Detection of Japanese PRTR Chemicals in a River Affected by Effluent from Industrial and Sewage Facilities

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ABSTRACT

There has been little long-term environmental monitoring for specified chemicals and information on PRTR chemicals in the water environment is necessary in order to evaluate and manage environmental risks. In this study, river water was collected at eight sites of an urban river in each season from 2010 to 2013, and environmental monitoring was performed on 359 PRTR chemicals (388 including isomers) using GC/MS and LC/MS/MS. As a result, 232 PRTR chemicals were detected. Most of the chemicals detected were for industrial use, with very low concentrations (less than 0.1 µg/L), and low detection ratios. This is the first large-scale monitoring of PRTR chemicals in Japan, and the need for and usefulness of environmental monitoring of PRTR chemicals have been confirmed.

Keywords: chemicals management, environmental monitoring, PRTR, river water

INTRODUCTION

A wide variety of chemicals are used in industry and society. The World Summit on Sustainable Development (WSSD) in 2002 adopted an international agreement to minimize the impact of chemicals on human health and the environment by 2020. Toward this goal, the Strategic Approach to International Chemicals Management (SAICM) was defined to develop better methods and criteria for determining the impact of chemicals on human health (UNEP, 2006). It is also emphasized in SAICM that reliable, affordable and practical analytical techniques for monitoring of chemicals for which there is significant concern in environmental media and biological samples should be developed and shared to assess the levels of contaminants in the environment.

In Japan, the Act on Confirmation, etc. of Release Amounts of Specific Chemical Substances in the Environment and Promotion of Improvements to the Management Thereof was established in 1999 (MOE, 2003). In this act, the pollutant release and transfer register (PRTR) scheme and the material safety data sheet (MSDS) scheme were defined, and the voluntary management for use of chemicals in each office was required. In the Japanese PRTR act, 562 chemicals for livelihood, industry or farming have been specified from the viewpoints of their hazard and environmental release. However, the status of use and environmental behavior of the PRTR chemicals are not well known, and therefore establishing their appropriate management is an urgent issue. Specifically, the concentrations of many PRTR chemicals in the environment have to be monitored in order to appropriately evaluate their environmental risks and to conduct reasonable management.

In this study, simultaneous environmental monitoring of 359 PRTR chemicals (388 including isomers) was conducted, and the detection results were analyzed statistically. Firstly, the number of detected or non-detected chemicals was compared with the data obtained from the PRTR report. Secondly, the characteristics of the water quality were identified by checking the uses of the chemicals detected. Thirdly, the detection frequencies and concentration levels were compared at each monitoring targets. Fourthly, the difference in the chemicals detected at each site and each season were investigated. Based on these results, the usefulness and necessity of environmental monitoring for PRTR chemicals were confirmed.

MATERIALS AND METHODS

Monitoring target PRTR chemicals

The list of target chemicals for environmental monitoring, all of which are specified as Japanese PRTR chemicals, is shown in Table 1 using their PRTR registration numbers. For each sample, 388 chemicals were analyzed in total, but there are only 359 chemicals on the list because some chemicals have isomers. For the names and properties of each chemical, please check the Chemical Risk Information Platform (CHRIP) (NITE, 2008).

Table 1 - List of target chemicals specified in the Japanese PRTR Act.

1-2, 1-5, 1-6, 1-7, 1-15, 1-16, 1-17, 1-18, 1-19, 1-21, 1-22, 1-23, 1-24, 1-25, 1-26, 1-27, 1-29, 1-32, 1-34, 1-37, 1-38, 1-39, 1-40, 1-41, 1-42, 1-46, 1-47, 1-48, 1-49, 1-50, 1-51, 1-52, 1-53, 1-54, 1-64, 1-67, 1-69, 1-73, 1-74, 1-76, 1-78, 1-79, 1-80, 1-81, 1-83, 1-86, 1-89, 1-90, 1-91, 1-92, 1-93, 1-95, 1-96, 1-97, 1-100, 1-101, 1-102, 1-109, 1-110, 1-111, 1-112, 1-113, 1-114, 1-115, 1-116, 1-117, 1-118, 1-119, 1-120, 1-121, 1-124, 1-125, 1-129, 1-130, 1-133, 1-135, 1-138, 1-140, 1-141, 1-143, 1-145, 1-146, 1-147, 1-148, 1-153, 1-154, 1-155, 1-156, 1-160, 1-162, 1-165, 1-166, 1-167, 1-168, 1-169, 1-170, 1-171, 1-172, 1-173, 1-174, 1-175, 1-180, 1-181, 1-182, 1-183, 1-184, 1-188, 1-189, 1-190, 1-191, 1-192, 1-193, 1-194, 1-195, 1-196, 1-197, 1-198, 1-200, 1-201, 1-202, 1-203, 1-204, 1-205, 1-206, 1-207, 1-208, 1-212, 1-213, 1-214, 1-215, 1-216, 1-217, 1-221, 1-222, 1-223, 1-224, 1-225, 1-229, 1-230, 1-231, 1-233, 1-236, 1-240, 1-245, 1-246, 1-247, 1-248, 1-249, 1-250, 1-251, 1-252, 1-253, 1-254, 1-258, 1-259, 1-260, 1-261, 1-262, 1-265, 1-266, 1-269, 1-271, 1-273, 1-275, 1-277, 1-281, 1-283, 1-286, 1-287, 1-289, 1-290, 1-291, 1-292, 1-293, 1-294, 1-295, 1-296, 1-297, 1-299, 1-301, 1-302, 1-306, 1-311, 1-312, 1-314, 1-315, 1-316, 1-319, 1-320, 1-323, 1-324, 1-326, 1-328, 1-330, 1-331, 1-334, 1-335, 1-336, 1-338, 1-339, 1-340, 1-344, 1-345, 1-346, 1-347, 1-348, 1-349, 1-350, 1-352, 1-353, 1-354, 1-355, 1-356, 1-357, 1-358, 1-359, 1-361, 1-362, 1-363, 1-364, 1-365, 1-367, 1-368, 1-369, 1-370, 1-371, 1-373, 1-376, 1-383, 1-388, 1-389, 1-390, 1-391, 1-393, 1-397, 1-398, 1-402, 1-403, 1-404, 1-408, 1-409, 1-410, 1-413, 1-414, 1-416, 1-417, 1-418, 1-419, 1-422, 1-425, 1-426, 1-427, 1-428, 1-429, 1-430, 1-431, 1-432, 1-434, 1-435, 1-436, 1-438, 1-439, 1-440, 1-441, 1-442, 1-443, 1-444, 1-445, 1-446, 1-447, 1-449, 1-450, 1-451, 1-452, 1-454, 1-457, 1-458, 1-459, 1-460, 1-461, 1-462, 2-2, 2-3, 2-5, 2-6, 2-8, 2-9, 2-10, 2-11, 2-13, 2-15, 2-18, 2-19, 2-20, 2-21, 2-22, 2-23, 2-26, 2-28, 2-29, 2-30, 2-31, 2-32, 2-33, 2-34, 2-35, 2-36, 2-37, 2-41, 2-42, 2-43, 2-44, 2-45, 2-46, 2-47, 2-48, 2-49, 2-50, 2-51, 2-52, 2-53, 2-55, 2-56, 2-57, 2-58, 2-59, 2-60, 2-62, 2-63, 2-64, 2-66, 2-67, 2-68, 2-69, 2-70, 2-71, 2-72, 2-74, 2-75, 2-76, 2-77, 2-78, 2-79, 2-80, 2-81, 2-82, 2-83, 2-86, 2-88, 2-89, 2-90, 2-91, 2-92, 2-94, 2-95, 2-96, 2-97, 2-98, 2-99

* There are only 359 chemicals on this list because some chemicals have isomers, although the monitoring targets in this study are 388 chemicals.

Sample collection and pretreatment

River water sampling was conducted at an urban river, Sakai River, in Japan's Kanagawa Prefecture, in each season from 2010 to 2013. The locations of the river water monitoring sites are shown in Fig. 1. In total, 96 environmental water samples were collected from eight of the public water quality monitoring sites officially specified by the local government of Kanagawa Prefecture.

Sakai River basin has factories and residential areas alternately from upstream to downstream, and also four sewage treatment plants (STPs) within a relatively short flow of about 40 km. The effluents from two STPs (A and B) are discharged into Sakai River between Site 2 and Site 3, and the effluents from the other two STPs are discharged into Sakai River between Site 5 and Site 6. Site 6 (2) is a site on one of Sakai River's tributaries.

The diagram of the pretreatment procedure used in this study is shown in Fig. 2. Water samples were concentrated using a solid-phase extraction (SPE) method using the Sep-Pak® Plus PS-2 (Nihon Waters K. K., Tokyo, Japan) cartridge and the Sep-Pak® Plus AC-2 (Nihon Waters K. K., Tokyo, Japan) cartridge. At the beginning of the SPE method, pre-conditioning was performed for each cartridge. The collected water samples were filtrated using a 1- μ m glass fiber filter, then 25 g/L of sodium chloride and 4 mL/L of 0.5 M- H_3PO_4 buffer were added. A total of 1 L of the sample solution was supplied to the series of PS-2 and AC-2 cartridges at a flow rate of 15 mL/min $\times$ 67 min. Three hundred and fifty L of N_2 was used for drying the cartridges (1 L/min $\times$ 35 min). Then, 10 mL of acetone (2 mL/min $\times$ 5 min) was supplied from the reverse direction to each cartridge. The extracted solutions were collected in glass tubes, and then concentrated to 1 mL by repeating nitrogen gas purging and inner wall washing. Final solutions for the instrumental analysis of GC/MS or LC/MS/MS were reconstituted with hexane or acetone. Details of the SPE, nitrogen gas purge procedure and recovery ratio followed the conventional method (Kameya *et al.*, 2010; Jinya *et al.*, 2011; Kameya *et al.*, 2012; Jinya, 2012; Kameya *et al.*, 2014). In a previous laboratory experiment, more than 80% of chemicals examined had a recovery ratio of 50 – 140%. Therefore, detected concentrations were used as the value whereby the concentration measured was rebated by the concentration ratio.

Fig. 1 - Locations of river water monitoring sites.

Fig. 2 - Procedure of pretreatment for water samples used in this study.

Instrumental analyses

In this study, 359 Japanese PRTR chemicals (388 including isomers) were analyzed, and 203 (= 562 – 359) others were excluded from the monitoring targets because the chemicals, such as metal compounds and volatile organic compounds, could not be analyzed under the same experimental conditions. Also, some chemicals could not be purchased commercially. Using the GC/MS system (QP2010 plus, Shimadzu, Kyoto, Japan), 287 chemicals (301 including isomers) were analyzed and using the LC/MS/MS system (TSQ Quantum Access MAX, Thermo Fisher Scientific, Kanagawa, Japan) 72 chemicals (87 including isomers) were analyzed.

The analysis by GC/MS was performed under the following conditions. The internal standard was added into the solution that had already been concentrated by the SPE method, and then 1 μL of the solution was injected with splitless mode at 250°C. The chromatography column, J&W DB-5 ms (30 m $\times$ 0.25 mm $\times$ 0.25 μm , Agilent Technologies, Tokyo, Japan), was used and the column temperature program was set to: (1) 40°C for the first 2 min, (2) 310°C at 8°C/min, (3) and 310°C for 5 min. Mass spectral analysis was conducted with the electron ionization (EI) mode and the total ion chromatogram (TIC) mode of a scan range from 33 to 600 amu and scan rate of 0.3 sec/scan. The analytical data was processed for identification and quantification using Compound Composer Software (Shimadzu, Kyoto, Japan) in which the retention time database, the mass spectrum database and the calibration curve database were already recorded (Kadokami *et al.*, 2005).

The analysis by LC/MS/MS was also performed under the following conditions. Methanol was added into the acetone solution that had already been concentrated by the SPE method, and then 5 μL of the solution was injected into the liquid chromatography column, Hypersil GOLD (50 mm $\times$ 2.1 mm $\times$ 1.9 μm , Thermo Fisher Scientific, Kanagawa, Japan). The matrix effect by river water contaminants was also investigated by adding the standards together with methanol into the sample solution. The mobile phase consisted of methanol (A) and 2 mM ammonium formate (B). The gradient conditions were as follows: The column was equilibrated with 1% mobile phase (A) for 0.5 min, and then increased to 40% until 4 min, 90% until 12.1 min, 99% until 18.5 min, and then returned to 1% until 19 min and equilibrated for 1 min. The flow rate was kept constant at 200 $\mu\text{L}/\text{min}$. Tandem mass spectral analysis was conducted with the electrospray ionization (ESI) mode and the multiple reaction monitoring (MRM) mode for positive or negative ion mode; spray voltage of 3,000 V for positive ion mode or 2,500 V for negative ion mode, tube lens voltage of 78 V, ion transfer capillary

temperature of 270°C, vaporizer temperature of 450°C, sheath gas (N₂) pressure of 50 psi, and auxiliary gas (N₂) pressure of 15 units. The analytical data was processed for identification and quantification using Xcalibur™ software (Thermo Fisher Scientific, Japan).

RESULTS AND DISCUSSION

Numbers of chemicals detected / non-detected and their uses

From the results of the monitoring for 359 PRTR chemicals for three years, 232 chemicals were detected. The numbers of chemicals detected/non-detected in the monitoring are shown in Fig. 3. Under the Japanese PRTR act, a PRTR report for Class I chemicals must be submitted because of their hazard and production volume, but no PRTR report for Class II chemicals is required because of their low production volume. A total of 184 Class I chemicals, which were reported in the PRTR data somewhere in Japan (METI, 2013), were detected. And only three Class I chemicals, which were not reported in the PRTR data, were detected. One hundred and twenty-three Class I chemicals in the target chemicals were not detected in this study. In contrast, 45 Class II chemicals were detected in this study, and 33 Class II chemicals were not detected. It was confirmed that even chemicals used in small amounts could be observed in river water as well as Class I chemicals.

The uses of the monitoring targets and the detected chemicals were classified as percentages of the number of chemicals and are shown in Fig. 4. There were three main groups for each use: (1) household (antimicrobial, surfactant, pharmaceutical), (2) pesticides (insecticide, herbicide, fungicide), and (3) industrial uses (all others). Industrial chemicals were the major type. The percentage of industrial use was higher in detected chemicals than that in monitoring targets. In contrast, the percentage of pesticides was lower in detected chemicals than that in monitoring targets. It was considered that there was less farmland in the surrounding area.

Fig. 3 - Numbers of PRTR chemicals detected / non-detected in monitoring. (compared to PRTR report in FY2011)

Fig. 4 - Usage of monitoring targets and detected chemicals.

Chemicals detected at monitoring sites and PRTR data reported from nearby areas

In previous reports, there were chemicals for which the removal in STPs was insufficient and they were discharged and detected in the river (Niina *et al.*, 2005; Kathryn *et al.*, 2012). At first, according to the PRTR data of FY 2011, seven facilities released 34 PRTR chemicals into Sakai River. Here, four of seven facilities were STPs. Only six chemicals in 34 types were target chemicals in this study: acrylamide (PRTR registration No. 1-2), EPN (1-48), simazine (1-113), thiobencarb (1-147), tetrachloroethylene (1-262) and trichloroethylene (1-281). Among them, five types, EPN (1-48), simazine (1-113), thiobencarb (1-147), tetrachloroethylene (1-262) and trichloroethylene (1-281), were discharged from the STPs. The results of the monitoring show that only three chemicals, simazine (1-113), thiobencarb (1-147) and tetrachloroethylene (1-262), were detected. Their concentrations were very low compared with the environmental water quality standards that were regulated for them. In contrast, some chemicals that have no PRTR reports were detected in high concentrations or at a high detection ratio as shown in the next section.

Detection frequency of PRTR chemicals

The detection ratio and median concentration for each chemical detected were calculated, and the distribution of the detection ratio for all the 388 (including isomers) monitoring target chemicals is shown in Fig. 5 (in ascending order of the detection ratio). Figure 5 is classified into three areas: area for non-detected chemicals, area for chemicals having a detection ratio of less than 50%, and area for chemicals having a detection ratio of more than 50%. Only 27 (7%) chemicals had a detection ratio greater than 50%, and a large portion of their uses was industrial use. In contrast, the detection ratios of pesticides were mostly less than 50%.

Fig. 5 - Distribution of the detection ratios in the total monitoring targets.

In the above 27 chemicals, there were 10 chemicals of which the median concentrations detected were greater than $0.1 \mu\text{g/L}$, while most of the chemicals detected were with low concentrations of less than $0.1 \mu\text{g/L}$. The European Union (EU) has set a maximum admissible concentration of $0.1 \mu\text{g/L}$ for individual pesticides and their related compounds in drinking water (EU, 1998) and the European Committee (EC) has set a ground water quality standard of $0.1 \mu\text{g/L}$ for pesticides (EC, 2006). Although there are differences in their hazards, the value of $0.1 \mu\text{g/L}$ might be a reference of contaminant. The detailed monitoring results of the chemicals, for which detection ratios higher than 50% and concentrations of more than $0.1 \mu\text{g/L}$ were observed, are shown in Table 2. Here, the values of travel blank were $0.02 \mu\text{g/L}$ for diethyl phthalate (1-353), $0.17 \mu\text{g/L}$ for di-n-butyl phthalate (1-354), $1.47 \mu\text{g/L}$ for bis(2-ethylhexyl)phthalate (1-355), $0.00 \mu\text{g/L}$ (n.d.) for phthalandione (1-413), and $1.81 \mu\text{g/L}$ for dicyclohexyl phthalate (2-78). The contamination through the pretreatment process in the laboratory may not be negligible. Therefore, it was confirmed that the quantification for five phthalates was reliable.

The relationship between the detection ratio and the median concentration is classified and shown in Table 3. There were 17 chemicals that had detection ratios of higher than 50% but low concentrations of less than $0.1 \mu\text{g/L}$, and 41 chemicals that had low detection ratios of less than 50% but high concentrations of more than $0.1 \mu\text{g/L}$. The other 320 (82%) chemicals had low detection ratios and low concentrations. These results confirmed that the pollution of the water quality by the PRTR chemicals in Sakai River was not so high.

Table 2 - Results of the monitoring for high detection ratios and high concentrations.

PRTR Registration No.	Name	Use	Detection ratio [%]	Median [µg/L]	95%tile [µg/L]	Blank [µg/L]
1-208	2,4-Di-tert-butylphenol	Antioxidant	98	0.14	0.85	N.D
1-269	Isophytol	Medical product	79	0.14	0.28	N.D
1-320	Nonylphenol	Surfactant	92	0.18	0.91	N.D
1-353	Diethyl phthalate	Plasticizer	98	0.24	4.01	0.02
1-354	Di-n-butyl phthalate	Plasticizer	100	0.34	0.95	0.17
1-355	Bis(2-ethylhexyl)phthalate	Plasticizer	100	3.81	14.87	1.47
1-413	Phthalandione	Plasticizer	57	0.18	0.89	N.D
1-440	Cumene hydroperoxide	Catalyzer	82	0.11	0.37	N.D
1-459	Tris(2-chloroethyl) phosphate	Flame retarder	92	0.18	0.63	N.D
2-78	Dicyclohexyl phthalate	Plasticizer	79	0.30	2.53	1.81

Table 3 - Relationship of detection ratio and concentration.

		Detection ratio	
Concentration (median)		low	high
	low	320	17
	high	41	10

1) Detection ratio more than / less than 50%.

2) Concentration more than / less than 0.1 µg/L.

PRTR chemicals detected in each season and at each monitoring site

The numbers of chemicals detected were counted by each monitoring site and each season, and summarized in Table 4. The numbers of chemicals detected at each site in each season ranged from 48 to 81 (from 12 – 21%). Among these, only 27 to 33 chemicals were detected at all sites. Similarly, only 28 to 35 chemicals were detected in all seasons. Approximately half the chemicals that might be detected at each site or in a season were detected at all sites or in all seasons. In other words, approximately half the chemicals might not be detected by the monitoring at each site in a season. For this reason, multiple monitoring at multiple points might be required in order to evaluate the presence of PRTR chemicals in a certain river.

A list of chemicals that were detected at all the monitoring sites is shown in Table 5 using their PRTR registration No., and a list of chemicals that were detected in all seasons is shown in Table 6. The chemicals listed in the tables were easy to detect everywhere or in every season. The detections of the other chemicals, including pesticides, had a unique tendency at a specific site and/or a specific season. For example, chemicals such as triclopyr (1-286), butyl benzyl phthalate (1-356), 2-naphthol (1-393), 1,3-propane sultone (2-79) and 2-methyl-5-nitroaniline (2-92) were detected at only one site, and chemicals such as aniline (1-18), bisphenol A (1-37), 1,3-xylene (1-80),

1,3,5-trimethylbenzene (1-297), 3-toluidine (1-299), 2-nitrotoluene (1-315) and methyl 4-hydroxybenzoate (1-334) were detected in only one season. In general, a pesticide is detected in one of two seasons, but the number of detected pesticides did not change in every season. Specific release sources might exist for those chemicals.

Table 4 - Number of chemicals detected at each site in each season.

season \ site	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	All sites
Spring	48	62	50	55	57	73	62	33
Summer	60	49	49	55	49	67	57	29
Autumn	53	55	50	62	49	48	51	27
Winter	60	60	77	59	81	69	78	29
All seasons	28	30	31	34	29	35	33	13

Table 5 - List of chemicals detected at all monitoring sites.

Season	PRTR registration No. of chemicals detected*
Spring	33 kinds 1-18, 1-53, 1-73, 1-74, 1-76, 1-86, 1-181, 1-208, 1-240, 1-269, 1-273, 1-296, 1-299, 1-320, 1-330, 1-334, 1-344, 1-349, 1-353, 1-354, 1-355, 1-359, 1-365, 1-368, 1-370, 1-383, 1-413, 1-416, 1-440, 1-459, 1-462, 2-49, 2-78
Summer	29 kinds 1-53, 1-74, 1-76, 1-86, 1-181, 1-207, 1-208, 1-240, 1-269, 1-296, 1-297, 1-320, 1-330, 1-344, 1-349, 1-353, 1-354, 1-355, 1-359, 1-365, 1-368, 1-383, 1-391, 1-413, 1-440, 1-459, 1-462, 2-49, 2-78
Autumn	27 kinds 1-53, 1-86, 1-133, 1-181, 1-188, 1-207, 1-208, 1-224, 1-269, 1-273, 1-296, 1-320, 1-330, 1-353, 1-354, 1-355, 1-359, 1-365, 1-368, 1-383, 1-391, 1-413, 1-416, 1-440, 1-459, 1-462, 2-78
Winter	29 kinds 1-37, 1-53, 1-73, 1-74, 1-80, 1-133, 1-207, 1-208, 1-224, 1-240, 1-269, 1-273, 1-296, 1-315, 1-320, 1-330, 1-344, 1-349, 1-353, 1-354, 1-355, 1-370, 1-391, 1-413, 1-416, 1-440, 1-459, 1-462, 2-78

*Please check CHRIP (NITE, 2008) for names and properties of chemicals.

Table 6 - List of chemicals detected in all seasons.

Site	PRTR registration No. of chemicals detected*
Site 1	28 kinds 1-53, 1-74, 1-188, 1-207, 1-208, 1-240, 1-269, 1-273, 1-296, 1-320, 1-330, 1-344, 1-349, 1-353, 1-354, 1-355, 1-359, 1-365, 1-368, 1-370, 1-391, 1-413, 1-416, 1-440, 1-459, 1-462, 2-78, 2-92
Site 2	30 kinds 1-53, 1-74, 1-188, 1-207, 1-208, 1-240, 1-269, 1-273, 1-296, 1-320, 1-330, 1-344, 1-349, 1-353, 1-354, 1-355, 1-359, 1-365, 1-368, 1-370, 1-391, 1-413, 1-416, 1-440, 1-459, 1-462, 2-78, 2-92
Site 3	31 kinds 1-18, 1-53, 1-74, 1-76, 1-86, 1-181, 1-188, 1-207, 1-208, 1-240, 1-269, 1-273, 1-296, 1-320, 1-330, 1-344, 1-349, 1-353, 1-354, 1-355, 1-359, 1-365, 1-368, 1-383, 1-391, 1-413, 1-440, 1-459, 1-462, 2-49, 2-78
Site 4	34 kinds 1-16, 1-53, 1-73, 1-74, 1-86, 1-133, 1-181, 1-207, 1-208, 1-224, 1-269, 1-273, 1-296, 1-319, 1-320, 1-330, 1-334, 1-344, 1-349, 1-353, 1-354, 1-355, 1-365, 1-368, 1-370, 1-383, 1-391, 1-413, 1-416, 1-440, 1-459, 1-462, 2-49, 2-78
Site 5	29 kinds 1-53, 1-74, 1-86, 1-133, 1-188, 1-207, 1-208, 1-240, 1-269, 1-273, 1-296, 1-297, 1-320, 1-330, 1-353, 1-354, 1-355, 1-356, 1-365, 1-368, 1-370, 1-383, 1-391, 1-413, 1-440, 1-459, 1-462, 2-49, 2-78
Site 6	35 kinds 1-53, 1-73, 1-74, 1-76, 1-86, 1-133, 1-153, 1-181, 1-188, 1-207, 1-208, 1-269, 1-273, 1-296, 1-320, 1-330, 1-349, 1-353, 1-354, 1-355, 1-365, 1-368, 1-370, 1-383, 1-391, 1-393, 1-413, 1-416, 1-428, 1-440, 1-459, 1-462, 2-49, 2-78, 2-79
Site 7	33 kinds 1-18, 1-53, 1-74, 1-76, 1-86, 1-133, 1-181, 1-207, 1-208, 1-240, 1-265, 1-269, 1-273, 1-296, 1-297, 1-320, 1-330, 1-344, 1-353, 1-354, 1-355, 1-359, 1-365, 1-368, 1-383, 1-413, 1-416, 1-428, 1-440, 1-459, 1-462, 2-49, 2-78

*Please check CHRIP (NITE, 2008) for names and properties of chemicals.

CONCLUSIONS

In this study, 359 PRTR chemicals (388 including isomers) were monitored for three years, and 232 chemicals were detected in total. This is the first large-scale monitoring of PRTR chemicals in Japan. Most of the chemicals detected had a very low concentration, and low detection ratio. Only 10 of the industrial chemicals were found at high detection ratios and high concentrations. Some chemicals were detected only at a specific site or in a specific season. Therefore, the usefulness and need for environmental monitoring of PRTR chemicals were confirmed in this study. Multiple monitoring at multiple points might be required in order to evaluate the presence of PRTR chemicals in a certain river.

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