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# Contamination by PCB's, DDT's, and Heavy Metals in Sediments of Ho Chi Minh City's Canals, Viet Nam

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The metropolitan region surrounding Ho Chi Minh city is the largest human and industrial centre of South Viet Nam with about 5 millions inhabitants and about 700 big factories and 22'500 artisanal plants (ENCO et al. 1994). One third of the Viet Nam gross national product (GNP) is produced in this region. Ho Chi Minh city is situated in a transitional delta formed by the two rivers Saigon and Dong Nai, lying between the hilly highland (east of South Viet Nam) and the large Mekong delta (at the west). Natural and constructed waternetworks are very developed all over the region and allow connections with the Mekong delta. Due to the flat topography, the hydrology of the Ho Chi Minh city's canals is highly influenced by the South China sea's tide, with a semidiurnal solar cycle.

The aquatic urban ecosystem is strongly influenced by long term discharge of untreated domestic and industrial wastewaters, stormwater runoff, accidental spills and direct solid waste dumping (EPFL et al.1996). All these released pollutants may have an impact on the water quality of the Saigon and Dong Nai rivers, which are used as drinking water supply for the city and other parts of the province. The protection of these resources is of prime importance for the development of this area. To remediate to this situation, the Ho Chi Minh city People's Committee has some projects, among them relocating low income people living along the banks, as well as dredging and canalizing some parts of these waterways.

PCB's and DDT's are recognized since long time as persistent hazardous environmental contaminants (Tolosa et al. 1995) and appear in the priority pollutant list of some western countries (Hedgecott 1994). It has been reported that some South Viet Nam soils present high PCB's and DDT's contents (Thao et al. 1993) and compared to other Asian countries, the contamination levels found in air, water and sediments of Vietnamese cities are among the highest (Iwata et al. 1994).

As sediments can be sensitive indicators for both spatial and temporal trends, we intended through this pilot study to assess the sediment contamination of the Saigon river and city's main canals by PCB's (congeners CB 28, 52, 101, 138, 153, 180), DDT's (*pp*'-DDT, *pp*'-DDD and *pp*'-DDE), as well as heavy metals (Cr, Cu, Pb, Zn).

## MATERIALS AND METHODS

For this pilot study, 9 sites have been chosen inside the urban waterways and 2 along the Saigon river (Figure 1). The top surface sediment has been sampled during the rainy season (30 - 31 September 1996) by using an Eckmann dredge.

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For each site, 3 samples, taken near the two banks and in the centre of the waterway, have been thoroughly pooled in similar amounts. The samples were transported in plastic bags and after arrival at the laboratory air dried at room temperature. The organic micropollutants have been analyzed in Switzerland whereas heavy metals have been determined in Viet Nam.

The sediment organic content has been estimated by calcinating 2 g of sample at 550 °C during 3 hours. The weight lost is assimilated to the organic content (ASTM 1981).

For organic micropollutants, the dry sediment was ground and sieved to 1 mm. All the glassware was cleaned with acetone and hexane prior use. The analytical procedure is similar to the one proposed by EPA (US EPA 1980). 10 g of dried sediment is soxhlet extracted with a mixture 1:1 of hexane:acetone during 24 hours. After concentration, the extract is cleaned up through a 4% water deactivated florisil column, desulfurized with activated powdered Cu chips and finally treated with conc. $H_2SO_4$. For some very dirty samples, a second florisil and desulfurization step has been performed. The recovery of the method for the different compounds has been determined by spiking non contaminated Fontainebleau sand with a standard solution. The experimental recoveries are comprised between 82.0 - 112.3% (mean: 95.5 %) for CB 52, 101, 138, 153, 180 and between 82.2 - 88.6 % (mean: 85.0 %) for *pp*'-DDT and its metabolites. The determination of the six CB's and the *pp*'-DDT, *pp*'-DDD, *pp*'-DDE was done by external quantification. The diluted extract was analyzed on two GC equipped with capillary columns of different polarities (DB-5 and Rtx-35) for identification and confirmation purpose. The detection limit for the CB's and for DDT's have been estimated on the basis of three time the baseline noise and are presented in Tables 1 and 2.

For the metal analysis, the ground sediment was sieved at 0.25 mm and the total metal content determined for 1 g of sample by digestion with 10 ml of *aqua regia* (de Vevey et al. 1993). Cr, Cu and Zn were measured by ICP emission mode. The detection limits are 1, 0.01 and 0.05 µg/ml respectively. Pb has been quantified by polarography with a detection limit of 0.05 µg/ml.

## RESULTS AND DISCUSSION

The results for the CB's content in Ho Chi Minh city sediments are presented in Table 1 and Figure 1. The total PCB content has been extrapolated on the basis of the Σ 6 CB's by multiplying with a value corresponding to the theoretical contribution of these 6 CB's to Aroclor 1254 (Sauvain et al. 1994).

PCB's have been detected at all sites except for site N°1; this site is upstream of the marine intrusion limit due to the China sea tide. A possible impact of the PCB's release from the city at this site through tide is therefore ruled out. The impact of the city on the Saigon sediments can be seen by the increase of the Σ 6 CB's content from site N° 1 to the confluence with Dong Nai river (site N° 2). The lowest observed values for the Σ 6 CB's content correspond to the rural/suburban sites (sites N°1, 2, 3, 11). The Nhieu Loc-Thi Nghe waterway, whose drainage area include the centre of the city and one part of the airport zone, is seriously contaminated by PCB's, with concentrations increasing from the upper reach to its junction with the Saigon river. The highest contamination is found along the Lo Gom-Tan Hoa canal (site N° 4). A net increase is observed from the suburban site N°3 to site N°4 but after, no clear trend is observed to the lower reach (sites N° 6 and 7) (Figure 1).

**Table 1.** CB's contamination of Ho Chi Minh city sediments (values corrected for recovery, expressed in ng/g dry weight).

| Site N° | CB 28 | CB 52 | CB 101 | CB 153 | CB 138 | CB 180 | Σ 6 CB's[a] | Total PCB[b] |
|---|---|---|---|---|---|---|---|---|
| 1 | n.d.[c] | n.d. | n.d. | n.d. | n.d. | n.d. | - | - |
| 2 | n.d. | 0.35 | 0.36 | 0.46 | 0.44 | 0.31 | 1.93 (0.26) | 9.3 |
| 3 | n.d. | 1.15 | 1.11 | 1.08 | 0.95 | 0.45 | 4.75 (0.67) | 22.8 |
| 4 | 6.80 | 16.78 | 25.97 | 26.76 | 28.72 | 17.73 | 122.76 (15.6) | 590.5 |
| 5[d] | - | - | - | - | - | - | - | - |
| 6 | n.d. | 6.79 | 8.47 | 8.27 | 8.61 | 4.92 | 37.05 (5.1) | 178.2 |
| 7 | 2.28 | 3.61 | 7.93 | 14.15 | 11.25 | 11.19 | 50.41 (6.3) | 242.5 |
| 8 | n.d. | 5.51 | 6.67 | 6.55 | 7.49 | 4.23 | 30.45 (4.1) | 146.5 |
| 9 | 5.37 | 11.30 | 19.35 | 16.82 | 18.55 | 7.96 | 79.35 (10.1) | 381.7 |
| 10 | 7.50 | 10.98 | 18.53 | 17.56 | 17.94 | 10.36 | 82.87 (10.2) | 398.6 |
| 11 | n.d. | 1.66 | 2.01 | 1.80 | 1.70 | 0.90 | 8.07 (1.12) | 38.8 |
| Min | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | - | - |
| Max | 7.5 | 16.78 | 25.97 | 26.76 | 28.72 | 17.73 | 122.76 | 590.5 |
| Median | - | 4.6 | 7.3 | 7.4 | 8.1 | 4.6 | 33.8 | 162.3 |
| Mean[e] | 5.5 | 6.5 | 10.0 | 10.4 | 10.6 | 6.5 | 46.4 | 223.2 |
| DL[f] | 0.26 | 0.25 | 0.18 | 0.14 | 0.15 | 0.12 | - | - |

[a]: Estimated error in bracket [b]: As Aroclor 1254 [c]: Not detected

[d]: Not quantified [e]: Mean of detected values [f]: Detection limits

It has been reported that PCB's levels in sewer films correlate with the grade of industrialization (Rieger et al. 1995). PCB's contamination may also be the result of diffuse processes like air deposition or domestic wastewater release (de Alencastro et al. 1985). This study suggests that the observed PCB's contamination of the Saigon sediments can be attributed to a large extent to the urban centre. Concerning the six studied congeners, it is interesting to note that the majority of the sites present a similar distribution. PCB's strongly associate with the suspended solid fraction of raw sewage (Roger 1996) and it appears that the main proportion binds to the settled solid phase. The similarity of the individual congener pattern observed here for the different sites could indicate that tide plays a role in the redistribution of PCB's throughout Ho Chi Minh city.

The results for the DDT's content in Ho Chi Minh city sediments are presented in Table 2 and Figure 1. *pp*'-DDT and its metabolites have been detected at all sites without exception. The spatial distribution of DDT's is similar to that found for PCB's, with low contamination in rural/suburban zones and high concentration in urban sediments. The highest recorded value for Σ DDT's is found at the low part of the Nhieu Loc-Thi Nghe canal. The possible sources for such a contamination are difficult to assess, but DDT's has been used in Viet Nam for the elimination of vector-transmitted diseases and for increasing agricultural yields (Iwata et al. 1994).

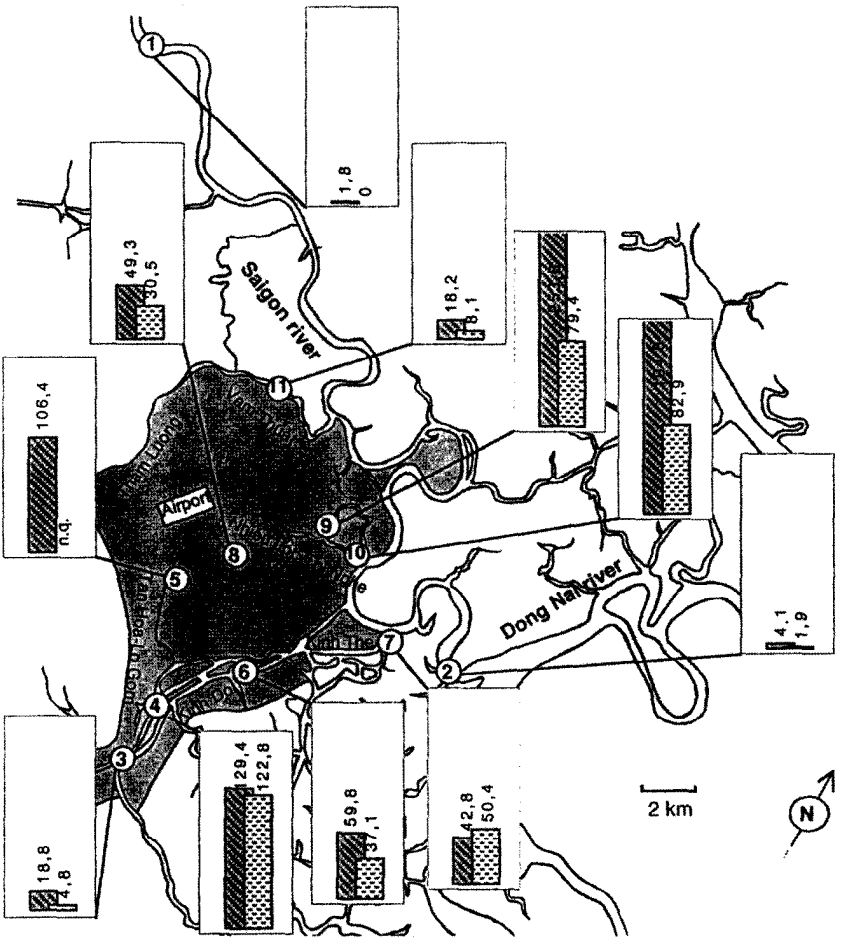


**Figure 1.** Selected sampling sites and geographical distribution of sediment contamination by Σ DDT's (dark bar) and Σ 6 CB's (light bar) in Ho Chi Minh city (values correspond to observed concentrations, see Table 1 and 2).

Ratios between *pp*'-DDT (and its metabolites) and Σ DDT's have been calculated (Figure 2) in order to evaluate whether DDT's inputs are recent or not. A predominance of *pp*'-DDT versus *pp*'-DDE and *pp*'-DDD is observed for sites N° 4, 7, 9. For these sites, the ratio *pp*'-DDT/Σ DDT's is the highest, suggesting that input of *pp*'-DDT may still occur at or near these places. A very low ratio *pp'*-DDT/Σ DDT's is observed for sites N° 3 and 5. It is surprising to see big differences in the *pp*'-DDT distribution for sites which are not so far from the very contaminated site N°4. A better knowledge of the complicated hydrodynamic and the anoxic conditions in these canals could bring some insight in the transport and fate of these pollutants released inside the city. The other sites (N°1, 2, 6, 8, 10 and 11) present a very similar distribution ratio, with a mean composition of 23.5 ± 2% for *pp*'-DDT/Σ DDT's, 42.0 ± 11% for *pp*'-DDE/Σ DDT's and 36.4 ± 11% for *pp*'-DDD/ Σ DDT's.

Compared to the data of Iwata et al (1994) for the Nhieu Loc-Thi Nghe canal, our results are 1-4 times lower for PCB's and 2-15 times lower for DDT's; the highest differences are observed for the upstream zone of the canal.

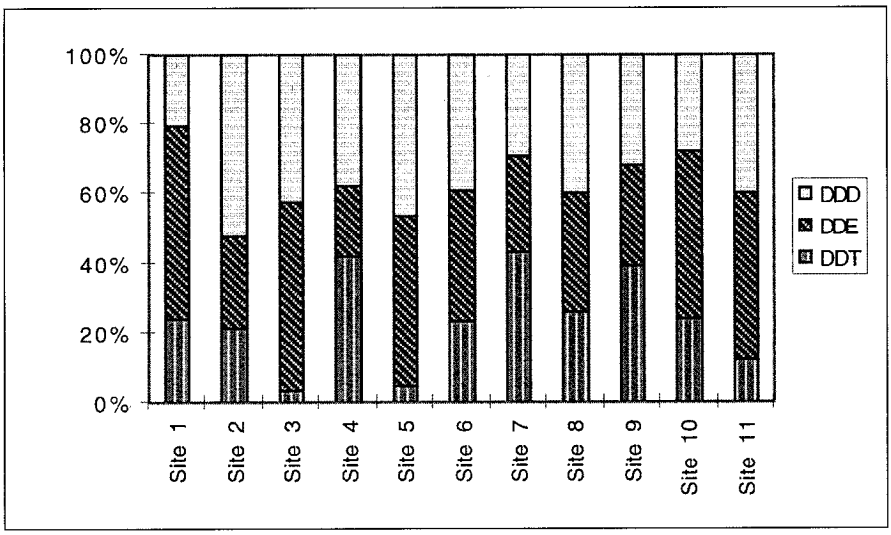


**Figure 2.** Contribution of the different DDT's metabolites to the Σ DDT's at the studied sites in Ho Chi Minh city.

**Table 2.** DDT's contamination of Ho Chi Minh city sediments (values corrected for recovery, expressed in ng/g dry weight).

| Site | Ignition loss (%) | *pp'*-DDE | *pp'*-DDD | *pp'*-DDT | Σ DDT's [a] |
|---|---|---|---|---|---|
| 1 | 7.2 | 0.98 | 0.36 | 0.42 | 1.76 (0.25) |
| 2 | 6.5 | 1.09 | 2.14 | 0.88 | 4.10 (0.61) |
| 3 | 7.7 | 10.17 | 8.01 | 0.61 | 18.79 (1.4) |
| 4 | 3.1 | 27.0 | 48.4 | 53. 9 | 129.4 (28.7) |
| 5 | 21.0 | 52.39 | 49.28 | 4.72 | 106.38 (8.4) |
| 6 | 11.4 | 22.87 | 23.28 | 13.67 | 59.82 (8.8) |
| 7 | 9.5 | 11.77 | 12.51 | 18.51 | 42.79 (9.6) |
| 8 | 3.3 | 17.10 | 19.60 | 12.64 | 49.33 (7.8) |
| 9 | 11.6 | 73.69 | 81.44 | 98.50 | 253.62 (52.6) |
| 10 | 15.0 | 94.06 | 53.56 | 46.72 | 194.33 (28.4) |
| 11 | 5.7 | 8.82 | 7.18 | 2.18 | 18.18 (1.9) |
| Min | 3.1 | 0.98 | 0.36 | 0.42 | 1.76 |
| Max | 21.0 | 94.1 | 81.4 | 98.5 | 253.6 |
| Median | 7.4 | 17.1 | 19.6 | 12.6 | 49.3 |
| Mean | 9.3 | 29.1 | 27.8 | 23.0 | 79.9 |
| DL [b] | - | 0.12 | 0.11 | 0.24 | - |

[a]: Estimated error in bracket. [b]: Detection limit

**Table 3.** Heavy metal content of Ho Chi Minh city sediments determined by *aqua regia* digestion (values expressed as mg/kg dry weight).

| Site | Cr | Cu | Pb | Zn |
|---|---|---|---|---|
| 1 | 108.0 | 16.6 | 20.31 | 54.2 |
| 2 | 175.0 | 24.1 | 19.85 | 90.8 |
| 3 | 170.0 | 22.4 | 41.1 | 133.7 |
| 4 | 406.0 | 361.4 | 550.8 | 671.3 |
| 5 | 405.0 | 175.8 | 95.2 | 1420.5 |
| 6 | 497.0 | 110.7 | 106.6 | 616.4 |
| 7 | 234.0 | 69.9 | 46.6 | 233 |
| 8 | 170.0 | 72.3 | 145.8 | 409.5 |
| 9 | 324.0 | 98.4 | 166.0 | 624.3 |
| 10 | 290.3 | 121.2 | 105.2 | 599.5 |
| 11 | 100.5 | 19.0 | 15.2 | 11.7 |
| Min | 100.5 | 16.6 | 15.2 | 11.7 |
| Max | 497.0 | 361.4 | 550.8 | 1420.5 |
| Median | 204.5 | 71.1 | 70.9 | 321.2 |
| Mean | 261.8 | 99.2 | 119.3 | 442.3 |

The results for the heavy metal contamination of Ho Chi Minh city sediments are presented in Table 3. Generally, the heavy metal concentration is lower outside the city than inside. Among the rural/suburban sites (sites N°1, 2, 3, 11), site N° 11 presents the lowest total heavy metal content and site N°3 the highest.

Inside the city, the total heavy metal contamination of the sediments is increasing following the order: site N°7 < 8 < 9 < 10 < 6 < 4 < 5. The most heavily polluted sites are located in the southern part of the city, along the Tan Hoa-Lo Gom water system. The highest total heavy metal concentration has been observed at site N° 5, where chemical, oil, textile and food industries as well as a lot of family scale factories are located. The Nhieu Lot-Thi Nghe water system (sites N°8, 9, 10) is also contaminated but to a smaller extent. The distribution of Cr, Cu and Pb in sediments is very similar for all sites except N°4, 8, 9. These three sites are characterised by a relative higher Pb content.

This pilot study shows that some sites are heavily polluted (mainly in the south part of the city and along the Nhieu Loc-Thi Nghe canal) and the observed concentrations may present environmental risks. The proposed remediation of the canals by dredging rises the question of the management of the excavated material. Different regulations concerning sediment quality have been proposed (for example, from Environment Canada concerning marine disposal of dredged material (Rochon 1985) or from US EPA for benthic organisms protection (Nowell 1994)). Following the recommendations from Environment Canada, all the urban sediments (sites N°4, 5, 6, 7, 8, 9, 10) exceed the recommended values for at least Cu, Cr and Zn and should not be dumped in marine environment. This is also true concerning the total PCB content, and this micropollutant family may present a chronic environmental risk. For DDT's, sites N°4, 7, 8, 9, 10 are over the proposed criteria for benthic organisms protection (Nowell 1994).

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