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Bioconcentration of Pesticides in Fish from Rivers and Lakes

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1. Introduction

Pesticide contamination of river and lake waters from agriculture use is a problem of worldwide importance. Many field data on the pesticide contamination of surface waters and aquatic organisms in rivers and lakes (Amaraneri & Pillala, 2001, Abdel-Halim et al., 2006; Agradi et al., 2000; California Environmental Protection Agency, 2002; California Regional Water Quality Control Board, 2002; California State Water Resources Control Board, 2002; Domagalski, 1996; 1997; Environment Canada, 2002; Ganapathy et al., 1997; Gfrerer et al., 2002a; 2002b; Harman-Fetcho et al., 1999; Hall, 2003; Laabs et al., 2002; Lekkas et al., 2004; Leong et al., 2007; Mansour et al., 2001; Mansour & Sidky, 2003; McConnell et al., 2004; Oros et al., 2003; Rovedatti et al., 2001; Struger et al., 2004; Sudo et al., 2002a; 2002b; 2004; Tanabe et al., 2001; Tsuda et al., 1996a; 1997a; 1998; 1999; Vitanov et al., 2003; Washington State Department of Ecology, 1999; 2000) have been reported in the world.

This chapter consisted of (1) Field surveys on pesticide contaminations in rivers and lakes, (2) Bioconcentration of pesticides in the field fish (3) Bioconcentration of pesticides in fish by laboratory experiments (4) Evaluation of the pesticide contamination in the field fish by their laboratory bioconcentration potential data

1. Diazinon, fenitrothion, malathion and fenthion were selected as insecticides and atrazine, simazine, simetryn, molinate and benthiocarb, mefenacet and pretilachlor as herbicides. Surveys on the contamination of the 4 insecticides (Abdel-Halim et al., 2006; Ministry of the Environment, Japan, 2001; Mansour & Sidky, 2003; Ohtsuki, 1994; Tsuda et al., 1992a; 1994; 1998; 2009) and the 7 herbicides (Chiba Prefecture, 2002; 2003; Kanagawa Prefecture, 2000; 2001; Ministry of the Environment, Japan, 1993; 1999; Takino et al., 1998; Tsuda et al., 1996a; 1997a; 2009; Watanugi et al., 1993) in water and fish from rivers and lakes in the world were reviewed from literatures in the past.
2. Bioconcentration factor (BCF) of each 11 pesticide in the field fish was calculated as its bioconcentration potential from the data on the pesticide concentration in the water and fish from the rivers and lakes in the world.
3. Laboratory BCF data of the 11 pesticides in fresh-water fish were reviewed from literatures in the past for the 4 insecticides (Allison & Hermanutz, 1977; De Bruijn & Hermens, 1991; Escartin & Porte, 1996; Fisher, 1985;Goodman et al., 1979; Kanazawa, 1975; 1978; 1981; 1983; 1987; Keizer et al., 1991; 1993; Lockhart et al., 1983; Miyamoto et al., 1979; Nihon Kagaku-busshitsu Anzen-Jyohou Center, 1992; Sancho et al., 1992; 1994; Seguchi & Asaka, 1981; Takimoto et al., 1984; 1987; Tsuda et

al., 1989a; 1990; 1992b; 1993; 1995; 1996b; 1997b; 1997c) and for the 7 herbicides (Du Preez & Van Vuren, 1992; Gorge & Nagel, 1990; Gunkel & Streit, 1980; Isensee, 1976; Kanazawa, 1981; 1983; Kearney et al., 1977; Martin et al., 1992; Sanders & Hunn, 1982; Tsuda et al., 1988; 1989b; 1992c; 1997d; 1999; Tsuda et al., unpublished data; Wang et al., 1992; Xu & Zhang, 1989). The BCF value of each pesticide in fish was evaluated as its bioconcentration potential.

4. (4) The contamination of the 10 pesticides except atrazine in the field fish was evaluated by comparing the field BCF data calculated from the field data with the laboratory BCF data of the 10 pesticides in fresh-water fish.

1.1 Field surveys on pesticide contaminations in rivers and lakes

Surveys on contamination of insecticides and herbicides in water and fish from rivers and lakes in the world were reviewed from literatures in the past. Diazinon, fenitrothion, malathion and fenthion were selected as insecticides and atrazine, simazine, simetryn, molinate and benthiocarb, mefenacet and pretilachlor as herbicides. These pesticides have been widely used not only in Japan but also in the world. The field data surveyed simultaneously for both of water and fish were summarized in Tables 1-1 and 1-2 for the 4 insecticides (Abdel-Halim et al., 2006; Ministry of the Environment, Japan, 2001; Mansour & Sidky, 2003; Ohtsuki, 1994; Tsuda et al., 1992a; 1994; 1998) and Tables 2-1 and 2-2 for the 7 herbicids (Chiba Prefecture, 2002; 2003; Kanagawa Prefecture, 2000; 2001; Ministry of the Environment, Japan, 1993; 1999; Takino et al., 1998; Tsuda et al., 1996a; 1997a; Watanugi et al., 1993). Further, recent survey data on contamination of 5 insecticides and 16 herbicides in water and fish from Lake Biwa in Japan (Tsuda et al., 2009) were summarized in Tables 3 and 4.

As shown in Tables 1-1 and 1-2, diazinon and fenitrothion were detected in the concentrations of < 0.005~0.175 and < 0.005~0.037 μg/l in water and 4.1 and 11 μg/kg in pale chub, respectively, from Tama River Basin, Japan in 1993. The two insecticides were detected in the pale chub at their high concentrations of the water but were not detected in common carp and crucian carp. Further in Japan, diazinon, fenitrothion, malathion and fenthion were detected in the concentration ranges of ND~0.51, ND~0.39, ND~0.20 and ND~0.11μg/l , respectively, in water from rivers in Shiga Prefecture from April in 1991 to March in 1992. Fenitrothion was detected in the concentration ranges of ND~2.1 μg/kg wet wt. in pale chub and fenthion was detected in the concentration ranges of ND~1.7 μg/kg wet wt. in ayu fish and ND~19.4 μg/kg wet wt. in dark chub. However, diazinon and

No.	Location	Country	Sampling date	Water (μg/l)			
				Diazinon	Fenitrothion	Malathion	Fenthion
1	Tama River Basin	Japan	Jul.-1993	< 0.005～0.175	< 0.005～0.037		< 0.005～< 0.005
1	Tama River Basin	Japan	Jun. -1993	< 0.005～0.175	< 0.005～0.037		< 0.005～< 0.005
1	Tama River Basin	Japan	Jul.-1993	< 0.005～0.175	< 0.005～0.037		< 0.005～< 0.005
2	River in Kanagawa Pref.	Japan	Aug.-2000			< 0.01～0.02	
3	Rivers in Shiga Pref. (n=7)	Japan	Apr.-1990～Mar.-1991	ND～0.70	ND～2.00	ND～ND	
3	Rivers in Shiga Pref. (n=7)	Japan	Apr.-1990～Mar.-1991	ND～0.70	ND～2.00	ND～ND	
4	Rivers in Shiga Pref. (n=7)	Japan	Apr.-1991～Mar.-1992	ND～0.51	ND～0.39	ND～0.20	ND～0.11
4	Rivers in Shiga Pref. (n=7)	Japan	Apr.-1991～Mar.-1992	ND～0.51	ND～0.39	ND～0.20	ND～0.11
4	Rivers in Shiga Pref. (n=7)	Japan	Apr.-1991～Mar.-1992	ND～0.51	ND～0.39	ND～0.20	ND～0.11
5	Ezura River	Japan	Apr.-1995～Mar.-1996				< 0.005～0.12
6	Shinkawagishi River	Japan	Jun.～Dec.-2000			< 0.01～0.03	
7	Lake Qarun	Egypt	Oct.-1998～Apr.-1999			42.0 (n=1)	
8	New Damietta Drainage canal	Egypt	Spring-1999	70.5 (n=1)		466 (n=1)	
9	New Damietta Drainage canal	Egypt	Winter-2001	24.6 (n=1)		71.9 (n=1)	

Table 1-1. Concentrations of insecticides in water from rivers and lakes

No.	Location	Fish species	Fish (μg/kg wet wt.)				Reference
			Diazinon	Fenitrothion	Malathion	Fenthion	
1	Tama River Basin	Pale chub	4.1 (n=1)	11 (n=1)		< 5 (n=1)	Ohtsuki, A. (1994)
1	Tama River Basin	Common carp	< 5～< 5	< 5～< 5		< 5～< 5	Ohtsuki, A. (1994)
1	Tama River Basin	Crucian carp	< 5 (n=1)	< 5 (n=1)		< 5 (n=1)	Ohtsuki, A. (1994)
2	River in Kanagawa Pref.	Common carp			< 1～< 1		Kanagawa Precture (2001)
3	Rivers in Shiga Pref. (n=7)	Pale chub	ND～45	ND～7	ND～ND		Tsuda et al. (1992)
3	Rivers in Shiga Pref. (n=7)	Ayu fish	ND～43	ND～1511	ND～ND		Tsuda et al. (1992)
4	Rivers in Shiga Pref. (n=7)	Pale chub	ND～ND	ND～2.1	ND～ND	ND～ND	Tsuda et al. (1994)
4	Rivers in Shiga Pref. (n=7)	Ayu fish	ND～ND	ND～ND	ND～ND	ND～1.7	Tsuda et al. (1994)
4	Rivers in Shiga Pref. (n=7)	Dark chub	ND～ND	ND～ND	ND～ND	ND～19.4	Tsuda et al. (1994)
5	Ezura River	Pale chub				< 1～15	Tsuda et al. (1998)
6	Shinkawagishi River	Common carp			< 1～< 1		Ministry of the Environment, Japan (2001)
7	Lake Qarun	Tilapia			6 (n=1)		Mansour, S.A. & Sidky, M.M. (2003)
8	New Damietta Drainage canal	Tilapia	43.0 (n=1)				Abdel-Halim, et al. (2006)
9	New Damietta Drainage canal	Tilapia	21.1 (n=1)		19.3 (n=1)		Abdel-Halim, et al. (2006)

Table 1-2. Concentrations of insecticides in fish from rivers and lakes

No.	Location	Sampling date	Water (μg/l)						
			Molinate	Simetryn	Benthiocarb	Mefenacet	Pretilachlor	Simazine	Atrazine
10	Lake Sagami (Kanagawa Pref.)	1999						< 0.01 (n=1)	0.02 (n=1)
11	Rivers in Kanagawa Pref. (n=3)	Aug.～Dec.-2000						< 0.01～< 0.01	< 0.01～0.02
12	Rivers in Chiba Pref. (n=10)	Jan.-2002						< 0.02～0.05	< 0.02～0.73
13	Rivers in Chiba Pref. (n=5)	Feb.-2003						< 0.02～0.04	< 0.02～< 0.02
14	Rivers in Shiga Pref. (n=7)	Apr.-1992～Mar.-1994		< 0.02～208	< 0.01～14.8		< 0.02～5.1	< 0.2～1.7	
14	Rivers in Shiga Pref. (n=7)	Apr.-1992～Mar.-1994		< 0.02～208	< 0.01～14.8		< 0.02～5.1	< 0.2～1.7	
14	Rivers in Shiga Pref. (n=7)	Apr.-1992～Mar.-1994		< 0.02～208	< 0.01～14.8		< 0.02～5.1	< 0.2～1.7	
15	Rivers in Shiga Pref. (n=7)	Apr.-1994～Mar.-1996	< 0.01～75.5	< 0.01～21.2	< 0.01～0.90	< 0.01～11.2	< 0.01～8.7	< 0.02～2.6	
15	Rivers in Shiga Pref. (n=7)	Apr.-1994～Mar.-1996	< 0.01～75.5	< 0.01～21.2	< 0.01～0.90	< 0.01～11.2	< 0.01～8.7	< 0.02～2.6	
15	Rivers in Shiga Pref. (n=7)	Apr.-1994～Mar.-1996	< 0.01～75.5	< 0.01～21.2	< 0.01～0.90	< 0.01～11.2	< 0.01～8.7	< 0.02～2.6	
16	Senjyo River in Shiga Pref.	Apr.-1997～Mar.-1998	< 0.01～6.22	< 0.01～2.88	< 0.01～0.64	< 0.01～2.75	< 0.01～4.02		
16	Tenjin River in Shiga Pref.	Apr.-1997～Mar.-1998	< 0.01～6.22	< 0.01～2.88	< 0.01～0.64	< 0.01～2.75	< 0.01～4.02		
16	Ezura River in Shiga Pref.	Apr.-1997～Mar.-1998	< 0.01～6.22	< 0.01～2.88	< 0.01～0.64	< 0.01～2.75	< 0.01～4.02		
17	Rivers (n=6)	Sep.-1998						< 0.05 ～0.08	< 0.05 ～0.09
17	Rivers (n=10)	Sep.-1998						< 0.05 ～0.08	< 0.05 ～0.09
18	Rivers (n=16)	Sep.～Oct.-1992	< 0.02 ～0.077	< 0.05 ～< 0.05	< 0.2 ～< 0.2				
19	Lake Hachiro	Sep.～Oct.-1992	< 0.02 ～< 0.02	0.10 ～0.11	< 0.2 ～< 0.2				
20	Lake Suwa	Sep.～Oct.-1992		0.27 ～0.27	< 0.2 ～< 0.2				
21	Lake Kawakitagata in Ishikawa Pref.	May-1989	13.9	6.6	2.2				
21	Lake Kawakitagata in Ishikawa Pref.	May-1989	13.9	6.6	2.2				
22	Lake Kawakitagata in Ishikawa Pref.	May-1990	16.2	6.8	3.7				
22	Lake Kawakitagata in Ishikawa Pref.	May-1990	16.2	6.8	3.7				
23	Lake Kawakitagata in Ishikawa Pref.	May-1991	13.0	7.7	2.8				
23	Lake Kawakitagata in Ishikawa Pref.	May-1991	13.0	7.7	2.8				
24	Lake Kawakitagata in Ishikawa Pref.	May-1992	6.4	4.2	4.4				

Table 2-1. Concentrations of herbicides in water from rivers and lakes in Japan

malathion were not detected in the three species of fish (pale chub, ayu fish and dark chub). In Egypt, malathion were detected in the concentrations of 42.0 μg/l in water and 6 μg/kg wet wt. in tilapia from Lake Qarun in 1998~1999, and diazinon and malathion were detected in the concentrations of 24.6 and 71.9μg/l in water and 21.1 and 19.3 μg/kg wet wt. in tilapia, respectively, from New Damietta Drainage canal in winter of 2001.

As shown in Tables 2-1 and 2-2, molinate, simetryn, benthiocarb, mefenacet and simazine were detected in the concentrations of < 0.01~75.5, < 0.01~21.2, < 0.01~0.90, < 0.01~11.2 and < 0.02~2.6 μg/l in water and < 2~1156, < 5~50, < 10~< 10, < 10~324 and < 20~< 20 μg/kg in ayu fish, respectively, from rivers in Shiga Prefecture, Japan from April in 1994 to March in 1996. Benthiocarb and simazine were not detected in the fish in spite of their detections in the river water. Further, molinate, simetryn and benthiocarb were detected in the concentrations of 13.9, 6.6 and 2.2 μg/l in water and 10~170, 30~40 and 250~540 μg/kg in carp, respectively, from Lake Kawakitagata in Ishikawa Prefecture, Japan in 1989.

No.	Location	Fish species	Fish (µg/kg wet wt.)							Reference
			Molinate	Simetryn	Benthiocarb	Mefenacet	Pretilachlor	Simazine	Atrazine	
10	Lake Sagami (Kanagawa Pref.)	Steed barbel						< 1 (n=1)	< 1 (n=1)	Kanagawa Prefecture, 2000
11	Rivers in Kanagawa Pref. (n=3)	Carp						< 1～< 1	< 1～< 1	Kanagawa Prefecture, 2001
12	Rivers in Chiba Pref. (n=10)	Carp						< 5～< 5	< 5～< 5	Chiba Prefecture, 2002
13	Rivers in Chiba Pref. (n=5)	Carp						< 5～6	< 5～< 5	Chiba Prefecture, 2003
14	Rivers in Shiga Pref. (n=7)	Dark chub		< 5～20	< 10～10					Tsuda et al., 1996a
14	Rivers in Shiga Pref. (n=7)	Ayu fish		< 5～150	< 5～224					Tsuda et al., 1996a
14	Rivers in Shiga Pref. (n=7)	Pale chub		< 5～120	< 5～84		< 5～10			Tsuda et al., 1996a
15	Rivers in Shiga Pref. (n=7)	Dark chub		4～10						Tsuda et al., 1997a
15	Rivers in Shiga Pref. (n=7)	Ayu fish	< 2～1156	< 5～50	< 10～< 10	< 10～324		< 20～< 20		Tsuda et al., 1997a
15	Rivers in Shiga Pref. (n=7)	Pale chub	< 5～637	< 5～47	< 5～114	< 5～151				Tsuda et al., 1997a
16	Senjyo River in Shiga Pref.	Dark chub	< 4～< 4	< 4～7	< 8～30	< 20～< 20				Takino et al., 1998
16	Tenjin River in Shiga Pref.	Pale chub	< 4～8	< 4～< 4	< 8～260	< 20～< 20				Takino et al., 1998
16	Ezura River in Shiga Pref.	Ayu fish	< 4～39	< 4～< 4	< 8～< 8	< 20～24				Takino et al., 1998
17	Rivers (n=6)	Pale chub						< 2～< 2	< 2～< 2	Ministry of the Environment, Japan, 1999
17	Rivers (n=10)	Crucian carp						< 2～< 2	< 2～< 2	Ministry of the Environment, Japan, 1999
18	Rivers (n=16)	Japanese dace	< 6 ～< 6	< 7.8 ～< 7.8	< 14 ～< 14					Ministry of the Environment, Japan, 1993
19	Lake Hachiro	Japanese dace	< 6 ～< 6	< 7.8 ～< 7.8	< 14 ～< 14					Ministry of the Environment, Japan, 1993
20	Lake Suwa	Japanese dace		< 7.8 ～< 7.8	< 14 ～< 14					Ministry of the Environment, Japan, 1993
21	Lake Kawakitagata in Ishikawa Pref.	Crucian carp	190	ND～30	70～730					Watanugi & Tsukabayashi, 1993
21	Lake Kawakitagata in Ishikawa Pref.	Carp	10～170	30～40	250～540					Watanugi & Tsukabayashi, 1993
22	Lake Kawakitagata in Ishikawa Pref.	Crucian carp	30～50	ND～ND	100～120					Watanugi & Tsukabayashi, 1993
22	Lake Kawakitagata in Ishikawa Pref.	Carp	80～230	ND～ND	140～920					Watanugi & Tsukabayashi, 1993
23	Lake Kawakitagata in Ishikawa Pref.	Crucian carp	30	ND	70					Watanugi & Tsukabayashi, 1993
23	Lake Kawakitagata in Ishikawa Pref.	Carp	140	20	560					Watanugi & Tsukabayashi, 1993
24	Lake Kawakitagata in Ishikawa Pref.	Carp	50～110	ND～ND	90～190					Watanugi & Tsukabayashi, 1993

Table 2-2. Concentrations of herbicides in fish from rivers and lakes in Japan

As shown in Table 3, two insecticides and 10 herbicides in water and 4 herbicides in two species of fish (Hasu and pale chub) were detected from east littoral zone of (C_{10}, C_{11} and C_{13}) of northern basin of Lake Biwa. As shown in Table 4, two insecticides and 12 herbicides

Pesticides	Use	Water (µg/l)	Fish (µg/kg)	
		(n=21)	Hasu (n=5)	Pale chub (n=7)
Isoprocarb	Insecticides	< 0.02～< 0.02	< 2～< 2	< 2～< 2
Fenobucarb		< 0.01～0.02	< 2～< 2	< 2～< 2
Diazinon		< 0.01～0.01	< 2～< 2	< 2～< 2
Fenitrothion		< 0.02～< 0.02	< 2～< 2	< 2～< 2
Fenthion		< 0.01～< 0.01	< 2～< 2	< 2～< 2
Molinate	Herbicides	< 0.01～0.53	< 2～< 2	< 2～7
Simazine		< 0.01～< 0.01	< 2～< 2	< 2～< 2
Propyzamide		< 0.01～< 0.01	< 2～< 2	< 2～< 2
Bromobutide		0.03～1.90	< 2～14	< 2～29
Simetryn		0.03～1.11	< 2～< 2	< 2～< 2
Alachlor		< 0.01～0.02	< 2～< 2	< 2～< 2
Esprocarb		< 0.01～0.07	< 2～7	< 2～10
Thiobencarb		< 0.01～< 0.01	< 2～< 2	< 2～< 2
Dimethametryn		< 0.02～0.06	< 2～< 2	< 2～< 2
Dimepiperate		< 0.01～< 0.01	< 2～< 2	< 2～< 2
Pretilachlor		< 0.01～0.23	< 2～< 2	< 2～< 2
Thenylchlor		< 0.01～0.03	< 2～< 2	< 2～< 2
Pyributicarb		< 0.02～< 0.02	< 2～< 2	< 2～< 2
Anilofos		< 0.02～< 0.02	< 2～< 2	< 2～< 2
Mefenacet		< 0.02～0.57	< 4～< 4	< 4～14
Cafenstrole		< 0.05～0.08	< 4～< 4	< 4～< 4

Table 3. Concentrations of pesticides in fish from east littoral zone of northern basin of Lake Biwa

Pesticides	Water (μg/l)	Bluegill (μg/kg)
	(n=21)	(n=14)
Isoprocarb	< 0.02～< 0.02	< 2～< 2
Fenobucarb	< 0.01～0.04	< 2～< 2
Diazinon	< 0.01～0.28	< 2～< 2
Fenitrothion	< 0.02～< 0.02	< 2～< 2
Fenthion	< 0.01～< 0.01	< 2～< 2
Molinate	< 0.01～1.40	< 2～14
Simazine	< 0.01～< 0.01	< 2～< 2
Propyzamide	< 0.01～< 0.01	< 2～< 2
Bromobutide	0.02～5.77	< 2～32
Simetryn	0.03～3.44	< 2～6
Alachlor	< 0.01～0.02	< 2～< 2
Esprocarb	< 0.01～0.44	< 2～59
Thiobencarb	< 0.01～0.06	< 2～< 2
Dimethametryn	< 0.02～0.13	< 2～< 2
Dimepiperate	< 0.01～< 0.01	< 2～< 2
Pretilachlor	< 0.01～0.46	< 2～6
Thenylchlor	< 0.01～0.13	< 2～< 2
Pyributicarb	< 0.02～< 0.02	< 2～< 2
Anilofos	< 0.02～0.10	< 2～7
Mefenacet	< 0.02～2.65	< 4～29
Cafenstrole	< 0.05～0.09	< 4～9

Table 4. Concentrations of pesticides in fish from littoral zone of Akanoi Bay in southern basin of Lake Biwa

in water and 8 herbicides in bluegill were detected from littoral zone of Akanoi Bay (North, Center and South) in southern basin of Lake Biwa. The two insecticides and 12 herbicides were detected in the water from the two littoral areas of Lake Biwa but the two insecticides were not and the only 8 herbicides were detected in the three species of fish from the locations. An example of concentration changes of the 8 herbicides in the water and bluegill from the littoral zone of Akanoi Bay (Center) in southern basin of Lake Biwa is shown in Fig. 1 throughout the survey from May to August in 2007. The concentrations of molinate, bromobutide, simetryne and mefenacet in the water were high in May and June. This result corresponds to the maximum use of the herbicides in paddy fields of Japan. Detections of the 8 herbicides in the fish corresponded well to those in the water, but the order of the herbicide concentrations in the fish was different from that in the water. For example, the concentration of esprocarb was low in the water but high in the fish. This is probably because bioconcentration potential of esprocarb is higher than the other herbicides.

2. Bioconcentration of pesticides in the field fish

Bioconcentration factor (BCF) of each pesticide in the field fish was calculated as its bioconcentration potential from the field data (Tables 1-1, 1-2, 2-1 and 2-2) on the pesticide concentration in the water and fish from the rivers and lakes in Japan and Egypt.

The BCF values are shown in Table 5 for the 4 insecticides (diazinon, fenitrothion, malathion and fenthion). The BCF values in the two or three species of fish from the rivers in Japan

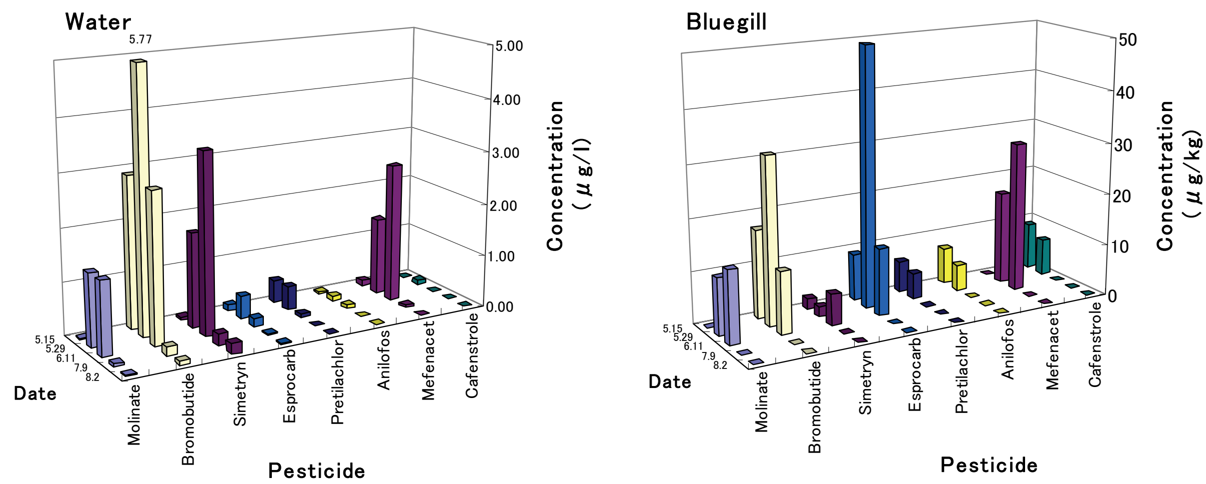

Fig. 1. Concentration changes of the 8 herbicides in the water and fish from the littoral zone of Akanoi Bay (Center) in southern basin of Lake Biwa throughout the survey from May to August in 2007.

were 20~150 for diazinon, 70~790 for fenitrothion and 20~240 for fenthion. For malathion, its BCF value could not be calculated because of its no detections in the common carp from the two rivers in Japan. This is probably due to its low bioconcentration potential. In Egypt, the BCF values in the tilapia from New Damietta Drainage canal were 0.6 and 0.9 for diazinon and 0.3 for malathion and that in the tilapia from Lake Qarun was 0.1 for malathion. The BCF values of diazinon (0.6 and 0.9) in the tilapia in Egypt were considerably lower than those (20~150) in the two species of fish (pale chub and ayu fish) in Japan.

No.	Species	Tissue	Location	Field BCF data (wet wt.)				Reference
				Diazinon	Fenitrothion	Malathion	Fenthion	
1	Pale chub		Tama River Basin	20 (n=1)	790 (n=1)			Ohtsuki, A. (1994)
1	Common carp		Tama River Basin	< 30～< 330 (n=2)	< 140～< 360 (n=2)			Ohtsuki, A. (1994)
1	Crucian carp		Tama River Basin	< 330 (n=1)	< 140 (n=1)			Ohtsuki, A. (1994)
2	Common carp		River in Kanagawa Pref.			< 50 (n=1)		Kanagawa Pre. (2001)
3	Pale chub	Whole body	Rivers in Shiga Pref. (n=7)	150 (n=5)	70 (n=2)			Tsuda et al. (1992)
3	Ayu fish	Whole body	Rivers in Shiga Pref. (n=7)	60 (n=1)	580 (n=1)			Tsuda et al. (1992)
4	Pale chub	Whole body	Rivers in Shiga Pref. (n=7)		190 (n=2)			Tsuda et al. (1994)
4	Ayu fish	Whole body	Rivers in Shiga Pref. (n=7)				20 (n=1)	Tsuda et al. (1994)
4	Dark chub	Whole body	Rivers in Shiga Pref. (n=7)				240 (n=1)	Tsuda et al. (1994)
5	Pale chub	Whole body	Ezura River				130 (n=1)	Tsuda et al. (1998)
6	Common carp	Whole body	Shinkawagishi River			< 50 (n=1)		Ministry of the Environment, Japan (2001)
7	Tilapia	Whole body	Lake Qarun			0.1 (n=1)		Mansour, S.A. & Sidky, M.M. (2003)
8	Tilapia	Muscle	New Damietta Drainage canal	0.6 (n=1)				Abdel-Halim, et al. (2006)
9	Tilapia	Muscle	New Damietta Drainage canal	0.9 (n=1)		0.3 (n=1)		Abdel-Halim, et al. (2006)

Table 5. BCF of insecticides in fish from field survey data

The BCF values in the rivers and lakes in Japan are shown in Table 6 for the 7 herbicides (molinate, simetryn, benthiocarb, mefenacet, pretilachlor, simazine and atrazine).The BCF values were 15~286 for molinate, 2~163 for simetryn, 56~248 for benthiocarb and 20~36 for mefenacet in the two or the three species of fish (ayu fish, pale chub and dark chub) and 19 for pretilachlor in the pale chub from the rivers. The BCF value of simazine was calculated as 150 (n=1) in the carp from a river but could not calculated in the carp or the pale chub from other rivers. Those of simazine in the carp and the pale chub were estimated to be < 100 and < 33, respectively. For atrazine, its BCF values could not be calculated at all in the three species of fish from the rivers. Those were estimated to be < 50 in Steed barbell, < 50 and < 6.8 in carp and < 22 in crucian carp. This is probably due to its low bioconcentration

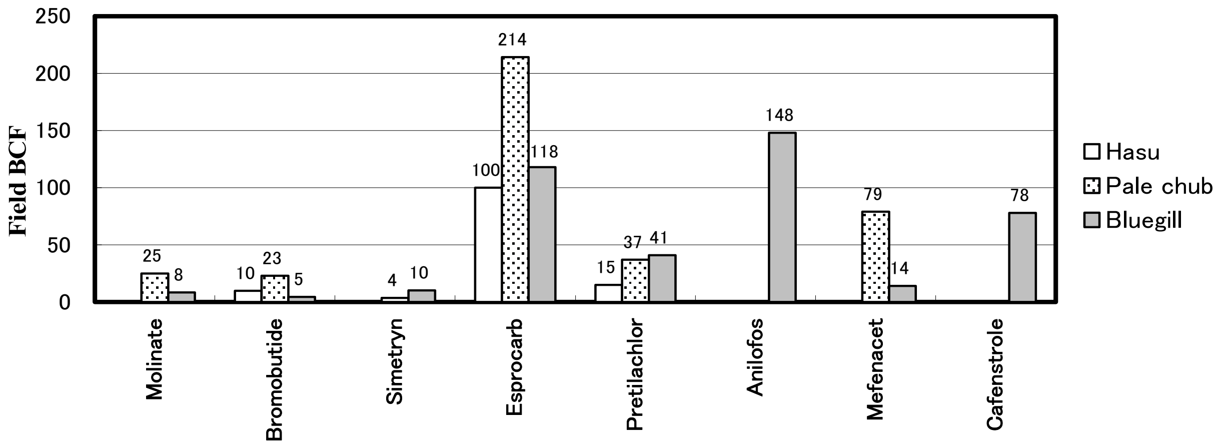

Fig. 2. Average BCF values of the 8 herbicides in the three kinds of fish from the field data

potential. The BCF values were 2.3~14 for molinate, 2.6~5.0 for simetryn, 25~200 for benthiocarb in the two species of fish (carp and crucian carp) from the Lake Kawakitagata.

BCF values of the 8 herbicides in each of the three species of fish (hasu, pale chub and bluegill) were calculated from the field data (Tables 3 and 4) in Lake Biwa and are shown in Fig. 2. The BCF values of the herbicides in the field fish were 8 and 25 for molinate, 5 ～ 23 for bromobutide, 4 and 10 for simetryn, 100 ～ 214 for esprocarb, 15 ～ 41 for pretilachlor, 148 for anilofos, 14 and 79 for mefenacet and 78 for cafenstrole. The BCF values were low for molinate, bromobutide and simetryn, middle for pretilachlor, mefenacet and cafenstrole and high for esprocarb and anilofos.

No.	Species	Tissue	Location	Field BCF data (wet wt.)							Reference
				Molinate	Simetryn	Benthiocarb	Mefenacet	Pretilachlor	Simazine	Atrazine	
10	Steed barbel		Lake Sagami (Kanagawa Pref.)							< 50 (n=1)	Kanagawa Prefecture, 2000
11	Carp		Rivers in Kanagawa Pref. (n=3)							< 50 (n=1)	Kanagawa Prefecture, 2001
12	Carp		Rivers in Chiba Pref. (n=10)						< 100 (n=1)	< 6.8 (n=1)	Chiba Prefecture, 2002
13	Carp		Rivers in Chiba Pref. (n=5)						150 (n=1)		Chiba Prefecture, 2003
14	Dark chub	Whole body	Rivers in Shiga Pref. (n=7)		2 (n=2)	248 (n=1)					Tsuda et al., 1996a
14	Ayu fish	Whole body	Rivers in Shiga Pref. (n=7)		20 (n=6)	56 (n=7)					Tsuda et al., 1996a
14	Pale chub	Whole body	Rivers in Shiga Pref. (n=7)		7 (n=7)	68 (n=8)		19 (n=1)			Tsuda et al., 1996a
15	Dark chub	Whole body	Rivers in Shiga Pref. (n=7)		30 (n=2)						Tsuda et al., 1997a
15	Ayu fish	Whole body	Rivers in Shiga Pref. (n=7)	15 (n=9)	20 (n=7)	141 (n=4)	36 (n=5)				Tsuda et al., 1997a
15	Pale chub	Whole body	Rivers in Shiga Pref. (n=7)	15 (n=7)	16 (n=6)	67 (n=4)	31 (n=3)				Tsuda et al., 1997a
16	Dark chub	Whole body	Senjyo River in Shiga Pref.		163 (n=2)						Takino et al., 1998
16	Pale chub	Whole body	Tenjin River in Shiga Pref.	286 (n=1)		214 (n=1)					Takino et al., 1998
16	Ayu fish	Whole body	Ezura River in Shiga Pref.	142 (n=3)			20 (n=1)				Takino et al., 1998
17	Pale chub	Whole body	Rivers (n=6)						< 33 (n=1)		Ministry of the Environment, Japan, 1999
17	Crucian carp	Whole body	Rivers (n=10)							< 22 (n=1)	Ministry of the Environment, Japan, 1999
18	Japanese dace	Muscle	Rivers (n=16)	< 78 (n=1)	< 229 (n=1)						Ministry of the Environment, Japan, 1993
19	Japanese dace	Muscle	Lake Hachiro		< 78 (n=1)						Ministry of the Environment, Japan, 1993
20	Japanese dace	Muscle	Lake Suwa		< 29 (n=1)	< 82 (n=1)					Ministry of the Environment, Japan, 1993
21	Crucian carp	Whole body	Lake Kawakitagata in Ishikawa Pref.	14 (n=1)	4.5 (n=1)	139 (n=2)					Watanugi & Tsukabayashi, 1993
21	Carp	Whole body	Lake Kawakitagata in Ishikawa Pref.	6.5 (n=3)	5.0 (n=3)	165 (n=3)					Watanugi & Tsukabayashi, 1993
22	Crucian carp	Whole body	Lake Kawakitagata in Ishikawa Pref.	2.5 (n=3)		31 (n=3)					Watanugi & Tsukabayashi, 1993
22	Carp	Whole body	Lake Kawakitagata in Ishikawa Pref.	7.9 (n=4)		99 (n=4)					Watanugi & Tsukabayashi, 1993
23	Crucian carp	Whole body	Lake Kawakitagata in Ishikawa Pref.	2.3 (n=1)		25 (n=1)					Watanugi & Tsukabayashi, 1993
23	Carp	Whole body	Lake Kawakitagata in Ishikawa Pref.	11 (n=1)	2.6 (n=1)	200 (n=1)					Watanugi & Tsukabayashi, 1993
24	Carp	Whole body	Lake Kawakitagata in Ishikawa Pref.	11 (n=6)		31 (n=6)					Watanugi & Tsukabayashi, 1993

Table 6. BCF of herbicides in fish from field survey data

3. Bioconcentration of pesticides in fish by laboratory experiments

Laboratory BCF data of the 11 pesticides in fresh-water fish were reviewed from literatures in the past and the BCF value of each pesticide in fish was evaluated as its bioconcentration potential.

Laboratory BCF data of the 4 insecticides in fresh-water fish are shown in Fig. 3 for diazinon (Allison & Hermanutz, 1977; Goodman et al., 1979; Kanazawa, 1975; 1978; 1981; 1983; Keizer et al., 1991; 1993; Nihon Kagaku-busshitsu Anzen-Jyohou Center, 1992; Seguchi & Asaka, 1981; Sancho et al., 1992; Tsuda et al., 1989a; 1990; 1995; 1997b; 1997c), Fig. 4 for fenitrothion (De Bruijn, & Hermens, 1991; Escartin & Porte, 1996; Fisher, 1985; Kanazawa, 1975; 1981; 1983; 1987; Lockhart et al., 1983; Miyamoto et al., 1979; Nihon Kagaku-busshitsu Anzen-Jyohou Center, 1992; Sancho et al., 1994; Takimoto et al., 1984; 1987; Tsuda et al., 1989a; 1990; 1995; 1997b; 1997c), Fig. 5 for malathion (Tsuda et al., 1989a; 1990; 1997b) and fenthion (De Bruijn & Hermens, 1991; Tsuda et al., 1992b; 1993; 1995; 1996b; 1997c). The average BCF value of each insecticide was 100 (n=12) for diazinon, 170 (n=10) for fenitrothion, 20 (n=2) for malathion and 340 (n=6) for fenthion. The order of the 4 insecticides in the BCF values was fenthion > fenitrothion > diazinon > malathion.

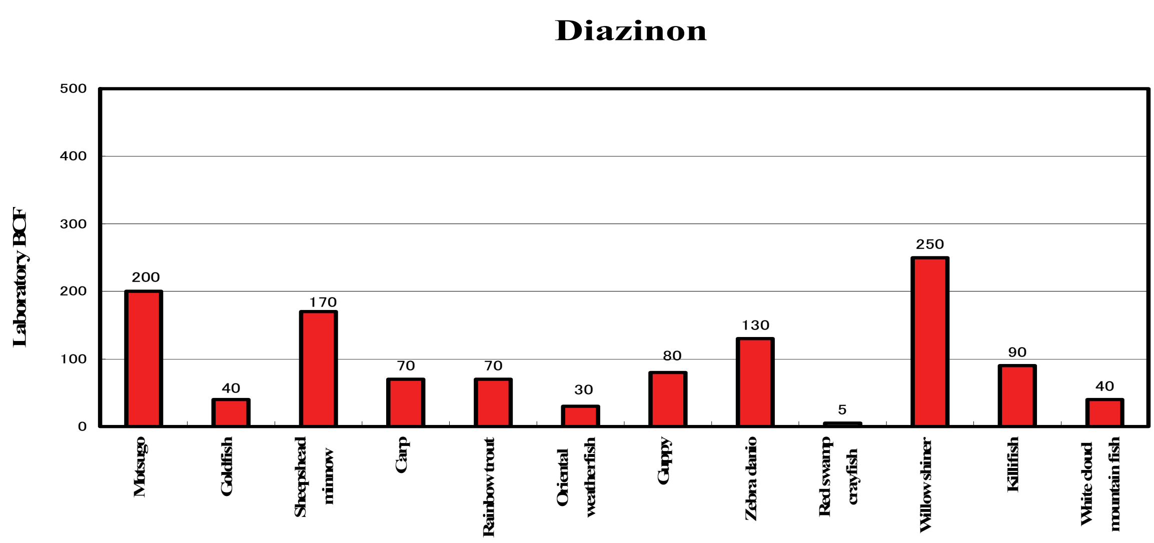

Fig. 3. Bioconcentration of diazinon in fresh-water fish

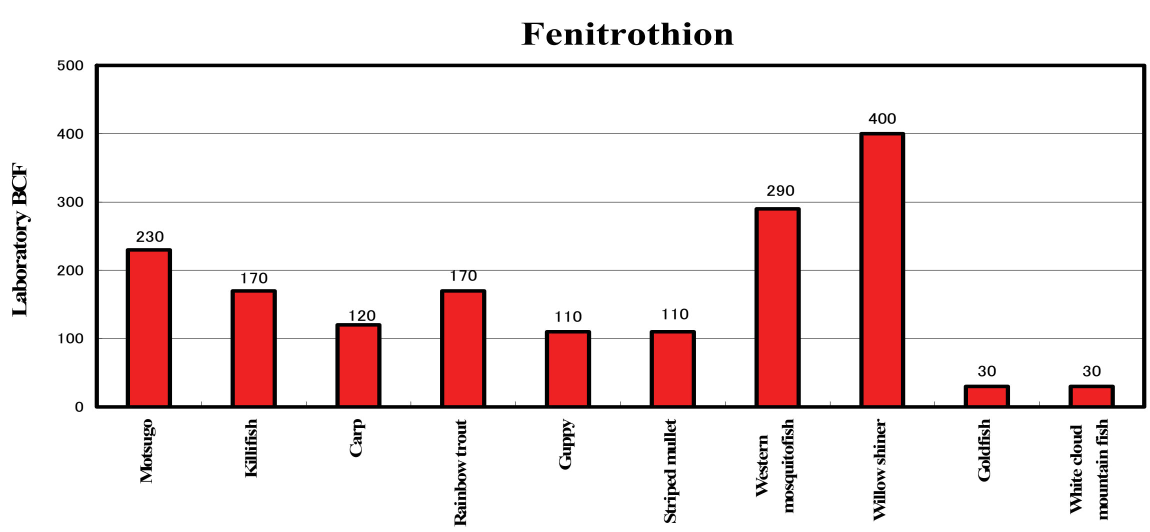

Fig. 4. Bioconcentration of fenitrothion in fresh-water fish

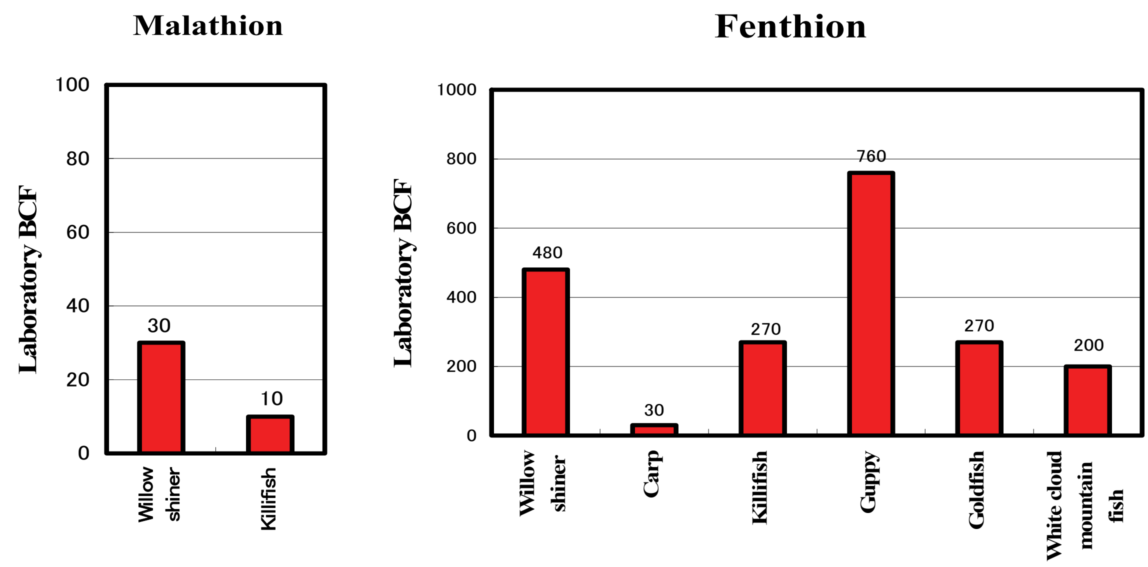

Fig. 5. Bioconcentration of malathion and fenthion in fresh-water fish

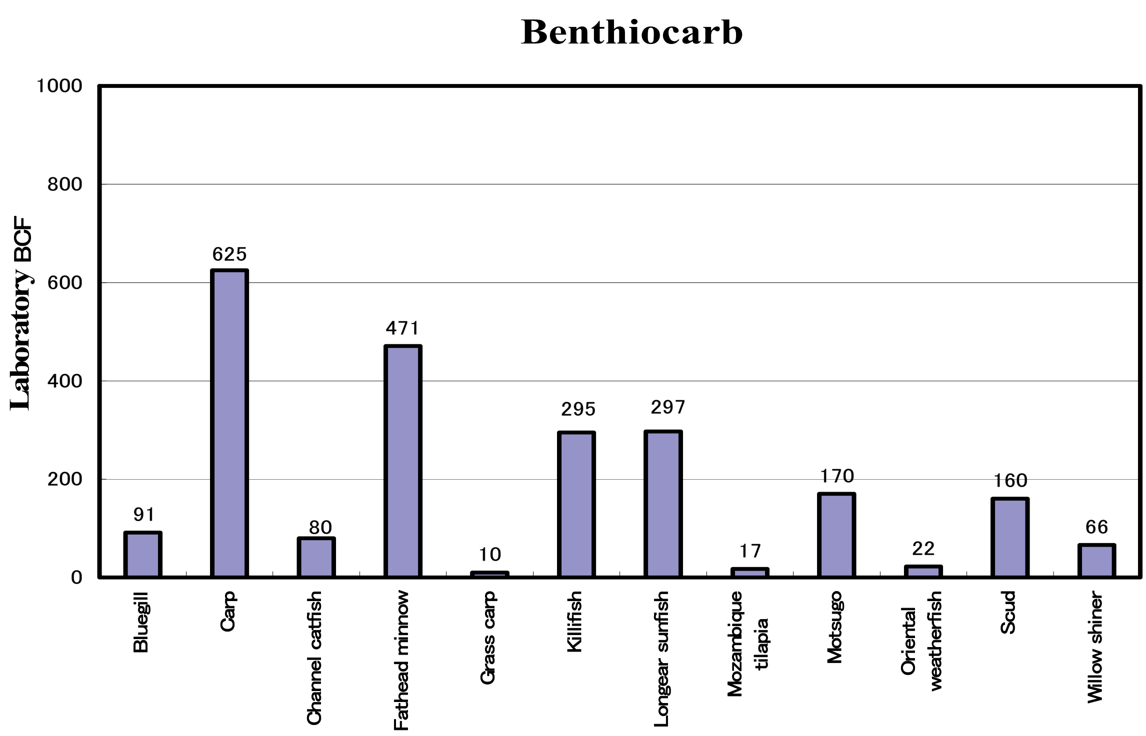

Fig. 6. Bioconcentration of benthiocarb in fresh-water fish

Those of the 7 herbicides in fresh-water fish are shown in Fig. 6 for benthiocarb (Kanazawa, 1981; 1983; Sanders & Hunn, 1982; Tsuda et al., 1988; 1989b; 1997d; Wang et al., 1992) and Fig. 7 for simetryn (Tsuda et al., 1988; 1989b; Xu & Zhang, 1989), molinate (Kanazawa, 1981; 1983; Martin et al., 1992; Tsuda et al., 1999), mefenacet (Tsuda et al., unpublished data), pretilachlor (Tsuda et al., unpublished data), simazine (Tsuda et al., 1992c) and atrazine (Isensee, 1976; Kearney et al., 1977; Gunkel & Streit, 1980; Gorge & Nagel, 1990; Du Preez & Van Vuren, 1992). The average BCF value of each herbicide was 192 (n=12) for benthiocarb, 35 (n=3) for simetryn, 19 (n=3) for molinate, 21 (n=2) for mefenacet, 33 (n=2) for pretilachlor, 3.9 (n=1) for simazine and 8.3 (n=3) for atrazine. The order of the 7 herbicides in the BCF values was benthiocarb > simetryn, pretilachlor ≧ mefenacet, molinate > atrazine, simazine.

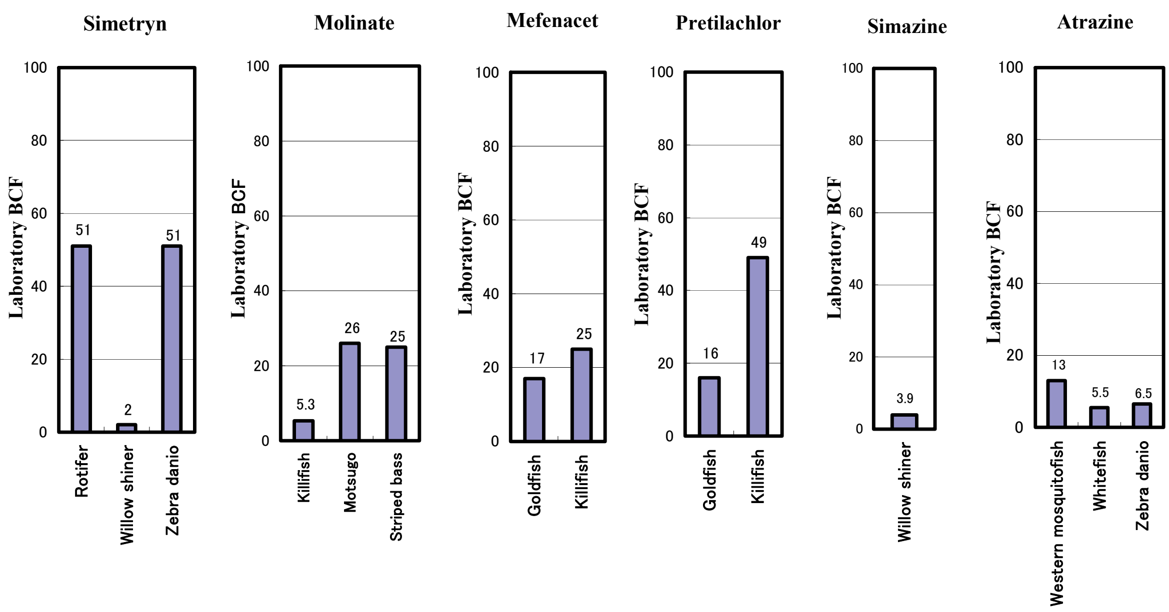

Fig. 7. Bioconcentration of simetryn, molinate, mefenacet, pretilachlor, simazine and atrazine in fresh-water fish

For benthiocarb, simetryn and atrazine, their bioconcentration in muscle and viscera (liver, kidney and gallbladder) of two species of fish (carp and bream) (Du Preez & Van Vuren, 1992; Tsuda et al., 1989b) is shown in Fig. 8. BCF values of benthiocarb were 26 in muscle, 63 in liver, 73 in kidney and 63 in gallbladder. Similarly, those of simetryn were 2.4 in muscle, 14 in liver, 8.1 in kidney and 11 in gallbladder. The order of the BCF values in the 4 parts of the carp for benthiocarb was slightly different from that of simetryn. But for both herbicides, the values of BCF in the viscera were higher than those in the muscle. Further in the bream, the BCF value in the liver was higher than that in the muscle.

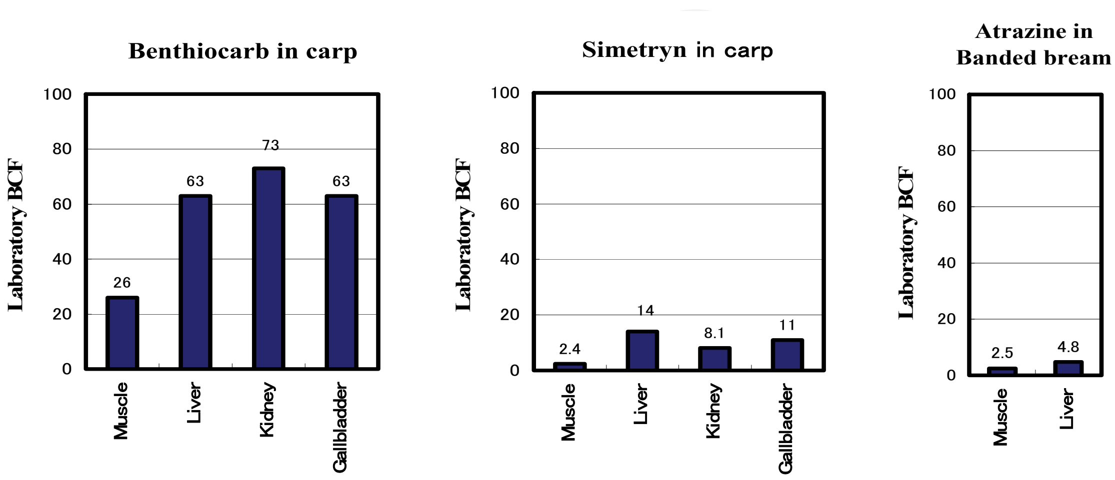

Fig. 8. Bioconcentration of benthiocarb, simetryn and atrazine in muscle and viscera of fresh-water fish

4. Evaluation of the pesticide contaminations in the field fish by their laboratory BCF data

The contaminations of the 10 pesticides in the field fish were evaluated by comparing the field BCF data with the laboratory BCF data.
The field BCF data of the 4 insecticides in the field fish (Table 5) and the laboratory BCF data (Figs. 3 - 5) are summarized and compared in Fig. 9. The field BCF data of the 4 insecticides were nearly equal to the laboratory BCF data. Similarly, the field BCF data (Table 6) and the laboratory BCF data (Figs. 6 - 7) of the 6 herbicides except atrazine are summarized and compared in Fig. 10. The field BCF data of the 4 insecticides and the 5 herbicides except simazine were nearly equal to the laboratory BCF data. It was revealed that the contamination of 9 pecticides except simazine in fish from the rivers and the lakes was approximately predicted by the laboratory BCF data.

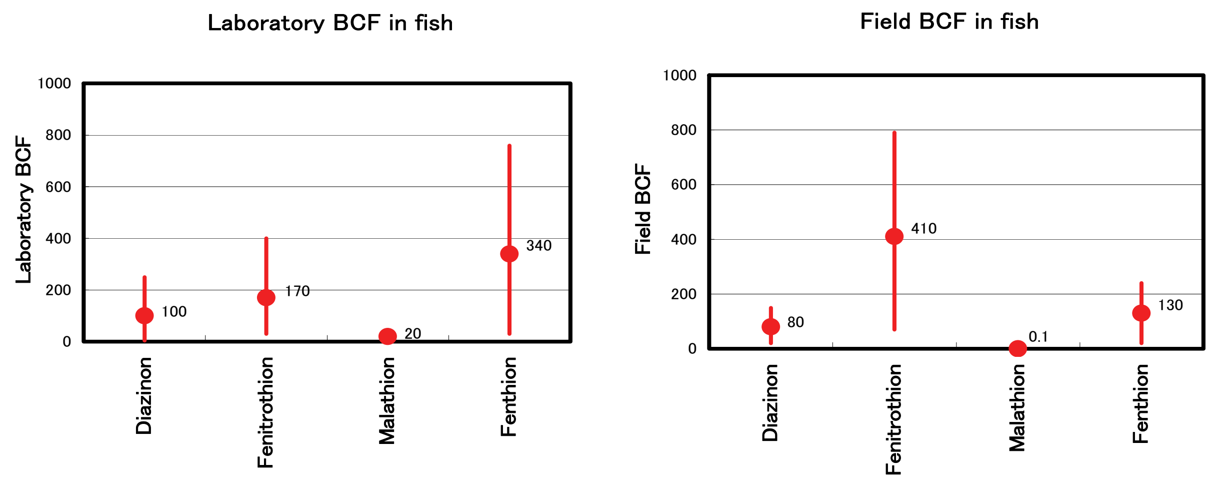

Fig. 9. Comparison of laboratory BCF data and field BCF data for 4 insecticides

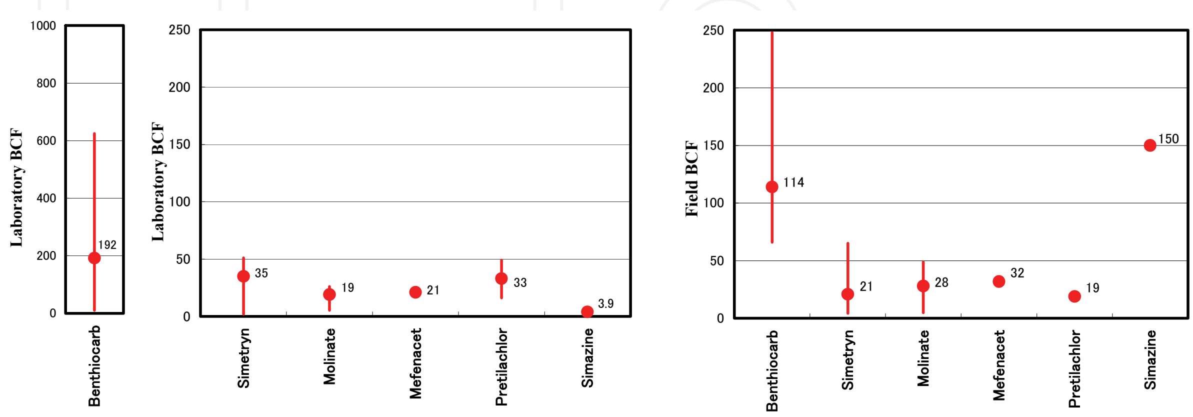

Fig. 10. Comparison of laboratory BCF data and field BCF data for 6 herbicides

Field BCF data of the 5 herbicides (molinate, bromobutide, simetryn, pretilachlor and mefenacet) in the fish from Lake Biwa (Fig. 2) and the laboratory BCF data are shown in Fig. 11. The average field BCF values were nearly equal to the average laboratory BCF values for molinate, bromobutide and pretilachlor but slightly lower for simetryn and slightly higher for mefenacet. The differences in the field and laboratory BCF values of simetryn and mefenacet are not wide, so both of the field and laboratory BCF data are considered to be the same levels for all of the 5 herbicides. From the comparison shown in Fig. 11, it was clarified that the contamination of the 5 herbicides in the fish from Lake Biwa could be approximately estimated by the laboratory BCF.

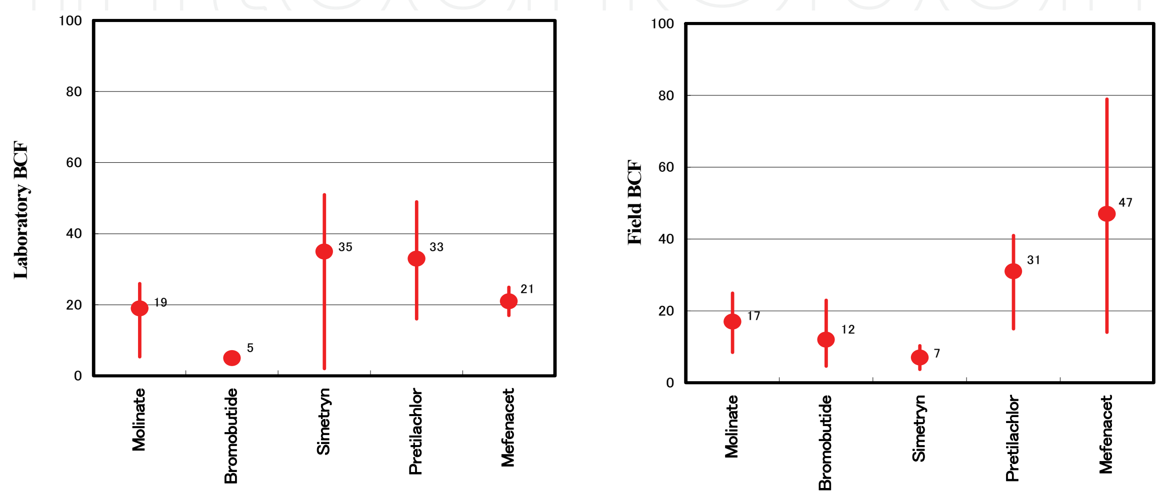

Fig. 11. Comparison of laboratory BCF data and field BCF data for 5 herbicides

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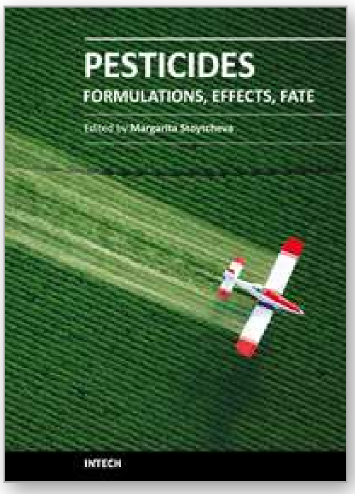

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This book provides an overview on a large variety of pesticide-related topics, organized in three sections. The first part is dedicated to the "safer" pesticides derived from natural materials, the design and the optimization of pesticides formulations, and the techniques for pesticides application. The second part is intended to demonstrate the agricultural products, environmental and biota pesticides contamination and the impacts of the pesticides presence on the ecosystems. The third part presents current investigations of the naturally occurring pesticides degradation phenomena, the environmental effects of the break down products, and different approaches to pesticides residues treatment. Written by leading experts in their respective areas, the book is highly recommended to the professionals, interested in pesticides issues.

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