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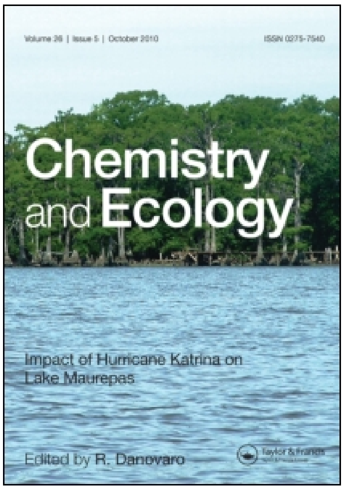

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Study of Fishes in the Chung-Kung Stream: Species Distribution and Organochlorine Pesticide Residues

H. -C. Wang[a]; C. Liu[a]; H. -J. Huang[a]; P. -Y. Chung[a]; K. -H. Huang[a]
[a] National Institute of Environmental Analysis, Environmental Protection Administration, Taipei, Taiwan, R.O.C.

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STUDY OF FISHES IN THE CHUNG-KUNG STREAM: SPECIES DISTRIBUTION AND ORGANOCHLORINE PESTICIDE RESIDUES

H.-C WANG, C. LIU, H.-J. HUANG, P.-Y. CHUNG and K.-H. HUANG

National Institute of Environmental Analysis, Environmental Protection Administration, Hsin-Tien City, Taipei, Taiwan, R.O.C.

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Fish of the Chung-Kung stream of Miau-Li County, northern Taiwan, were sampled on seven occasions from March 1994 through to August 1995. A total of 45 species belonging to seven orders and 25 families were caught at 6 sites along the stream. There were ten species of Cyprinidae, and four or fewer of the other 24 families. Major species found upstream at site F were *Varicorhinus barbatulus* and *Hemimyzon formosanum*. This section of the stream is considered unpolluted if these water quality sensitive species are present. *Acrossocheilus formosanus* and *Crossostoma lacustre* can thrive in slightly polluted water and occurred in the middle reaches at site D. *Zacco pachycephalus* could also survive in mildly polluted water and occurred at site C. The major species at site B were tilapia (*Oreochromis* hybrid species) and thus this section was considered heavily polluted. Site A in the lower, tidal, reaches contained species of Mugilidae and was considered as moderately polluted.

Thirty seven fish muscle samples were analyzed for residues of nine organochlorine pesticides. Only 4-4′DDD was detected in the majority of the samples (70%). Trace amounts of heptachlor-epoxide, endrin, 4,4′ DDT (< 10 ng g^{-1}) were found in 13–23% of samples. These low levels were considered a persistent residue of the use of organochlorine pesticides before they were banned 20 years ago.

KEY WORDS: Fish, organochlorine pesticides, fish species distribution, DDT/DDE, biomarker.

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INTRODUCTION

The Chung-Kung stream in the northern part of Taiwan starts in Miau-Li county in the mountainous area at 2616 m altitude. It flows westward with a total length of 54 km and ends in Taiwan Strait. A dense population and growing industrial development is concentrated in the downstream area. Industrial and municipal effluents and improper garbage disposal are the major sources of pollution of the stream. Some agricultural practices upstream may also have an influence on water quality (Tseng, 1990; WRPC, 1988). Since the Chung-Kung stream is one of the secondary (defined as secondary, Taiwan Government Regulation, 1983) rivers of Taiwan, there are only scattered reports of the fish species found in this stream; this study is the first complete survey of the fish species distribution of the stream.

Chlorinated pesticides were popular agrochemicals used in Taiwan. Most were banned in the seventies due to their persistence in the environment. Lindane was the last to be banned in 1985. Levels of organochlorine pesticide residues have been found to be decreasing in the paddy rice field soils after the pesticides were banned.

For example, DDT declined from 92 ppb in 1974 to 47 ppb in 1981 (Lee and Lee, 1985). Lin *et al.* (1982) reported organochlorine pesticide residues in sediments in near-shore areas of Taiwan where the levels of 4,4'DDT were 8 to 70 ppb, The pesticides levels in fish prior to the ban on their use were reported by Jeng and Sung (1984). There are few recent studies reported on fish. The organochlorine pesticides residues in fish from the Chung-Kung stream would thus be a useful reference point to establish a current background level for exposure in the aquatic environment.

MATERIALS AND METHODS

Sampling Sites and Species

The Chung–Kung stream runs from east to west into Taiwan Strait in northern Taiwan. Figure 1 shows a map of the area and the six sampling sites, A to F. Distances from the sea for sites A through F are 1, 6, 9, 15, 21, and 32 km. The total length of the stream from the coast to the source is 54 km. Identified sources of pollution are municipal and industrial wastes and agriculture. Fish were caught using gill nets, cast nets or electric shock equipment. Samples were taken every quarter from March 1994 through to August 1995. For analysis of organochlorine residues, the species analyzed were *Liza macrolepsis*, *Pomadassys nageb*, and *Mugil cephalus* for site A, tilapia and *Channa* sp. at site B, Tilapia at site C, tilapia, *Parasilurus asotus*, *Anguilla japonica*, *Carassius auratus*, and *Sicyopterus japonicus* for site D. At sites E and F, *Acrossocheilus formosanus* and *Zacco pachycephalus* were analyzed. Fish of tilapia species and *Liza macrolepsis* caught from uncontaminated culture ponds were used as controls.

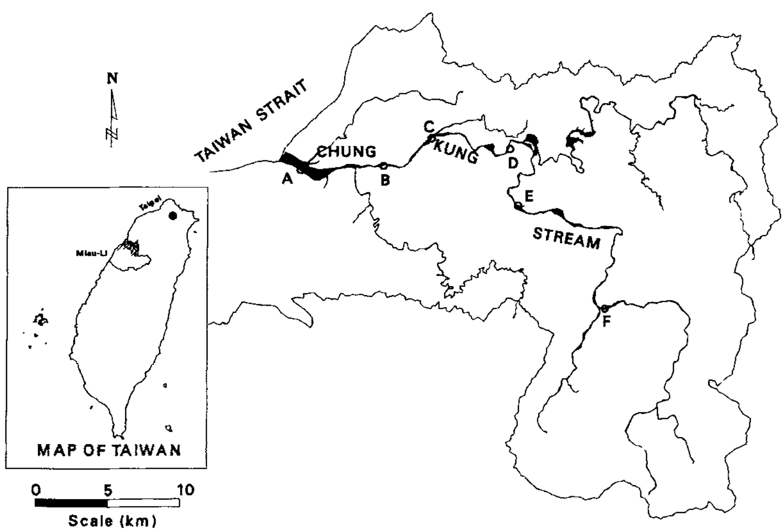

Figure 1 Map of Chung-Kung stream in Taiwan and sampling sites indicated by capital letters. #Chung-Kung stream.

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Fish caught were identified, counted and measured in the field. Unidentified species were brought back to the laboratory for further identification (Cheng and Yu, 1986; Miyadi *et al.*, 1976; Shen 1983, 1984; Tseng, 1986). On site, muscle tissue was dissected and pooled for the same species and same sampling site if the tissue quantity was small. Muscle samples were kept on ice in the field and then kept frozen at $-80°$C in the laboratory until analysis.

Methods of Analysis

Muscle samples were freeze-dried and then ground to a homogeneous powder. Organochlorine residues were analyzed on 2 g (dry weight) of sample using AOAC (Assoc. Official Analytical Chemists, 1990 a, b) methods. Florisil was used to clean up the sample extract. Only trace analytical grade solvents were used. Nine organic pesticide residues were detected, including lindane, heptachlor, aldrin, heptachlor epoxide, 4,4'DDE, dieldrin, endrin, 4,4' DDD, 4,4' DDT. A DB5 capillary column (J&W Scientific Co.) on a HP 5890 gas chromatograph with electron capture detector was used for analysis. Detection limits were 0.63 ng g^{-1} for lindane, 1.4 ng g^{-1} for heptachlor, 0.86 ng g^{-1} for aldrin, 1.37 ng g^{-1} for heptachlor epoxide, 2.19 ng g^{-1} for 4,4'DDE, 5.04 ng g^{-1} for dieldrin, 1.99 ng g^{-1} for endrin, 3.89 ng g^{-1} for 4,4'DDD and 4.07 ng g^{-1} for 4,4'DDT. The recovery of all but two pesticides was 75 to 120%. The average recovery of dieldrin was $56 \pm 62\%$ and of endrin was $54 \pm 38\%$ for six analyses. No correction for % recovery was made to the results.

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RESULTS

Different species of fish have their own environmental requirements and this affects their distribution in the Chung-Kung stream. This distribution is shown in Table I which shows the systematic classification of species found on the seven sampling occasions for each site. Overall, 46 species of fish were found in the Chung-Kung; they belonged taxonomically to 25 families and 7 orders. Ten species belong to the family Cyprinidae, while for other families, four or fewer species were found. The fishes found were grouped into three categories, primary freshwater species, secondary freshwater species, and peripheral freshwater species, on the basis of adaptation to salt water and migratory behaviour (Miyadi *et al.* 1976), according to their distribution (Tab. II). More species (21) were found at site A than elsewhere; these are peripheral (euryhaline) species and were seldom found at sites further upstream. Overall, 21 species were found at site A, 9 species at site B, 16 at site C, 19 at site D, 12 at site E, and 12 at site F. There was an increasing trend of species from site B to site D (Fig. 2). This is consistent with pollution originating at site D, downstream. However, there was no increase in the number of species further upstream. This could be due to the presence of weirs and dams above site D which would have blocked the way for secondary (migratory) freshwater species which could otherwise move upstream. The primary (stenohaline) freshwater species found in the upper reaches will be less influenced by weirs and dams.

Table I Taxonomic classification of fish species found in Chung-Kung stream (presence = X). Tilapia is used as a common name to represent the wild *Tilapia zilla* and a hybrid originating from cross breeding of *Oreochromis nitolica* and *O. mossambica.*

Order	*Family*	*Scientific Name*	*St.A*	*St.B*	*St.C*	*St.D*	*St.E*	*St.F*
		Zacco pachycephalus			X	X	X	X
		Acrossocheilus formosanus				X	X	X
		Pseudogobio brevirostris			X	X	X	X
	Cyprinidae	*Carassius auratus*		X	X	X	X	X
		Culter erythropterus		X	X	X		
Cypriniformes		*Varicorhinus barbatulus*					X	X
		Candidia barbata				X		X
		Pseudorasbora parva			X			
		Cyprinus carpio			X			
		Cirrhinus molitorella				X		
	Cobitidae	*Cobitis taenia*			X	X	X	X
	Homalopteridae	*Crossostoma lacustre*				X	X	X
		Hemimyzon formosanum				X	X	X
	Siluridae	*Parasilurus asotus*				X	X	
Siluriformes	Bagridae	*Leiocassis adiposalis*			X	X	X	X
	Ariidae	*Aris thalassinus*	X					
Channiformes	Channidae	*Channa sp.*		X				
		Channa maculata			X			
Elopiformes	Megalopidae	*Megalops cyprinoides*	X	X				
	Elopidae	*Elops hawaiensis*	X					
Anguilliformes	Anguillidae	*Anguilla japonica*			X	X		
		Anguilla marmorrata				X		X
		Liza formosae	X					
	Mugilidae	*Liza carinata*	X	X				
		Liza macrolepsis	X	X	X			
		Mugil cephalus	X					
	Teraponidae	*Terapon jarbua*	*X*					
	Centropomidae	*Ambassis urotaenia*	X	X				
	Haemulidae	*Pomadassys nageb*	X					
		Pomadassys maculatus	X					
	Gerridae	*Gerres abbreviatus*	X					
	Cichlidae	*Oreochromis sp*		X	X	X		
Perciformes		*Tilapia zillii*		X	X	X		
	Eleotridae	*Eleotris fusca*			X			
		Rhinogobius similis			X	X	X	X
	Gobiidae	*Rhinogobius giurinus*			X	X		
		Sicyopterus japonicus				X	X	
		Periophthalmus cantonensis	X					
	Percichthyidae	*Lateolabrax japonicus*	*X*					
	Serranidae	*Epinnephelus amblycephalus*	X					
	Sparridae	*Acanthopagrus latus*	X					
		Acanthopagrus schlegeli	X					
	Lutjanidae	*Lutjanus argentimaculatus*	X					
	Polynemidae	*Eleutheronema tetradactylum*	X					
	Sciaenidae	*Johnius sina*	X					
Clupeiformes	Dorosomatidae	*Clupanodom punctatus*	X					

Most of the tilapia species present in Chung-Kung stream are hybrids of *Oreochromis niloticus* and *O. mossambicus.* They are most abundant downstream at site B. Their presence and dominance is evidence of serious pollution of the river.

A total of 37 muscle samples of 11 species of fish were analyzed for nine organochlorine residues. The results are shown in Table III on a dry weight basis.

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Table II Catagories of fish species found in Chung-Kung stream. Primary species live entirely in fresh water; secondary species include anadromous and catadromous species and tolerant non-migratory species (such as *Gambusia* and tilapias). Peripheral species live in estuarine and coastal waters, migrating into fresh water to complete their life cycles and include perciformes, Elopiformes, and milkfish.

Primary Freshwater Fish	*Secondary Freshwater Fish*	*Peripheral Freshwater Fish*
*Zacco pachycephalus** (*F*)	*Anguilla japonica** (*D*)	*Aris thalassinus*
*Acrossocheilus formosanus** (*E*)	*Anguilla marmorrata*	*Megalops cyprinoides*
Pseudogobio brevirostris	*Oreochromis sp** (*B,C,D*)	*Elops hawaiensis*
*Carassius auratus** (*D*)	*Tilapia zillii*	*Liza formosae*
Culter erythropterus	*Eleotris fusca*	*Liza carinata*
Varicorhinus barbatulus	*Sicyopterus japonicus** (*D*)	*Liza macrolepsis** (*A*)
Candidia barbata		*Mugil cephalus** (*A*)
Pseudorasbora parva		*Terapon jarbua*
Cyprinus carpio		*Ambassis urotaenia*
Cirrhinus molitorella		*Pomadassys nageb** (*A*)
Cobitis taenia		*Pomadassys maculatus*
Crossostoma lacustre		*Gerres abbreviatus*
Hemimyzon formosanum		*Periophthalmus cantonensis*
*Parasilurus asotus** (*D*)		*Lateolabrax japonicus*
Leiocasis adiposalis		*Epinnephelus amblycephalus*
Channa maculata		*Acanthopagrus latus*
*Channa sp.** (*B*)		*Acanthopagrus schlegeli*
Rhinogobius similis		*Lutjanus argentimaculatus*
Rhinogobius giurinus		*Eleutheronema tetradactylum*
		Johnius sina
		Clupanodon punctatus

*species taken for organochlorine pesticides analysis with site of sample fish taken in brackets.

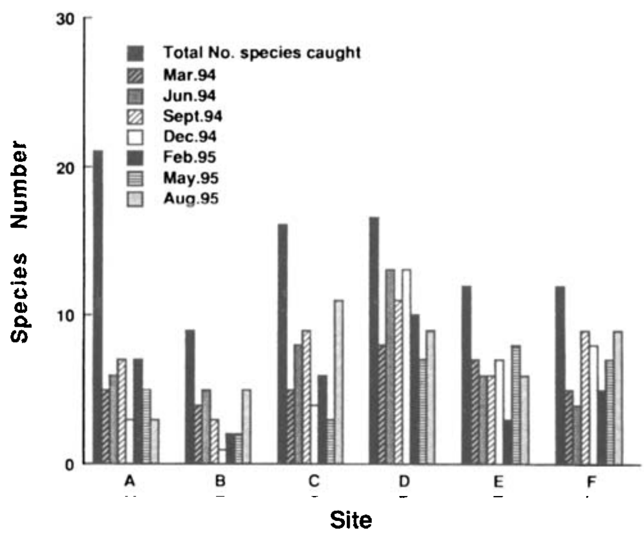

Figure 2 Number of fish species found in Chung-Kung stream at each sampling site and season. "Total" refers to the total species caught at each site over the full sampling period.

DDT and its metabolites were those most commonly found, with 4,4′DDE found in 70% of samples, in the concentration range 2.3 to 26 ng g^{-1}. 4,4′DDD and 4,4′DDT were found in 16% and 22% of samples, with levels ranging from 4 to 7 ng g^{-1}. Endrin and heptachlor epoxide were found in 16% and 13.5% of samples, with levels

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Table III Organochlorine residues concentrations of Chung-Kung stream fish muscle (ng/g dry weight).

Site	*Species*	*No. in samples*	*Lindane*	*Heptachlor*	*Aldrin*	*Hepa-epoxide*	*4,4′-DDE*	*Dieldrin*	*Endrin*	*4,4′-DDD*	*4,4′-DDT*
A	3	11	1.8	6.7	2.3 –3.4	3.5	2.6–24.5	ND	2.2–5.1	4.1–5.9	4.2–6.7
			(9)	(9)	(18)	(9)	(64)	(0)	(27)	(36)	(45)
B	2	10	ND	ND	ND	1.7	2.3–10.0	ND	2.7	ND	ND
			(0)	(0)	(0)	(10)	(80)	(0)	(10)	(0)	(0)
C	1	5	ND	ND	ND	1.7	3.1–5.6	ND	ND	ND	ND
			(0)	(0)	(0)	(20)	(60)	(0)	(0)	(0)	(0)
D	5	8	ND	ND	ND	ND	2.7–26.1	ND	ND	3.9–4.4	6.0
			(0)	(0)	(0)	(0)	(75)	(0)	(0)	(25)	(13)
E&F	2	3	ND	ND	ND	2.7–8.4	8.2–9.6	ND	2.6–8.0	ND	4.7–6.9
			(0)	(0)	(0)	(67)	(67)	(0)	(67)	(0)	(67)

Range of concentrations and percentage of samples higher than method detection limit in brackets below. ND: not detected or below method detection limit. None of the 9 organochlorine pesticides was detected for control fish from culture ponds.

ranging from 2 to 8 ng g^{-1}. Lindane, heptachlor and aldrin were found in about 5% or less of samples, with levels ranging from about 2 to 7 ng g^{-1}. Dieldrin was not found in any of the 37 samples analyzed. Nor were organochlorine pesticides residues found in tilapia species or *Liza macrolepsis* taken as controls from culture ponds.

No systematic differences were found between different sites or different sampling times. Tilapia species were major species at site B and *Liza macrolepsis* at site A; the former has higher muscle DDT concentrations than the tilapia group. At site A, *L. macrolepsis* also had trace amounts of lindane, heptachlor and aldrin in a small portion of the fish catch at site A.

DISCUSSION

In northern Taiwan, the rainy season is from May to October water flow in the stream varies greatly between dry and wet seasons. In Chung-Kung stream, the average flow at site F in December is 1.0 cm s^{-1}, compared with 13.8 cm s^{-1} in August, while at site B flows are 1.7 cm s^{-1} in December, 34.7 cm s^{-1} in August. Flow downstream is moderated by weirs and dams, but in general is 2- to 3- fold greater downstream. The water pollution problem is thus more serious at the end of the dry season, since contaminants then are least diluted, and at the start of the wet season when all contaminants accumulated through the dry season are carried off in the large volume of stream flow. There was evidently a decrease in fish species caught in the dry season or at the start of the rainy season (December 1994 to May 1995) at the most polluted site (site B), when only 1 or 2 species (compared with nine in total) were found. At this site tilapia species were the major species found. However, at other sites, there was no variation between wet and dry seasons in the number of species caught.

A river pollution index has been used by Government (DOEP 1994), specifying four levels of pollution in terms of dissolved oxygen, biochemical oxygen demand, suspended solids and ammonium-N. The Chung-Kung stream is unpolluted at site E (DO > 6.5 mg l^{-1}, BOD < 3.0 mg l^{-1}, SS < 20 mg l^{-1}, NH_3-N < 0.5 mg l^{-1}), slightly polluted at site D, moderately polluted at site C (DO 2.0–4.5 mg l^{-1}, BOD 5.0–15 mg l^{-1}, SS 50–100 mg l^{-1}, NH_3-N 1.0–3.0 mg l^{-1}), and seriously polluted at site B (DO < 2.0 mg l^{-1}, BOD > 15 mg l^{-1}, SS > 100 mg l^{-1}, NH_3-N > 3.0 mg l^{-1} (DOEP, 1994). The fish species found at these sites correlate well with these physical and chemical characteristics. By comparison, the Tan-Shui river (the third largest in Taiwan) has somewhat higher diversity with 56 species belonging to 9 taxonomic orders and 23 families (Wang, 1986). Fewer, but generally similar, species belonging to primary, secondary and peripheral freshwater fish groups (Miyadi *et al.*, 1976), were found in the Chung-Kung stream, with a distribution typical of rivers in Taiwan. The fish species distribution could be a good indicator of water quality to monitor the effectiveness of pollution control. Because of the reduced diversity at site B, the Chung-Kung stream is a priority for demonstration of the Government pollution abatement programme.

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Fishes in Michigan rivers in the United States had higher values of organochlorine residues in muscle tissue for dieldrin and p.p′ DDE, which ranged from 0.06 to 106.5 ppb (ng g^{-1}) and 0.06 to 638.2 ppb (ng g^{-1}) respectively (Giesy *et al.*, 1994). For three fish species in the river Douro, Spain (Bernal *et al.*, ·1993) the mean concentration of the major organochlorine residues found were 23–91 ng g^{-1} for 4,4′DDT and 41–77 ng g^{-1} for 4,4′DDE on a wet weight basis. The fishes of Chung-Kung stream contained much lower residues than those in these studies. Our findings are consistent with other studies in Taiwan which showed similar low levels of organochlorine pesticides residues in human milk (Lee *et al.*, 1985) and in paddy rice field soils (Lee and Lee, 1985). Organochlorine levels found 20 years ago (1972–1974) in fish muscle from the Ta-tu and Pu-tzu rivers in central Taiwan had mean values for tilapia muscle of 30–82 ppb (ng g^{-1}) for total BHC (benzene hexachloride), 22–75 ppb (ng g^{-1}) for total DDT and 0 (non-detected)-26 ppb (ng g^{-1}) for dieldrin. No endrin or heptachlor were detected at that time (Jeng and Sung, 1985). Our study shows much lower levels compared to those reported a decade ago by Jeng and Sung. It is reasonable to conclude that only trace amounts of organochlorine residues are now present in the fishes of Chung-Kung stream since their use was banned 10 to 20 years ago. (Endrin was banned in January, 1972, DDT in July 1974, heptachlor and aldrin in October 1975, lindane in February 1985).

These low levels of organochlorine residues are found consistently at all sampling sites in the Chung-Kung stream, although more pesticides and slightly higher levels were found in fish muscle samples from site A, mainly in *Liza macrolepsis*. Since this is a peripheral freshwater fish (Yoshino and Senou, 1984) the residues found could have originated from other sources than Chung-Kung. Another possibility is that different species differ in their ability to accumulate pesticides (e.g. from diet). Further studies are needed to explore these possible explanations.

Although dieldrin was not detected in the samples analyzed, this could be due to the low recovery of the method used; further verification is needed to confirm the absence of residues of this pesticide in fish of the Chung-Kung stream.

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