

Predicting herbicides concentrations in paddy water and runoff to the river basin

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Abstract: This study was conducted to investigate the dissipation pattern and runoff of herbicides to the river basin from the paddy fields. Pesticide paddy field model (PADDY) was applied to predict herbicide concentration in paddy fields. A field study was conducted in a paddy farm of Higashi Hiroshima City, Hiroshima Prefecture, Japan in the year of 2003 paddy season. The herbicides were mefenacet, thiobencarb, and bensulfuron methyl. The sample water was analyzed by using gas chromatography and HPLC after solid phase extraction. Predicted dissipation rate of thiobencarb in paddy water was higher ($DT_{50} = 4.36$) than that measured, with a lower k value (-0.069). Two weeks after application no thiobencarb was detected in the drainage channel and down stream. In the down stream, thiobencarb was detected until 3 d after application, with a range of 0.02% to 0.08% of applied herbicide. The predicted dissipation rate (k) and half-life (DT_{50}) of mefenacet was not significantly different from that of measured. In the drainage channel, upstream and downstream mefenacet was found during the whole study period. In downstream, the maximum concentration of mefenacet was present 0.61% of applied in the paddy field on 3DAH. The dissipation rate (k) of BSM varied from -0.0860 to -0.1059 to with half-life (DT_{50}) 3.5 and 2.84 d. In upstream water, no BSM was detected except trace amounts (0.01 $\mu\text{g/L}$) at 3 d after application. However, in the drainage channel 8%, 6% and 1.58% of applied BSM was present at 0, 1 and 3 d after application respectively. In the down stream, the highest concentration was 1.06%, shortly after application.

Keywords: paddy field; pesticide paddy field model (PADDY); herbicide; dissipation; runoff

Introduction

Public concern has recently been growing over the runoff of pesticides applied to agricultural land and the potential contamination of drinking water and adverse effects on aquatic ecosystems. In Japan, more than half of all agricultural land is paddy fields, from which pesticides can easily flow out through drainage into public water areas such as rivers and lakes (Inao, 2003). Many researchers have measured pesticide losses from small paddy fields in Japan (Izuka, 1982; Hori, 1982; Nakamura, 1982; Tsukamoto, 1983; Mikuriya, 1983; Numabe, 1992; Ebise, 1993; Nohara, 1996; Sasagawa, 1996). Most of them reported that the maximum concentrations during observation periods ranged from 10 to 100 mg/L for herbicides, and 1 to 10 mg/L for fungicides and insecticides. The transportation of pesticides from larger land areas has also been examined. In the USA, Willfred *et al.* (Willfred, 1993) investigated the Mississippi River and its tributaries in July and August 1991. Molinate and thiobencarb were found in the tributaries with maximum concentrations of 2.6 and 0.06 mg/L, respectively, in the dissolved phase. In Greece, Albanis *et al.* (Albanis, 1994) estimated the percentages of the total amount of molinate released by rivers into the Thermaikos Gulf as 0.8% and 0.25% for the years of 1992 and 1993, respectively.

Important factors that determine the distribution of pesticides include their mobility from soil to water and their life span in soil and water. Problems may occur due to offsite movement with drift to sensitive crops, runoff with rainfall, or leaching into soil if rainfall occurs soon after application. Other factors include the extent of pesticide contamination, related to the amount and frequency of their application, as well as to climatic and irrigation conditions (Landon, 1994; Clay, 1998). Because these factors may differ significantly

from place to place and year to year, intensive long-term studies are needed. Such studies will be useful in analyzing the long term effects on the environment and to assess the potential risks to aquatic ecosystems. In addition, knowledge of movement and degradation of an herbicide can help agricultural scientists design management practices that will result in protection of offsite areas from herbicide contamination.

In Japan, in rice-producing areas river water is the main source for irrigation (about 88% of total water use), and this is introduced to a main canal by weirs and then diverted to branch canals (Hasegawa, 1995). Drainage water from paddy fields is used repeatedly in other paddy fields of downstream. The flow of irrigation and drainage water in rice paddies can be classified as three major scales, such as field level, farm level and river basin. The behaviour and concentration of pesticides in surface water can be conceptualized based on the three points.

In this study, dissipation pattern and runoff of herbicides to the river basin from the paddy fields was investigated. Pesticide paddy field model (PADDY) was applied to predict and validate the herbicide runoff potential to the drainage channel and river system.

1 Materials and methods

1.1 Pesticide paddy field model (PADDY)

The pesticide paddy field model (PADDY) for predicting pesticide concentration in water and soil of paddy fields and the runoff to the aquatic environment was first developed and evaluated by Inao and Kitamura (Inao, 1999). This model was focused on granule formulation, widely used herbicides on paddy fields in Japan. Initially this model was applied to paddy field plots to predict the concentration of molinate and simetryn. Later on, it was applied for a wide range of

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herbicides, and in filed level landscape level, such as block and district level (Inao, 2001; 2003). Many models have been developed and applied to predict the pesticide runoff and degradation in soil and aquatic environment (surface and ground water). However, the PADDY field model is based on paddy fields, and so it is particularly well suited to the herbicides used in paddy farming.

The herbicide applied in paddy fields can be quantified by considering the main processes: dissolution of herbicide from granules into water, adsorption and desorption, run off, leaching, volatilization and degradation. Herbicide uptake by plants was not considered in this model.

1.2 Equation for herbicide concentration of water surface in the paddy field

The herbicide concentration in paddy field water was calculated using the following Equation:

$$V_o d_{C_{wo}}/dt = V_o k_s (C_{ws} - C_{wo}) - Q_s C_{wo} - Q_g C_{wo} - M_o k_{des} (K_f C_{wi} - C_{so}) - K_L A C_{wo} - V_o k_{dw} C_{wo}$$

Where, V_o is the volume of paddy field water; C_{wo} is the pesticide concentration in paddy field (mg/L); k_s is the desolution rate constant; C_{ws} is the water solubility of pesticide; Q_s is the outflow rate of water; Q_g is the penetration rate of water; M_o is the weight of surface soil solid; K_f is the freundlich adsorption coefficient; K_L is the overall mass transfer coefficient; A is the area of paddy field; k_{dw} is the first order degradation rate constant.

The volumetric flow rate into and out of paddy fields is constant (i.e., inflow rate = outflow rate + penetration rate + evaporation rate = constant), and the volume of paddy field water is also constant.

1.3 Study area

The study of herbicide dissipation and runoff was carried out in a rice producing area Higashi Hiroshima City in the Kurose Basin, Hiroshima Prefecture, Japan. The city area is 288.25 km², of which about 12% is agricultural land, and about 95% of that agricultural land is under paddy cultivation. The altitude is approximately 200 m above sea level and the city is located in the Saijo basin under the Kurose watershed, which is surrounded by mountains of about 500 m above sea level. The study area is regarded as a typical paddy cultivating area in Japan. A small river (Nukui River) flowing over the study site is used as the main irrigation channel and termed as "upstream". Rice paddy fields are spread along the basin of the river. The river banks on both sides are protected by concrete blocks. In the area, water was distributed to individual farms by pump and then from one field to another as shown in Fig.1. The drainage canal of the farm flows through the river, which ultimately flows to the main river, which is termed as "downstream".

In the monitored farm, rice was transplanted at the end of May and one-shot herbicide Ulfues 1 kg granules (mefenacet 3.0%, thiobencarb 15% and bensulfuron methyl 0.51%) was applied at a rate of 10 kg/hm² under flooded conditions for 5 d after transplanting on June 2, 2003, when almost all others farm has completed transplanting within the month of May. Therefore, the chance of herbicide residue being carried out by irrigation water was minimal. The irrigation and drainage water was used for two fields of the

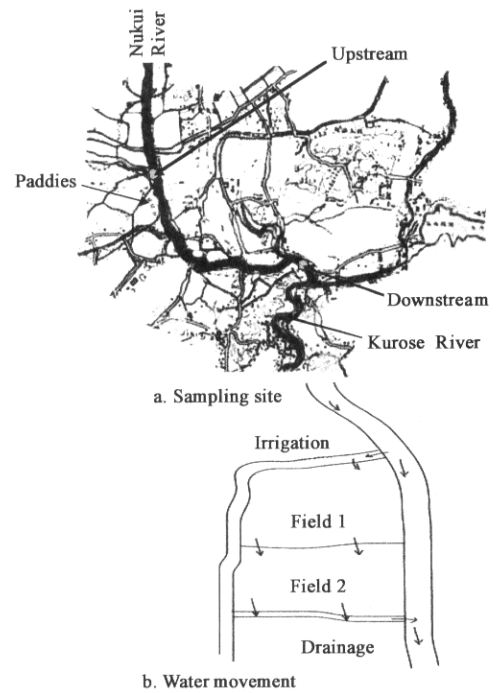


Fig.1 Map of sampling locations in the study site
a. sampling site; b. water movement

farm (Fig.1).

1.4 Water sampling

Water samples were collected from the upstream, three paddy fields, downstream and outlet to the downstream. The sampling was made at or around 0, 1, 3, 7, 14, 21, 28 and 35 d after herbicide application using glass bottles. Samples were taken from random spots in each of the paddy fields. From each of the sampling point 1000 ml samples were collected during the whole study period. The water samples were brought to the laboratory immediately and analyzed using gas chromatography and HPLC after solid phase extraction. The method used for the residue analysis was developed at the Pesticide Analysis Laboratory of Hiroshima Prefecture Agriculture Experiment Center.

1.5 Analysis of the samples

A Sep-Pak Cartridge Rack (Nippon Millipore Co.) was used for solid phase extraction and elution. Herbicides and other reagents were purchased from Kanto Chemicals (Japan). All solvents used were of pesticide residue-grade. Water samples were filtered through the No.7 filter paper of 4 μm pore size with Hyflo-Super-Cel (Kiriyaama, Japan) to remove the particles. Sep Pak-PS2 (C18) cartridge (Waters, Ireland) 2 per sample, were preconditioned by washing with 10 ml acetonitrile and 30 ml distilled water, and dried with a water aspirator. A 200 ml volume of filtered water with 2 repetitions of each sample was passed through the cartridge at a flow rate of 10 ml/min. The herbicides trapped on the cartridge were eluted with 10 ml of acetonitrile. The elutes were passed through sodium sulfate by phase separators silicone treated filter paper (15.0 cm diameter, Whatman) to remove water. Elutes were then concentrated to 1 ml by using a rotary evaporator, followed by nitrogen gas concentration until dried. The extracts were then redissolved in 1 ml acetone and the resulting solution was analyzed by using a gas chromatograph and HPLC.

A Shimadzu GC-14A gas chromatograph with FTD-8 (Flame thermionic detector) was used for the analysis. The glass column was a chromosorb (w) HP (i. d. 3 mm and length 1.0 m) with 1.5% silicone OV-17 and 1.95% silicone DC QF-1. The column temperature was 190 °C for 4 min, with an increase of 30 °C/min and the final temperature was 230 °C for 11 min, with an injection temperature of 250 °C, and a detector temperature of 280 °C. The GC was equipped with an automatic sampler with the injection volume set to 2 μ l. The temperature program was the same for all the herbicides. The recovery for thiobencarb was 96.5% ($SD = 3.6, n = 3$) and 93.1% for mefenacet ($SD = 4.3, n = 3$).

Bensulfuron methyl was analysed using High Performance Liquid Chromatography (HPLC), using an ODS column with a UV detector. Limit of detection was 0.01 μ g/L and recoveries of BSM ranged 75%—100% at the level of 1.0 μ g/L.

The stream flow and stream width of the upstream and downstream were recorded on each sampling date.

1.6 Data analysis

Dissipation rates were calculated using simple first order kinetics (SFOK). The equation $C = C_0 e^{-kt}$ was used for the first order kinetics, where C is the amount of herbicide (mg/L water) at time t ; C_0 is the amount of herbicide (mg/L water) at time 0; k is the rate constant (d^{-1}) and t is the time (d). Initial concentrations of herbicide (C_0) were calculated on the basis of the total amount of water (in L) in the paddy field at the time of application and the total amount of herbicide active ingredient (g) applied, assuming that 100% of active ingredient had been dissolved in the water. The dissipation rate constant (k) was calculated by linear regression from the transformed first order rate equation, $\ln C = \ln C_0 - kt$. Half-life (DT_{50}) was calculated using the equation $-\log(2)/k$ (Kohno, 1986). Data were analyzed using SPSS 11.0 for Windows.

The measured concentration of herbicides mefenacet and thiobencarb in the farm paddy field were compared with the concentrations predicted by the model using input parameters (Table 1). The predicted concentration of BSM was not calculated.

2 Results and discussion

2.1 Environmental conditions of the study site

In the study area, the surface layer of the paddy fields comprised of alluvial soil, classified as sandy loam with 15.5% clay content and 1.89% humus, bulk density of 0.75 g/ml, and porosity of 0.72. The cation exchange capacity (CEC) varies from 8.6 to 11.0 meq/100g soil. The water pH of the study paddy fields were acidic at the early stage and acidic to neutral at the later stage varying from 6.2 to 7.5. The mean annual rainfall of this area was 1071 mm in 2003, the corresponding mean annual temperature ranged from 3.3 °C in January to 26.4 °C in July. Minimum temperature of paddy water was 18.2 °C at early May and rose up to 32.5 °C at early June. However, precipitation and water flow in downstream are shown in Fig. 2. There was no significant rainfall event until two weeks after herbicide application.

2.2 Thiobencarb concentration in paddy and other surface water

Table 1 Model input parameters for mefenacet and thiobencarb

Parameter	Value	
	Mefenacet	Thiobencarb
Physiochemical properties		
Molecular weight, g/mol	298.4	257.8
Water solubility (C_{ws}), mg/L	4 (20 °C)	30 (20 °C)
Vapor pressure, mmHg	4.8×10^{-11} (20 °C)	2.2×10^{-5} (20 °C)
Equilibrium constants		
Henry constants (-)	2.0×10^{-10a}	2.7×10^{-7as}
Adsorption constant related to organic carbon (K_{oc})	1000 ^b	1380 ^{bb}
Adsorption coefficient (K_d), L/kg	18.9 ^c	26 ^c
Freundlich exponent ($1/n$)	1	1
Rate constants		
Dissolution (k_d), 1/d	3.0×10^{-1d}	3.4×10^{-7dd}
Adsorption (k_{ads}), 1/d	4.0×10^{-2e}	5.1×10^{-1e}
Desorption (k_{des}), 1/d	4.0×10^{-2f}	5.1×10^{-1f}
Volatilization (K_L), m/d	3.5×10^{-2g}	5.05×10^{-2g}
Degradation in water (k_{dw}), 1/d	2.8×10^{-2h}	2.3×10^{-2h}
Degradation in sediment soil (k_{ds}), 1/d	2.8×10^{-2i}	2.3×10^{-2i}

Notes: ^{a,b,d,i} obtained from Inao *et al.* (2003); ^{as,bb} obtained from Mabury *et al.* (1996); ^c estimated from K_{oc} with organic carbon content in soil (1.89%); ^{dd} measured value; ^e assumed to be equal to k_{des} ; ^f obtained from Inao *et al.* (1999); ^g calculated value; ^h calculated by the Liss and Slater method (Ref. Liss and Slater, 1974); ⁱ assumed to be equal to k_{ds} ; ⁱⁱ calculated value

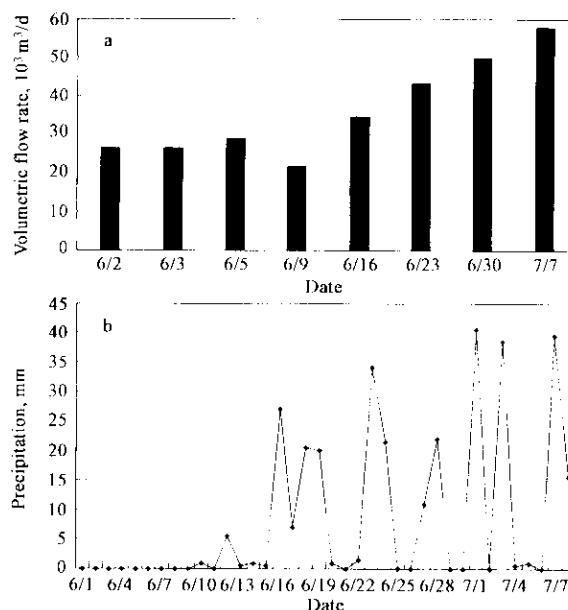


Fig. 2 Changes in environmental condition
a. volumetric flow rate in down stream; b. precipitation

Dissipation pattern of thiobencarb was similar in predicted and measured concentration (Fig. 3a). Measured concentration of thiobencarb in paddy fields reached peak at 3 d after herbicide application, degraded fast, and decreased to trace levels after one month of application showing normal distribution curve. The measured concentration of thiobencarb in paddy water was slightly higher than the predicted, but the trend was similar during the whole period (Fig. 4a). During the whole study period, thiobencarb concentration was higher in paddy field 2 than in field 1 but statistically was not significant (Table 2). The reason might be that with the irrigation water herbicide runoff to the field 2. Except one day after herbicide application, thiobencarb concentration in the drainage channel was similar to that of the paddy fields. However, 2 weeks after application no thiobencarb was detected in drainage channel

and in down stream. In down stream, thiobencarb was detected until 3 days after application, with a range of 0.02% to 0.08% of the applied herbicide.

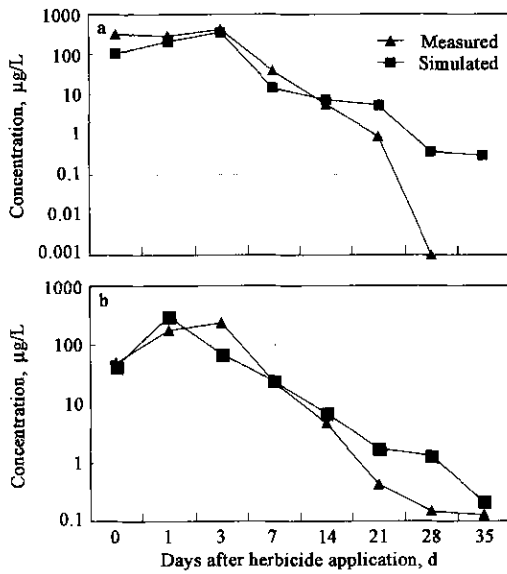


Fig. 3 Comparison between simulated and measured concentrations of herbicides in paddy water
a. thiobencarb; b. mefenacet

The rate of dissipation (k) and the half-life (DT_{50}) of thiobencarb in the two paddy fields were quite similar, 3 and 2.95 days in field 1 and field 2 respectively (Table 3) .

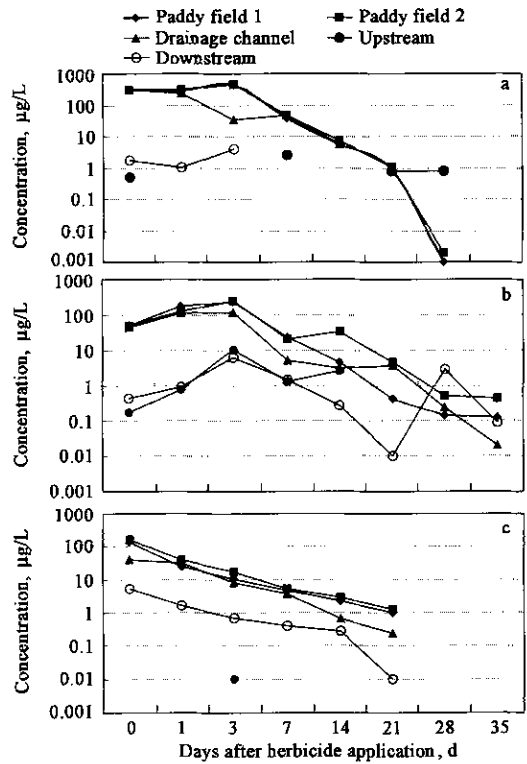


Fig. 4 Measured concentration of herbicides detected in the different sampling points
a. thiobencarb; b. mefenacet; c. bensulfuron methyl

Table 2 Measured concentrations(µg/L)of thiobencarb in paddy and surface water

Date	Days after herbicide application	Sampling site					Percentage of applied in paddy field	
		Paddy field 1	Paddy field 2	Drainage channel	Upstream	Downstream	Drainage channel	Downstream
June 2, 2003	0	313.28	320.16	318.43	0.52	1.79	6.37	0.04
June 3, 2003	1	286.80	313.66	243.13	nd	1.01	4.86	0.02
June 5, 2003	3	417.55	461.89	34.58	nd	4.08	0.69	0.08
June 9, 2003	7	39.65	46.53	46.29	2.60	nd	0.93	nd
June 16, 2003	14	5.63	7.35	5.43	nd	nd	0.11	nd
June 23, 2003	21	0.91	1.09	nd	0.78	nd	nd	nd
June 30, 2003	28	0.00	0.00	nd	0.78	nd	nd	nd
July 7, 2003	35	< 0.01	< 0.01	nd	nd	nd	nd	nd

Note: nd = not detected

However, the predicted dissipation rate of thiobencarb in paddy water using the PADDY field model was higher ($DT_{50} = 4.36$) than that measured for both the paddy fields, with a lower k value (-0.069). Quick dissipation and shorter half-life of thiobencarb could be anticipated from its higher water solubility(20 mg/L) and lower adsorption coefficient ($K_d = 13.6$).

2.3 Mefenacet concentration in paddy and other surface water

The simulated and measured concentration of mefenacet in paddy field was larger on one and three days after application (Fig. 3b). Mefenacet was detected in the paddy water until 35 days after herbicide application (Fig. 4b). There were no significant differences between concentrations of the two paddy fields. Mefenacet was found during the whole study period in the drainage channel, upstream and downstream (Table 4) . In down stream , the highest amount

Table 3 Half-life (DT_{50}), dissipation rate and R^2 values of the study herbicides

		Herbicide	k	R^2	DT_{50}
Measured:					
Field 1	Thiobencarb	- 0.1003	0.9388 ($p < 0.001$)	3	
	Mefenacet	- 0.048	0.8279 ($p = 0.002$)	6.27	
	Bensulfuron methyl	- 0.1059	0.804 ($p = 0.01$)	2.84	
Field 2	Thiobencarb	- 0.1022	0.9522 ($p < 0.001$)	2.95	
	Mefenacet	- 0.0549	0.8423 ($p = 0.001$)	5.48	
	Bensulfuron methyl	- 0.086	0.8353 ($p = 0.011$)	3.5	
Drainage canal	Thiobencarb	- 0.0746	0.827 ($p = 0.04$)	4.04	
	Mefenacet	- 0.117	0.930 ($p = 0.02$)	2.57	
	Bensulfuron methyl	- 0.0509	0.750 ($p = 0.08$)	5.91	
Predicted:					
	Thiobencarb	- 0.069	0.8658 ($p = 0.001$)	4.36	
	Mefenacet	- 0.05825	0.8720 ($p = 0.001$)	5.17	

Notes: DT_{50} = half life (in days); computed using the equation $-\log(2)/k$; k = dissipation rate; slope of the regression lines

of mefenacet (6.08 $\mu\text{g/L}$) was detected on three days after application, which corresponds with the upstream and drainage channel concentrations. The underlying cause might be that, mefenacet has lower water solubility (4 mg/L) and

higher adsorption coefficient ($K_d = 24.07$), and for this reason much of its residues could have been adsorbed by the soil, leaving only a small portion in water which may again desorb in water (Ferdinand, 2000).

Table 4 Measured concentrations($\mu\text{g/L}$) of mefenacet in paddy and surface water

Date	Days after herbicide application	Sampling site					Percentage of applied in paddy field	
		Paddy field 1	Paddy field 2	Drainage channel	Upstream	Down stream	Drainage channel	Downstream
June 2, 2003	0	49.76	48.81	43.51	0.17	0.42	4.35	0.04
June 3, 2003	1	178.56	125.01	108.23	0.75	0.93	10.82	0.09
June 5, 2003	3	233.27	248.47	121.01	10.65	6.08	12.10	0.61
June 9, 2003	7	23.05	20.64	5.08	1.27	1.43	0.51	0.14
June 16, 2003	14	4.54	33.86	3.07	2.53	0.27	0.31	0.03
June 23, 2003	21	0.42	4.50	3.71	< 0.01	0.01	0.37	0.00
June 30, 2003	28	0.15	0.52	0.25	< 0.01	2.84	0.02	0.28
July 7, 2003	35	0.13	0.44	0.02	< 0.01	0.09	0.00	0.01

The dissipation rate (k) and half-life (DT_{50}) of mefenacet predicted by applying the PADDY field model, was not significantly different from that of measured (Table 5). The dissipation rate of field 1 was -0.048 (k) with longer half-life ($DT_{50} = 6.27$ d), whereas in field 2, k and DT_{50} were -0.0549 and 5.48 respectively, compared to predicted -0.0582 (k) and 5.17 d (DT_{50}).

2.4 Bensulfuron methyl concentration in paddy and other surface water

Dissipation of BSM in the paddy field water, drainage channel, upstream and downstream is shown in Fig. 4c. Observed peak concentration was 139.97 and 162.65 $\mu\text{g/L}$ in field 1 and in field 2 respectively (Table 5). This occurred shortly after application (0 d). On 1, 3, 7, 14 and 21 d after application, the concentration had dropped rapidly to

24.57, 10.37, 4.63, 2.28 and 0.98 $\mu\text{g/L}$ in field 1. In field 2, concentrations were slightly higher as, 40.73, 16.81, 5.21, 2.85 and 1.29 $\mu\text{g/L}$ on 1, 3, 7, 14 and 21 d after application respectively. Three weeks after herbicide application, BSM in the treated paddy water had decreased to trace levels. This is in agreement with previous studies demonstrating similar dissipation patterns (Okamoto, 1998). 21 d after application, no BSM was detected in the drainage channel and downstream. In upstream water, no BSM was detected except trace amounts (0.01 $\mu\text{g/L}$) at 3 d after application. However, in the drainage channel 8, 6 and 1.58% of applied BSM was present at 0, 1 and 3 d after application respectively. In the down stream, the highest concentration was 1.06%, shortly after application.

The dissipation rate of BSM in field 1 was faster ($k =$

Table 5 Measured concentrations($\mu\text{g/L}$) of bensulfuron methyl in paddy and surface water

Date	Days after herbicide application	Sampling site					Percentage of applied in paddy field	
		Paddy field 1	Paddy field 2	Drainage channel	Upstream	Downstream	Drainage channel	Downstream
June 2, 2003	0	139.97	162.65	41.54	nd	5.39	8.15	1.06
June 3, 2003	1	24.57	40.73	31.94	nd	1.66	6.26	0.32
June 5, 2003	3	10.37	16.81	8.06	0.01	0.70	1.58	0.14
June 9, 2003	7	4.63	5.21	3.65	nd	0.39	0.72	0.08
June 16, 2003	14	2.28	2.85	0.66	nd	0.27	0.13	0.05
June 23, 2003	21	0.98	1.29	0.24	nd	0.01	0.05	0.00
June 30, 2003	28	< 0.01	< 0.01	nd	nd	nd	nd	nd
July 7, 2003	35	nd	nd	nd	nd	nd	nd	nd

- 0.1059) with shorter half-life ($DT_{50} = 2.84$ d). The dissipation rate (k) in field 2 was -0.0860 and half-life was 3.5 d (Table 5).

The herbicides concentrations found in the downstream were much lower than in previous studies. Study (Maru, 1985) found maximum concentrations of 52.6, 58.0 and 14.1 mg/L for molinate, simetryn, and thiobencarb in the main river in Chiba Prefecture and estimated that the exportation rate of these pesticides to be, 11.3%, 6.7%, and 2.2% respectively of the applied amounts in 1981, and 6.0%, 5.7% and 1.4% in 1984. Yamaguchi, *et al.* (Yamaguchi, 1999) surveyed pesticide pollution in the Yodo River basin and about 30 pesticides were detected, with mean concentrations ranging from 0.3 ng/L of quintozene to 300 ng/

L of thiobencarb, and pesticide losses ranged from 0.26% for chlomethoxyfen to 12% for simetryn. Fukushima, *et al.* (Fukushima, 1995) reported that the highest concentration of 20 mg/L for isoprothiolane, diazinon, molinate, and simetryn and over 1 mg/L for thiobencarb, in April 1990 and August 1994, in the Yodo River basin. The average concentrations in the Seta River monitored in April 1990 and August 1994, were 0.1--1.0 mg/L for molinate, simetryn and thiobencarb, approximately 0.1 mg/L for isoprothiolane, less than 0.1 mg/L for oxadiazon, and less than 0.01 mg/L for diazinon and fenitrothion (Fukushima, 1995). Monthly observations showed that the loads of simazine, iprofenfos and fenitrothion from the Lake Biwa basin from April to December in 1990 to be 130, 250 and 21 kg, respectively, accounting

for 52%, 30% and 5% of the downstream loading of the Yodo River (Yamaguchi, 1999). In addition, the maximum concentration in the Seta River which flows into Lake Biwa was about 20 mg/L for molinate, 10 mg/L for simetryn and less than 5 mg/L for oxadiazon, as reported by Sasagawa, *et al.* (Sasagawa, 1996).

One reason behind the lower herbicide concentration in downstream and upstream might be having no to low precipitation during the first two weeks after herbicide application (Fig. 2). The rainfall immediate after herbicide application is an important factor for effective runoff. Lower concentration of herbicides in the entry route was due to that the precipitations were lower at the early stage of herbicide application. The field runoff can only be observed when precipitation exceeded 10 mm/d and at least 2% of the precipitations become field runoff (Neumann, 2002). Late transplanting of the study paddy fields, when transplantation of other farms had been completed in the study area, may be another reason. Soil adsorption is one mechanism that accounts for the dissipation of herbicides in paddy water. Once the herbicides adsorbed to soil, with the passing of time the chance of desorption into the water is least (Okamoto, 1998).

Monitoring and fate of herbicides in paddy water, drainage canal and streams provides an effective means for assessing the flow of herbicides in to and through public drinking water supplies and aquatic ecosystems. With the qualitative information provided as a result of this studies, the potential impact of studied herbicides such as thiobencarb, mefenacet and BSM on human and aquatic non-target organisms can be inferred based on the levels of herbicides detected and comparing these with the predicted concentration as well as with the established no effect levels on a variety of organisms. Knowledge of the dissipation of most widely used herbicides at the site of application, the paddy, drainage, upstream and down stream, represents the important components in the overall assessment of herbicide movement into aquatic systems.

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