行政院國家科學委員會專題研究計畫 成果報告

建立河川底泥中多氯聯苯污染之環境復育方法
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建立河川底泥中多氯聯苯污染之環境復育方法
Establishment of Environmental Remediation for Polychlorinated Biphenyls Contaminated River Sediments

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一、　中英文摘要

本計畫主軸在於多氯聯苯污染之環境復育，研究主要分為兩方面，一是多氯聯苯在台灣河川底泥中的流佈與變遷，二是利用自然環境模擬槽進行多氯聯苯之自然降解實驗。第一部份之研究中，自 2005 年十月至 2006 年 12 月，總共採集 28 處二仁溪底泥樣品進行分析，結果顯示，底層之多氯聯苯污染高於表層，下游近出海口處之污染高於南莊橋上游，多氯聯苯總濃度最高為 6.175 ppm。多氯聯苯同類物中，含 5 到 6 個氯基的多氯聯苯均來自商品用多氯聯苯(Aroclors)，含 3 到 4 個氯基的多氯聯苯應來自其它多氯聯苯之脫氯產物。研究亦發現，近年來高含氯量之多氯聯苯之變化不大，可見其自然脫氯降解情形不佳，且多氯聯苯污染有向出海口移動的趨勢。

第二部份的研究重點在於架設自然環境模擬槽(SAB)，5 種二仁溪底泥中常見的多氯聯苯單品，包含 2,3,4-chlorobiphenyl (2,3,4-CBp)、2,4,2',5'-CBp、2,5,3',4',-CBp、2,3,4,2',4',5-CBp 以及 2,4,5,2',4',5'-CBp, 被混入底泥土壤，填入多孔性管柱再裝設到 SAB 中。在三個月的培養期間，只有 2,3,4-CBp 有明顯的降解，並產生 2,4-CBp 的脫氯產物，至於其它同類物只有少量分解與產物生成。雖然大部分多氯聯苯單品可被脫氯分解，但在 7 個月後，也僅有 2,3,4-CBp 和 2,4,2',5'-CBp 可被完全降解，結果顯示二仁溪底泥中確有多氯聯苯降解微生物存在，但仍須更多努力才能改善多氯聯苯的自然降解效率。

關鍵詞：環境復育、多氯聯苯、二仁溪、脫氯作用

Abstract

In order to investigate the environmental remediation of polychlorinated biphenyls (PCBs) contamination in the river sediment in southern Taiwan. Two major researches including the transition of polychlorinated biphenyls contamination in Taiwan river sediment and the dechlorination of polychlorinated biphenyls in a Simulated Aquarium Box (SAB) were performed. For the first research, different layers of sediments from 28 locations of Erh-Jen River were collected from October, 2005 to December, 2006, separately. After extraction and GC analysis, the results showed the PCBs concentration in the lower layers were higher than the upper layers, and in the downstream locations were higher than the upstream locations. The total PCBs concentration of all samples were range from 0 ~ 6.175 ppm. Among all PCB congeners, the highly chlorinated ones with 5 ~ 6 chlorines were originated from Aroclors, and the less chlorinated ones with 3 ~ 4 chlorines were possibly from the dechlorination of highly chlorinated PCBs. By comparing the concentration and distribution of PCBs contaminant in a sequence of time, the results suggested that the dechlorination of PCBs was seemingly inhibited in recent years and the persisted PCBs contamination was moving toward the sea.

In second research, a Simulated Aquarium Box (SAB) was constructed in a purpose of evaluating polychlorinated

biphenyls (PCBs) dechlorination in the natural sediment environment. River sediments amended with different PCB congeners including 2,3,4-chlorobiphenyl (2,3,4-CBp), 2,4,2',5'-CBp, 2,5,3',4',-CBp, 2,3,4,2',4',5-CBp, and 2,4,5,2',4',5'-CBp, were separately put into porous plastic columns. After 3 months of incubation, only the concentration of 2,3,4-CBp significantly decreased and 2,4-CBp was found as the dechlorination product. For the other congeners, their concentrations were slightly decreasing, and small amount of products were found. Although most of the tested PCB congeners could be dechlorinated after 7 months, only 2,3,4-CBp and 2,4,2',5'-CBp were completely degraded within one year of incubation. It suggested that PCBs dechlorinating consortia were existed in the river sediment and the PCBs dechlorination could happened in the natural sediment environment, but some effort must be made for the improvement of the dechlorination efficiency.

Keywords : Environmental remediation, Polychlorinated biphenyls, Erh-Jen River, dechlorination

二、 緣由與目的

Polychlorinated biphenyls (PCBs) are organic chemicals with characteristics similar to that of DDT and 1 of 11 persistent organics pollutants (POPs) a class of chemical compounds in which 1–10 chlorine atoms are attached to the biphenyl molecule(Erickson 1997, UNEP 1999). It can be seen from the structure that a large number of chlorinated compounds are possible. The 209 possible compounds are called congeners. PCBs can also be categorized by degree of chlorination. Toxic congeners carry between 5 and 10 chlorine atoms, mostly in the para- and meta-positions, however, the congener substituted at the 3,4-ortho positions are considered the most toxic (Gannon and Dodson 1990, Mcleese et al. 1980). The properties of each PCB congener are dependent on the degree of chlorination. The industrially produced PCBs have properties ranging from highly mobile liquids that are colorless and oily to more viscous and increasingly darker liquids, to yellow and then black resins. Lower chlorinated PCBs (the mono-, di-, tri-, and tetra-chlorinated PCBs) tend to be colorless oily liquids.

PCBs are persisted in the environment and found in air, water, soil, and food. PCBs entered the air, water, and soil (Garcia et al. 1996, Lead et al. 1996, Fuoco et al. 1996) during their manufacture, use, and disposal, from accidental spills and leaks during their transport, and from leaks or fires in products containing PCBs. PCBs can travel long distances in the air and can be deposited in areas far away from where they were released (ATSDR, 1993). PCBs have low-to-moderate toxicity. Treated samples of animals show an LD50 ranging from 0.5 g/kg to 11.3 g/kg of body weight. Most of the effects are the result of repetitive or chronic exposure. PCBs absorbed by humans and animals through the skin, the lungs, and the gastrointestinal tract.

Er-Jen River had received family and animal husbandry waste water, and also the effluent from industrial parks. After decade of uncontrolled discharging, Er-Jen River became the most serious polluted River in southern Taiwan, and the pollutants in this section had the tendency to expand and spread. In this study, sediments from different locations of Er-Jen River were sampled and test the content of PCBs. By analyzing the distribution of PCBs congeners in geographical and historical, the fate of PCB contamination could be told, and the necessary steps for diminishing PCBs damage could be developed.

Microbial dechlorination entails the action of both an electron acceptor and donor; specifically, when the chlorine atom of the aryl compound accepts an electron and be taken off from the molecule, a hydrogen atom was taken into the molecule in return (Holliger et al. 1992). The ability

of various monocyclic halogenated compounds, including halobenzoates to prime PCBs dechlorination has also been studied and various bromo-analogues found to be effective in priming PCBs dehalogenation, suggesting that the communities are enriched on the basis of their ability to dehalogenate monocyclic aromatics effectively to dechlorinated PCBs (DeWeerd and Bedard, 1999). Er-Jen River was polluted by PCBs for several decades, the dechlorination ability of microorganisms from river sediment has been tested (Chen 2001a, 2001b). However, most of the tests were performed in the fully artificial condition, and the natural environmental decchlorination activity was never revealed. The objective of the present study was to determine compound selectivity, relative dechlorination rates of the PCBs, and the influence of depth on the dechlorination rate carried out by an anaerobic microbial consortium from sediment of Er-Jen River. By a Simulated Aquarium Box (SAB), Where in situ dechlorination was observed. Hence, it is interesting to explore on the factors that influencing PCBs dechlorination by anaerobes from natural water bodies and sediments.

三、 結果與討論

1.**Transistion of polychlorinated biphenyls contamination in Taiwan river sediment**

Sediment samples were collected from Er-Jen River, Tainan, Taiwan during from October, 2005 to December, 2006. Totally 28 sites were separate to 3 group (Table 1), first group is located in the northern bank of Er-Jen River from San-Yeh-Kon Creek to Nan-Ding Bridge (SN area), including 9 sites which named as S1, S2, S3, S4, S5, S6, S7, L1 and L2. Eleven sites of second group were located in the northern bank of Er-Jen River from Nan-Ding Bridge to the Mouth of Er-Jen River (NNM area), including NS1, NS2, NS3, NS4, NS5, NS6, NS7, L3, L4, L5 and L6. Eight sites of third group were located in the southern bank of Er-Jen River from Nan-Ding Bridge to the mouth of Er-Jen River (SNM area), including NNS1, NNS2, NNS3, L7, L8, L9, L10 and L11. Every site was collected for two locations, one was closed to the river flow called "inside sample" and the other was away from the flow called "outside sample." All sediment samples were collected as a column with a depth of 60 cm. When a sediment sample carried back to laboratory, it was separate to 3 layers, the upper layer was 0~20 cm in depth, the middle layer was 20~40 cm, and the lower layer was 40~60 cm. All sediment samples were kept at 4°C before extracted and analyzed.

The Sub-total concentrations of all PCB congeners in Er-Jen River sediment from layers of different sites were listed in Table 2. As Table 2 revealed, the sub-total concentrations of PCB congeners were ranged from 0 ~ 6.175 ppm. In the inside points, the upper layer with a highest PCBs concentration of 3.442 ppm, the middle layer with 6.875 ppm and the lower layer with 0.727ppm. It's different from the outside points, the highest PCBs happen in lower layer with a concentration of 3.881 ppm, and the upper is 2.057 ppm, the lower is 2.113 ppm, individually. The results suggested that the inside points were flushed often by river water, it leaded to the great variation of PCBs concentration in different depth of sediments. But the inside points were with a more similar PCB contamination in all three layers from same point. According to the PCBs contamination attribution, it showed that San-Yeh-Kon Creek leaded to a higher PCBs concentration in Haikou section than the other sections. And highly chlorinated PCBs that thought to be more toxic materials were verified to be stored in the bottom mud in the rivers and creeks.

Table 3 showed the major PCB congeners existed in different locations. Comparing to previous works in 1997 and 2003, PCBs contamination was gradually moving downstream toward the Taiwan Strait. And the gross concentration decreased a little, it was not because the

dechlorination of highly chlorinated PCB congeners but form the effect of spread and diffusion. By checking the distribution of PCB congeners in sediments, highly chlorinated PCBs with 6 chlorines such as 23452'5'-, 23462'3'-, 23463'4'-, 2342'4'5'-, 2352'3'6'-CBp, with 7 chlorines, 234562'5'-, 23462'4'5'-, 23562'3'6'-CBp, and with 8 chlorines 23562'3'5'6'-CBp were still remained in some sediments and the concentration did not decrease obviously. In the L3 ~ L6 sites and NNS1 ~ NNS3 sites, the PCBs concentration was significantly higher than the others sites, and also with more highly chlorinated PCB congeners accumulated. It suggested whenever PCBs congeners settled down in this area, the dechlorination was not happening vigorously.

2.Dechlorination of polychlorinated biphenyls in a Simulated Aquarium box

SABs (Figure 1) were size wide 18 inches, high 18 inches and long 36 inches include 2 boxes. First box was filled with sediment and river water. Second box was filled with river water only. Column installed in SAB were with the size of 30 cm long. and diameter in 5 cm. Totally 25 sediment columns were installed in the first box. PCB congeners including 2,3,4-chlorobiphenyl (2,3,4-CBp), 2,4,2',5'-CBp, 2,5,3',4',-CBp, 2,3,4,2',4',5-CBp, and 2,4,5,2',4',5'-CBp were prepared in acetone solution, spiked in to sediments and then filled up the columns, separately. The final concentration of PCB congeners were ranged from 4 ppm to 10 ppm. Collected sediments were mixed with yeast extracts as additional nutrients before filled into columns.

2,3,4-CBp dechlorination

After 220 days of incubation in SAB, Er-Jen River sediment microbes showed 2,3,4-CBp-dechlorination ability with the help of yeast extract and the major product was 2,4-CBp (Table 4). For every layer, the lowest ORP values of were less than –300mV. And after 320 days, the spiked 234-CBp was completely dechlorinated in all layers.

There was a slight difference between the 5 layers, the dechlorination seemingly inhibited in the upper layer (layer 1) since the maximum concentration of the dechlorination product, 24-CBp in layer 1 was significantly lower than the lower layers. The reason might be the upper layers always receive some oxygen and could not reach a strictly anaerobic condition.

242'5'-CBp dechlorination

Table 5 showed that except layer 1, the other lower layers (layer 2 ~ layer 5) dechlorinated 242'5'-CBp after 320 days of incubation. The dechlorination product was 252'-CBp, different to the finding of Thai Canal study, it was told that 242'5'-CBp could be dechlorinated to 242'-CBp and 252'-CBp in an equal amount.

253'4'-CBp dechlorination

During the first 220 days of incubation in SAB, Er-Jen River sediment microbes showed no dechlorination ability to 253'4'-CBp. After 320 days, 253'4'-CBp was partially dechlorinated to the product of 342'-CBp (Table 6), and more than 70 % of spiked 253'4'-CBp was remained. However the upper layer (layer 1) could not develop the dechlorination to 253'4'-CBp.

2342'4'5'-CBp dechlorination

Similar to the dechlorination of 253'4'-CBp, the first 220 days showed no dechlorination ability, and after 320 days, 2342'4'5'-CBp was partially dechlorinated to the product of 2452'4'-CBp (Table 7). But only trace of 2452'4'-CBp was found within the incubation period, and more than 90 % of spiked 2342'4'5'-CBp was remained. The upper layer (layer 1) also could not develop the dechlorination to 2342'4'5'-CBp.

2452'4'5'-CBp dechlorination

The dechlorination of 253'4'-CBp was significant in SAB, after 320 days, 2452'4'5'-CBp was completely dechlorinated to 4 products, including 242'4'-CBp, 2452'5'-CBp as two major products and 242'5'-CBp, 2452'4'-CBp as minor products (Table 8). The

dechlorination of the upper layers and lower layers is similar.

四、計畫成果自評

1. The laboratory works in previous researches also showed the possibility of field remediation to PCBs contamination. However, according to recent researches and this study, PCBs in Er-Jen River sediments was seemingly becoming less-transformable and moving downstream to the sea. Therefore, the activity of fishing around this area must beware of PCBs spreading and any kind of utilization of river sediment and water in this area shall be with limits.
2. By constructing a natural environment-simulated system, the environmental fate of pollutants and the degradation ability of indigenous microbes can be evaluated. In this study, a Simulated Aquarium Box (SAB) was designed and built up. The transformation test of PCBs in SAB was also performed. The result suggested that SAB is a suitable and applicable system for the preliminary research for PCBs environmental remediation.
3. The dechlorination test of PCBs in batch experiments by transferring sediment mixed culture from Er-Jen River to serum bottles. Although nutrients were amended, the degradation of PCBs was rarely happen. In the contrast with Ho-Tsin River, the consortia from Ho Tsin River were more active in degrading HCB and PCBs under the same conditions. It suggested that after years of environmental transitions in Er-Jen River, the indigenous PCBs dechlorination consortia gradually losing their ability to dechlorinate PCBs. It will be a warning to those who expect the PCB contamination in Er-Jen River can be depleted by environmental attenuation in recent years. And some constructive step must be taken to control the PCBs pollution in Er-Jen River, rather than wait and see.

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Figures and Tables

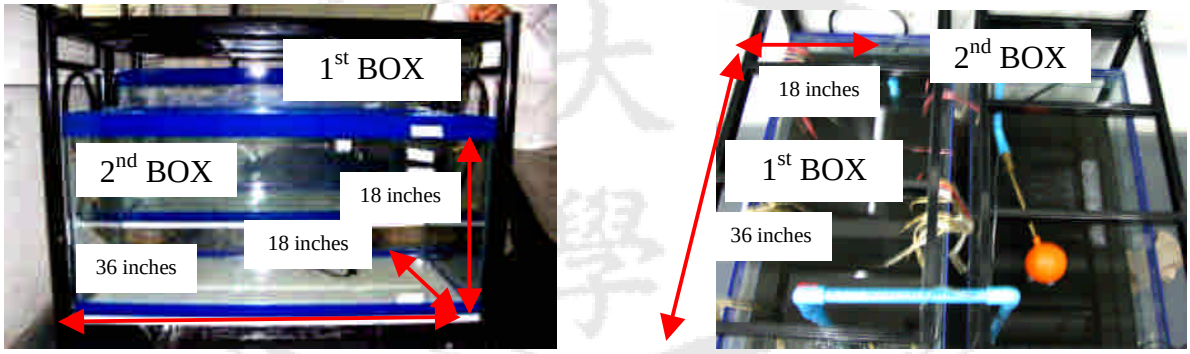

Figure 1. Simulated Aquarium Boxes (SABs)

Table 1. Location of sampling sites along Er-Jen River

Reference point	2535836	165495	Sampling time	2006.6.16
Sites (SN area)	inside		outside	
	X-coordinate(E)	Y-coordinate(N)	X-coordinate(E)	Y-coordinate(N)
S1	2535806	165548	2535805	165551
S2	2535899	165661	2535895	165660
S3	2535944	165760	2535940	165756
S4	2535979	165881	2535973	165877
S5	2535989	165981	2535985	165977
S6	2535975	166074	2535973	166072
S7	2535957	166190	2535955	166191
Reference point	2535834	165487	Sampling time	2006.6.17
Sites (NNM area)	inside		outside	
	X-coordinate(E)	Y-coordinate(N)	X-coordinate(E)	Y-coordinate(N)
NS1	2535714	165439	2535711	165439
NS2	2535651	165345	2535648	165341
NS3	2535589	165242	2535586	165245
NS4	2535475	165067	2535473	165066
NS5	2535399	164969	2535397	164973
NS6	2535325	164855	2535323	164859
NS7	---	---	2535183	164698
NNS1	2535532	165410	2535534	165410
NNS2	2535439	165278	2535441	165276
NNS3	2535290	165093	2535312	165007
Reference point	2535835	165493	Sampling time	2006.9.13
Sites (SNM area)	inside		outside	
	X-coordinate(E)	Y-coordinate(N)	X-coordinate(E)	Y-coordinate(N)
L1	2535843	165582	2535841	165582
L2	2535807	165545	2535803	165550
L3	2535705	165427	2535703	165427
L4	2535670	165369	2535669	165372
L5	2535283	164817	2535279	164819
L6	2535199	164695	2535192	164695
L7	2535532	165414	2535534	165412
L8	2535396	165202	2535397	165201
L9	2535315	165090	2535318	165088
L10	2535102	164797	2535104	164795
L11	---	---	2535162	164147

Table 2. The gross amount of PCB congeners in different Er-Jen River sediment samples

Sites	inside -upper layer	inside -middle layer	inside -lower layer	outside -upper layer	outside -middle layer	outside -lower layer
SN area						
S1	0.0343	0.0356	0.0388	0.1911	0.1041	0.0889
S2	0.0327	0.1318	0.1627	0.0135	0.0011	1.9713
S3	0.0457	0.0606	0.0689	0.0584	1.6203	0.6545
S4	0.2262	0.2049	0.2502	0.2789	0.8682	0.3356
S5	0.1703	0.8873	0.7424	1.5841	0.6352	0.0131
S6	0.0928	0.4012	0.1489	0.1255	0.0762	0.5086
S7	0.0220	0.0918	0.1607	2.3071	0.3286	0.5292
L1	0.0395	0.1306	0.0213	0.0499	0.0225	0.0496
L2	0.0706	0.0163	0.0110	0.0349	0.0180	0.0483
NNM area						
NS1	3.4424	0.2586	0.0862	0.0929	0.0473	0.1750
NS2	0.1246	0.3356	0.2939	0.1914	0.2808	0.2357
NS3	0.0938	0.1430	0.1685	0.1085	0.4424	0.2653
NS4	0.1101	0.2101	0.6178	0.6249	0.2123	0.3222
NS5	0.0968	0.0460	0.1812	0.2042	0.1114	0.1243
NS6	0.0525	0.0717	0.0700	0.0458	0.0109	0.0121
NS7	0.0116	0.0000	0.0000	0.1219	0.1411	0.1436
L3	0.0218	0.0368	0.5422	0.2590	0.0866	3.8810
L4	0.3282	0.1899	0.0848	0.0006	0.0034	0.0956
L5	0.0646	0.0732	0.0625	0.0412	0.2007	0.1399
L6	0.0836	0.0501	0.0000	0.0213	0.0707	0.0000
SNM area						
NNS1	0.9705	0.3209	0.2751	0.2150	2.1130	0.2494
NNS2	0.9747	6.1749	0.7276	1.4659	0.5962	0.5679
NNS3	0.2772	0.8320	0.0857	0.6475	0.0680	0.9232
L7	0.0978	0.0751	0.4261	0.4195	0.5975	0.2799
L8	0.0308	0.0959	0.1289	2.0567	0.3018	0.2482
L9	0.0432	0.1505	0.8619	0.1540	0.1073	0.4878
L10	0.0048	0.0137	0.0030	0.0059	0.0076	0.0000
L11	0.0000	0.0000	0.0000	0.1399	0.0057	0.0073

Table 3. PCB congeners distribution in different Er-Jen River sediment samples

SN area	Major PCB congeners in sediment (-CBp)
S1	44'-,236-,263'-,232'-,264'-,233'-,342'-,252'6'-,354'-,232'6'-,2454'-,23452'3'4'-,234563'4'-
S2	4-,22'-,26-,35-,34-,34'-,252'-,242'-,254'-,244'-,233'-,342'-,252'6'-,354'-,232'6'-,252'5'-,2463'-,242'5'-,232'5'-,2462'6'-243'5'-,2454'-,2352'4'-,2452'5'-,343'4'-,2353'4'-,2342'3'6'-,2452'4'5'-,2342'4'5'-,23463'4'-,234563'-,23462'4'5'-,234562'5'-
S3	44'-,236-,263'-,254'-,233'-,342'-,252'6'-,354'-,232'6'-,344'-,232'4'-,2363'-,2342'-,2364'-,243'5'-,2454'-,233'4'-,2344'-,2362'3'-,2352'5'-,2342'4'-,2362'3'6'-,2352'3'6'-,23562'3'-,23452'5'-,23562'3'6'-
S4	33'-,246-,253'-,2362'-,354'-,232'6'-,344'-,232'4'-,2363'-,243'5'-,2453'-,2462'4'-,2354'-,2342'5'-,23464'-,2352'3'6'-,23462'3'-
S5	33'-,246-,235-,352'-,254'-,233'-,342'-,252'6'-,354'-,232'6'-,242'5'-,2346-,243'5'-,2454'-,253'4'-,233'4'-,2344'-,2362'3'-,2352'5'-,2342'4'-,2362'3'6'-,2353'4'-,23562'3'-
S6	252'5'-,2463'-,232'5'-,2462'6'-,2342'-,2364'-,243'5'-,232'3'-,2362'6'-,253'4'-,243'4'-,2362'5'-,2352'3'-,2342'5'-,23464'-,343'4'-,2363'4'-,2453'4'-
S7	23-,24'-,262'-,34-,34'-,242'-,232'-,264'-,253'-,244'-,233'-,342'-,252'6'-,234'-,242'6'-,252'5'-,2463'-,242'5'-,242'4'-,2452'-,2464'-,2346-,344'-,232'4'-,2363'-,2342'-,2364'-,232'3'-,2362'6'-,2454'-,243'4'-,2362'5'-,233'4'-,2344'-,2362'3'-,2352'5'-,2452'4'-,3452'4'-,2452'3'-,2342'5'-,23464'-,2342'4'-,2362'3'6'-,343'4'-,2363'4'-,2342'3'-,23562'5'-,2453'4'-,2342'3'6'-,2452'4'5'-,2343'4'-,23452'5'-,23562'3'6'-,2342'4'5'-,23463'4'-,234563'-
L1	245-, 252'5'-, 2463'-, 232'5'-, 2462'6'-, 2342'-, 2364'-, 253'4'-, 243'4'-, 2362'5'-, 233'4'-, 2344'-, 2362'3'-, 2352'5'-, 343'4'-, 2363'4'-, 2453'4'-, 2362'4'5'-
L2	233'-, 342'-, 252'6'-, 252'5'-, 2463'-, 232'5'-, 2462'6'-, 344'-, 232'4'-, 2363'-, 2342'-, 2364'-, 253'4'-, 243'4'-, 2362'5'-
NNM area	Major PCB congeners in sediment
NS1	3-,23-,24'-,262'-,253'-,243'-,244'-,252'5'-,2463'-,242'5'-,242'4'-,2452'-,2464'-,2342'-,2364'-,232'3'-,2362'6'-,2454'-,243'4'-,2362'5'-,2362'4'-,3454'-,2453'4'-,234562'3'-
NS2	3-,22'-,26-,232'-,264'-232'5'-,,2462'6'-,2342'-,2364'-,243'5'-,232'3'-,2362'6'-,2453'4'-,2342'4'5'-,23463'4'-,234563'-
NS3	3-,,262'-,242'-,232'-,264'-,252'5'-,2463'-,232'5'-,2462'6'-,2342'-,2364'-,232'3'-,2362'6'-,253'4'-,243'4'-,2362'5'-,2453'4'-,23452'4'5'-,23563'4'5'-
NS4	3-,262'-,242'-,232'-,264'-,234'-,242'6'-,242'4'-,2452'-,2464'-,232'5'-,2462'6'-,2342'-,2364'-,232'3'-,2362'6'-,243'4'-,2362'5'-,2453'4'-,2362'4'5'-
NS5	242'-,232'-,264'-,233'-,342'-,252'6'-,232'5'-,2462'6'-,2342'-,2364'-,243'5'-,232'3'-,2362'6'-,243'4'-,2362'5'-
NS6	242'-,235-,352'-,252'5'-,2463'-,2342'-,2364'-,243'5'-,243'4'-,2362'5'-,343'4'-,2363'4'-,2453'4'-,3453'4'-,23452'3'-,23562'3'5'-
NS7	2342'-,2364'-,243'5'-,232'3'-,2362'6'-,243'4'-,2362'5'-
L3	3-,23'-,23-,24'-,262'-,34-,34'-,44'-,242'-,236-,263'-,232'-,264'-,253'-,244'-,233'-,342'-,252'6'-,252'5'-,2463'-,242'5'-,242'4'-,2452'-,2464'-,232'5'-,2462'6'-,344'-,232'4'-,2363'-,253'4'-,243'4'-,2362'5'-,233'4'-,2344'-,2362'3'-,2352'5'-,2352'4'-,2452'5'-,2452'4'-,3452'4'-,2452'3'-,2342'5'-,23464'-,343'4'-,2363'4'-,2342'3'-,23562'5'-,2453'4'-,2362'45'-,2342'3'6'-,2452'4'5'-,2343'4'-,23452'5'-,23562'3'6'-,2342'4'5'-,23463'4'-,234563'-,3453'4'-,23452'3'-,23562'3'5'-,2342'3'4'-,2453'4'5'-
L4	23-,24'-,235-,352'-,2362'-,252'5'-,2463'-,242'4'-,2452'-,2464'-,232'5'-,2462'6'-,253'4'-,243'4'-,2362'5'-,2352'4'-,2452'5'-,343'4'-,2363'4'-,2453'4'-,2342'3'6'-,2452'4'5'-,23452'5'-,23562'3'6'-,2342'4'5'-,23463'4'-,234563'-,3453'4'-,23452'3'-,23562'3'5'-,23453'4'-,23462'3'4'-,23562'3'5'6'-
L5	232'-,264'-,2362'-,252'5'-,2463'-,2346-,2342'-,2364'-,253'4'-,243'4'-,2362'5'-,2453'4'-,2362'4'5'-,2343'4'-,2342'45'-,23463'4'-,234563'-,3453'4'-,23452'3'-,23562'3'5'-
L6	235-,352'-,2362'-,2342'-,2364'-,253'4'-,23452'4'5'-,23563'4'5'-,23463'4'5'-

Table 3. PCB congeners distribution in different er-jen river sediment samples (continued)

SNM area	Major PCB congeners in sediment
NNS1	23-,24'-,262'-,34-,34'-,236-,232'-,264'-,244'-,233'-,342'-,252'6'-,234'-,242'6'-,252'5'-,2463'-,242'5'-,242'4'-,2452'-,2464'-,344'-,232'4'-,2363'-,2342'-,2364'-,243'5'-,232'3'-,2362'6'-,2454'-,253'4'-,243'4'-,2362'5'-,2362'4'-,233'4'-,2344'-,2362'3'-,2352'5'-,2452'4'-,3452'4'-,2452'3'-,2342'5'-,23464'-,343'4'-,2363'4'-,2342'3'-23562'5'-,2453'4'-,2342'3'6'-,2452'4'5'-,2343'4'-,23452'5'-,23562'3'6'-,2342'4'5'-,23463'4'-,234563'-,2342'3'4'-,2453'4'5'-
NNS2	3-,22'-,26-,23-,262'-,34-,34'-,242'-,232'-,264'-,253'-,243'-,244'-,233'-,342'-,252'6'-,234'-,242'6'-,2362'-,252'5'-,2463'-,242'5'-,242'4'-,2452'-,2464'-,232'5'-,2462'6'-,344'-,232'4'-,2363'-,2342'-,2364'-,243'5'-,232'3'-,2362'6'-,2462'5'-,2454'-,253'4'-,243'4'-,2362'5'-,233'4'-,2344'-,2362'3'-,2352'5'-,2352'4'-,2452'5'-,2452'4'-,3452'4'-,2352'3'-,2452'3'-,2342'5'-,23464'-,343'4'-,2363'4'-,2342'3'-,23562'5'-,2352'3'6'-,2453'4'-,2342'3'6'-,2452'4'5'-,2343'4'-,23452'5'-,23562'3'6'-,2342'4'5'-,23463'4'-,234563'-,2453'4'5'-,23453'4'-,23462'3'4'-,23562'3'5'6'-
NNS3	3-,22'-,26-,262'-,34-,34'-,44'-,236-,263'-,232'-,264'-,245-,244'-,233'-,342'-,252'6'-,234'-,242'6'-,252'5'-,2463'-,242'5'-,242'4'-,2452'-,2464'-,232'5'-,2462'6'-,344'-,232'4'-,2363'-,2342'-,2364'-,243'5'-,253'4'-,243'4'-,2362'5'-,233'4'-,2344'-,2362'3'-,2352'5'-,2352'4'-,2452'5'-,2452'4'-,3452'4'-,2352'3'-,2452'3'-,2342'5'-,23464'-,343'4'-,2363'4'-,2342'3'-,23562'5'-,2453'4'-,2342'3'6'-,2452'4'5'-,2343'4'-,23452'5'-,23562'3'6'-
L7	34-,34'-,242'-,232'-,264'-,244'-,233'-,342'-,252'6'-,242'5'-,232'5'-,2462'6'-,2342'-,2364'-,253'4'-,243'4'-,2362'5'-,233'4'-,2344'-,2362'3'-,2352'5'-,2352'4'-,2452'5'-,2452'4'-,3452'4'-,2342'5'-,23464'-,343'4'-,2363'4'-,2453'4'-,2362'4'5'-,2342'3'6'-,2452'4'5'-,23462'4'6'-,2343'4'-,3453'5'-,2463'4'5'-,23452'5'-,23562'3'6'-,2342'4'5'-,23463'4'-
L8	24'-,233'-,234-,342'-,252'6'-,343'-,2346-,2356-,253'4'-3452'-,2462'3'-,243'4'-,353'5'-,23562'-,2362'5'-,2452'6'-,2343'-,23462'-
L9	3-,23-,24'-,34-,34'-,242'-,232'-,264'-,244'-,233'-,342'-,252'6'-,234'-,242'6'-,252'5'-,2463'-,242'5'-,242'4'-,2452'-,2464'-,344'-,232'4'-,2363'-,2342'-,2364'-,253'4'-,243'4'-,2362'5'-,233'4'-,2344'-,2362'3'-,2352'5'-,2352'4'-,2452'5'-,2452'4'-,3452'4'-,2452'3'-,23464'-,343'4'-,2363'4'-,2453'4'-,2343'4'-,2342'4'5'-,23463'4'-,234563'-
L10	23'-,252'5'-,2463'-,253'4'-
L11	252'5'-,2463'-,253'4'-,243'4'-,2362'5'-,2453'4'-,2342'4'5'-,23463'4'-,234563'-

Table 4. Dechlorination of 234-CBp in a Simulated Aqurium Box

Tested Congener	**Layers**	**Dechlorination occurrence**	**Product**	**Dechlorination completed time (days)**	**Maximum concentration of products (ppm)**
234-CBp	Layer 1 (0~5 cm)	+	24-CBp	NC *	0.31
	Layer 2 (5~10 cm)	+	24-CBp	320	0.76
	Layer 3 (10~15 cm)	+	24-CBp	320	0.88
	Layer 4 (15~20 cm)	+	24-CBp	320	0.80
	Layer 5 (20~25 cm)	+	24-CBp	320	0.72

*Dechorination not Completed

Table 5. Dechlorination of 242’5’-CBp in a Simulated Aqurium Box

Tested Congener	Layers	Dechlorination occurrence	Product	Dechlorination completed time (days)	Maximum concentration of products (ppm)
242’5’-CBp	Layer 1 (0~5 cm)	-	---	---	---
	Layer 2 (5~10 cm)	+	252’-CBp	320	1.20
	Layer 3 (10~15 cm)	+	252’-CBp	320	1.04
	Layer 4 (15~20 cm)	+	252’-CBp	320	1.33
	Layer 5 (20~25 cm)	+	252’-CBp	320	1.30

*Dechorination not Completed

Table 6. Dechlorination of 253’4’-CBp in a Simulated Aqurium Box

Tested Congener	Layers	Dechlorination occurrence	Product	Dechlorination completed time (days)	Maximum concentration of products (ppm)
253’4’-CBp	Layer 1 (0~5 cm)	-	342’-CBp	---	---
	Layer 2 (5~10 cm)	+	342’-CBp	NC *	0.34
	Layer 3 (10~15 cm)	+	342’-CBp	NC	0.58
	Layer 4 (15~20 cm)	+	342’-CBp	NC	0.45
	Layer 5 (20~25 cm)	+	342’-CBp	NC	0.37

*Dechorination not Completed

Table 7. Dechlorination of 2342’4’5’-CBp in a Simulated Aqurium Box

Tested Congener	Layers	Dechlorination occurrence	Product	Dechlorination completed time (days)
2342’4’5’-CBp	Layer 1 (0~5 cm)	-	---	---
	Layer 2 (5~10 cm)	(+)*	2452’4’-CBp	NC **
	Layer 3 (10~15 cm)	(+)	2452’4’-CBp	NC
	Layer 4 (15~20 cm)	(+)	2452’4’-CBp	NC
	Layer 5 (20~25 cm)	(+)	2452’4’-CBp	NC

* Partially dechorinated
** Dechorination not Completed

Table 8. Dechlorination of 2452’4’5’-CBp in a Simulated Aqurium Box

Tested Congener	Layers	Dechlorination occurrence	Major products	Minor products	Dechlorination completed time (days)
2452’4’5’-CBp	Layer 1 (0~5 cm)	+	242’4’-CBp 2452’5’-CBp	242’5’-CBp	320
	Layer 2 (5~10 cm)	+	242’4’-CBp 2452’5’-CBp	242’5’-CBp	320
	Layer 3 (10~15 cm)	+	242’4’-CBp 2452’5’-CBp	242’5’-CBp 2452’4’-CBp	320
	Layer 4 (15~20 cm)	+	242’4’-CBp 2452’5’-CBp	242’5’-CBp 2452’4’-CBp	320
	Layer 5 (20~25 cm)	+	242’4’-CBp 2452’5’-CBp	242’5’-CBp	320

* Partially dechorinated
** Dechorination not Completed

出席國際學術會議心得報告

計畫編號	NSC 95-2313-B-041-004
計畫名稱	建立河川底泥中多氯聯苯污染之環境復育方法
出國人員姓名 服務機關及職稱	陳意銘副教授　嘉南藥理科技大學環境資源管理系
會議時間地點	越南，河內百科大學(HUT)，2006.10.12～2006.10.13
會議名稱	河內百科大學第 20 屆科技研討會
發表論文題目	Investigation on Remediation Potential to Polychlorinated Biphenyls (PCBs) Contamination in River Sediment

一、參加會議經過

前言

本校於 2004 年 11 月 29 日與 HUT 締盟姊妹校，其後續國際合作，不管是雙方師生互訪、輪辦國際研討會、博碩生共同指導、國際期刊論文之共同發表以及專利之跨國聯合申請等，均有豐碩之成果展現。

摘要

10/12/2006，參加 HUT 第 20 屆科技研討會之環境科技論壇，發表環境復育技術論文。

10/13/2006，參與 HUT 第 20 屆科技研討會大會議程，主持台灣實用環境技術論壇。

二、與會心得

在 HUT 參訪期間，第一感受到的是這一所學校在學界及政界影響力。HUT 位處河內市，乃越南政治中心，各國大使館均分佈於該城市；更值得一提的是，HUT 又是科技大學首屈一指之著名大學，歷年來，從該校卸任校長，均擔任政府部門重要職務，例如，教育暨訓練部長及科技部長，此次參加「台灣實用環境技術技轉論壇」之與會人員中，也有一位女士 Dr. Nguyen Hong Khanh 為越南國家科技研究院環境技術研究所副主任 (據 INEST 人員告知，該女士為越南副總理夫人)。另外，在校慶典禮當中，看到象徵權力中

心之越南黨書記，亦蒞臨會場，受邀請致詞之貴賓有教育暨訓練部長、俄羅斯大使、法國某一大學校長。除此之外，參與該盛典的國外貴賓計有二百人左右，有來自韓國、日本、台灣(本校三位、大葉大學二位、某一製造研究所、與本校同行之南台灣環境科技公司一人)、及歐洲部份國家(德國、法國、比利時、瑞典等)。在典禮當中，配合影片，HUT 校長介紹該校歷史以及重要政策措施以及與西方國家之合作關係，當然其他貴賓致詞時，則談到該校對整個越南朝向現代化及全球化之貢獻。整個典禮下來，個人聯想到本校之狀況，本校創立已四十年，再經過十年，本校可以對學界、政界或與西方國家發揮多大影響力，我們如何創造未來更有影響力的歷史，這是值得深思的一件事；另外，從 HUT 典禮中我也聯想到「一所大學如果沒有足以自豪的文化與歷史，就無法永續生存與經營」，本校除了著重科技發展之外，有關人文、科技素養的培養亦不容忽視。

此外，在 HUT 參訪期間，第二感受到的是歐洲各國家之大學在 HUT 經營之深且久。從演講資料得知，這些大學長期有計畫地提供高等教育訓練給 HUT 學生或學者，例如：博、碩士學位，他們不僅提供這些資源，並且，當這些學成歸國的學者回到本校後，仍然繼續協助其設立系、所、研究中心，或者持續研究合作關係，所以，我們可以想像，他們對這一所大學的影響是如何的深遠。用一個盧明俊教授分享的例子來說，如果嘉南大學能培養出一位來自 HUT 之博士生，未來他/她的論文發表，均掛有嘉南藥理科技大學的名字，他/她好像是一幅活廣告一樣，走到那裏就廣告到那裏，我們學校是否願意作這樣的長遠投資，就像韓國 LG 所下的功夫，到處可以看到 LG 的 logo 廣告(Life is Good)。

此次參訪，我們除了讓「嘉南藥理科大學」在 HUT 取得重要地位外(我們是日、韓之專家學者的重要競爭者)，我們也在此國際場合中，為「台灣」取得發聲的地位與機會。