

## RECENT LEVELS OF POLYCHLORINATED BIPHENYLS IN WATER AND SEDIMENTS OF THE SEWER SYSTEM IN HANOI, VIETNAM

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### Introduction

Covering an area of some 1000 km<sup>2</sup> and having a population of 6.5 million people, Hanoi (the capital and second largest city of Vietnam) and its vicinity is the major industrial and economic region in North Vietnam. Flowing inside the Hanoi City, mainly to the south and southeast, with a total length of about 70 km, the rivers To Lich, Lu, Set, Kim Nguu, and a part of the Nhue River, serve as important open sewer system for the drainage of rainwater and municipal wastewater, but are also used for agricultural irrigation in urban and suburban areas. During the recent decades, the fast development of industry in conjunction with high population growth has led to toxic chemicals to enter the rivers. It was reported that 95% of the capital's wastewater effluents are discharged without treatment and an estimated 450 000 m<sup>3</sup>/day are discharged untreated into the rivers Lu, Set, To Lich and KimNguu in Hanoi City.

Polychlorinated biphenyls are known as complex mixtures, which have been widely used as cooling agents and lubricants in electrical equipments (capacitors, transformers, etc.) since 1960s. Approximately 27,000 – 30,000 tons PCBs contained oils were imported into Vietnam from the former USSR, China, Rumania, and Australia during 1960-1990 (Sinh et al. 1999; MONRE, 2006). Although the use of PCBs has been officially banned in Vietnam since 1995 (Sinh et al., 1999), these toxic chemicals are still observed at relatively high concentrations in various environmental compartments in Hanoi City (Kishida et al., 2007; Toan et al., 2007) and also in human breast milk (Minh et al., 2004) of Hanoi citizens. However, knowledge on the contamination levels of PCBs in sewer systems of medium to large Asian cities like the Hanoi City is still limited.

This paper reported the concentrations of PCBs in water and sediments of the sewer system of Hanoi City. In addition, the temporal trend of the pollution, by comparing with previous measurements, the possible sources, and the potential toxicity to the aquatic environments are discussed.

### Material and methods

#### *Sample collection*

Twenty-two sediment samples were collected on 18 May 2006 and forty four water samples were collected on September 2009 (rainy season) and December 2009 (dry season) from the sewer system in Hanoi City (Fig. 1). The samples were collected in urban (TL1, TL2, TL3, TL4, L1, L2, L3, S1, S2, KN1, KN2) and suburban districts (TL5, TL6, TL7, N1, N2, YS1-6).

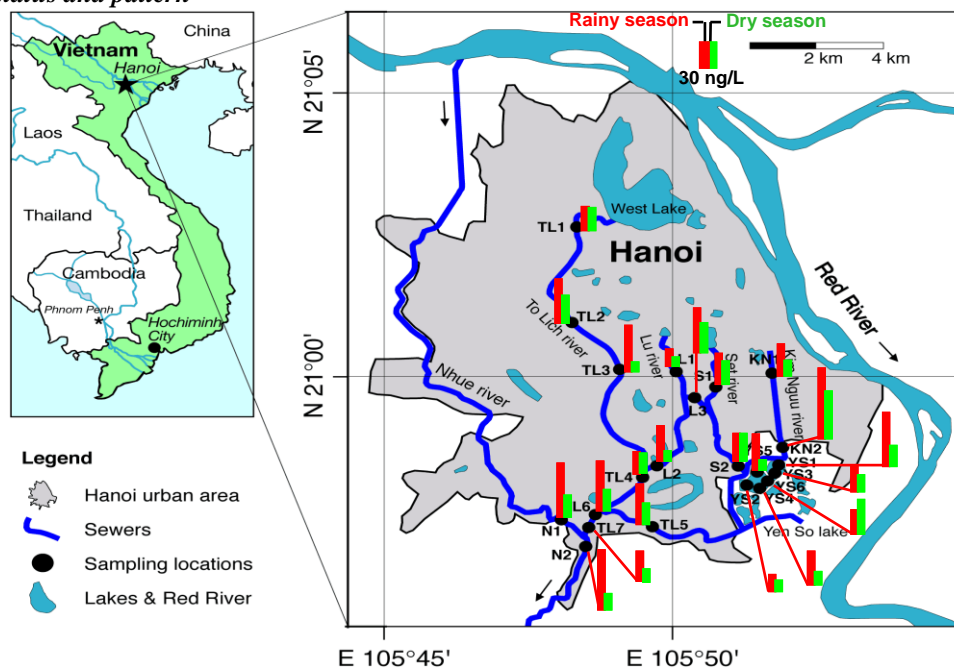
#### *Chemical analysis*

Collected samples were shipped within 1 h to the laboratory (CETASD); then, sediment samples were air-dried, ground, sieved to 1 mm, and stored at 20°C, meanwhile water samples were stored at 4°C until analysis. Water and sediment samples were analyzed for PCBs applying the EPA 3620B, EPA 8082, and EPA 8081A methods with slight modifications for sample extraction and extract cleanup. Relative concentrations of PCBs in this study are not adjusted to recovery rates and the sediment concentrations of PCB are expressed on a dry weight (d.w.) basis. The quality assurance consisted of MS turning, analysis of method blanks, reproducibility and repeatability tests, as well as the analysis of certified reference materials. Recovery rates (72–121%) were obtained for all compounds for the spiked samples.

The total sediment concentration of PCB (PCBs) was calculated based on the sum of seven PCB congeners (IUPAC No.: PCB 28, 52, 101, 118, 138, 153 and 180) by multiplication with the value of four, which corresponds to the theoretical contribution of those congeners to Aroclor 1254 (Froescheis et al., 2000). Meanwhile, the concentration of PCBs in water was calculated based on the sum of 44 PCB congeners (IUPAC No.: 1, 3, 8, 9, 10, 12, 15, 18, 19, 33, 35, 37, 38, 44, 52, 54, 57, 74, 77, 78, 79, 81, 99, 104, 114, 118, 123, 126, 153, 155, 156, 157, 162, 167, 169, 188, 189, 194, 195, 202, 205, 206, 208, 209).

## Results and discussion

### Pollution status and pattern



**Fig. 1.** Water concentrations of PCBs in Hanoi Sewer system.

Figure 1 shows the water concentrations of PCBs in Hanoi sewer system in both the rainy season and dry season. In general, the water concentrations of PCBs ranged from 8.6-34 ng/l (mean 88 ng/l), of which the PCBs concentrations in rainy season (ranged from 19-88 ng/l, mean 45 ng/l) are around two times higher than those in dry season (ranged from 8.7-58 ng/l, mean 23 ng/l). It was reported that PCBs in different compartments of the Hanoi sewer system are recognized originated from the working transformers, stockpiles storing likely PCB containing oils and electrical equipments. Therefore, the higher concentrations of PCBs in surface water in rainy season should be explained by the higher amount of the rainwater playing as runoff water to carrying PCBs into Hanoi sewer system.

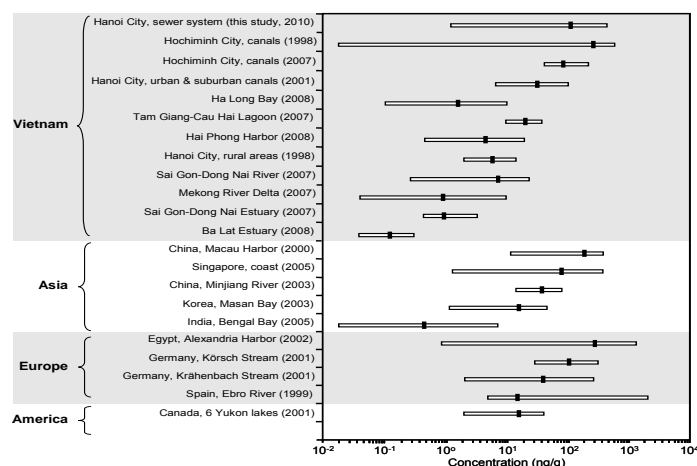
Except for the Set River, relatively higher concentrations of PCBs were observed at the downstream of the rivers, where being located with highly industrial activities and high population. This trend was observed more clearly in the rainy season. For example, the water concentrations of PCBs in the rainy season at the upstream and the downstream, respectively, were 37 ng/l (KN1) and 88 ng/l (KN2) in the Kim Nguu River; 19 ng/l (L1) and 43 ng/l (L2) in the Lu River; 27 ng/l (TL1) and 60 ng/l (TL6) in the To Lich River. Therefore, the observation made in this study raises concern on the possible sources of PCBs at the downstream of the rivers of the Hanoi sewer system.

The sediment concentrations of PCBs spanned a relatively wide range. They were observed ranging from 1.3-384 ng/g (mean 104 ng/g). The spatial distribution shows significantly higher concentrations of PCBs in the

rivers Kim Nguu and Set. As a result, the Yen So Lake, a reservoir receiving water from these two rivers, is polluted with relatively high levels of PCBs (20-384 ng/g). Pollution sources from industrial and workshop activities along the course of the rivers must be taken into account since PCBs showed increased concentrations down stream (in the rivers Set and Lu).

### Temporal trend of PCBs in sediments

The sediment concentrations of PCBs varied from 22-153 ng/g in the Nhue River, 1.3-70 ng/g in the To Lich River, 42-122 ng/g in the Lu River, 36-139 ng/g in the Set River, 237-328 ng/g in the Kim Nguu River, and 20-384 ng/g in the Yen So Lake. In the SaiGon-Dong Nai River Basin, Hochiminh City, PCB levels were reported to decline 3-6 times lower than those in the early 1990s. However, PCB levels in sediment of Hanoi showed an opposite trend. Ranging from 1.3-384 ng/g (mean 104 ng/g), the sediment levels of PCBs measured in this study revealed a clear increase compared to 0.79-40 ng/g (mean 13 ng/g) in 1997 (quantification using Aroclor 1254) and 15-120 ng/g (mean 45 ng/g) in 1999. Hence, the observation made in this study raises serious concern on the increase of PCB levels in Hanoi City.



**Fig. 2.** Concentration ranges and mean values of PCBs in recently collected sediments from various locations in the world.

### Comparison of PCB levels in Vietnam with other regions of the world

A comprehensive comparison of PCB levels in recently collected sediments from various locations in Vietnam and in the world is presented in Fig. 2. It can be recognized that among the reported locations in Vietnam, the levels of PCBs (mean 104 ng/g) in sediments of the Hanoi sewer system are highest followed by the Hochiminh City canals. The result indicates Hanoi City itself likely comprises sources of PCBs. Furthermore, the sediment levels of PCBs in the Hanoi sewer system are comparable to those found in the highly polluted Alexandria Harbor (Egypt) and Macau Harbor (China). The total organic carbon content (TOC) has a significant influence on the sediment concentration of PCBs as these compounds are highly sorptive with high  $K_{OC}$  values. In general, the TOC values in sewers and lake in Hanoi City (1.0-11%, mean 6.2%) are higher than those in Hochiminh City canals (3.2-4.9%), the Saigon-Dong Nai River and the estuary (0.44-4.8%). This could explain the higher concentrations of PCBs in Hanoi sewer system in comparison with those in the South of Vietnam in the recent study. The TOC values in sediments of other reported locations, including the Tam Giang-Cau Hai Lagoons, the Ba Lat Estuary, the Ha Long Bay, and the Hai Phong Harbor were also reported lower than those in Hanoi sewer system.

Similar to sediment, water concentrations of PCBs in Hanoi sewer system were recognized relatively higher in comparison with those recently reported from various locations in the world (Tab. 1). This indicates the possible pollution source of PCBs from rivers in Hanoi City. The levels of PCBs in rivers water and sediments of the Hanoi sewer system are the highest recorded in Vietnam so far, indicating that the pollution originates from sources within the city itself.

The findings of this study provide valuable information for the public and environmental authorities of Vietnam to mitigate the discharge of toxic chemicals into the aquatic environment via the sewer system. In addition, the assessment of the sources of PCBs should be given adequate attention, particularly in light of the fact that water of the sewer rivers is used for agricultural irrigation and therefore pose a threat to accumulate in food.

**Table 1.** Concentrations PCBs in water in different locations in the world.

Research area	Sample number	Year	Isomer number	Total PCBs (ng/l)
Hanoi sewer system (this study)	44	2009	44	8.6 -88
Bay of Bengal, India	2	1998	na	1.93-4.46
Newark Bay Estuary, USA	73	2002	114	3.45-56
Venice Lagoon, Italy	2	2003	54	1.2-10.5
Okinawa Island, Japan	6	2002	na	1.59-2.58
Mississippi River, USA	28	2004	6	22.2-163.4
Houston Ship Channel, USA	53	2003	209	0.49-12.5
Campeche, Mexico	11	2000	na	0.07-3.40

### **Hazard assessment**

In order to obtain an overall view on the possible toxic effects to the benthic and epibenthic organisms in the Hanoi sewer system, the sediment concentrations of PCBs were compared with the interim sediment quality guideline (ISQG) and the probable effective level (PEL), issued by the Canadian Council of Ministers of Environment (CCME, 2002). In general, the PCBs concentrations (except for sample YS3, 384 ng/g) were lower than the PEL value (340 ng/g as for Aroclor 1254), and only half of them exceed the ISQG value (60 ng/g as for Aroclor 1254).

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