Probabilistic Ecological Risk Assessment of Paddy Herbicide in Japanese River Waters using Uncertainty Analysis

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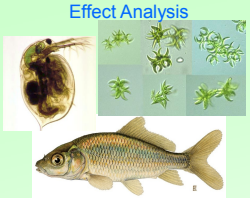
Introduction

■Pesticide Registration Scheme in Japan

Effect Analysis



Acute toxicity test for Fish, Crustacean, Algae

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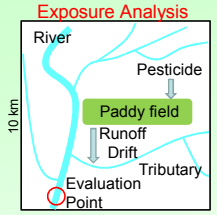
AEC = Minimum Value of EC_{50} or LC_{50}/Uncertainty Factor

Exposure Analysis



PEC is calculated based on Standard Scenario In Model Basin

PEC≦AEC ➡ Short-term aquatic risk is evaluated to be insignificant

Paddy herbicide directly outflow from paddy fields to rivers through drainage channel.

↓

Concern higher aquatic risk than upland field pesticides

Simetryn, a triazine herbicide, is commonly used in Japanese paddy field.

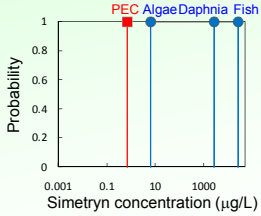
■Simetryn Registration Criteria

Cyprinus carpio LC_{50} ・・・ 25900 μg/L (UF10)
Daphnia magna EC_{50} ・・・ 2550 μg/L (UF10)
P. subcapitata EC_{50} ・・・ 6.29 μg/L (UF1)
→AEC = 6.2 μg/L
PEC (Tier 2) = 0.71 μg/L

↓

Fulfilling the criteria (PEC<AEC)

However,
The risk assessment scheme is …
fully Deterministic!
not Quantitative!



For a more realistic risk assessment, the parameters for toxicity and exposure should be expressed as probabilistic distribution, not as a fixed value.

We used uncertainty analysis of ecotoxicity and exposure assessment to conduct probabilistic ecological risk assessment of simetryn.

Abbreviations:
EC_{50}: 50% Effect Concentration
LC_{50}: 50% Lethal Concentration
PEC: Predicted Environmental Concentration
AEC: Acute Effect Concentration
UF: Uncertainty Factor

Effect Analysis

■ Short-term ecotoxicity of simetryn

Ranked genus mean acute values (GMAV) of acute toxicity (EC_{50} or LC_{50}) to freshwater organisms (collected from open literature).

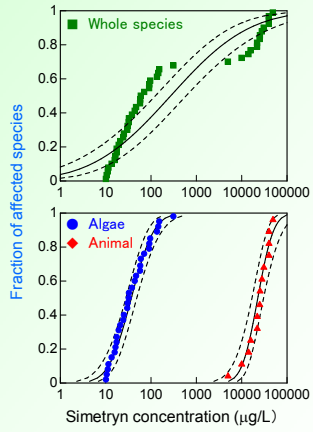
i	Genus	Taxonomic group	GMAV (μg/l)
1	*Gonium*	green algae	10.2
2	*Pandorina*	green algae	10.6
3	*Carteria*	green algae	11.2
4	*Chlorogonium*	green algae	11.6
5	*Anabaena*	cyanobacteria	13.6
6	*Monomastix*	Prasinophyceae	15.9
7	*Chroomonas*	cryptophyte algae	16.6
8	*Chlamydomonas*	green algae	17.5
9	*Microcystis*	cyanobacteria	17.6
10	*Coelastrum*	green algae	19.5
11	*Pediastrum*	green algae	21.1
12	*Pseudokirchneriella*	green algae	24.6
13	*Phormidium*	cyanobacteria	25.4
14	*Cryptomonas*	cryptophyte algae	30.1
15	*Leptolyngbya*	cyanobacteria	30.7
16	*Aulacosira*	diatom	32.4
17	*Echinosphaerium*	green algae	32.8
18	*Micractinium*	green algae	38.3
19	*Closterium*	Charophyceae	44.0
20	*Merismopedia*	cyanobacteria	47.2
21	*Achnanthidium*	diatom	57.8
22	*Staurastrum*	Charophyceae	58.4
23	*Navicula*	diatom	59.9
24	*Synedra*	diatom	71.1
25	*Penium*	Charophyceae	91.5
26	*Euastrum*	Charophyceae	92.5
27	*Pseudanabaena*	cyanobacteria	96.8
28	*Nitzshia*	diatom	136.3
29	*Eudorina*	green algae	146.1
30	*Cosmarium*	Charophyceae	153.0
31	*Chlorella*	green algae	313.5
32	*Daphnia*	crustacean	5000
33	*Sigara*	aquatic insect	10000
34	*Paratya compressa*	crustacean	14200
35	*Oryzias*	fish	15811
36	*Cloeon*	aquatic insect	22000
37	*Micronecta*	aquatic insect	22000
38	*Carassius*	fish	25000
39	*Cyprinus*	fish	25446
40	*Misgurnus*	fish	28000
41	*Monia*	crustacean	30800
42	*Procambarus*	crustacean	40000
43	*Orthetrum albistylum*	aquatic insect	40000
44	*Sympetrum*	aquatic insect	40000
45	*Bufo bufo*	amphibian	49000

High Sensitivity ↓ Low Sensitivity

Species Sensitivity Distribution

Sensitivity to chemicals toxicity was described by statistical distribution.

Useful for quantitative assessment



SSD was well fitted to log-normal distribution when algae and other animals were separated.

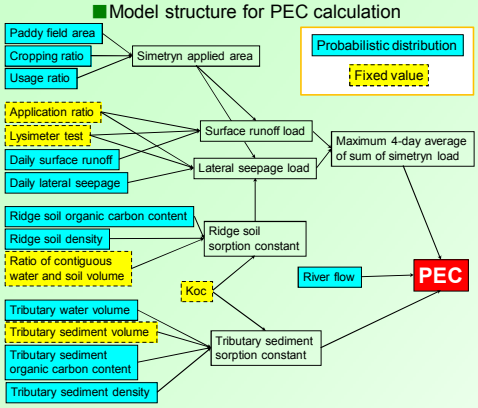
5 percentile of SSD for algae (HC_5)

8.2 μg/L

(5.0-11.8 μg/L for 90% CI).

Exposure Analysis

■Model structure for PEC calculation



Simetryn PEC in river water was calculated as peak concentration of one application using environmental model and standard scenario.

The value of PEC for standard scenario was 0.71 μg/L.

The details of PEC calculation are described as: "http://www.acis.famic.go.jp/eng/shinsei/13-3987.pdf"

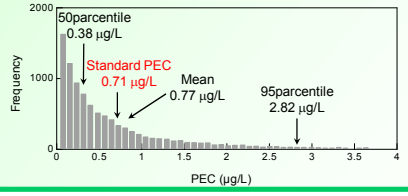
■ Parameter distributions for Monte Carlo simulation

Parameter	Standard value	Distribution	Value	Min-Max
Paddy field area	500 ha	Log-normal	Mean=1060, SD=726	0.0-3872
Cropping ratio		Triangular	Mode=65.3	52.3-80.7
River flow	3 m^3/s	Log-normal	GM=2.71, GSD=1.56	0.87-9.18
Usage rate of simetryn	10 %	Exponential	l=0.15	0.0-31.0
Soil sorption constant (Koc)	6915 cm^3/g	Fixed	6915	
Daily surface runoff	30 m^3/ha/day	Triangular	Mode=30	20-40
Daily lateral seepage	20 m^3/ha/day	Uniformal		18-22
Ridge soil density	1 g/cm^3	Normal	Mean=1.01, SD=0.29	0.23-2.14
Ratio of contiguous water and soil volume	2.4 -	Fixed	2.4	
Ridge soil organic carbon content	2.9 %	Log-normal	GM=2.71, GSD=1.56	0.1-24.3
Tributary water volume	86400 m^3/day	Log-normal	Mean=86400, SD=40466	
Tributary sediment volume	2000 m^3	Fixed	2000	
Tributary sediment density	1 g/cm^3	Normal	Mean=1.01, SD=0.29	0.23-2.14
Tributary sediment organic carbon content	1.2 %	Log-normal	Mean=1.2, SD=1.08	

Regional variability of parameters for PEC calculation were described as statistical distributions using various statistical data.

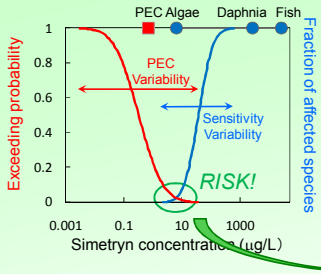
The distribution of PEC was quantified by Monte Carlo analysis (10000 times) using software Crystal Ball ver.7.3.

■ The distribution of PEC estimated by Monte Carlo simulation



As the results of Monte Carlo analysis, the mean of PEC was 0.77 μg/L, the 50 percentile was 0.38 μg/L, and the 95 percentile was 2.8 μg/L.

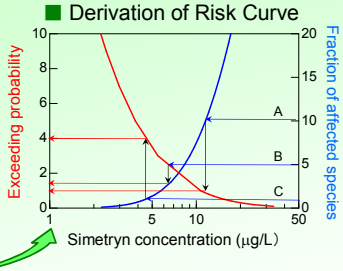
Risk Characterization



The values of PEC were fitted to log-normal distribution. The SSD for algae (Blue curve) was compared to the distribution of PECs (Red curve).

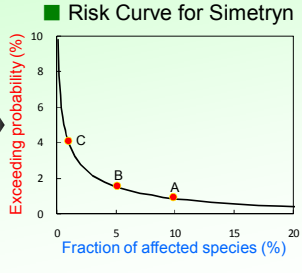
Joint probability curve (Risk Curve) was derived by plotting the probability of exceeding a certain PEC versus the fraction of species affected at that concentration.

■ Derivation of Risk Curve



Zoom

■ Risk Curve for Simetryn



The probability of exceeding HC_5 (5% of algal species are affected) was estimated to be 1.5% by Risk Curve (point B).

Consequently, we will be able to compare risks by quantifying the risk as probability.

When risk reduction action is conducted, the effectiveness can be assessed by comparing reduced risks and costs.