreign direct investments (Diaconu, 2014) and due to relatively cheap labor force. In some cases, there is widespread pollution of air, water and soil and minimal actions to mitigate the pollution (Damrongsiri et al., 2016). Such processes may lead to high population exposure to industrial and transportation pollution and may result in adverse health outcomes.

As a result of growing pollution, the population in SE Asia may be exposed to chemicals via occupational exposures and through their diet, air, water, and consumer products, via dermal, oral uptake or inhalation. Exposure to chemical mixtures via multiple pathways complicates exposure characterization using traditional environmental media concentration estimations. Human biomonitoring (HBM), which is a direct measurement of chemicals or their metabolites in human tissues and fluids (National Research Council (NRC), 2006), is an effective tool for measuring human exposure to environmental chemicals.

Population based HBM can identify specific at risk groups for high environmental exposures and can therefore by used to design public health interventions. For example, population-based biomonitoring in New York City (NYC) identified skin care products as a previously unrecognized source of exposure to inorganic mercury among NYC residents (McKelvey et al., 2011). In response, the NYC Health Department embargoed products and notified store owners and the public that skin-lightening creams and other skin care products that contain mercury are dangerous and illegal.

HBM is also an important tool for understanding health effects of environmental chemicals and population susceptibility to these compounds. HBM can be used in epidemiological studies in combination with health data to demonstrate an association between the body burden of pollutants and their health effects (World Health Organization (WHO) Europe, 2015). Finally, HBM is a powerful tool for tracking the effectiveness of public health interventions, such as phasing out of lead in gasoline and restrictions on smoking in public places (Centers for Disease Control and Prevention (CDC), 2017).

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In this framework and considering the usefulness of HBM to perform an integrated assessment of environmental exposure, there is increasing awareness for HBM in developed countries. Several countries have already initiated HBM national programs in order to improve the detection, diagnosis, treatment and prevention of disease, injury, and harmful environmental exposures in populations (Centers for Disease Control and Prevention (CDC), 2017).

Despite evidence of increased exposure, there are no national HBM programs in most of the SE Asian countries. In recent years, however, HBM studies have been conducted in several countries in South-East Asia. In November 2016, the World Health Organization organized a Workshop on Human Biomonitoring (HBM) to Support Chemical Risk Assessment in Bangkok, Thailand. Participants from several SE Asian countries (Indonesia, India, Bhutan, Thailand, Malaysia and Myanmar) presented HBM experiences, goals achieved and challenges for the future.

This review presents recent HBM studies in five selected SE Asian countries. The purpose of the review is to highlight data and progress in the field of HBM in SE Asia and to provide recommendations for further development of this field.

2. Methods

We searched PubMed for reviews and papers published in English after 1998 and focused on those published after 2003. The searched terms were: ("human biomonitoring" or "biomonitoring") and ("lead" or "arsenic" or "cadmium" or "chromium" or "mercury" or "organophosphates" or "organochlorines" or "organochlorides" or "dioxins" or ("organic" and "toxins") or "PFOS" or "PFOA" or "cotinine" or "air pollution" or "polluted air" or "particulate matter" or "air quality" or "water"), for the relevant countries, excluding papers regarding indoor air pollution. In addition, we searched for relevant documents published by the World Health Organization (WHO) as well as the U.S Centers for Disease Control and Prevention (CDC). We excluded studies in occupational settings. We briefly present results of these studies. For a subsample of studies, we evaluated quality control and quality assurance (QC/QA), such as the sampling strategy, the conditions under which the samples were shipped and stored, the laboratory accreditations and any international collaboration (Supplementary Table 1).

3. Results

We found a total of 47 HBM studies conducted in 2003–2017 (Table 1). The vast majority were conducted in Thailand; the majority focused on exposure to heavy metals.

4. Thailand

Thailand is an agricultural country that went through rapid and massive industrialization that led to a variety of environmental problems, particularly air pollution. The major sources of air pollution in Thailand are industry, transportation, and biomass burning (Vichit-Vadakan and Vajanapoom, 2011). Due to high ambient levels of lead, the Thai Government initiated a program to eliminate lead in gasoline (towards the end of the previous century), which was considered as successful (Sayeg, 1998). In addition, intensive farming in the last decades contributed to exposure of the Thai population to a variety of toxic pesticides and also to water pollution.

In recent years there have been several biomonitoring studies in Thailand. Most of the HBM studies in Thailand are focused on heavy metals, mostly lead, and on pesticides.

4.1. Organic compounds

Thailand is an agricultural country and one of the world's major food exporters. There is widespread use of pesticides to protect crops and to increase yields. There was a four-fold increase in the usage of pesticides in the last decade (Panuwet et al., 2012).

Organochlorines were widely used in the last century but most were phased out gradually in crop production in Thailand in the late 1970s. However, due to the stability and persistence of organochlorines and their residues, they are still found in nanogram levels in water, sediment, and aquatic organisms collected in Thailand's agricultural regions (Panuwet et al., 2012). Currently, there is widespread use of organophosphates in Thai agriculture. This widespread use leads to high rate of intoxication due to exposure to organophosphates. Therefore, biomonitoring of organochlorines and of organophosphates is of high importance and was conducted in several studies published in recent years.

4.1.1. Organochlorines

Stuetz et al. (2001) measured the levels of DDT, heptachlor, HCB and HCH in 25 breast milk samples taken from Thai women that came from regions where DDT was widely used (Stuetz et al., 2001). DDT was detected in all samples (median level of 209 ng/mL), while heptachlor was detected in 15 of the samples (median level of 4.4 ng/mL). The estimated daily intakes of DDT, heptachlor and heptachlor-epoxide by breastfed infants exceeded the acceptable daily intakes as recommended by the WHO, by up to 20 times.

In a study published in 2006, Asawasinsopon et al. collected maternal blood and umbilical cord blood from 39 Thai mothers and their newborns. Levels of pp′-DDE (1,1-dichloro-2,2-di(4-chlorophenyl) ethylene), p-p′-DDT (1,1,1-trichloro-2,2-di(4-chlorophenyl)ethane), p-p′-DDD (1,1-dichloro-2,2-di(4-chlorophenyl) ethane, dieldrin, and total thyroxine (TT(4)) were measured both in the maternal blood and in newborn cord blood. The researchers found high levels of pp′-DDE and p-p′-DDT in both matrices (maternal bloods and newborn cord bloods). The researchers also found a positive association between maternal blood and newborn cord blood levels of p-p′-DDT, p-p′-DDE, p-p′-DDD, and dieldrin. In addition, a negative association was found between the newborn's TT(4) and the newborn's levels of organochlorines (p-p′-DDT, p-p′-DDE, and p-p′-DDD), suggesting that exposure to DDT and its

Table 1
Summary of the biomonitoring studies reviewed from select SE Asian countries (2003–2017).

Country	Category	Heavy metals	Organic
Thailand	Number of studies	11	9
	Compounds	Lead, cadmium, arsenic, mercury	Organophosphates, organochlorines
Bangladesh	Number of studies	8	1
	Compounds	Lead, cadmium, arsenic, selenium	Organochlorines
Myanmar	Number of studies	2	–
	Compounds	Lead	–
Malaysia	Number of studies	2	8
	Compounds	Lead, cadmium, arsenic, mercury	Dioxins, organochlorines, perfluorinated compounds (PFOS/PFOA), phthalates, bisphenols, nicotine
Indonesia	Number of studies	5	1
	Compounds	Lead, mercury	Polybrominated diphenyl ethers (PBDE), organochlorines
Total		28	19