Present status and estimation method of pollutant load in wet weather flow from urban areas

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Abstract This paper describes Japanese present status of controlling nonpoint source pollution from urban areas, the field survey on urban pollution load and the related load estimation method. Promotion of point source control has increased a relative importance of nonpoint source control, however urban nonpoint pollutant load through separate sanitary sewers are not yet fully addressed, while drastic measures on combined sewer overflows alleviation were initiated in Japan. Then, the current framework and status of urban nonpoint pollution control were reviewed, and the field survey was conducted targeting on conventional water qualities, heavy metals, endocrine disrupting chemicals, and so forth. The estimation method of urban nonpoint pollution load was also investigated such as a use of prior dry weather days as an independent variable. This research began in fiscal 2004 and is ongoing.

Keywords nonpoint source, nonpoint pollution, pollution load, field survey, estimation method

Introduciton

Promotion of point source control has increased a relative importance of nonpoint source control, however nonpoint pollution are not yet fully addressed in Japan. Sewage works and other water pollution controls had focussed on point sources, which contributed to conservation or restoration of ambient water quality, still the achievement ratio of water qualtiy standards are not satisfactory especially in closed water bodies in the nation. In terms of watershed management, nonpoint pollution control should be considered for control efficiency.

Urban nonpoint pollution loads are to be mainly tackled through sewage works, but pollution loads from separate storm sewers has not been vigorously controlled while combined sewer overflows (CSOs), inclusive of urban nonpoint pollution loads, have become a target of controls. New goals for CSOs control are to reduce the pollution loads under the level of separate serwer systems, to halve the overflow events from stormwater outlests to satisfy secure in terms of public health, and to eliminate the debris. Subsequently, the Enforcement Order of Sewerage Law was amended to set technical standards of stormwater outlets structure such as weir height and screen installation as well as wet weather water quality standard for CSOs (BOD 40mg/l) and monitoring requirement of CSOs at least once a year for BOD. Also, the relevant manuals of planning and monitoring were formulated, the national programs for CSOs control were initiated to subsidise the control projects, and the special research and development project were conducted (**Sakakibara et al., 2005**). On the other hand, runoff from separate storm sewers is not distinctly a target of control, unlike the Stormwater National Pollutant Discharge Ellimination System (NPDES) permit in the United States. Comprehensive Basin-wide Plans for Sewage Works (CBPSW) in Japan perform as high-ranking schemes of sewage works, and set allocate allowable pollution load to each pollution source including urban nonpoint source (**JSWA, 1999**). In practice, however, allowable pollution loads could not be necessarily allocated to the urban nonpoint source pollution in an effectively manner. Though "Tentative Guideline on Urban Nonpoint Pollution Control" (**MLIT and JIWET, 2002**) provides the relevant technical information on planning and related researches in accordance with higher-ranking schemes such as CBPSW, there could be room for further knowledge and technical improvement to better planning and the related researches.

Overall, urban nonpoint pollution load through separate sanitary sewers are not yet fully addressed in Japan, and further knowledge and technical improvement could serve for better planning and the related researches. Especially, quantification of runoff pollution loads from urban areas and load reduction by control measures is a key aspect. Then, the current framework and status of urban nonpoint pollution control were reviewed, and the field survey was conducted targeting on conventional water qualities, heavy metals, endocrine disrupting chemicals, and so forth. The estimation method of urban nonpoint pollution load was also investigated such as a use of prior dry weather days as an independent variable[1].

Methods

Current framework and status

The current frameworks and status of urban nonpoint pollution control were reviewed mainly through the literature. The relevant planning based on laws, the supporting documents, and the financial programmes are included in this review.

Field survey

Field surveys were conducted in three study sites; Drainage areas A, B and C. Their profiles are shown in **Table 1**. Each drainage area is located in an urban area served by a separate sewer system in the same prefecture. The impervious area ratio of each drainage area was estimated to be around 60%. The surveys were carried out at the storm sewer outlets of three drainage areas simultaneously during the same rainfall, concerning four rainfall events as of the end of the fiscal 2005. To clarify the runoff characteristics and to calculate the pollution loads, the rainfall close to the sampling point and the flow rate at the sampling point were also measured.

The sample was obtained by manually taking 14 to 20 bottles from each investigation point. The water quality constituents that were analyzed were SS, VSS, BOD, COD_{Mn}, TN, and TP, but some surveys also analyzed the samples for their content of heavy metals (copper, zinc, lead, cadmium) plus Benzo [a] pyrene (B(a)P) and Bisphenol A (BPA). At the same time as the sampling, turbidity and electric conductivity (EC) were measured with water quality sensor.[2]

Load estimation method

To enhance the reliability and to facilitate easier estimation methods, a regression method was researched. The runoff load was produced by pollutants accumulated on the ground surface then washed off by rainwater. Such pollutants consist of atmospheric depositions, tire scraps, fallen leaves, and other waste materials, and the friction velocity when they are transported varies according to rainfall and rainfall intensity. Thus, meteorological and precipitation conditions are assumed to be the major factors that determine the runoff load in each drainage area. In emulation of the method of **Nakamura (1993)**, multiple regression analyses were performed with the rainfall and the prior dry weather days for each event as the explanatory variables (**Eq. 1**) in order to predict the runoff load. The data of the said field survey was used for the analysis.

[1] The contents of the field survey and the load estimation method was derived from **Fujiu et al. (2005)**, **Fujiu et al. (2006)**, **Tamoto and Yoshida (2005)**, **Tamoto et al. (2005)**, and **Tamoto et al. (2007)**.

[2] Not all measured water quality data are described in this paper for lack of space.

Table 1 Profile of Study Sites

	Area (ha)	Impervious area ratio	Land use	Arterial roads
Drainage area A	95	69%	High/medium-rise residential Commercial	Included
Drainage area B	18	67%	Residential	Included
Drainage area C	67	61%	Residential	Not included

$L = a \cdot \Sigma r + b \cdot NDD$ -- **Eq. 1**

(where *L*: Specific load per rainfall event (kg/ha); Σr: total rainfall per event (mm); *NDD*: Number of prior dry weather day (day); *a*, *b*: constants)

Results and Discussion

Current framework and status

Runoff from separate storm sewers is not distinctly a target of control. Comprehensive Basin-wide Plans for Sewage Works (CBPSW) in Japan perform as high-ranking schemes of sewage works, and set allocate allowable pollution load to each pollution source including urban nonpoint source (**JSWA, 1999**). In practice, however, allowable pollution loads could not be necessarily allocated to the urban nonpoint source pollution in an effectively manner. In formulation of CBPSW, at first, generating loads including non-point source on a watershed are estimated using unit pollution load data, and runoff loads are calculated through pollution analysis. Secondary, the allowable load is calculated based on the water quality standard at a target point in the concerned water body, and the pollution load that should be reduced, referred to as the reduction load, is determined as a difference of the total generating load and the allowable load. Lastly, the reduction load is distributed to each pollution source category such as public sewerage, industrial, livestock, and non-point source (e.g. urban, farm). On the estimation process of generating loads of urban non-point source, existing data in other watersheds are frequently applied instead of collecting data for a target watershed for the reasons of costs and the difficulty of performing field surveys. In CBPSW, unit loads are used for most sources, and the unit loads of urban nonpoint pollution shown in **JSWA (1999)** are as in **Table 2**.

As a technical guidance, "Tentative Guideline for Urban Nonpoint Pollution Control" (**MLIT and JIWET, 2002**) was published for providing the knowledge of urban nonpoint pollution control as well as the relevant planning and research methods. The Guideline includes detailed description in accordance with higher-ranking schemes such as CBPSW, however it could have been scarcely referenced in practice. This situation, with urban nonpoint pollution allocation practices in CBPSW, could indicate that there is room for further knowledge and technical improvement to better planning and the related researches.

For promotion of nonpoint pollution control, financial support programmes from the national government are prepared by the name of "Program of Supporting Next Generation Sewerage Project." Still, the adopted projects are limited as is shown in **Fig 1**.

Overall, urban nonpoint pollution load through separate sanitary sewers are not yet fully addressed in Japan, and further knowledge and technical improvement should be sought to better planning and the related researches.

- Program of Supporting Next Generation Sewerage Project
  - Water Environment Creation Project
    - Type of Water Circulation Restoration (178)
    - **Type of Nonpoint Pollution Control (3)**
  - Recycle Promotion Project
    - Type of Recycled Resources Utilisation (163)
    - Type of Potential Energy Utilisation (7)
  - Function Upgrade Promotion Project
    - Type of New Technology Utilisation (30)
    - Type of Advanced IT (15)

(Number of projects adopted from fiscal 1996 to 2005)

Fig 1 Program of Supporting Next Generation Sewerage Project with Number of Adopted Projects

Table 2 Unit Loads of Urban Nonpoint Source

Research Organisation	Research area		Unit load (kg/ha/year)					Estimation method
	Municipality	Drainage area (ha)	SS	BOD	COD_{Mn}	T-N	T-P	
Saito and Okazawa	middle-size city	13.69	735	191	34	4.5	1.6	Product of annual average concentration, annual precipitation, and runoff percentage
	large-size city	17.17	562	166	102	14.1	1.3	
Environment Agency	Kitakyushu city	-	2,390	605	378	33.5	6.5	
	Kobe city	-	1,304	168	208	34.2	5.8	
	Yamagata city	-	904	102	90	17.6	3.0	
	Chiba city	-	105	59	55	19.1	0.9	
Public Works Research Institute	Kobe city	17.17	1,134	167	159	23.1	1.9	Summation of pollution loads per rainfall event, which are estimated with correlation equation between event precipitation and runoff load
		26.75	755	41	101	11.1	0.9	
Japan Institute of Wastewater Engineering Technology	Shiga town	46.71	151	39	53	8.5	1.9	
	Otsu city	66.18	210	24	34	6.4	0.7	
	Chino city	7.81	435	157	222	39.6	3.0	
	Okaya city	5.5	1,410	87	126	11.1	2.7	
	Abiko city	15.88	183	36	45	11.6	0.9	
	Ushiku city	67	314	28	43	5.0	0.6	
	Tsukuba city	5.26	463	53	71	7.8	0.8	
Ibaraki Prefecture	-	-	-	-	42.7	5.5	0.55	-
Shiga Prefecture	-	-	-	-	52.6	14.1	0.73	-
-	-	-	-	-	102.6	25.0	0.89	-
Max			2,390	605	378	39.6	6.5	
Min			105	24	34	4.5	0.6	
Mean			737	128	107	16.2	1.9	

Note : Extracted from Guidline and Comentary on CBPSW. "-" means not described.

Field survey

Characteristics of the observed rainfalls are described in **Table 3**. Selected constituents concentration of each study site in Rainfall 3 is shown in time series in **Fig 2** to **Fig. 4**. Concentration varies by order of magnitude, corresponding to the rainfall runoff flow. First flushes are observed with their variation of degree among constituents and drainage areas.

In order to characterise concentrations of rainfall runoff, which can vary widely during a storm event, Event Mean Concentrations (EMCs) were calculated (**Table 4**). Comparison with Environmental Quality Standards (EQSs) (**EA, 1971**) or Predicted No Effect Concentrations (PNECs) (**MOE, 2003**) shows EMCs of almost all constituents exceed EQSs or PNECs, and they could have not an ignorable effect on receiving waters. Especially, EMC of zinc, recently incorporated into EQSs, is larger than the standard almost by order of ten. EMC of BPA is much lower than PNEC while EMC of B(a)P exceeds PNEC. Overall, though not so heavily polluted, rainfall runoff through storm sewers could be a source of ambient water quality degradation.

Specific load per rainfall event are shown in **Table 5**. The variation of specific loads is also observed among different rainfalls similarly to EMCs. The analysis of relationship between specific loads, and total precipitation or number of prior dry weather days shows a tendency of good linear relationship, which leads to the load estimation method of using multiple regression.

Table 3 Characteristics of Observed Rainfalls

	Rainfall 1			Rainfall 2			Rainfall 3			Rainfall 4		
	NDD (d)	Total (mm)	Max (mm/hr)	NDD (d)	Total (mm)	Max (mm/hr)	NDD (d)	Total (mm)	Max (mm/hr)	NDD (d)	Total (mm)	Max (mm/hr)
Drainage area A	7	14.0	2.5	10	6.0	2.5	63	37.5	11.0	3	16.5	6.0
Drainage area B	7	15.0	3.5	10	9.5	2.5	63	42.5	10.5	-	-	-
Drainage area C	7	14.5	3.0	10	8.0	2.5	63	34.0	9.5	12	13.5	5.5

Note ; NDD: Number of prior dry weather days (d), Total: Total precipitation (mm), Max: Maximum precipitation intensity (mm/hr), "-" measn field survey was not conducted.

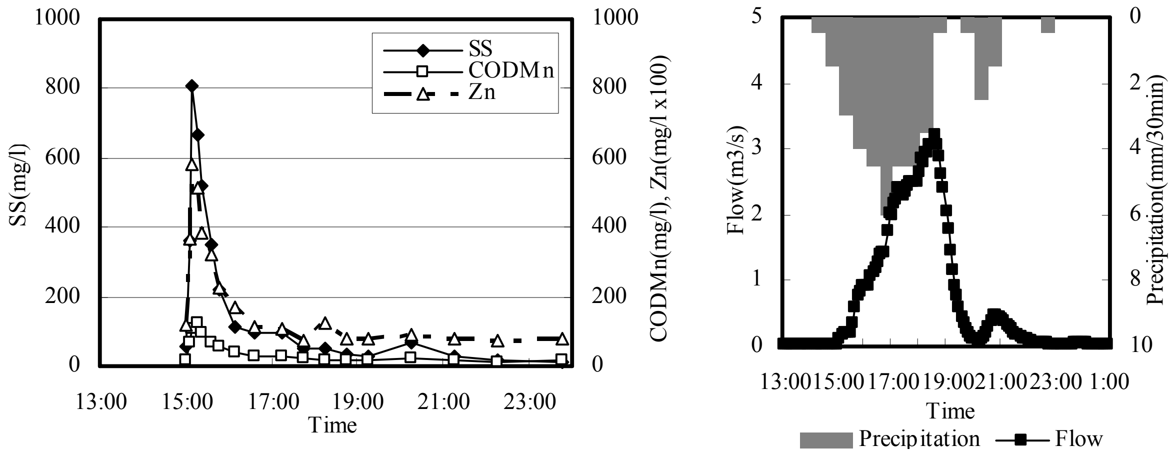

Fig 2 Runoff Concentration and Flow of Rainfall 3 from Drainage Area A

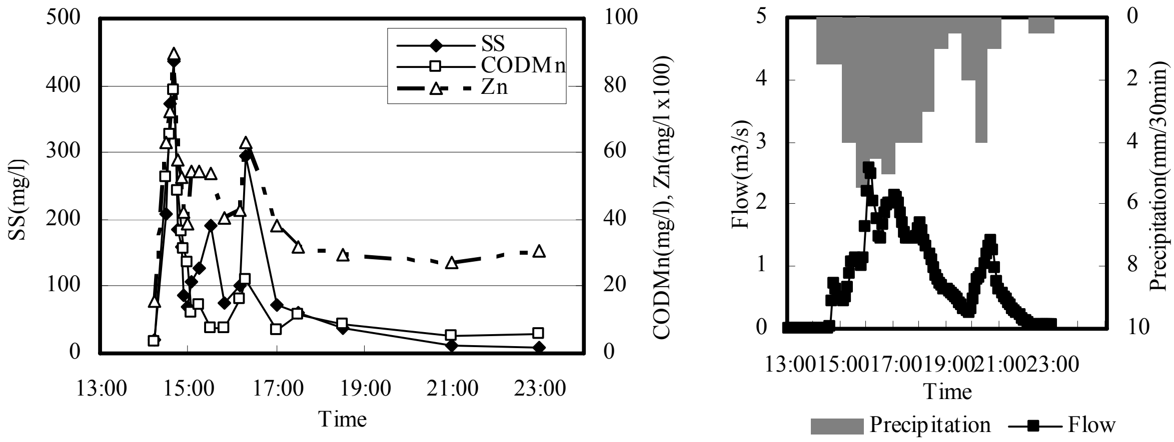

Fig 3 Runoff Concentration and Flow of Rainfall 3 from Drainage Area B

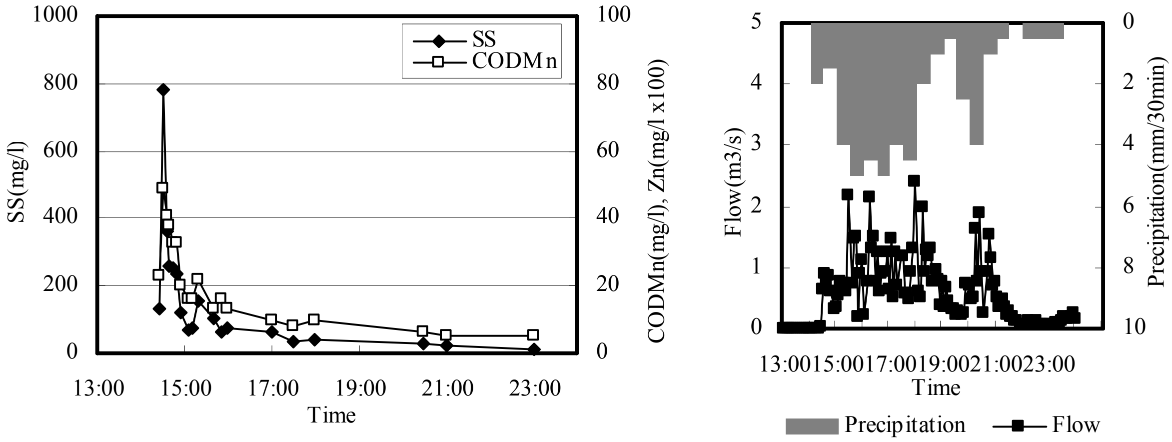

Fig 4 Runoff Concentration and Flow of Rainfall 3 from Drainage Area C

Table 4 Event Mean Concentrations of Urban Runoff

		SS (mg/L)	BOD (mg/L)	COD_{Mn} (mg/L)	TN (mg/L)	TP (mg/L)	Cu (mg/L)	Zn (mg/L)	Pb (mg/L)	Cd (mg/L)	BPA (μ g/L)	B(a)P (μg/L)
Drainage area A	Rainfall 1	66	12.8	15.5	2.9	0.30	-	0.07	0.008	0.001	0.21	0.007
	Rainfall 2	86	19.8	29.3	4.0	0.51	0.06	0.35	N.D.	N.D.	0.23	0.025
	Rainfall 3	72	11.2	23.5	2.4	0.27	0.27	1.10	0.006	N.D.	0.08	0.011
	Rainfall 4	62	5.4	12.0	2.0	0.22	0.03	0.25	0.021	0.004	-	-
	Mean	71	12.3	20.1	2.8	0.32	0.12	0.44	0.009	0.001	0.17	0.015
Drainage area B	Rainfall 1	27	4.0	5.7	2.1	0.12	0.00	0.04	2.300	3.354	0.11	0.018
	Rainfall 2	83	21.3	28.9	3.3	0.25	0.04	0.38	0.015	N.D.	0.67	0.041
	Rainfall 3	84	6.5	11.0	2.1	0.24	0.20	0.38	0.000	N.D.	-	-
	Mean	65	10.6	15.2	2.5	0.20	0.08	0.26	0.772	1.118	0.39	0.030
Drainage area C	Rainfall 1	31	4.6	9.0	2.1	0.12	0.03	0.09	N.D.	N.D.	0.08	0.014
	Rainfall 2	54	12.4	20.2	2.4	0.16	0.05	0.14	0.001	N.D.	0.16	0.033
	Rainfall 3	68	7.0	11.4	1.6	0.19	-	-	-	-	-	-
	Rainfall 4	29	3.2	6.5	1.7	0.07	0.12	0.07	0.014	0.003	-	-
	Mean	46	6.8	11.8	1.9	0.14	0.07	0.10	0.005	0.001	0.12	0.023
EQS		25	(2, 3)	(3, 5)	(0.4, -)	(0.03, 0.05)	-	0.03	0.01	0.01	-	-
PNEC		-	-	-	-	-	-	-	-	-	11	0.005

Note : "N.D." means not detected. "-" means deficiency, not measured, or not applicable. In EQS of BOD, CODMn, TN, and TP, (,) means (EQS of receiving water of Drainage areas A and B, EQS of receiving water of Drainage area C).

Table 5 Specific Loads of Urban Runoff

		SS (kg/ha)	BOD (kg/ha)	COD_{Mn} (kg/ha)	TN (kg/ha)	TP (kg/ha)	Cu (g/ha)	Zn (g/ha)	Pb (g/ha)	Cd (g/ha)	BPA (mg/ha)	B(a)P (mg/ha)
Drainage area A	Rainfall 1	3.83	0.751	0.908	0.172	0.0174	-	4.4	0.49	0.035	12.04	0.42
	Rainfall 2	2.25	0.519	0.767	0.104	0.0135	1.6	9.1	N.D.	N.D.	6.05	0.65
	Rainfall 3	22.95	3.566	7.478	0.763	0.0845	84.6	349.2	1.87	N.D.	24.79	3.65
	Rainfall 4	4.44	0.382	0.852	0.145	0.0156	1.8	17.8	1.53	0.250	-	-
	Mean	8.37	1.304	2.501	0.296	0.0327	29.3	95.1	0.97	0.071	14.29	1.58
Drainage area B	Rainfall 1	0.17	0.026	0.037	0.013	0.0008	0.0	0.2	0.02	0.022	0.73	0.12
	Rainfall 2	0.47	0.122	0.165	0.019	0.0014	0.2	2.2	0.09	N.D.	3.84	0.23
	Rainfall 3	1.34	0.103	0.175	0.033	0.0039	3.2	6.0	0.00	N.D.	-	-
	Mean	0.66	0.083	0.126	0.022	0.0020	1.1	2.8	0.03	0.007	2.28	0.18
Drainage area C	Rainfall 1	0.14	0.020	0.040	0.009	0.0005	0.1	0.4	N.D.	N.D.	0.35	0.06
	Rainfall 2	0.27	0.063	0.103	0.012	0.0008	0.3	0.7	6.18	N.D.	0.84	0.17
	Rainfall 3	2.21	0.226	0.372	0.051	0.0061	-	-	-	-	-	-
	Rainfall 4	0.32	0.035	0.071	0.019	0.0008	1.3	0.7	0.16	0.029	-	-
	Mean	0.73	0.086	0.146	0.023	0.0021	0.6	0.6	2.11	0.010	0.59	0.11

Note : "N.D." means not detected. "-" means deficiency, or not measured.

Load estimation method

Using the data of the field survey in Drainage areas A and C, multiple regression analyses were conducted for SS, BOD, COD_{Mn}, TN, TP, and zinc according to **Eq. 1**. The regression result is summarised in **Table 6**, and the comparison between the measured and estimated values are shown in **Fig 5** and **Fig 6**. The comparison revealed that regardless of the drainage areas, the estimated values conformed with the measured values in most cases.

Generally, there are several principal estimation methods for urban nonpoint pollution loads as shown in **Table 7**. In Method (1), average annual concentration of runoff is calculated from several EMCs, and that multiplied by runoff percentage and annual precipitation is an estimation of annual unit load. In Method 2, field survey is conducted in each land use such as roof and road, and a runoff load is summed up. Method (3) reflects each rainfall event, so does Method (4) with prior dry weather days considered. Regardless of methods, more data produce more reliable estimation results, and it is desirable that more appropriate data are obtained. In terms of the fact that Methods (1) and (2) do not explicitly consider meteorological or hydrological information in each rainfall event, Methods (3) or (4) could have more reliable estimation results with not a large data required. The above analysis adopted Method (4), which suggested that the method is a viable option, and more data acquisition and analysis are ongoing.

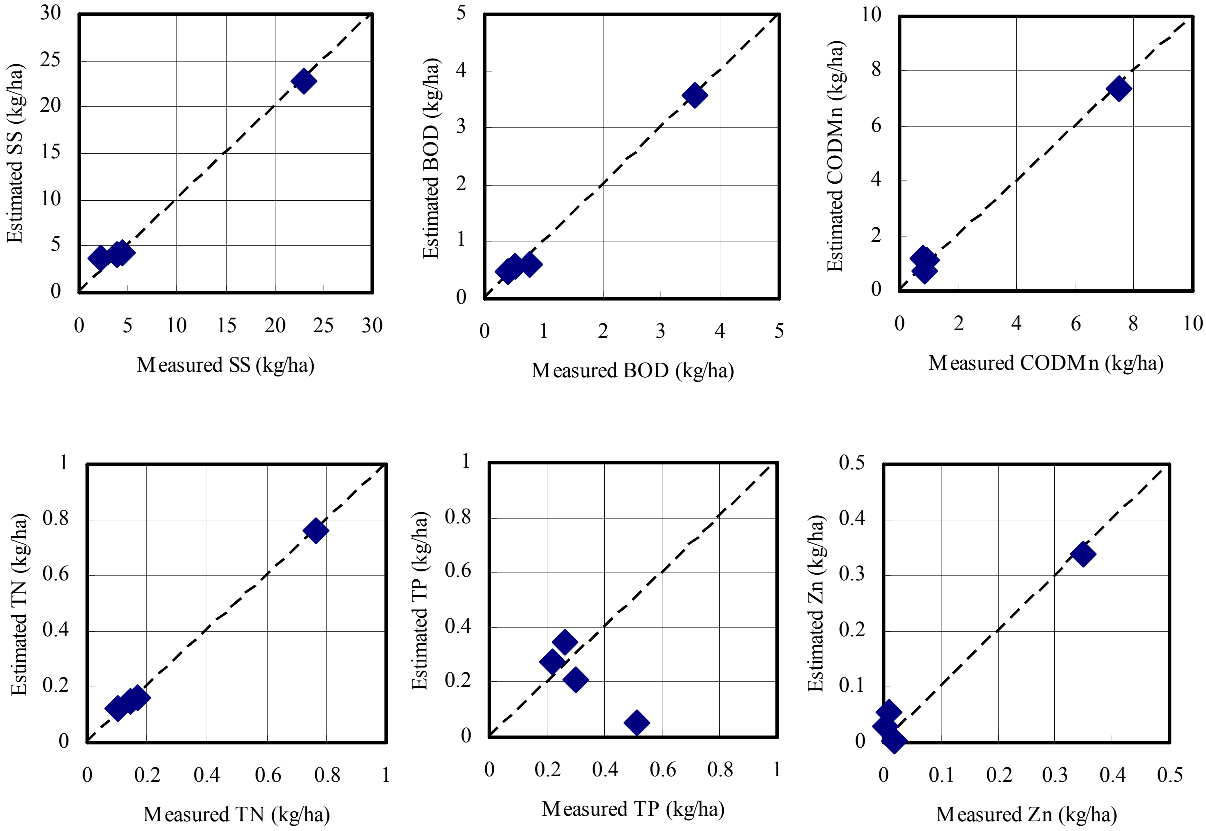

Fig 5 Comparison of Measured and Estimated Values (Drainage area A)

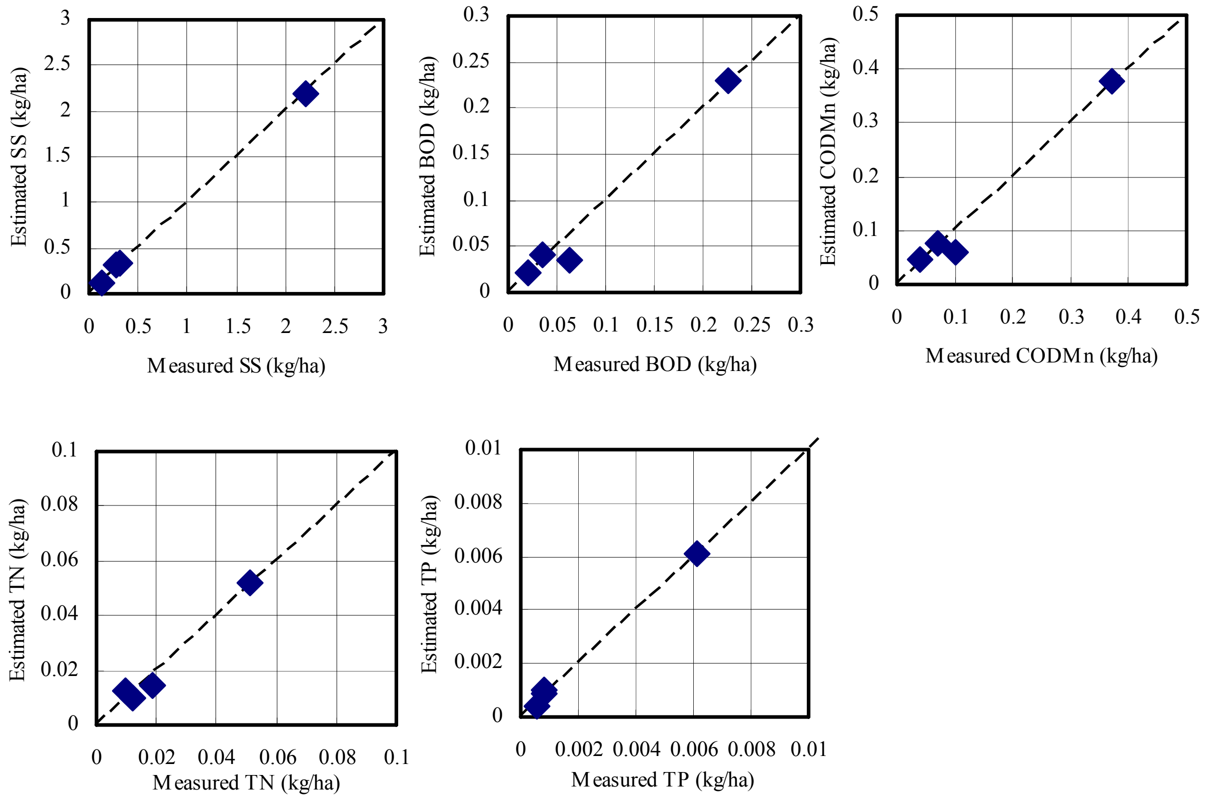

Fig 6 Comparison of Measured and Estimated Values (Drainage area C)

Table 6 Result of Regression

		SS	BOD	COD_{Mn}	TN	TP	Zn
Drainagre area A	a (kg/ha/mm)	0.211	0.021	0.025	0.0077	0.0174	-0.0010
	b (kg/ha/day)	0.243	0.046	0.106	0.0077	-0.0050	0.0062
Drainage areaC	a (kg/ha/mm)	-0.0120	-0.0003	0.0005	0.00065	-0.00003	-
	b (kg/ha/day)	0.0414	0.0038	0.0057	0.00048	0.00011	-

Table 7 Principal Estimation Methods for Pollution Loads

No.	Method	Equation	Notation
(1)	Product of annual average concentration, annual precipitation, and runoff percentage	$\sum L = k \cdot C \cdot \sum R$	$\sum L$: Unit load (kg/ha/year) k: Runoff percentage C: Annual average concentration (kg/ha/mm) $\sum R$: Annual precipitation (mm/year) A: Catchment area (ha) D_i: Runoff coefficient for land use "i" for pollution at the concerning point L_i: Pollution load from land use "i" A_i: Area of land use "i" in catchment area (ha) L: Pollution load per a rainfall event (kg/ha) $\sum r$: Event precipitation (mm) a, b: Coefficients in multiple regression equation NDD: Number of prior dry weather days (day)
(2)	Summation of pollution loads from each land use area	$\sum L = (1/A) \cdot \sum (D_i \cdot L_i \cdot A_i)$	
(3)	Summation of pollution loads per rainfall event, which are calculated with correlation equation between event precipitation and runoff load	-	
(4)	Summation of pollution loads per rainfall event, which are calculated with multiple regression equation	$L = a \cdot \sum r + b \cdot NDD$	

Conclusion

The Japanese current framework and status of urban nonpoint pollution control was reviewed, and it was pointed out that the control has not yet been vigorously addressed though there are a planning framework, a technical guidance, and a financial programme to support the control. Further knowledge and technical improvement should be sought to better planning and the related researches.

Field survey was conducted, focusing on the clarification of the state of runoff of conventional constituents, heavy metals and endocrine disrupting chemicals. It revealed that concentration in time series varied by order of magnitude, corresponding to the rainfall runoff flow, and runoff quality characteristics varied among drainage areas. EMCs of almost all analysed constituents exceeded EQSs or PNECs, and they could have not an ignorable effect on receiving waters.

A load estimation method was researched based on the field survey data. A multiple regression equation, incorporating meteorological or hydrological information in each rainfall event, could produce more reliable estimation results with not a large data required, and more data acquisition and analysis are ongoing.

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Outline

[1] Review of the current framework/status of urban nonpoint pollution control

[2] Field survey of urban runoff, focusing on conventional, heavy metals, and endocrine disrupting chemicals

[3] Research on load estimation methods of urban runoff

National Institute for Land and Infrastructure Management, Japan

2

] Current framework/status

[CBPSW as hihg-ranking scheme]

- Comprehensive Basin-wide Plans for Sewage Works (CBPSW) in Japan perform as high-ranking schemes of sewage works.
- Allowable pollution loads are allocated to each pollution source in order to achieve environmental water quality standards.
- "--- in case closed water areas are targeted, ---- allowable pollution loads are allocated also to nonpoint sources such as *urban areas* and agricultural."

[Investigation on load reduction measures]

"Load reduction in domestic and commercial wastewater is made by sewerage construction, while *other load reduction* is made by each source, and the control measures should be clarified".

"--- in case urban areas are targets of load reduction, the reduction loads and the measures should be clarified. As control measures of *urban nonpoint pollution*, there are "Plans of CSOs abatement," and "Program of supporting next generation sewerage projects (Type of nonpoint pollution control)."

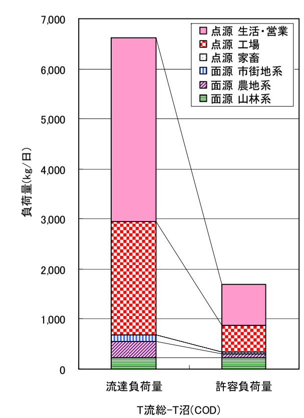
3

[Formulation of CBPSW]

(1) Generating loads including non-point source on a watershed are estimated using unit pollution load data, and runoff loads are calculated through pollution analysis.

(2) The allowable load is calculated based on the water quality standard at a target point in the concerned water body, and the pollution load that should be reduced (=reduction load) is determined as a difference of the total generating load and the allowable load.

(3) The reduction load is distributed to each pollution source category such as public sewerage, industrial, livestock, and non-point source (e.g. urban, farm).



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[Issues of load allocation to urban areas]

- In practice, allowable pollution loads could not be necessarily allocated to the urban nonpoint source pollution in an effectively manner.
- On the estimation process of generating loads of urban non-point source, existing data in other watersheds are frequently applied instead of collecting data for a target watershed for the reasons of costs and the difficulty of performing field surveys.

[Planning of urban nonpoint pollution control]

"Tentative Guideline for Urban Nonpoint Pollution Control" provides the knowledge of urban nonpoint pollution control as well as the relevant planning and research methods.
The Guideline includes detailed description in accordance with higher-ranking schemes such as CBPSW.

[Planning steps]
Investigate prioritisation of block areas.
Select areas to be controlled, and viable control measures.
Determine control measures and the scale (for cost-minimisation)

[Issue]
The Guideline could have been scarcely referenced in practice.

[Financial assistance]

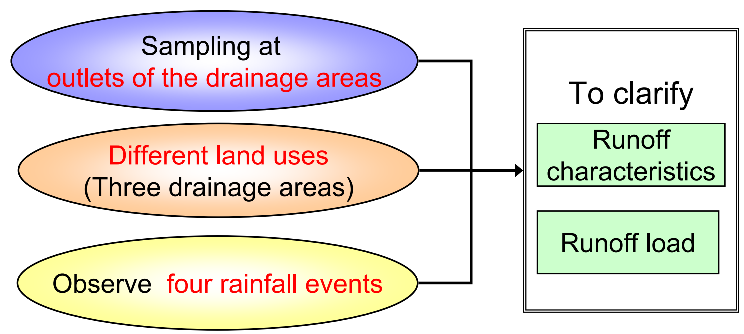
- National subsidy program to promote newly required roles of sewage works, such as water environment creation, recycle promotion, and coping with IT.
- Type of nonpoint pollution control = Pollution load reduction in initial rainfall runoff or gray water

Program of Supporting Next Generation Sewerage Project
- Water Environment Creation Project
  - Type of Water Circulation Restoration (178)
  - **Type of Nonpoint Pollution Control (3)**
- Recycle Promotion Project
  - Type of Recycled Resources Utilisation (163)
  - Type of Potential Energy Utilisation (7)
- Function Upgrade Promotion Project
  - Type of New Technology Utilisation (30)
  - Type of Advanced IT (15)

(Number of projects adopted from fiscal 1996 to 2005)

[2] Field survey

- Analyze runoff quality from urban areas served by separate storm sewers



Constituents analysed

Conventional	SS	BOD	COD_{Mn}	TN	TP
Heavy metals	Cu	Pb	Cd	Zn	
Endocrine disrupting chemicals	Benzo [a] pyrene	Bisphenol A			

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Study sites

[Drainage are A]

Area: 95ha
Impervious area: 69%
Land use:
High/medium rise residential, Commercial
Arterial road: Included

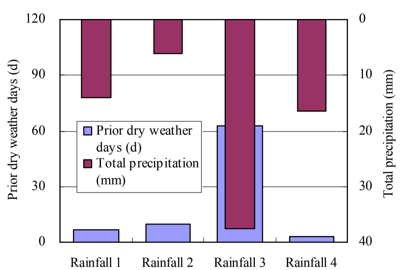
[Drainage area B]

Area: 18ha
Impervious area: 67%
Land use: Residential
Arterial road: Included

[Drainage C]

Area: 67ha
Impervious area: 61%
Land use: Residential
Arterial road: Not included

Observed rainfalls



Drainage area A

14 to 20 samples / rainfall event

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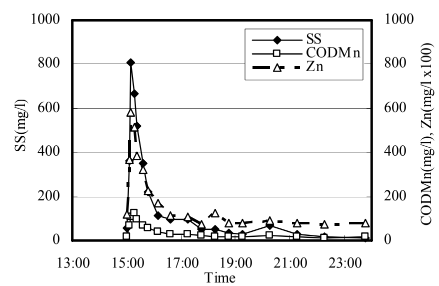
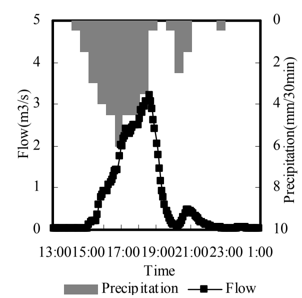
Result in Rainfall 3

[Drainage area A]





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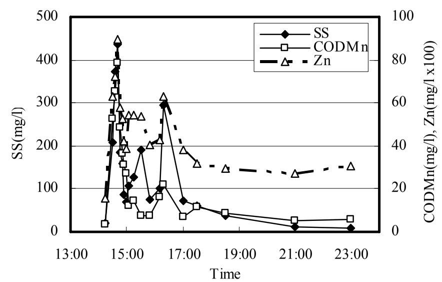
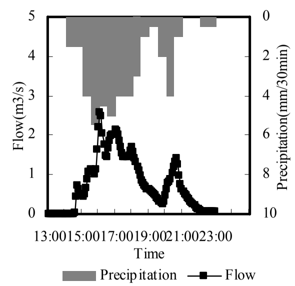
[Drainage area B]





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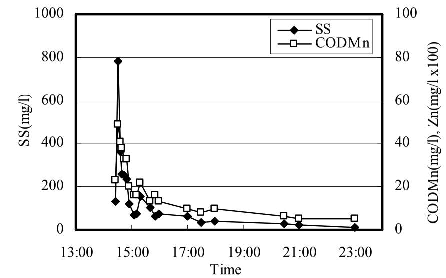
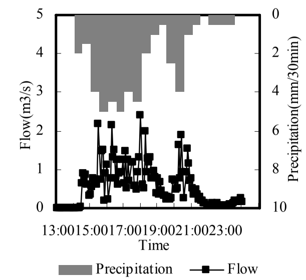
[Drainage area C]





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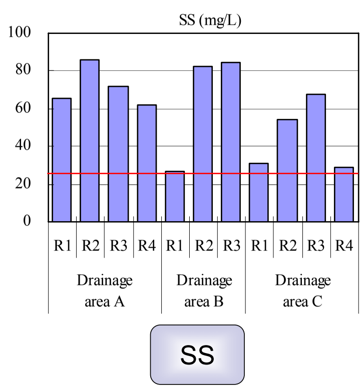
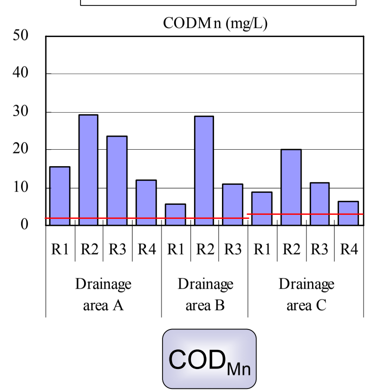
Ⅾ.ent mean concentration [SS, COD_{Mn}]

$$EMC = \frac{M}{V} = \frac{\int_0^{tr} c(t)q(t)dt}{\int_0^{tr} q(t)dt}$$





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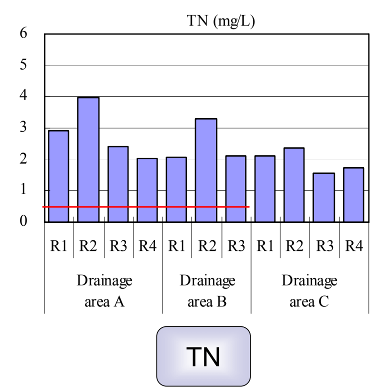
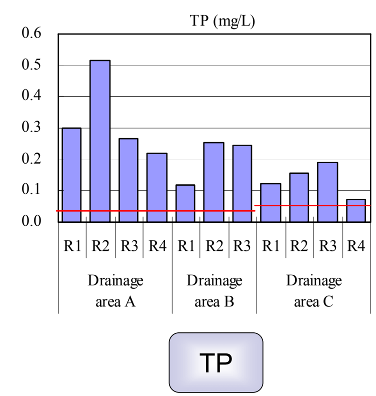
[TN, TP]





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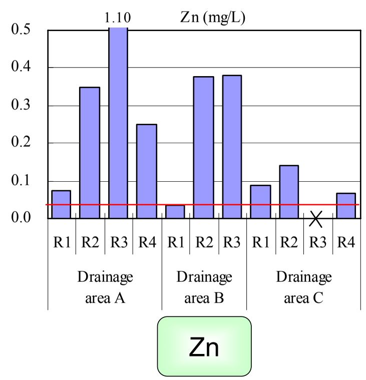
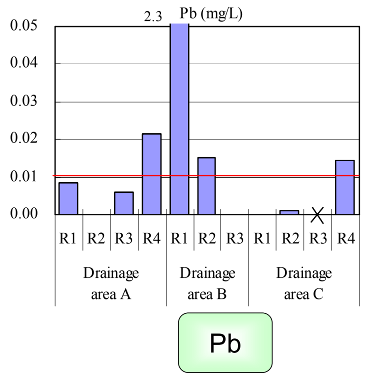
[Zn, Pb]





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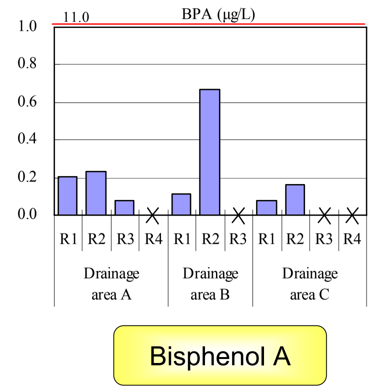
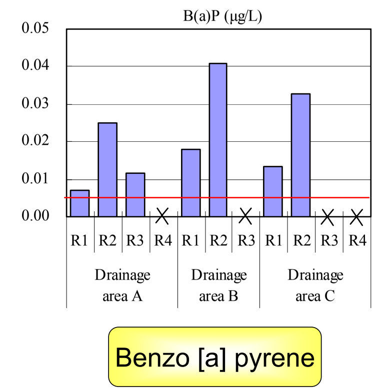
[B(a)P, BPA]





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] Load estimation method

Pollutants to be conveyed
→ Meteorological condition

Pollutants to be conveyed
→ Meteorological condition

$$L = a \cdot \Sigma r + b \cdot NDD$$

L : Specific load per rainfall event (kg/ha)
Σ*r* : Total rainfall per event (mm)
NDD : Number of prior dry weather day (day)
a, *b* : Parameters

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Data of regression analysis

		SS (kg/ha)	BOD (kg/ha)	COD_{Mn} (kg/ha)	TN (kg/ha)	TP (kg/ha)	Zn (g/ha)	Σ*r* (mm)	*NDD* (day)
Drainage area A	Rainfall 1	3.83	0.751	0.908	0.172	0.0174	4.4	7	14.0
	Rainfall 2	2.25	0.519	0.767	0.104	0.0135	9.1	10	6.0
	Rainfall 3	22.95	3.566	7.478	0.763	0.0845	349.2	63	37.5
	Rainfall 4	4.44	0.382	0.852	0.145	0.0156	17.8	3	16.5
Drainage area C	Rainfall 1	0.14	0.020	0.040	0.009	0.0005	0.4	7	14.5
	Rainfall 2	0.27	0.063	0.103	0.012	0.0008	0.7	10	8.0
	Rainfall 3	2.21	0.226	0.372	0.051	0.0061	-	63	34.0
	Rainfall 4	0.32	0.035	0.071	0.019	0.0008	0.7	12	13.5

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Result of regression

		SS	BOD	CODMn	TN	TP	Zn
Drainagre area A	*a* (kg/ha/mm)	0.211	0.021	0.025	0.0077	0.0174	-0.0010
	b (kg/ha/day)	0.243	0.046	0.106	0.0077	-0.0050	0.0062
Drainage areaC	*a* (kg/ha/mm)	-0.0120	-0.0003	0.0005	0.00065	-0.00003	-
	b (kg/ha/day)	0.0414	0.0038	0.0057	0.00048	0.00011	-

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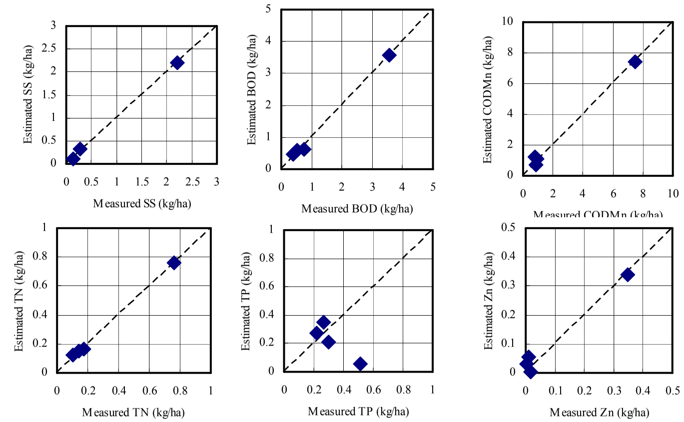
Comparison estimated/measured

(Drainage area A)



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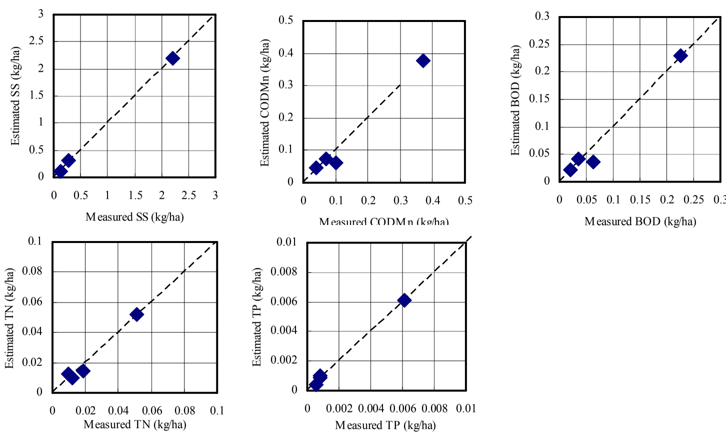
rainage area C)



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Principal estimation methods

No.	Method	Equation
(1)	Product of annual average concentration, annual precipitation, and runoff percentage	$\sum L = k \cdot C \cdot \sum R$
(2)	Summation of pollution loads from each land use area	$\sum L = (1/A) \cdot \sum (D_i \cdot L_i \cdot A_i)$
(3)	Summation of pollution loads per rainfall event, which are calculated with correlation equation between event precipitation and runoff load	-
(4)	Summation of pollution loads per rainfall event, which are calculated with multiple regression equation	$L = a \cdot \sum r + b \cdot NDD$

ΣL: Unit load (kg/ha/year)
k: Runoff percentage
C: Annual average concentration (kg/ha/mm)
ΣR: Annual precipitation (mm/year)
A: Catchment area (ha)
D_i: Runoff coefficient for land use "i" for pollution at the concerning point
L_i: Pollution load from land use "i"
A_i: Area of land use "i" in catchment area (ha)
L: Pollution load per a rainfall event (kg/ha)
Σr: Event precipitation (mm)
a, b: Coefficients in multiple regression equation
NDD: Number of prior dry weather days (day)

Conclusion

- The Japanese current framework/status of urban nonpoint pollution control was reviewed.
  The control has not yet been vigorously addressed though there are a planning framework, a technical guidance, and a financial programme.
  Further knowledge and technical improvement should be sought to better planning and the related researches.

- Field survey revealed concentration in time series varied by order of magnitude, corresponding to the rainfall runoff flow, and runoff quality characteristics varied among drainage areas.
  EMCs of almost all analysed constituents exceeded EQSs or PNECs, and they could have not an ignorable effect on receiving waters.

Cont.

- A load estimation method was researched based on the field survey data.
  A multiple regression equation, incorporating meteorological or hydrological information in each rainfall event, could produce more reliable estimation results with not a large data required.
  More data acquisition and analysis are ongoing.