

Urban Environmental Engineering 1

Taro Urase

BIOGRAPHICAL INFORMATION

- 1990 B.Eng., Urban Eng., Univ. of Tokyo
- 1995 Dr. of Eng. (Equivalent to Ph.D.) Graduate School of Engineering, Univ. of Tokyo
- 1995 Research Associate of Urban Eng., Univ. of Tokyo
- 1997 Associate Professor, Environmental Science Center, Univ. of Tokyo
- 1999 Associate Professor, Dept. of Civil Engineering, Tokyo Institute of Technology

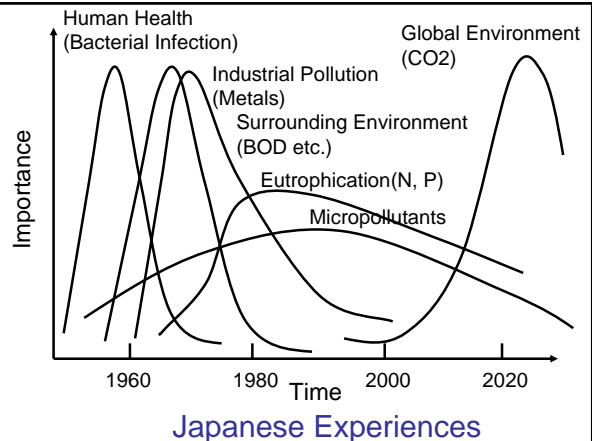
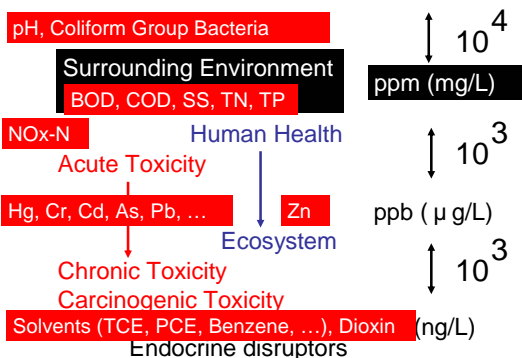
AFFILIATIONS:

- Japan Society of Civil Engineers
- International Water Association
- The International Solid Waste Association
- Japan Society of Waste Management Experts
- Japan Society on Water Environment
- Membrane Society of Japan
- Japan Society for Environmental Chemistry
- Society of Environmental Science Japan

Today's Lecture

- Overview of organic pollution and eutrophication
- Organic Pollution (BOD, COD, DO)
 - Japanese history
 - Indicators
 - Fundamental equations for concentration change [Streeter Phelps's equation]
- Nutrients (N, P)
 - Indicators
 - Fundamental equations [Vollenweider equation]
 - Stratification and water quality
- Treatment technology

Concentration Level



Environmental quality standards for the protection of human health

Table 1.1.1 Environmental quality standards related to the protection of human health (mg l⁻¹ or less, the same for surface and groundwater)

parameters	standards	parameters	standards
cadmium	0.01	cis-1, 2-dichloroethylene	0.04
total cyanide	ND	1, 1, 1-trichloroethane	1.0
lead	0.01	1, 1, 2-trichloroethane	0.006
chromium (VI)	0.05	trichloroethylene	0.03
arsenic**	0.01	tetrachloroethylene	0.01
total mercury	0.0005	1, 3-dichloropropene (D-D)	0.002
alkyl mercury	ND	thiuram	0.006
PCBs	ND	CAT (simazine)	0.003
dichloromethane	0.02	thiobencarb	0.02
carbon tetrachloride	0.002	benzene	0.01
1, 2-dichloroethane	0.004	selenium	0.01
1, 1-dichloroethylene	0.02		

The standard values are the same for all public waters.

Environmental quality standards for the protection of living environment

category	water use	standards ¹				
		pH	BOD	SS	DO	CG
AA	Water supply class 1 : conservation of natural environment, and uses listed in A-E	6.5-8.5	1	25	7.5	50
A	Water supply class 2 : fishery, class 1 ; bathing and uses listed in B-E	6.5-8.5	2	25	7.5	1,000
B	Water supply class 3 : fishery, class 2, and uses listed in C-E	6.5-8.5	3	25	5	5,000
C	Fishery class 3 ; industrial water, class 1, and uses listed in D-E	6.5-8.5	5	50	5	—
D	Industrial water class 2 ; agricultural water ; and uses listed in E	6.0-8.5	8	100	2	—
E	Industrial water class 3 ; conservation of living environment	6.0-8.5	10	*	2	—

The standard values are dependent on the category of the public waters

In the case of lakes and in the case of coastal waters, COD is used instead of BOD.

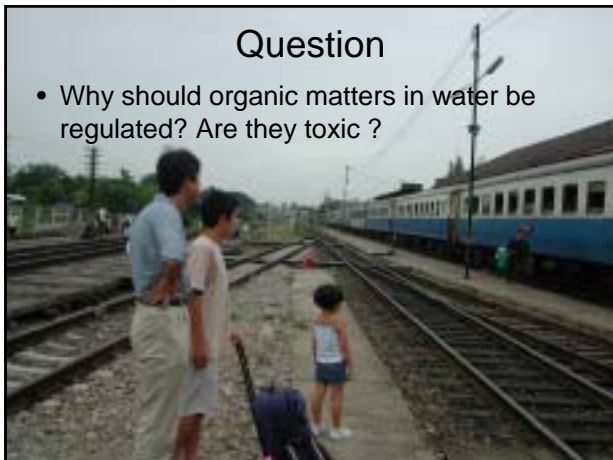
category	water use	standards				
		pH	COD	SS	DO	CG
AA	Water supply class 1 ; fishery class 1 ; conservation of natural environment, and uses listed in A-C	6.5-8.5	1	1	7.5	50
A	Water supply classes 2 and 3 ; fishery class 2 ; bathing and uses listed in B-C	6.5-8.5	3	5	7.5	1,000
B	Fishery class 3 ; industrial water class 1 ; agricultural water, and uses listed in C	6.5-8.5	5	15	5	—
C	Industrial water class 2 ; conservation of living environment	6.0-8.5	8	*	2	—

BOD, COD, TOC

- All of these parameters are related to organic pollution.
- BOD₅ measures the oxygen utilized for the biochemical degradation of organic material.
- COD measures the content of organic matter which can be oxidized by a specified chemical reagent (such as K₂Cr₂O₇ in most countries and KMnO₄ in the case of Japan).
- TOC measures carbon content.

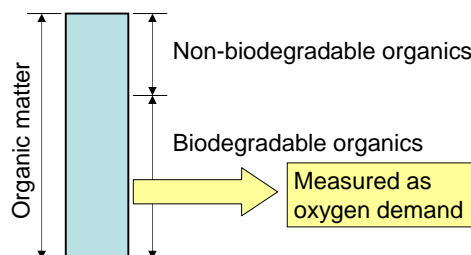
Question

- Why should organic matters in water be regulated? Are they toxic ?



BOD

- BOD₅ measures the oxygen utilized for the biochemical degradation of organic matter.



BOD, COD, TOC

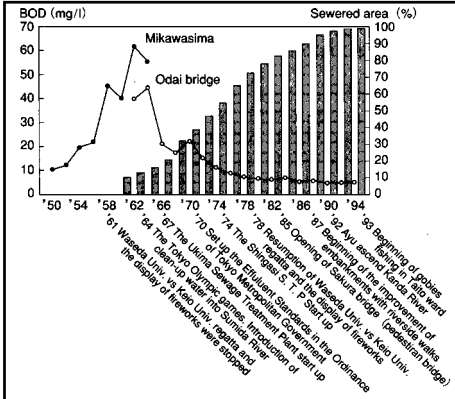
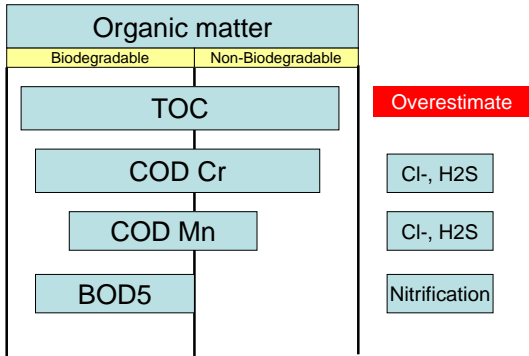


Fig. 16-3 Change of water quality of Sumida River and sewerage area

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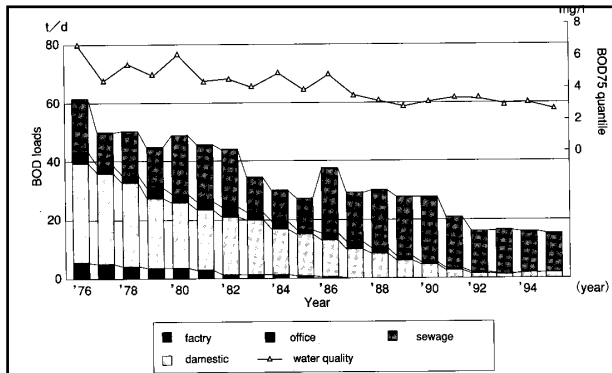
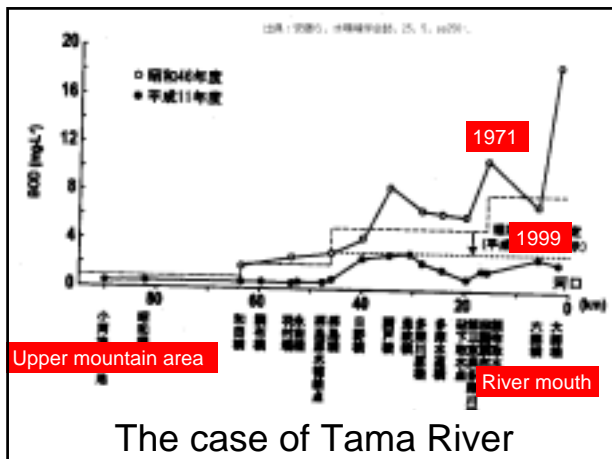


Fig. 16-9 BOD loading into Sumida River and its water quality

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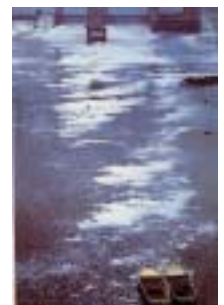
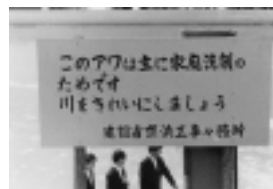


The case of Tama River

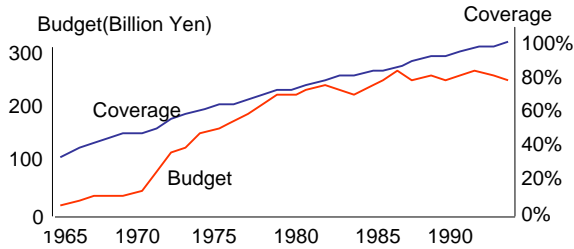


The case of Tama River

Foaming at the Denen-chohu(1970)



Coverage of and budget spent for public sewer in Tokyo 23 ward area



We reached 100% coverage of public sewer in Tokyo 23 ward area.

BOD₅

- $BOD_5 = DO_0 - DO_5$, if dilution is not necessary.
- BOD measures oxygen demand in the decomposition of biodegradable organic matter.
- If the water contains NH_3-N and seed microorganisms include nitrifying bacteria, $BOD = \text{Carbonaceous BOD} + \text{Nitrogenous BOD}$
- BOD has limitations when we want to measure BOD for toxic wastewater or seawater.
- BOD is useful to evaluate river water quality and biodegradable wastewater

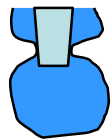
Why 5 days for BOD ?



The retention time of water in the tidal zone of the Thames River is 5 days.

Measurement of BOD₅

- $BOD_5 = (DO_0 - DO_5)$, if dilution is not necessary .
- DO can be measured by the azide modification of the iodometric method or by membrane electrode method.
- DO₅ can be measured by using a glassware like the right figure.



Other BODs

- U-BOD. U-BOD measures the ultimate biodegradability for 30 days or longer, while BOD₅ measures readily biodegradable organic matter.
- D-BOD (Dissolved BOD). When we analyze water samples, we sometimes need the distinction of dissolved BOD and Particulate BOD. P-BOD can be measured by total BOD subtracted by D-BOD.

COD

- COD measures the content of organic matter which can be oxidized by a specific chemical reagent (such as $K_2Cr_2O_7$ in most countries and $KMnO_4$ in the case of Japan).
- COD is useful when we want to measure organic content of water which contains slowly or non biodegradable matters.
- COD is useful when we want to discuss lake water quality, because water retention time is longer than 5 days.
- Salt content may interfere the measurement of COD.

Measurement of COD

- Digest sample for a certain time (Typically two hours) by using the glassware like
- Titration method is used.
- There are many CODs like COD_{Cr} and COD_{Mn} with various heating condition and heating time, and digestion pH.



Various CODs

COD(Cr): $K_2Cr_2O_7$, 2 Hours heating by direct gas burner with open reflux or with closed reflux.

COD(Mn): $KMnO_4$, 30 minutes in 100 Celsius degree hot bath.

COD(OH): $KMnO_4$, 20 minutes in 100 Celsius degree hot bath. This method is used for sea water in Japan. (However, I do not recommend)

Comparison of COD(Cr) and COD(Mn) of standard solutions which theoretically give oxygen consumption of 100 mg/L.

Solution	COD(Cr)	COD(Mn)
Formic acid	99.4	14
Stearic acid	92.5	0
Methanol	95.3	27
Glucose	97.6	59
Starch	86.5	61
Glutamic acid	102	6

TOC

- TOC measures carbon content. TOC is expressed as mgC/L, while BOD and COD are expressed as mgO/L.
- TOC measures CO_2 gas when sample is broken down completely.
- Instrumental analysis with high temperature combustion method is often used.
- It is difficult to measure accurately the samples containing high SS by the high temperature combustion method using instruments.

TOC Instrumental Analysis

- The instrument measures CO_2 concentration when sample is burned at 600 Celsius degree to 950 Celsius degree. Higher temperature is preferable for complete decomposition, while lower temperature reduces interference caused by salts.
- $TOC = TC - IC$. If IC is high, acid pretreatment of sample is required to release IC.

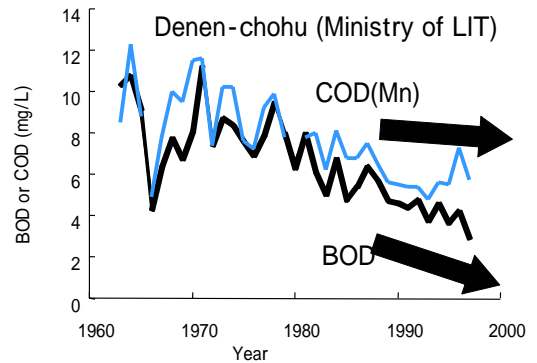
DOC

- DOC (Dissolved Organic Carbon) is often measured.
- The ratio of DOC to E_{260} is often used to evaluate biodegradability of the samples.

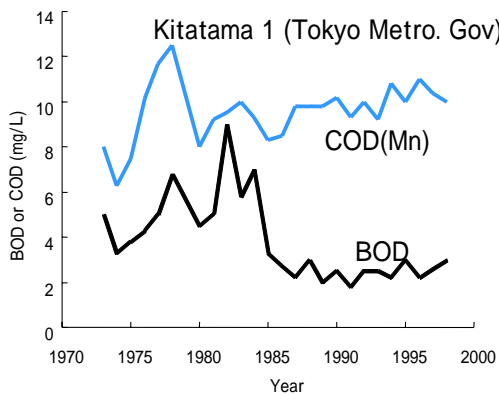
Typical values

	Domestic wastewater	Treated wastewater	Tama River Tokyo
BOD5 (mgO/L)	200	5	3
CODcr (mgO/L)	300	30	10
TOC (mgC/L)	80	7	3

Change in BOD and COD in the Tama River

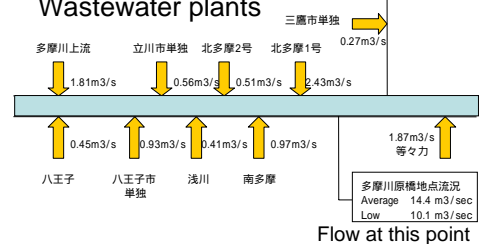


Change in BOD and COD in the treated wastewater



The Flow Volume of Tama River.
Contribution of treated wastewater is more than 80% of the low flow.

Yellow arrow represent the flow from Wastewater plants



The ratio of pollution loading originating from treated wastewater (%) 東京都環境科学研究所, 1996

項目	July	October	January
T-N	59	51	64
NH ₄ -N	83	49	77
NO _x -N	48	53	50
T-P	63	62	73
C-BOD	49	26	48
COD	54	45	58
TOC	53	42	59
SS	16	9	25
Cl ⁻	62	53	57
SO ₄ ²⁻	45	32	45

Homework

- Which organic pollution indicators (BOD, COD, TOC) should be used for monitoring ...
- 1) Environmental quality
- 2) Effluent from factories
- 3) Domestic wastewater
- 4) Mass balance in research

Small scale activated sludge plant

