DOCTORAL THESIS

Evaluation of organochlorines and heavy metals in the Pearl River Delta and Hong Kong, with emphasis on bioaccumulation in freshwater fish

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Evaluation of Organochlorines and Heavy Metals in the Pearl River Delta and Hong Kong, with Emphasis on Bioaccumulation in Freshwater Fish

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Abstract

The present study aims to investigate the concentrations of organochlorines (HCHs, DDTs and PCBs) and heavy metals (Cu, Zn, Pb, Ni, Cr, Cd, As and Hg) in freshwater fish and sediment collected from the Pearl River Delta as well as Hong Kong, with emphasis on the uptake PCBs and Hg in fish.

i. Higher levels of Hg, HCHs, DDTs and PCBs were recorded in the fish flesh collected from the Pearl River Delta with the ranges of 17.5-267 ng/g dry wt for Hg, <0.01-7.8 ng/g lipid for HCHs, 22.3-381 ng/g lipid for DDTs and 60-480 ng/g lipid for PCBs respectively, while the fish collected from the fish ponds in Hong Kong contained 15.8-55.4 ng/g dry wt for Hg, <0.1-13.7 ng/g lipid for HCHs, 44-80 ng/g lipid for DDTs and 32-132 ng/g lipid for PCBs, respectively. The results suggested that the Pearl River Delta was more polluted than Hong Kong. Nevertheless, levels of Hg, HCHs and DDTs in fish flesh were lower than the NEPA maximum permissible limits in foodstuffs. As to PCBs, 16% of fish collected from the Pearl River Delta exceeded the U.S.EPA guideline. The calculated dietary intakes of Hg, HCHs and DDTs in the present study were less than the previous investigation on foodstuffs obtained from 12 provinces.

ii. The levels and patterns of organochlorines including DDTs, HCHs, and PCBs were investigated in sediments and tilapia collected from river systems (Shing Mun River, Tai Po River and Lam Tsuen River) in the New Territories of Hong Kong and compared to those collected from fish ponds (Au Tau, Mai Po and San Tin). The ranges of DDTs, HCHs and PCBs in river sediments were 2.8-8.6, 0.05-2.1 and 43-

461 ng/g dry wt, respectively. All these values were significantly higher ($p<0.05$) than the pond sediments. Low chlorinated congeners (mono- to tetra-chlorobiphenyls) were enriched in river sediments accounting for 70-80% of total PCBs. The concentrations of DDTs, HCHs and PCBs in tilapia flesh collected from Fo Tan and Tai Wai (28.2-40.1, 2.04-3.76 and 267-310 ng/g dry wt respectively) were also significantly higher ($p<0.05$) than those collected from fish ponds. Higher chlorinated PCBs (tetra- to hepta-chlorobiphenyls) were commonly found in tilapia accounting for almost 60% of the total PCBs. The effect of lipid content in organochlorines accumulation was not significant ($p<0.05$), in general.

iii. In terms of heavy metals (Cu, Zn, Pb, Ni, Cr, Cd, Hg and As) in sediments sampled from rivers (Shing Mun River, Tai Po River and Lam Tsuen River) and fish pond (Mai Po) in Hong Kong, the concentrations of these metals in river sediments were significantly ($p<0.05$) higher than those collected from the fish pond except As. The highest metal concentrations of Cu, Zn, Ni, Cd, Cr and Hg were recorded in the sediment collected from Fo Tan at Shing Mun River, with the values of 449, 1220, 67.0, 4.03, 85.4 and 0.43 mg/kg dry wt, respectively. On average, the total metal contamination in sediments followed the order of Fo Tan >Tai Wai > Tai Wo > Siu Lek Yuen > Tai Po > Mai Po. As to arsenic, the highest concentration in sediment was recorded in the fish pond at Mai Po (14 mg/kg dry wt). Different metals seemed to accumulate in different organs of fish (muscle, gill, skin, and viscera). A substantial amount of heavy metals was observed in tilapia which lived in contaminated environments (Fo Tan and Tai Wai), when compared to those collected from the fish pond. Tilapia collected from Fo Tan contained the highest concentrations of Cu (168 μg/g dry wt) and Zn (266 μg/g dry wt).

iv. The levels of Hg observed in freshwater fish and fish pond sediments collected from the Pearl River Delta were 17.5-267 ng/g dry wt and 96 ng/g -1.67 μg/g dry wt, respectively. As to samples collected from fish ponds in Hong Kong, the concentrations of Hg were 15.8-55.4 ng/g dry wt in fish flesh and 57-94 ng/g dry wt in fish pond sediments. The accumulation of Hg in fish related to the spatial difference of Hg in sediment. Significant linear relationships were obtained for the concentrations of Hg in grass carp (r^2=0.51, n=12), big head (r^2=0.97, n=12) and tilapia (r^2=0.55, n=24).

v. Six species of freshwater fish including black bass, tilapia, common carp, big head, silver carp and grass carp cultured in a wastewater treatment system were used to study the bioaccumulation of Hg, DDTs, HCHs and PCBs. After sedimentation (ponds S1-S2) and aeration (ponds A1-A2), the treated wastewater was used for fish culture (ponds C1-C4). Comparing the levels of Hg, DDTs and PCBs in the sediments of the inlet (S1) and outlet (C4) of the system, about 59% of Hg, 58% of DDTs and 85% of PCBs were removed after sedimentation and aeration. HCHs were undetectable in all the sediment samples. The influence of feeding habits of the six fish species in Hg accumulation was apparent. In general, the highest levels ($p<0.05$) of Hg (56.7 ng/g dry wt) were found in black bass, moderately in big head (33.8 ng/g dry wt), silver carp (20.8 ng/g dry wt) and grass carp (26.3 ng /g dry wt), and the least in common carp (18.9 ng/g dry wt) and tilapia (13.7 ng/g dry wt). Black bass contained the highest ($p<0.05$) levels (lipid base) of both DDTs (0.76 μg/g) and PCBs (3.4 μg/g), followed by tilapia (DDTs: 0.090 μg/g and PCBs: 3.1 μg/g), grass carp (DDTs: 0.087 μg/g and PCBs: 2.1 μg/g), silver carp (DDTs: 0.038 μg/g and PCBs: 1.6 μg/g) and big head (DDTs: 0.040 μg/g and PCBs: 0.87 μg/g). The homologue

pattern of PCBs varied among fish species. There were marked differences in average chlorine numbers among fish species with different feeding habits, and the average chlorine numbers observed in fish flesh were 3.5 for grass carp, 4.5 for big head, 4.8 for silver carp, 5.0 for black bass and 5.2 for tilapia. These results indicated that feeding habits intervened PCBs accumulation process.

vi. Sediment-associated PCBs were accumulated in tilapia when exposed to contaminated sediments. Ingestion of sediment and/or contact of contaminated particulates were the primary routes for the uptake of sediment-sorbed PCBs rather than water. Tilapia exposed to spiked sediment and river sediment accumulated significantly higher levels of PCBs (27.5 and 3.9 μg/g lipid respectively) than those exposed to contaminated water (1.6 μg/g lipid). The biota-sediment accumulation factors (BSAFs) of PCBs domains ranged from 0.2 to 4. PCBs congeners containing four to seven chlorine atoms on the biphenyl rings showed relatively higher accumulation potential. Minor effects of lipid contents, weight and length of fish were observed on PCBs accumulation.

TABLE OF CONTENTS

	Page
Declaration	i
Abstract	ii
Acknowledgements	vi
Chapter I. Introduction	
1.1 Overview of the Pearl River Delta	1
1.2 Historical and present perspectives of pesticides and PCBs management	5
1.2.1 Pesticides	5
1.2.2 PCBs	9
1.3 Water quality in the Pearl River Delta	10
1.4 Dike-pond system for fish culture in the Pearl River Delta	12
1.5 Freshwater quality in Hong Kong	16
1.6 Bioaccumulation of heavy metals and organochlorines	19
1.7 Aim and objectives of the research	20
Chapter II. Screening of Organochlorines in Freshwater Fish Collected from the Pearl River Delta	
2.1 Introduction	23
2.2 Materials and Methods	
2.2.1 Description of sampling sites	27
2.2.2 Sediment and fish sampling	30
2.2.3 Sample preparation and chemical analyses	32
2.2.4 Gas chromatography conditions	33
2.2.5 Data analysis	34
2.3 Results	35
2.4 Discussion	39
2.4.1 HCHs	39
2.4.2 DDTs	40
2.4.3 PCBs	41
2.5 Conclusion	43
Chapter III. Residues of Organochlorines in Sediments and Tilapia Collected from Inland Water Systems of Hong Kong	
3.1 Introduction	45
3.2 Materials and Methods	
3.2.1 Descriptions of the study sites	47
3.2.2 Sediment and fish sampling	48
3.2.3 Sampling preparation and chemical analyses	50
3.2.4 Gas chromatography conditions	50
3.2.5 Data analysis	52
3.3 Results	
3.3.1 Organochlorines in sediments	53
3.3.2 Organochlorines in freshwater fish	56
3.4. Discussion	

3.4.1 Organochlorines in sediments 58
3.4.2 Organochlorines in tilapia 61
3.5 Conclusion 63

Chapter IV. Metal Concentrations in Sediments and Tilapia Collected from Inland Waters of Hong Kong
4.1 Introduction 67
4.2 Materials and Methods
4.2.1 Sediment and fish sampling 70
4.2.2 Analysis of Cu, Zn, Pb, Ni, Cd and Cr 72
4.2.3 Analysis of As 73
4.2.4 Analysis of Hg 74
4.2.5 Chemical fractionation of metals in sediments 76
4.2.6 Statistical analysis 76
4.3 Results 77
4.4 Discussion
4.4.1 Heavy metal concentrations in sediments 81
4.4.2 Heavy metal concentrations in different organs of tilapia 87
4.4.3 Relationships between different chemical fractions of metals in sediments and their accumulation in fish 90
4.5 Conclusion 91

Chapter V. Mercury in Freshwater Fish collected from the Pearl River Delta and Hong Kong, with Emphasis on the Dietary Influence
5.1 Introduction 95
5.2. Materials and Methods
5.2.1 Ecological survey
5.2.1.1 Sampling of fish and sediments in the Pearl River Delta 97
5.2.1.2 Sampling of fish and sediments in Hong Kong 98
5.2.2 Study of Hg accumulation in fish with different feeding modes during their growth 98
5.2.3 Sample preparation and Hg analysis 102
5.2.4 Data analysis 103
5.3 Results
5.3.1 Concentrations of Hg in sediments 104
5.3.2 Concentrations of Hg in fish 104
5.3.3 Feeding habits affecting Hg accumulation in different fish species 106
5.4 Discussion
5.4.1 Hg concentrations in sediments and fish 109
5.4.2 Feeding habits affecting Hg accumulation in fish 114
5.5 Conclusion 119

Chapter VI. Bioaccumulation of Organochlorines in Freshwater Fish with Different Feeding Modes
6.1 Introduction 120
6.2 Materials and Methods

6.2.1 Description of the system 123
6.2.2 Fish sampling 125
6.2.3 Sample preparation and analysis 125
6.2.4 Data analysis 127
6.3 Results 127

6.4 Discussion
6.4.1 Residue levels of DDTs, HCHs and PCBs in fish and sediments 134
6.4.2 PCBs levels in fish with different feeding habits 136
6.5 Conclusion 139

Chapter VII. Accumulation of PCBs in Tilapia from Contaminated Sediment
7.1 Introduction 140
7.2 Materials and Methods
7.2.1 Fish and sediment collection 143
7.2.2 Preparation of PCBs-spiked sediment 144
7.2.3 Accumulation of PCBs from contaminated sediments 144
7.2.4 Accumulation of PCBs from contaminated water 145
7.2.5 Chemical analysis of samples 146
7.2.6 Gas chromatography conditions 147
7.2.7 Data analysis 148
7.3 Results
7.3.1 Fish 148
7.3.2 Bioaccumulation of PCBs from sediment 151
7.3.3 Bioaccumulation of PCBs from contaminated water 153
7.4 Discussion
7.4.1 Routes of PCBs uptake by tilapia: sediment and water 153
7.4.2 Accumulation of PCBs in tilapia 156
7.5 Conclusion 161

Chapter VIII. General Discussion and Conclusion
8.1 Public health concern and risk assessment
8.1.1 Mercury 162
8.1.2 HCHs and DDTs 164
8.1.3 PCBs 166
8.2 Factors affecting bioaccumulation of Hg and organochlorines 168
8.3 The use of wastewater for fish culture 171
8.4 General conclusion 175
8.5 Comments for future study 177

Appendices
A1. List of papers published, accepted and submitted to journals or presented in meetings. 179
A2. **Zhou HY, Cheung RYH, Chan KM and Wong MH** (1998) Metal concentrations in sediments and tilapia collected from inland waters of Hong Kong. *Water Research*, 32, 3331-3340. 180

References 190

VITA 212