Environmental Process Engineering
Fall Semester, 2009

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- Time: Mon.,Wen. PM. 2:30-4:00 Class room: 302-520
- No textbook, Handout materials
- Grade: Attendance: 10% , Homework: 10%
  Exams: 80% [Mid exam & Final exam, 100 pts each]

Class Schedule

- **Week 1** [9/3]: Water Pollution Issues, Nature of water pollution
- **Week 2** [9/7, 9/9]: Water Quality Parameters
- **Week 3** [9/14, 9/16]: Water Quality Parameters
- **Week 4** [9/21, 9/23]**:** Water Treatment Process/Wastewater Treatment Process
- **Week 5** [9/28, 9/30]: Particles in Water/Coagulation, Nanoparticle
- **Week 6** [10/5, 10/7]: Oxidation Process/Disinfection
- **Week 7** [10/12, 10/14]: Chlorination process/disinfection byproducts
- **Week 8** [10/19, 10/21]: Advanced Oxidation - Ozone
- **Week 9** [10/26, 10/28]: Advanced Oxidation – Photochemistry/UV
- **Week 10** [11/2, 11/4]: Advanced Oxidation – Fenton related chemistry
- **Week 11** [11/9, 11/11]: Innovative Environmental Processes 1 - Electrochemical disinfection
- **Week 12** [11/16, 11/18]: Innovative Environmental Processes 2 - Environmental Electrochemistry
- **Week 13** [11/23, 11/25]: Innovative Environmental Processes 3 - Environmental Electrochemistry
- **Week 14** [11/30, 12/2]: Innovative Environmental Processes 4 - Biofilm control
- **Week 15** [12/7, 12/9]: Innovative Environmental Processes 5- Biofilm control

How is water pollution in the neighborhood of our house?

Beijing Olympic and Algal Bloom (2008)

How is water being polluted?

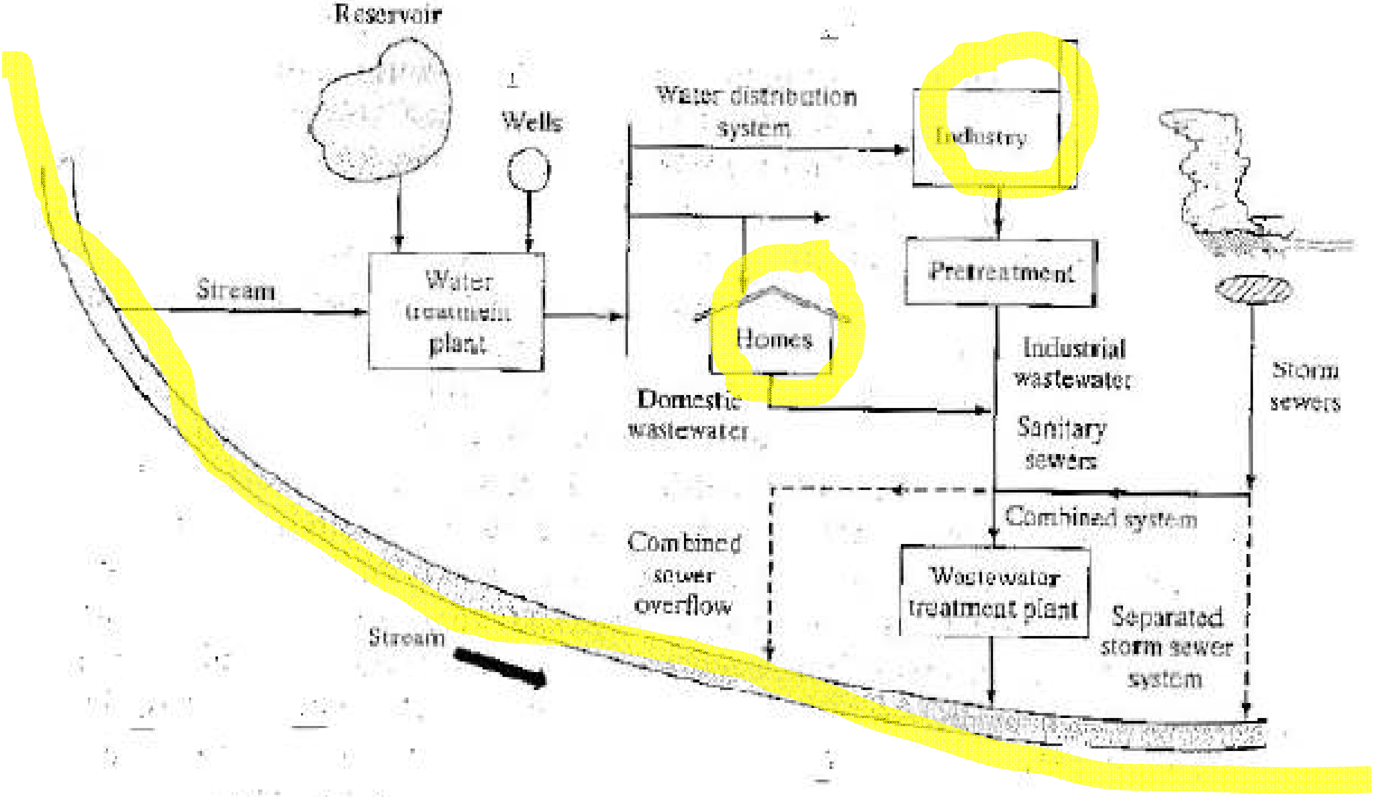
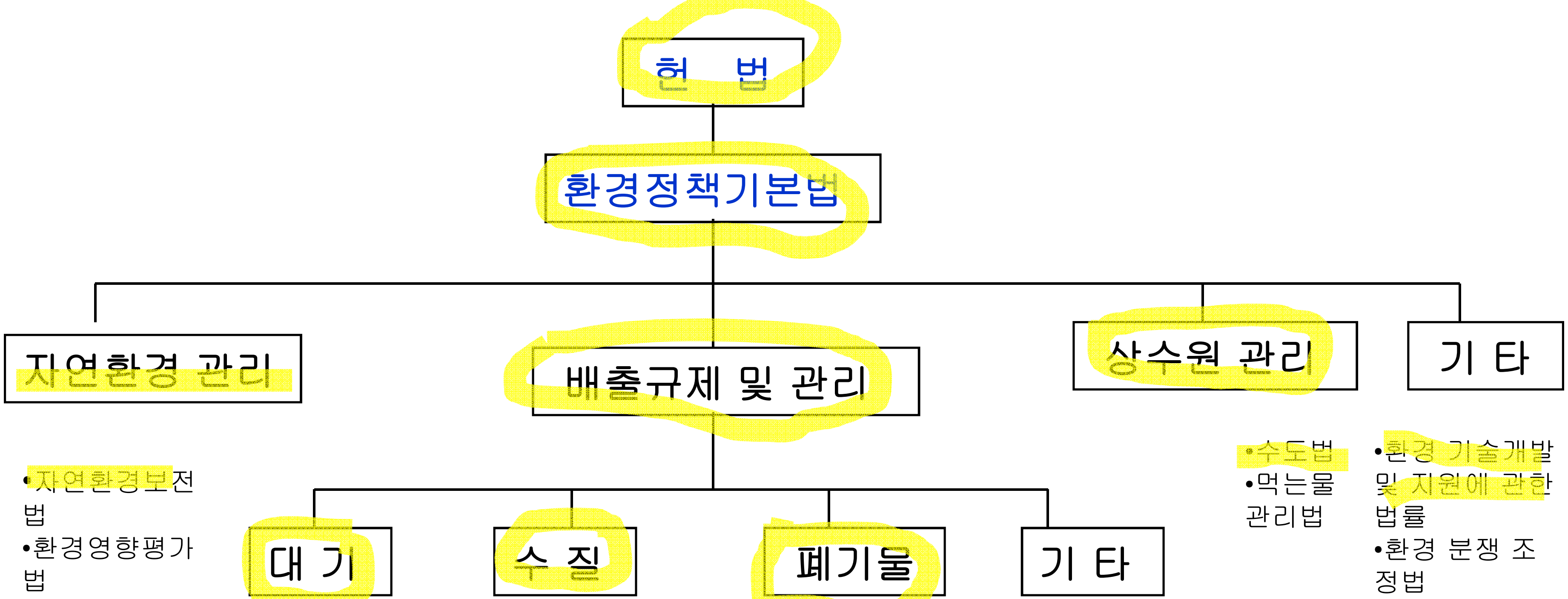


FIGURE 6.1 Water and wastewater systems. In older parts of cities, storm and sanitary sewers are combined, which can lead to untreated wastewater discharges during rainy conditions.

Small streams in Han river, Seoul



헌 법

환경정책기본법

자연환경 관리

- 자연환경보전법
- 환경영향평가법
- 독도등도서지역의 생태계 보전에 관한 특별법
- 자연공원법
- 토양환경보전법
- 습지보전법
- 조수보호및 수렵에 관한 벌률

배출규제 및 관리

대 기

- 대기환경보전법
- 소음· 진동 규제법
- 지하생활 공간 공기질 관리법

수 질

- 수질환경 보전법
- 오수· 분뇨 및 축산폐수의 처리에 관한 법률
- 하수도법
- 한강수계상수원수질개선 및 주민지원 등에 관한 법률

폐기물

- 폐기물 관리법
- 자원절약과 재활용 촉진에 관한 법률
- 폐기물처리시설설치 촉진 및 주변 지역 지원등에 관한 법률
- 폐기물의 국가간 이동 및 그 처리에 관한 법률

기 타

- 유해화학물질 관리법
- 환경범죄의 단속에 관한 특별법

상수원 관리

- 수도법
- 먹는물관리법

기 타

- 환경 기술개발 및 지원에 관한 법률
- 환경 분쟁 조정법
- 환경개선 특별회계법
- 환경개선 비용부담법
- 환경관리 공단법
- 수도권 매립지관리공사의 설립및 운영등에 관한 법률

3-2. Environmental Acts

Under the provision of Article 35 of the Constitution, “All citizens shall have the right to a healthy and agreeable environment. The State and all citizens shall endeavor to protect the environment.” The Environmental Acts solidify environmental rights, guaranteed by Article 35 of the Constitution. The concept of Environmental Acts can be interpreted in both a broad and a narrow sense according to its scope. The Environmental Acts in a broad sense include all laws that stipulate the ‘environment,’ ‘natural environment,’ or ‘living environment,’ as regulated in Article 3.1 of the Framework Act on Environmental Policy. In a narrow sense, the Environmental Law signifies laws that the Ministry of Environment directs according to Article 40 of the Government Organization Act or laws related to the preservation of the natural environment and living environment and the prevention of environmental pollution.

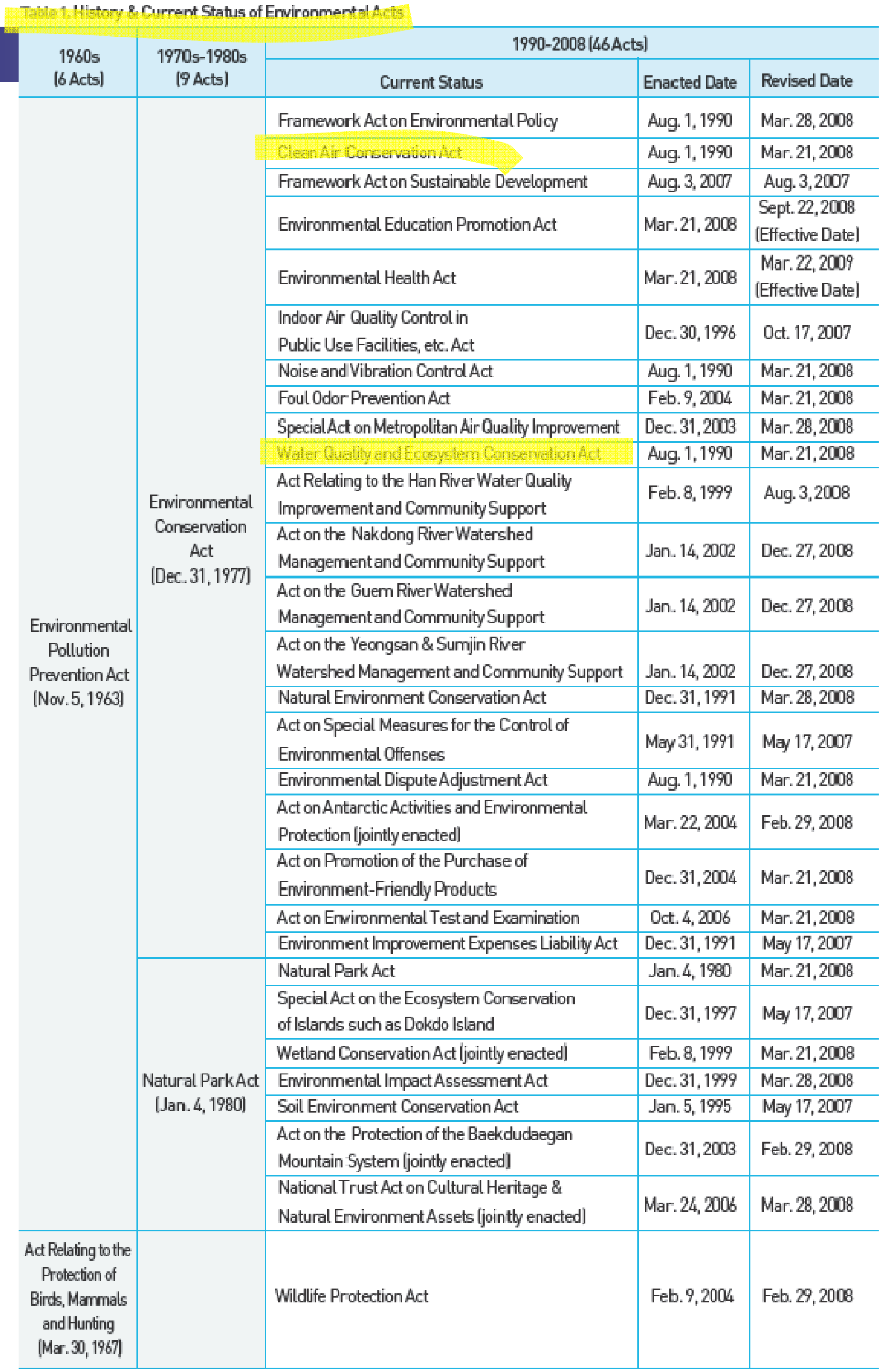
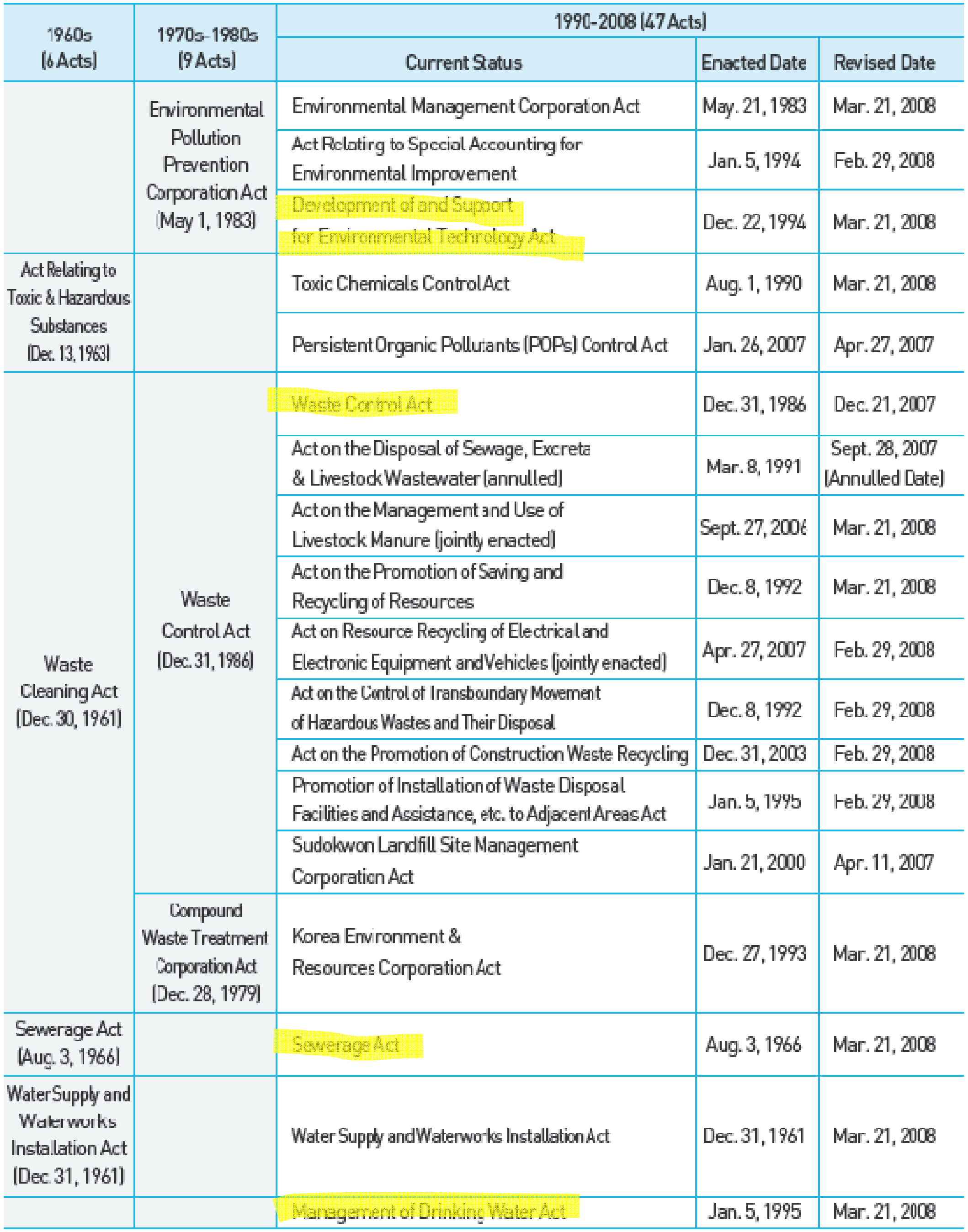


Table 1. History & Current Status of Environmental Acts

1960s (6 Acts)	1970s-1980s (9 Acts)	1990-2008 (46 Acts)		
		Current Status	Enacted Date	Revised Date
Environmental Pollution Prevention Act (Nov. 5, 1963)	Environmental Conservation Act (Dec. 31, 1977)	Framework Act on Environmental Policy	Aug. 1, 1990	Mar. 28, 2008
		Clean Air Conservation Act	Aug. 1, 1990	Mar. 21, 2008
		Framework Act on Sustainable Development	Aug. 3, 2007	Aug. 3, 2007
		Environmental Education Promotion Act	Mar. 21, 2008	Sept. 22, 2008 (Effective Date)
		Environmental Health Act	Mar. 21, 2008	Mar. 22, 2009 (Effective Date)
		Indoor Air Quality Control in Public Use Facilities, etc. Act	Dec. 30, 1996	Oct. 17, 2007
		Noise and Vibration Control Act	Aug. 1, 1990	Mar. 21, 2008
		Foul Odor Prevention Act	Feb. 9, 2004	Mar. 21, 2008
		Special Act on Metropolitan Air Quality Improvement	Dec. 31, 2003	Mar. 28, 2008
		Water Quality and Ecosystem Conservation Act	Aug. 1, 1990	Mar. 21, 2008
		Act Relating to the Han River Water Quality Improvement and Community Support	Feb. 8, 1999	Aug. 3, 2008
		Act on the Nakdong River Watershed Management and Community Support	Jan. 14, 2002	Dec. 27, 2008
		Act on the Guem River Watershed Management and Community Support	Jan. 14, 2002	Dec. 27, 2008
		Act on the Yeongsan & Sumjin River Watershed Management and Community Support	Jan. 14, 2002	Dec. 27, 2008
		Natural Environment Conservation Act	Dec. 31, 1991	Mar. 28, 2008
		Act on Special Measures for the Control of Environmental Offenses	May 31, 1991	May 17, 2007
		Environmental Dispute Adjustment Act	Aug. 1, 1990	Mar. 21, 2008
		Act on Antarctic Activities and Environmental Protection (jointly enacted)	Mar. 22, 2004	Feb. 29, 2008
		Act on Promotion of the Purchase of Environment-Friendly Products	Dec. 31, 2004	Mar. 21, 2008
		Act on Environmental Test and Examination	Oct. 4, 2006	Mar. 21, 2008
		Environment Improvement Expenses Liability Act	Dec. 31, 1991	May 17, 2007
	Natural Park Act (Jan. 4, 1980)	Natural Park Act	Jan. 4, 1980	Mar. 21, 2008
		Special Act on the Ecosystem Conservation of Islands such as Dokdo Island	Dec. 31, 1997	May 17, 2007
		Wetland Conservation Act (jointly enacted)	Feb. 8, 1999	Mar. 21, 2008
		Environmental Impact Assessment Act	Dec. 31, 1999	Mar. 28, 2008
		Soil Environment Conservation Act	Jan. 5, 1995	May 17, 2007
		Act on the Protection of the Baekdudaegan Mountain System (jointly enacted)	Dec. 31, 2003	Feb. 29, 2008
		National Trust Act on Cultural Heritage & Natural Environment Assets (jointly enacted)	Mar. 24, 2006	Mar. 28, 2008
Act Relating to the Protection of Birds, Mammals and Hunting (Mar. 30, 1967)		Wildlife Protection Act	Feb. 9, 2004	Feb. 29, 2008



1960s (6 Acts)	1970s-1980s (9 Acts)	1990-2008 (47 Acts)		
		Current Status	Enacted Date	Revised Date
	Environmental Pollution Prevention Corporation Act (May 1, 1983)	Environmental Management Corporaton Act	May. 21, 1983	Mar. 21, 2008
		Act Relating to Special Accounting for Environmental Improvement	Jan. 5, 1994	Feb. 29, 2008
		Development of and Support for Environmental Technology Act	Dec. 22, 1994	Mar. 21, 2008
Act Relating to Toxic & Hazardous Substances (Dec. 13, 1963)		Toxic Chemicals Control Act	Aug. 1, 1990	Mar. 21, 2008
		Persistent Organic Pollutants (POPs) Control Act	Jan. 26, 2007	Apr. 27, 2007
Waste Cleaning Act (Dec. 30, 1961)	Waste Control Act (Dec. 31, 1986)	Waste Control Act	Dec. 31, 1986	Dec. 21, 2007
		Act on the Disposal of Sewage, Excreta & Livestock Wastewater (annulled)	Mar. 8, 1991	Sept. 28, 2007 (Annulled Date)
		Act on the Management and Use of Livestock Manure (jointly enacted)	Sept. 27, 2006	Mar. 21, 2008
		Act on the Promotion of Saving and Recycling of Resources	Dec. 8, 1992	Mar. 21, 2008
		Act on Resource Recycling of Electrical and Electronic Equipment and Vehicles (jointly enacted)	Apr. 27, 2007	Feb. 29, 2008
		Act on the Control of Transboundary Movement of Hazardous Wastes and Their Disposal	Dec. 8, 1992	Feb. 29, 2008
		Act on the Promotion of Construction Waste Recycling	Dec. 31, 2003	Feb. 29, 2008
		Promotion of Installation of Waste Disposal Facilities and Assistance, etc. to Adjacent Areas Act	Jan. 5, 1995	Feb. 29, 2008
		Sudokwon Landfill Site Management Corporation Act	Jan. 21, 2000	Apr. 11, 2007
	Compound Waste Treatment Corporation Act (Dec. 28, 1979)	Korea Environment & Resources Corporation Act	Dec. 27, 1993	Mar. 21, 2008
Sewerage Act (Aug. 3, 1966)		Sewerage Act	Aug. 3, 1966	Mar. 21, 2008
Water Supply and Waterworks Installation Act (Dec. 31, 1961)		Water Supply and Waterworks Installation Act	Dec. 31, 1961	Mar. 21, 2008
		Management of Drinking Water Act	Jan. 5, 1995	Mar. 21, 2008

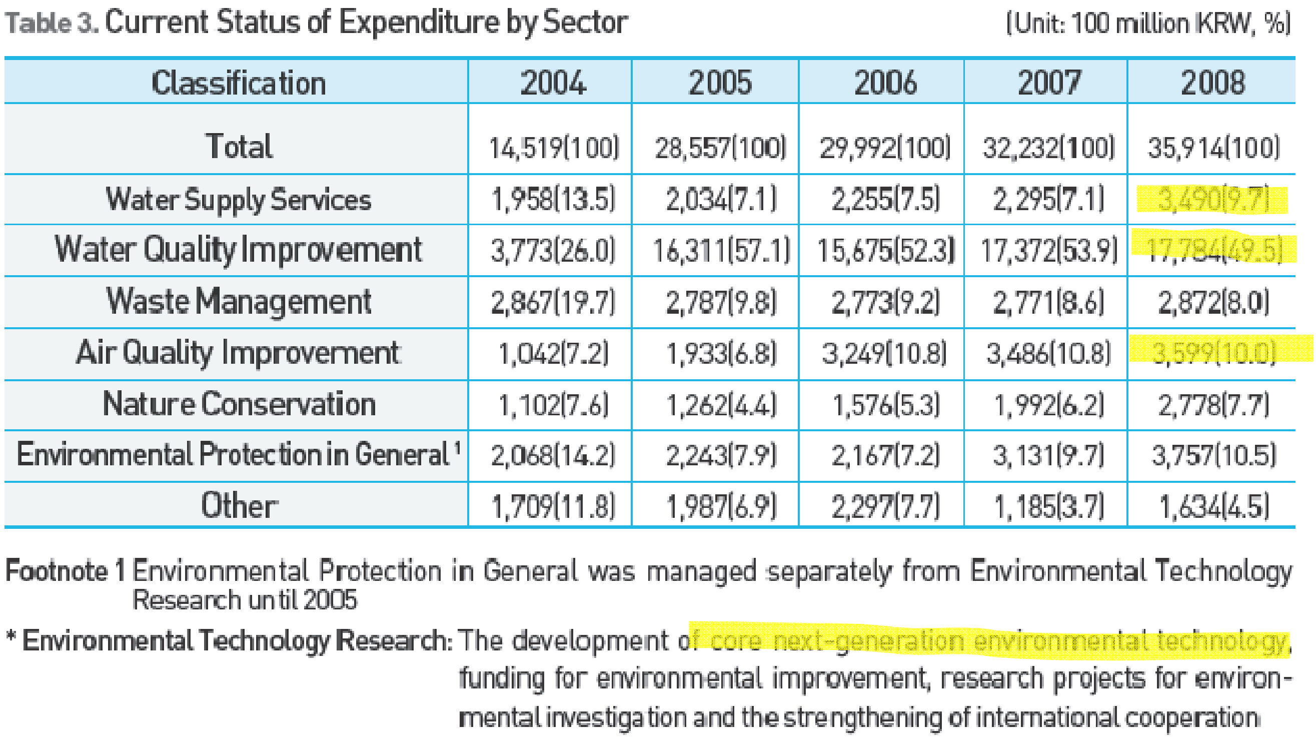
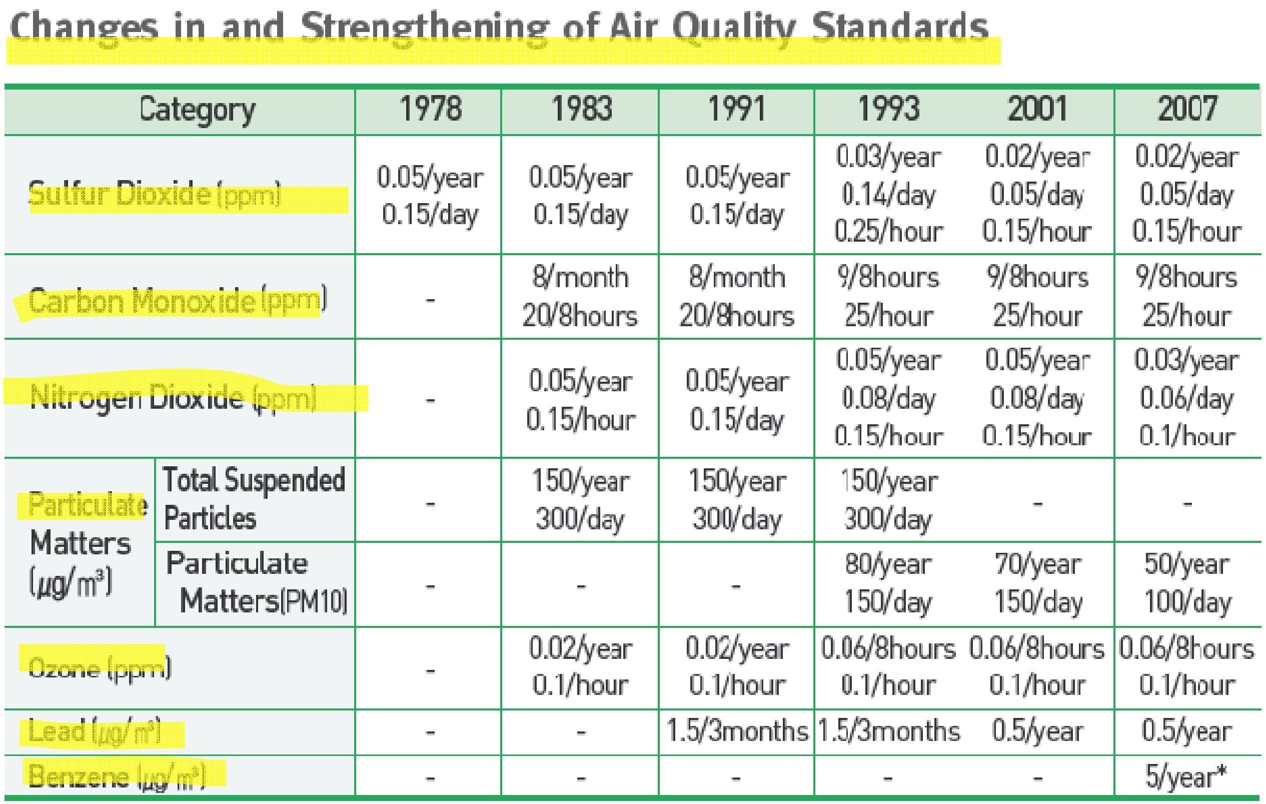


Table 3. Current Status of Expenditure by Sector (Unit: 100 million KRW, %)

Classification	2004	2005	2006	2007	2008
Total	14,519(100)	28,557(100)	29,992(100)	32,232(100)	35,914(100)
Water Supply Services	1,958(13.5)	2,034(7.1)	2,255(7.5)	2,295(7.1)	3,490(9.7)
Water Quality Improvement	3,773(26.0)	16,311(57.1)	15,675(52.3)	17,372(53.9)	17,784(49.5)
Waste Management	2,867(19.7)	2,787(9.8)	2,773(9.2)	2,771(8.6)	2,872(8.0)
Air Quality Improvement	1,042(7.2)	1,933(6.8)	3,249(10.8)	3,486(10.8)	3,599(10.0)
Nature Conservation	1,102(7.6)	1,262(4.4)	1,576(5.3)	1,992(6.2)	2,778(7.7)
Environmental Protection in General[1]	2,068(14.2)	2,243(7.9)	2,167(7.2)	3,131(9.7)	3,757(10.5)
Other	1,709(11.8)	1,987(6.9)	2,297(7.7)	1,185(3.7)	1,634(4.5)

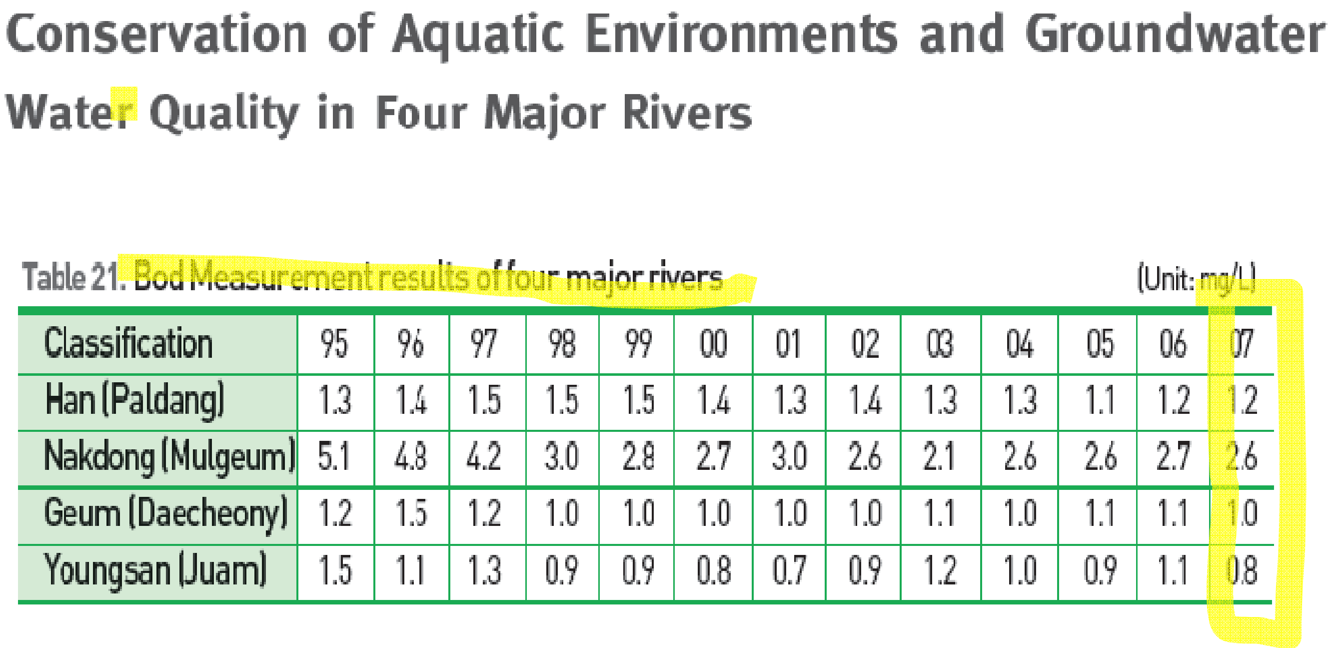
Footnote 1 Environmental Protection in General was managed separately from Environmental Technology Research until 2005

*** Environmental Technology Research:** The development of core next-generation environmental technology, funding for environmental improvement, research projects for environmental investigation and the strengthening of international cooperation



Changes in and Strengthening of Air Quality Standards

Category		1978	1983	1991	1993	2001	2007
Sulfur Dioxide (ppm)		0.05/year 0.15/day	0.05/year 0.15/day	0.05/year 0.15/day	0.03/year 0.14/day 0.25/hour	0.02/year 0.05/day 0.15/hour	0.02/year 0.05/day 0.15/hour
Carbon Monoxide (ppm)		-	8/month 20/8hours	8/month 20/8hours	9/8hours 25/hour	9/8hours 25/hour	9/8hours 25/hour
Nitrogen Dioxide (ppm)		-	0.05/year 0.15/hour	0.05/year 0.15/day	0.05/year 0.08/day 0.15/hour	0.05/year 0.08/day 0.15/hour	0.03/year 0.06/day 0.1/hour
Particulate Matters (μg/m^3)	Total Suspended Particles	-	150/year 300/day	150/year 300/day	150/year 300/day	-	-
	Particulate Matters(PM10)	-	-	-	80/year 150/day	70/year 150/day	50/year 100/day
Ozone (ppm)		-	0.02/year 0.1/hour	0.02/year 0.1/hour	0.06/8hours 0.1/hour	0.06/8hours 0.1/hour	0.06/8hours 0.1/hour
Lead (μg/m^3)		-	-	1.5/3months	1.5/3months	0.5/year	0.5/year
Benzene (μg/m^3)		-	-	-	-	-	5/year*



Conservation of Aquatic Environments and Groundwater

Water Quality in Four Major Rivers

Table 21. Bod Measurement results of four major rivers (Unit: mg/L)

Classification	95	96	97	98	99	00	01	02	03	04	05	06	07
Han (Paldang)	1.3	1.4	1.5	1.5	1.5	1.4	1.3	1.4	1.3	1.3	1.1	1.2	1.2
Nakdong (Mulgeum)	5.1	4.8	4.2	3.0	2.8	2.7	3.0	2.6	2.1	2.6	2.6	2.7	2.6
Geum (Daecheony)	1.2	1.5	1.2	1.0	1.0	1.0	1.0	1.0	1.1	1.0	1.1	1.1	1.0
Youngsan (Juam)	1.5	1.1	1.3	0.9	0.9	0.8	0.7	0.9	1.2	1.0	0.9	1.1	0.8

Since 1998, river basin management system (e.g., total maximum daily load management system), expansion of infrastructure, reinforcement of the emission standard

Rate of Meeting Aquatic Environmental Standard

Watershed	'00	'01	'02	'03	'04	'05	'06
Nation	27.8 (54/194)	29.4 (57/194)	37.6 (73/194)	49.0 (95/194)	36.6 (71/194)	42.3 (82/194)	35.6 (69/194)
Han	38.5	42.3	53.8	57.7	53.8	53.8	42.3
Nakdong	20.0	22.5	32.5	55.0	32.5	45.0	32.5
Geum	34.2	26.3	31.6	44.7	34.2	44.7	36.8
Youngsan	8.3	25.0	25.0	41.7	16.7	16.7	25.0
Sumjin	16.7	16.7	33.3	33.3	16.7	16.7	50.0
Others	23.9	26.1	32.6	41.3	30.4	34.8	30.4

Current Status of Waterworks Supply

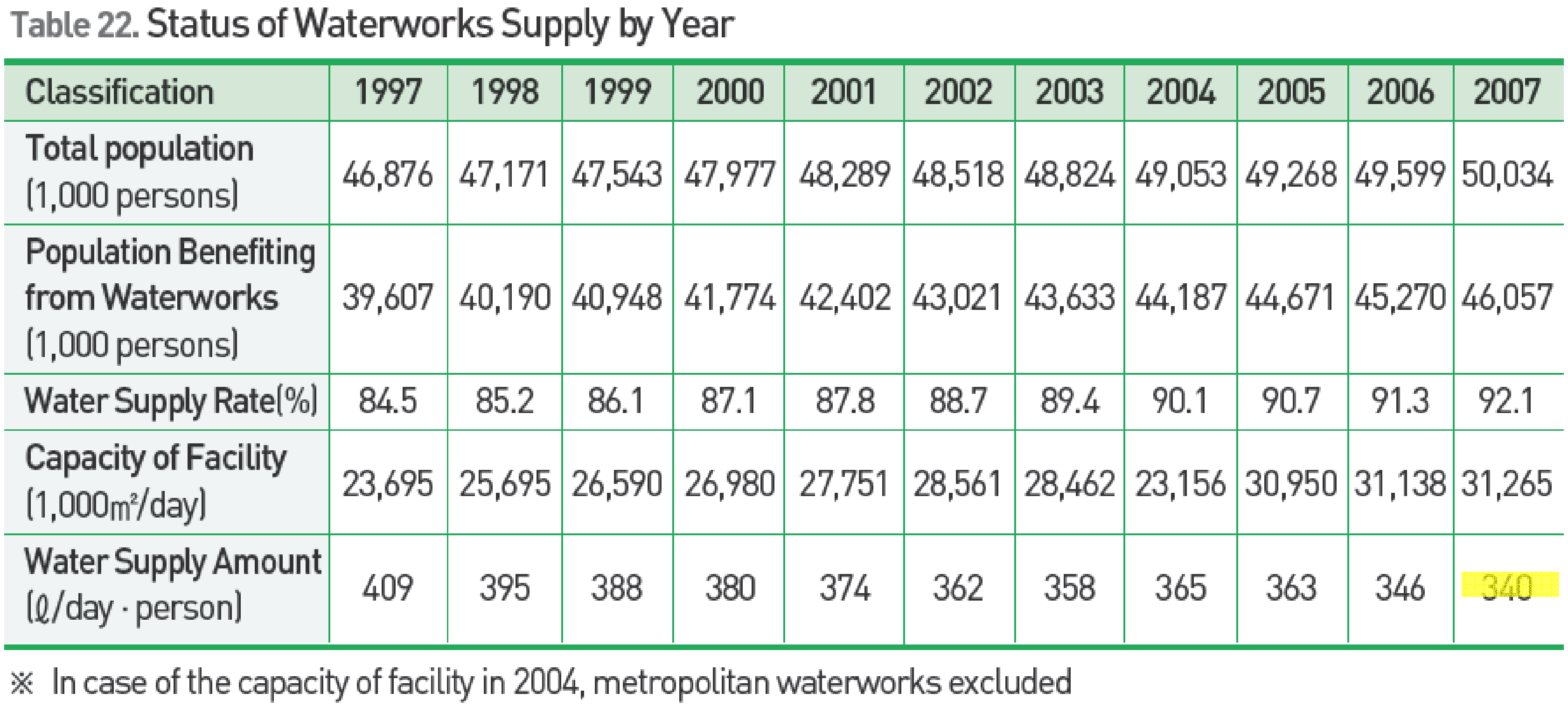


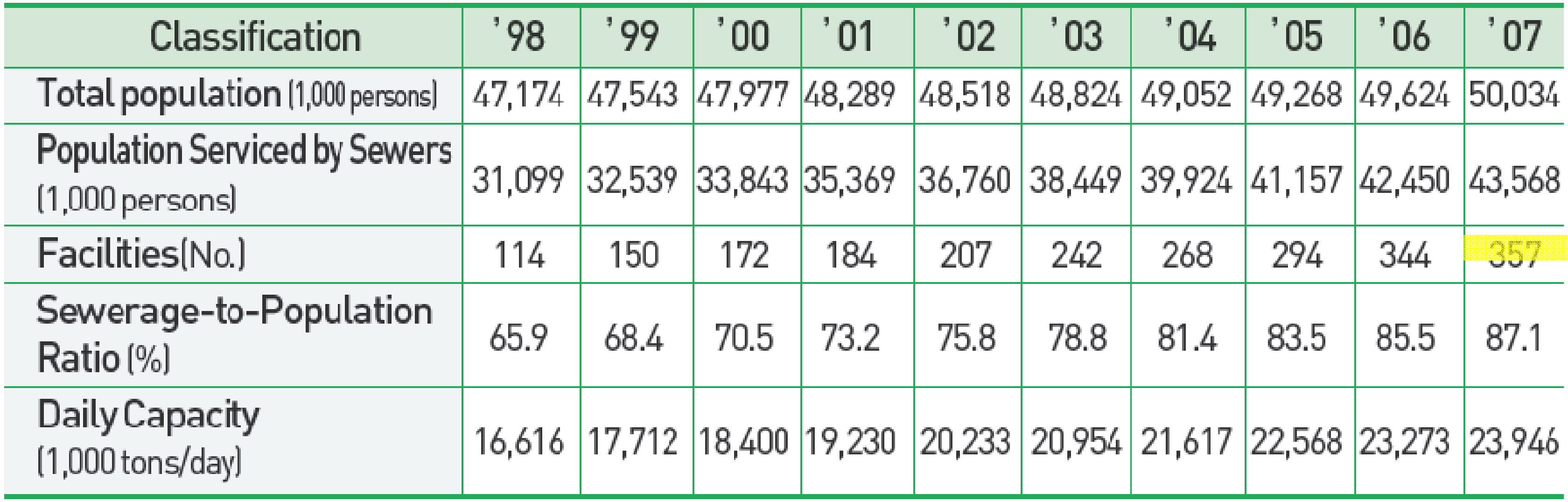
Table 22. Status of Waterworks Supply by Year

Classification	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Total population (1,000 persons)	46,876	47,171	47,543	47,977	48,289	48,518	48,824	49,053	49,268	49,599	50,034
Population Benefiting from Waterworks (1,000 persons)	39,607	40,190	40,948	41,774	42,402	43,021	43,633	44,187	44,671	45,270	46,057
Water Supply Rate(%)	84.5	85.2	86.1	87.1	87.8	88.7	89.4	90.1	90.7	91.3	92.1
Capacity of Facility (1,000㎥/day)	23,695	25,695	26,590	26,980	27,751	28,561	28,462	23,156	30,950	31,138	31,265
Water Supply Amount (ℓ/day · person)	409	395	388	380	374	362	358	365	363	346	340

※ In case of the capacity of facility in 2004, metropolitan waterworks excluded

Current Status of Sewerage Service

Table 24. Trend of Sewerage Service



Classification	'98	'99	'00	'01	'02	'03	'04	'05	'06	'07
Total population (1,000 persons)	47,174	47,543	47,977	48,289	48,518	48,824	49,052	49,268	49,624	50,034
Population Serviced by Sewers (1,000 persons)	31,099	32,539	33,843	35,369	36,760	38,449	39,924	41,157	42,450	43,568
Facilities(No.)	114	150	172	184	207	242	268	294	344	357
Sewerage-to-Population Ratio (%)	65.9	68.4	70.5	73.2	75.8	78.8	81.4	83.5	85.5	87.1
Daily Capacity (1,000 tons/day)	16,616	17,712	18,400	19,230	20,233	20,954	21,617	22,568	23,273	23,946

Current Status of Sewer Pipelines Facilities

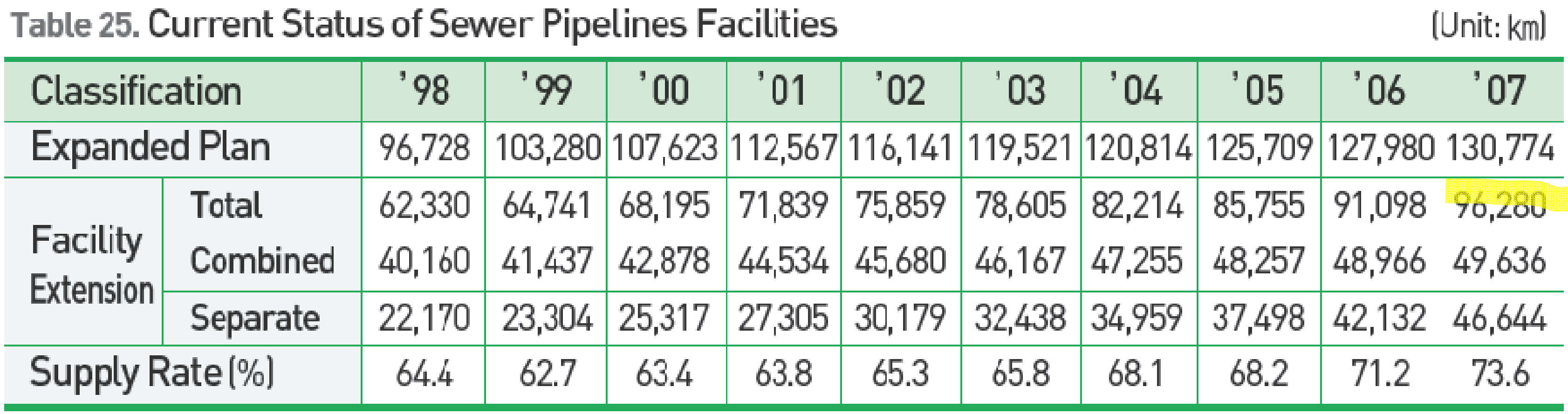


Table 25. Current Status of Sewer Pipelines Facilities (Unit: ㎞)

Classification		'98	'99	'00	'01	'02	'03	'04	'05	'06	'07
Expanded Plan		96,728	103,280	107,623	112,567	116,141	119,521	120,814	125,709	127,980	130,774
Facility Extension	Total	62,330	64,741	68,195	71,839	75,859	78,605	82,214	85,755	91,098	96,280
	Combined	40,160	41,437	42,878	44,534	45,680	46,167	47,255	48,257	48,966	49,636
	Separate	22,170	23,304	25,317	27,305	30,179	32,438	34,959	37,498	42,132	46,644
Supply Rate (%)		64.4	62.7	63.4	63.8	65.3	65.8	68.1	68.2	71.2	73.6

Water & Aquatic Ecosystem

Rivers and Streams

- **Standard for Human Health Protection (River, Streams and Lakes)**

Pollutants	Standard Value (㎎/L)
Cadmium (Cd)	≤0.005
Arsenic (As)	≤0.05
Cyanide (CN)	Not Detected (Limit of Detection 0.01)
Mercury (Hg)	ND (LOD 0.001)
Organic Phosphorus	ND (LOD 0.0005)
Polychlorinated Biphenyls (PCB)	ND (LOD 0.0005)
Lead (Pb)	≤0.05
Hexachromium (Cr6+)	≤0.05
Alkyl Benzene Sulfate (ABS)	≤0.5
Carbon Tetrachloride (CCl4)	≤0.004
1,2-Dichloroethylene	≤0.03
Tetrachloroethylene (PCE)	≤0.04
Dichloromethane	≤0.02
Benzene	≤0.01
Chloroform	≤0.08
Di-Ethylhexyl Phthalate (DEHP)	≤0.008
Antimony (Sb)	≤0.02

- Standard for the Living Environment

Grade		State(Character)	Standard					
			pH	BOD(mg/L)	SS(mg/L)	DO(mg/L)	Coliforms (No./100mℓ)	
							Total Coliforms	Fecal Coliforms
Very Good	Ia		6.5~8.5	≤1	≤25	≥7.5	≤50	≤10
Good	Ib		6.5~8.5	≤2	≤25	≥5.0	≤500	≤100
Fairly Good	II		6.5~8.5	≤3	≤25	≥5.0	≤1,000	≤200
Fair	III		6.5~8.5	≤5	≤25	≥5.0	≤5,000	≤1,000
Fairly Poor	IV		6.0~8.5	≤8	≤100	≥2.0	-	-
Poor	V		6.0~8.5	≤10	No floating matters such as garbage	≥2.0	-	-
Very Poor	VI		-	>10	-	<2.0	-	-

Remarks

1. Water Quality by Grade & State of Aquatic Ecosystems

   a. Very Good : Higher concentrations of DO (Dissolved Oxygen), no pollutant, excellent condition of ecosystems, and residential use after a simple purification process (e.g., filtration and sterilization)

   b. Good : High DO levels, few pollutants, good condition of ecosystems, and residential use after a general purification process (e.g., sedimentation, filtration, and sterilization)

   c. Fairly Good : Good DO levels, a few pollutants, good and moderate condition of ecosystems, and residential/ swimming pool use after a general purification process (e.g., sedimentation, filtration, and sterilization)

   d. Fair : Moderate concentrations of DO, general pollutants, moderate condition of ecosystems, residential use after an advanced purification process (e.g., sedimentation, filtration, carbon block filtration, and sterilization) and industrial use after a general purification process

   e. Fairly Poor : Low concentrations of DO, many pollutants, an agricultural use, and an industrial purpose after an advanced purification process

   f. Poor : Lower concentrations of DO, a significant amount of pollutants, an industrial use after an advanced purification process (e.g., sedimentation, filtration, carbon block filtration, sterilization, and reverse osmosis), and no effect of bad or unpleasant odor on daily life

   g. Very Poor : Little DO, polluted water, and few fish to survive

   h. A certain grade of water can be used for lower-grade water purpose.

   i. An appropriate water treatment in line with the status of pollution by item (e.g., pH) and the method of water treatment, allows lower-grade water to be used for higher-grade water purpose.

- Water Quality by Grade & Biological Features of Aquatic Ecosystem

Grade	Biological Indicator Species		Habitats & Features
	Benthos	Fish	
Very Good~Good	Gammarus, Korean Fresh Water Crayfish, Drunella Aculea, Cincticostella Levanidovae, Plecoptera, Rhyacophila, Glossosoma KUa, Hydatophylax Nigrovittatus McLachlan, Psilotreta Kisoensi	Trout, Moroco SP, Fresh Water Salmon, Chinese Minnow, etc.	- Crystal clear water, and high flow velocity - Rocks and pebbles at the bottom - Very little attached algae
Good~Fair	Melanian snail, Glossiphonia, Rhoenanthus (Potamanthindus), Ephemera Orientalis, Uracanthella Rufa, Caenis Rishinoae, Psephenoides sp. 1, Macronema Radiatum McLachlan	Shiri, Dark C Sweetfish, Mandarin Fish, etc.	- Clear water, and normally high or moderate flow velocity - Rock and gravel at the bottom - A bit attached algae
Fair~Fairly Poor	Lymnaeidae, Arhynchobdellidae, Water boatman , Orthetrum Albistylum Specisum,	Dace fish, Korean Piscivorous Chub, False (Goby) Minnow, Stone Moroko, etc.	- Low water turbidity, and normally low flow velocity - Small gravel and sand at the bottom - Much attached green algae
Fairly Poor~ Very Poor	Physa Acuta, Tubifex, Red Sea Bass, Mothfly, Hover fly	Crucian (Prussian) Carp, Carp, Loach, Catfish, etc.	- High water turbidity and low flow velocity - Sand and silt at the bottom; and the color of water is black. - Much attached brown/gray algae

Lakes

- Standard for Human Health Protection

This standard is the same as that of rivers and streams for human health protection

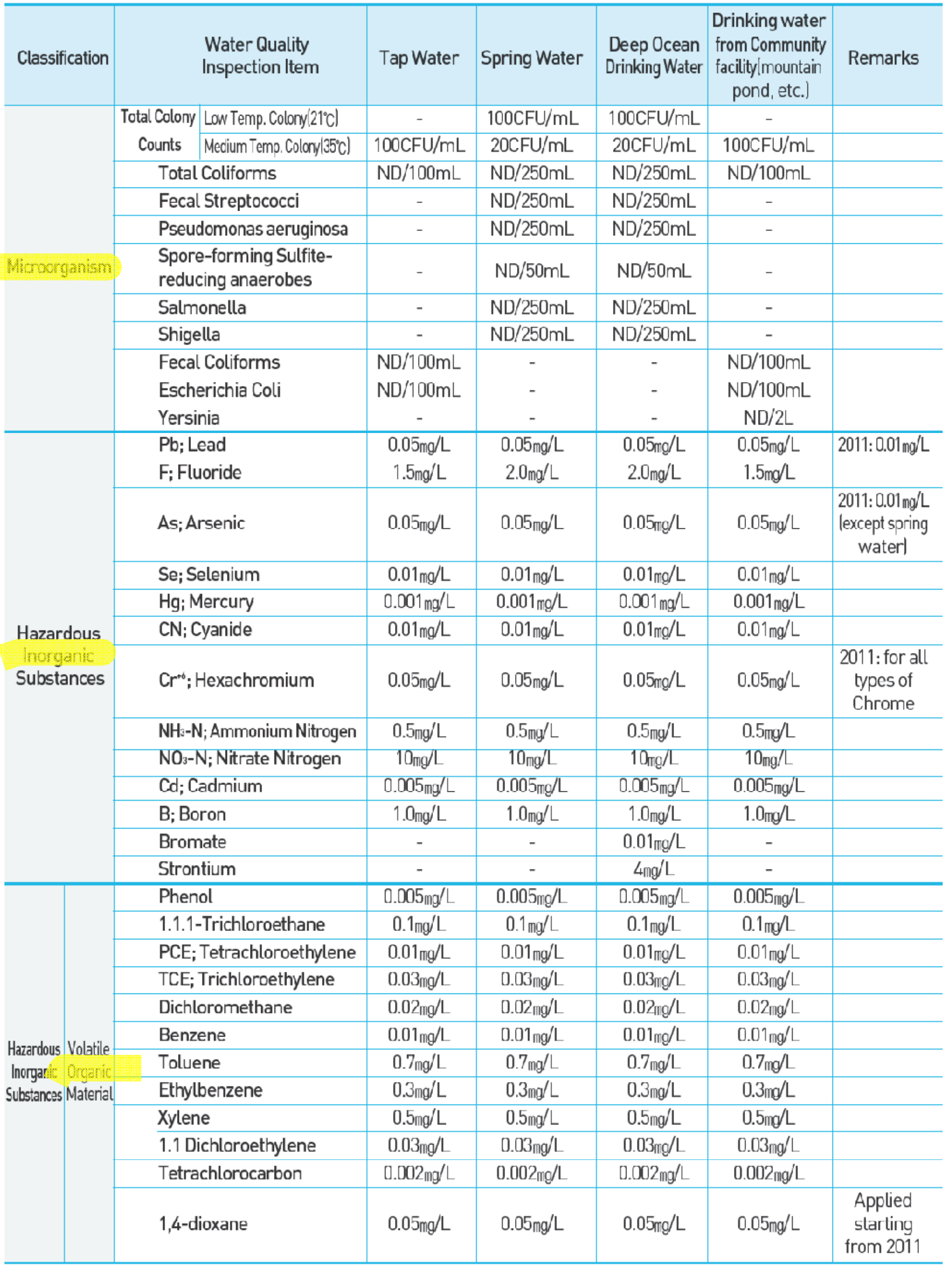
- Standard for the Living Environment

Grade		Standard									
		State (Character)	pH	COD (mg/L)	SS (mg/L)	DO (mg/L)	T-P (mg/L)	T-N (mg/L)	Chl-a (mg/m³)	E-Coliforms (No./100mL)	
										Total Coliforms	Fecal Coliforms
Very Good	Ia		6.5~8.5	≤2	≤1	≥7.5	≤0.01	≤0.2	≤5	≤50	≤10
Good	Ib		6.5~8.5	≤3	≤5	≥5.0	≤0.02	≤0.3	≤9	≤500	≤100
Fairly Good	II		6.5~8.5	≤4	≤5	≥ 5.0	≤0.03	≤0.4	≤14	≤1,000	≤200
Fair	III		6.5~8.5	≤5	≤15	≥5.0	≤0.05	≤0.6	≤20	≤5,000	≤1,000
Fairly Poor	IV		6.0~8.5	≤8	≤15	≥2.0	≤0.10	≤1.0	≤35	-	-
Poor	V		6.0~8.5	≤10	No floating garbage	≥2.0	≤0.15	≤1.5	≤70	-	-
Very Poor	VI		-	>10	-	<2.0	>0.15	>1.5	>70	-	-

Remarks

1. When the ration of total nitrogen to total phosphorate is less than 7, the criteria of total phosphorate shall not be applied, and on the other hand, the ratio is more than 16, the criteria of total nitrogen shall not be applied.
2. Water quality by grade and the status of aquatic ecosystems is the same as the first column of A. Rivers and Streams, (2) the Standard for the Living Environment.
3. Design of characters is the same as the first column of A. Rivers and Streams, (2) the Standard for the Living Environment.

Drinking Water



Classification	Water Quality Inspection Item		Tap Water	Spring Water	Deep Ocean Drinking Water	Drinking water from Community facility(mountain pond, etc.)	Remarks
Microorganism	Total Colony Counts	Low Temp. Colony(21℃)	-	100CFU/mL	100CFU/mL	-	
		Medium Temp. Colony(35℃)	100CFU/mL	20CFU/mL	20CFU/mL	100CFU/mL	
	Total Coliforms		ND/100mL	ND/250mL	ND/250mL	ND/100mL	
	Fecal Streptococci		-	ND/250mL	ND/250mL	-	
	Pseudomonas aeruginosa		-	ND/250mL	ND/250mL	-	
	Spore-forming Sulfite-reducing anaerobes		-	ND/50mL	ND/50mL	-	
	Salmonella		-	ND/250mL	ND/250mL	-	
	Shigella		-	ND/250mL	ND/250mL	-	
	Fecal Coliforms		ND/100mL	-	-	ND/100mL	
	Escherichia Coli		ND/100mL	-	-	ND/100mL	
	Yersinia		-	-	-	ND/2L	
Hazardous Inorganic Substances	Pb; Lead		0.05mg/L	0.05mg/L	0.05mg/L	0.05mg/L	2011: 0.01mg/L
	F; Fluoride		1.5mg/L	2.0mg/L	2.0mg/L	1.5mg/L	
	As; Arsenic		0.05mg/L	0.05mg/L	0.05mg/L	0.05mg/L	2011: 0.01mg/L (except spring water)
	Se; Selenium		0.01mg/L	0.01mg/L	0.01mg/L	0.01mg/L	
	Hg; Mercury		0.001mg/L	0.001mg/L	0.001mg/L	0.001mg/L	
	CN; Cyanide		0.01mg/L	0.01mg/L	0.01mg/L	0.01mg/L	
	Cr^{+6}; Hexachromium		0.05mg/L	0.05mg/L	0.05mg/L	0.05mg/L	2011: for all types of Chrome
	NH_3-N; Ammonium Nitrogen		0.5mg/L	0.5mg/L	0.5mg/L	0.5mg/L	
	NO_3-N; Nitrate Nitrogen		10mg/L	10mg/L	10mg/L	10mg/L	
	Cd; Cadmium		0.005mg/L	0.005mg/L	0.005mg/L	0.005mg/L	
	B; Boron		1.0mg/L	1.0mg/L	1.0mg/L	1.0mg/L	
	Bromate		-	-	0.01mg/L	-	
	Strontium		-	-	4mg/L	-	
Hazardous Inorganic Substances	Volatile Organic Material	Phenol	0.005mg/L	0.005mg/L	0.005mg/L	0.005mg/L	
		1.1.1-Trichloroethane	0.1mg/L	0.1mg/L	0.1mg/L	0.1mg/L	
		PCE; Tetrachloroethylene	0.01mg/L	0.01mg/L	0.01mg/L	0.01mg/L	
		TCE; Trichloroethylene	0.03mg/L	0.03mg/L	0.03mg/L	0.03mg/L	
		Dichloromethane	0.02mg/L	0.02mg/L	0.02mg/L	0.02mg/L	
		Benzene	0.01mg/L	0.01mg/L	0.01mg/L	0.01mg/L	
		Toluene	0.7mg/L	0.7mg/L	0.7mg/L	0.7mg/L	
		Ethylbenzene	0.3mg/L	0.3mg/L	0.3mg/L	0.3mg/L	
		Xylene	0.5mg/L	0.5mg/L	0.5mg/L	0.5mg/L	
		1.1 Dichloroethylene	0.03mg/L	0.03mg/L	0.03mg/L	0.03mg/L	
		Tetrachlorocarbon	0.002mg/L	0.002mg/L	0.002mg/L	0.002mg/L	
		1,4-dioxane	0.05mg/L	0.05mg/L	0.05mg/L	0.05mg/L	Applied starting from 2011

Classification		Water Quality Inspection Item	Tap Water	Spring Water	Deep Ocean Drinking Water	Drinking water from Community facility(mountain pond, etc.)	Remarks
Hazardous Inorganic Substances	Pesticide	Diazinon	0.02㎎/L	0.02㎎/L	0.02㎎/L	0.02㎎/L	
		Parathion	0.06㎎/L	0.06㎎/L	0.06㎎/L	0.06㎎/L	
		Fenitrothion	0.04㎎/L	0.04㎎/L	0.04㎎/L	0.04㎎/L	
		Carbaryl	0.07㎎/L	0.07㎎/L	0.07㎎/L	0.07㎎/L	
		1,2-Dibromo-3-Chloropropan	0.003㎎/L	0.003㎎/L	0.003㎎/L	0.003㎎/L	
	Disinfection Residues	Free Residual Chlorine	4.0㎎/L	-	-	-	
		THMs; Trihalomethanes	0.1㎎/L	-	-	-	
		Bromodichloromethane	0.03㎎/L	-	-	-	Applied starting from 2009
		Dibromochloromethane	0.1㎎/L	-	-	-	Applied starting from 2009
		Chloroform	0.08㎎/L	-	-	-	
		Chloralhydrate	0.03㎎/L	-	-	-	
		Dibromoacetonitrile	0.1㎎/L	-	-	-	
		Dichloroacetonitrile	0.09㎎/L	-	-	-	
		Trichloroacetonitrile	0.004㎎/L	-	-	-	
		HAA; Haloacetic acid	0.1㎎/L	-	-	-	
Materials that are Offensive to Human Sensory System		Hardness	300㎎/L	500㎎/L	500㎎/L	1,200㎎/L	
		Consumption of $KMnO_4$	10㎎/L	10㎎/L	10㎎/L	10㎎/L	
		Odor (except disinfection)	ND	ND	ND	ND	
		Taste (except disinfection)	ND	ND	ND	ND	
		Cu; Copper	1㎎/L	1㎎/L	1㎎/L	1㎎/L	
		Color	5 PCU	5 PCU	5 PCU	5 PCU	
		ABS; Alkyl Benzene Sulfate	0.5㎎/L	ND	ND	0.5㎎/L	
		pH	5.8~8.5	5.8~8.5	5.8~8.5	5.8~8.5	
		Zn; Zinc	3㎎/L	3㎎/L	3㎎/L	3㎎/L	
		Cl-; Chloride	250㎎/L	250㎎/L	250㎎/L	250㎎/L	
		Total Solids	500㎎/L	500㎎/L	500㎎/L	500㎎/L	
		Fe; Iron	0.3㎎/L	0.3㎎/L	0.3㎎/L	0.3㎎/L	
		Mn; Manganese	0.3 ㎎/L	0.3㎎/L	0.3㎎/L	0.3㎎/L	2011: 0.05㎎/L (only for tap water)
		Turbidity	0.5 NTU	1 NTU	1 NTU	1 NTU	
		SO_4^{+}; Sulfate	200㎎/L	200㎎/L	200㎎/L	200㎎/L	
		Al; Aluminum	0.2㎎/L	0.2㎎/L	0.2㎎/L	0.2㎎/L	
Water Purification Standard		Viruses	99.99% removed	-	-	-	
		Giardia lambia	99.9% removed	-	-	-	

Discharge Water Quality

Sewerage Treatment Facility

Standard Classification		BOD (mg/L)	COD (mg/L)	SS (mg/L)	T-N (mg/L)	T-P (mg/L)	Total Coliforms (No./mℓ)
Sewerage Act	Specific Areas	≤10	≤40	≤10	≤20	≤2	
	Other Area	≤20	≤40	≤20	≤60	≥8	≤3,000

Remarks

1. Of special management areas at the Han river watersheds, designated in accordance with article 22 of the Framework Act on Environmental Policy, the Paldang special countermeasure area for the protection of water quality and the Jamsil water reservoir shall be subject to the standard for the special management area since January 1st 2002.
2. The Han river watersheds (except for the Jamsil water reservoir) and the Nakdong /Geum/Youngsan/Sumjin river watersheds shall be subject to the standard for the special management area since January 1st 2004.
   However, they shall be subject to regional standards, if discharge water from sewerage treatment facilities does not inflow into major rivers and streams and there is no water supply facility at the discharge point in accordance with article 3(15) of the Water Supply & Waterworks Installation Act.
3. Regions excluding the areas subject to the standard for the special management zone shall follow regional standards, but shall be subject to the aforementioned special standard since January 1st, 2008.
4. Regarding total nitrogen and total phosphate, the areas subject to the standard for the special management zone shall follow regional standards in the winter season of December to March.
5. The standard for the number of coliforms shall be applied to all areas since January 1st, 2003. A more reinforced standard for discharge water, i.e., 1,000coliforms/ml shall be applied to the areas below.
   (1) Clean areas under annexed list 5 of enforcement regulations of the Water Quality Conservation Act.
   (2) The areas within 10km of upstream distance from water source protection areas and boundaries, in accordance with article 5 of the Water Supply and Waterworks Installation Act
   (3) The areas within 15km of upstream distance from water supply facilities, in accordance with article 3(15) of the Water Supply and Waterworks Installation Act

Wastewater Treatment Facility

Standard / Period	BOD (mg/L)	COD (mg/L)	SS (mg/L)	T-N (mg/L)	T-P (mg/L)	Total Coliforms (No./mℓ)
By Dec. 31, 2007	≤30(30)	≤40(40)	≤30(30)	≤60(60)	≤8(8)	-
Jan. 1, 2008.~Dec.31, 2012	≤20(30)	≤40(40)	≤20(30)	≤40(60)	≤4(8)	≤3,000
From Jan. 1, 2013	≤10(10)	≤40(40)	≤10(10)	≤20(20)	≤2(2)	≤3,000(3,000)

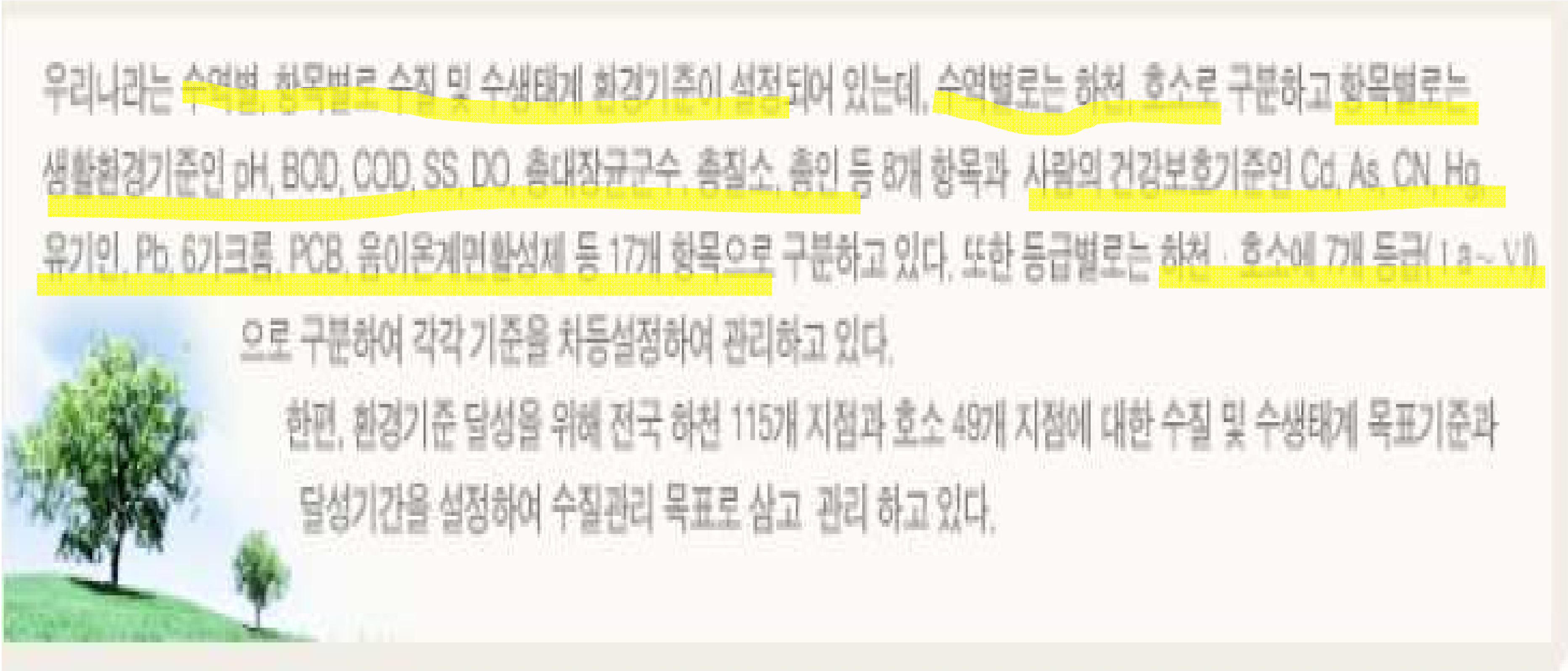
Remarks

1. The standards for water discharged from waste treatment facilities of industrial and agro-industrial complexes are decided and notified by the Minister of Environment, with a request from an operator of the aforementioned facility. Pollutants (e.g., phenol) which discharge water contains refer to ones which are treatable at the facilities within the permissible discharge standard applied to specific areas, in accordance with article 8, annexed list 5 (2) of the Water Quality Conservation Act.
2. The parentheses in the Table above show the standard for the quality of water discharged from the waste treatment facility at agro-industrial complexes.

Public Treatment Facility for Human/Livestock Waste

Standard Classification	BOD (mg/L)	COD (mg/L)	SS (mg/L)	Total Coliforms (No./mℓ)	Others (mℓ/L)
Human Waste Treatment Facility	≤30	≤50	≤30	≤3,000	T-N : ≤60 T-P: ≤8
Livestock Waste Treatment Facility	≤30	≤50	≤30	≤3,000	T-N: ≤60 T-P: ≤8

수질 및 수생태계 환경기준



우리나라는 수역별, 항목별로 수질 및 수생태계 환경기준이 설정되어 있는데, 수역별로는 하천, 호소로 구분하고 항목별로는 생활환경기준인 pH, BOD, COD, SS, DO, 총대장균군수, 총질소, 총인 등 8개 항목과 사람의 건강보호기준인 Cd, As, CN, Hg, 유기인, Pb, 6가크롬, PCB, 음이온계면활성제 등 17개 항목으로 구분하고 있다. 또한 등급별로는 하천 · 호소에 7개 등급(Ⅰa ~ Ⅵ)으로 구분하여 각각 기준을 차등설정하여 관리하고 있다.

한편, 환경기준 달성을 위해 전국 하천 115개 지점과 호소 49개 지점에 대한 수질 및 수생태계 목표기준과 달성기간을 설정하여 수질관리 목표로 삼고 관리 하고 있다.

Important water quality parameters

1. pH
2. BOD(Biochemical Oxygen Demand)
3. COD (Chemical Oxygen Demand)
4. SS (Suspended Solid)
5. DO
6. Total coliform
7. Total Nitrogen
8. Total Phosphorus

하천 – 생활환경기준 (7등급)

등급		상태 (캐릭터)	기 준					
			수소이온 농도(pH)	생물화학적 산소요구량 (BOD) (mg/L)	부유 물질량 (mg/L)	용존 산소량 (mg/L)	대장균군 (군수/100mL)	
							총 대장균군	분원성 대장균군
매우 좋음	Ia		6.5~8.5	1 이하	25 이하	7.5 이상	50 이하	10 이하
좋음	Ib		6.5~8.5	2 이하	25 이하	5.0 이상	500 이하	100 이하
약간 좋음	II		6.5~8.5	3 이하	25 이하	5.0 이상	1,000 이하	200 이하
보통	III		6.5~8.5	5 이하	25 이하	5.0 이상	5,000 이하	1,000 이하
약간 나쁨	IV		6.0~8.5	8 이하	100 이하	2.0 이상	–	–
나쁨	V		6.0~8.5	10 이하	쓰레기등이 떠있지 아니할것	2.0 이상	–	–
매우 나쁨	VI		–	10 초과	–	2.0 미만	–	–

호소 – 생활환경기준

등급		상태(캐릭터)	기 준								
			수소이온농도(pH)	생물화학적산소요구량(COD)(mg/L)	부유물질량(SS)(mg/L)	용존산소량(DO)(mg/L)	총인(T-P)(mg/L)	총질소(T-N)(mg/L)	클로로필-a(Chl-a)(mg/m³)	대장균군(군수/100mL)	
										총대장균군	분원성대장균군
매우 좋음	Ia		6.5~8.5	2 이하	1 이하	7.5 이상	0.01 이하	0.2 이하	5 이하	50이하	10이하
좋음	Ib		6.5~8.5	3 이하	5 이하	5.0 이상	0.02 이하	0.3 이하	9 이하	500 이하	100 이하
약간 좋음	II		6.5~8.5	4 이하	5 이하	5.0 이상	0.03 이하	0.4 이하	14 이하	1,000 이하	200 이하
보통	III		6.5~8.5	5 이하	15 이하	5.0 이상	0.05 이하	0.6 이하	20 이하	5,000 이하	1,000 이하
약간 나쁨	IV		6.0~8.5	8 이하	15 이하	2.0 이상	0.10 이하	1.0 이하	35 이하	–	–
나쁨	V		6.0~8.5	10 이하	쓰레기 등이 떠있지 아니할 것	2.0 이상	0.15 이하	1.0 이하	70 이하	–	–
매우 나쁨	VI		–	10 초과	–	2.0 미만	0.15 초과	1.5 초과	70 초과	–	–

BOD(Biochemical Oxygen Demand)

~ the amount of oxygen required by bacteria while stabilizing decomposable organic matter under aerobic conditions

1) organic matter can serve as food for bacteria
2) energy is derived from its oxidation

~ the most important water quality parameter in stream pollution control activities

~ generally discharge criteria ~ 20 mg/L

~ high BOD ➔ anaerobic conditions (H_2S, NH_3, H_2, CH_4)

~ the samples must be protected from the air to prevent reaeration in analysis

~ limited solubility of oxygen in water; 9 mg/L at 20℃ → dilution of samples is required

~ the presence of toxic substance ➔ not feasible

~ essential nutrients required for microbial growth ~ N &P, trace elements

~ a mixed group of organisms ➔ seeding

BOD(Biochemical Oxygen Demand)

※ Aerobic Decomposition

$Organic\ matter + O_2 \rightarrow CO_2 + H_2O + new\ cells + stable\ products\ (NO_3\ ,\ PO_4,\ SO_4, \ldots)$

※ Anaerobic Decomposition

$Organic\ matter \rightarrow CO_2 + H_2O + New\ cells + unstable\ products\ (H_2S,\ NH_3,\ CH_4, \ldots)$

- **CBOD** (carbonaceous oxygen demand)
- **NBOD** (nitrogenous oxygen demand)

The quantitative relationship between carbon content and oxygen consumption

$$C_nH_aO_bN_c + \left(n + \frac{a}{4} - \frac{b}{2} - \frac{3}{4}c\right)O_2 \longrightarrow nCO_2 + \left(\frac{a}{2} - \frac{3}{2}c\right)H_2O + cNH_3$$

~ it is possible to interpret BOD data in terms of organic matter which the amount of oxygen is used during its oxidation

~ this concept is fundamental to an understanding of the rate at which BOD is exerted

~ microbial activity - population numbers, temperature 20℃, 5 days

- 20 days for complete consumption

a reasonably large % of total BOD - 5-day BOD

~ 70-80% of the total BOD

~ minimize interferences from ammonia oxidation

The Nature of the BOD reaction

$$\frac{-dC}{dt} \propto C \qquad \frac{-dC}{dt} = kC$$

1st order equation

C : the concentration of oxidizable organic matter (pollutants) for BOD consideration

$$\frac{-dC}{dt} \propto kL$$

L_o : the ultimate demand (mg/L)

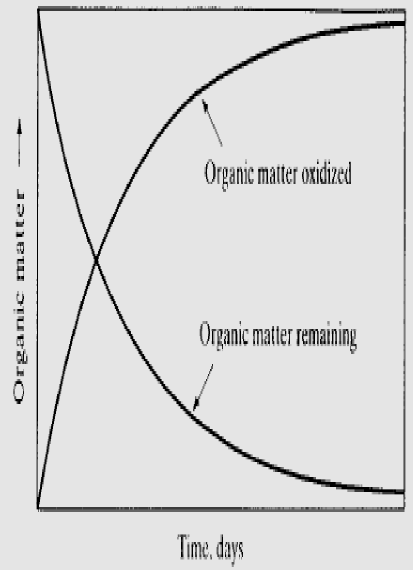


FIGURE 5.10 Two equivalent ways to describe the time dependence of organic matter in a flask.

$e^{-2.303Kt}$

$$\boxed{\frac{L_t}{Lo} = e^{-kt} = 10^{-Kt}}$$

$$K = 2.303 / k$$

$$L_t = L_o\,(10^{-Kt})$$

Meaning? ~ the amount of pollutants (demand) remaining after any time t has elapsed

is a fraction of L corresponding to 10^{-Kt} ~ BOD that has not exerted “

Environmental engineer ~ interested in the BOD exterted

Then, what is BOD exerted ($y = BOD_t$) ?

$$y = BOD_t = Lo - \underset{(= L_t)}{\underline{L\,o \cdot 10^{-Kt}}} = Lo(1-10^{-Kt})$$

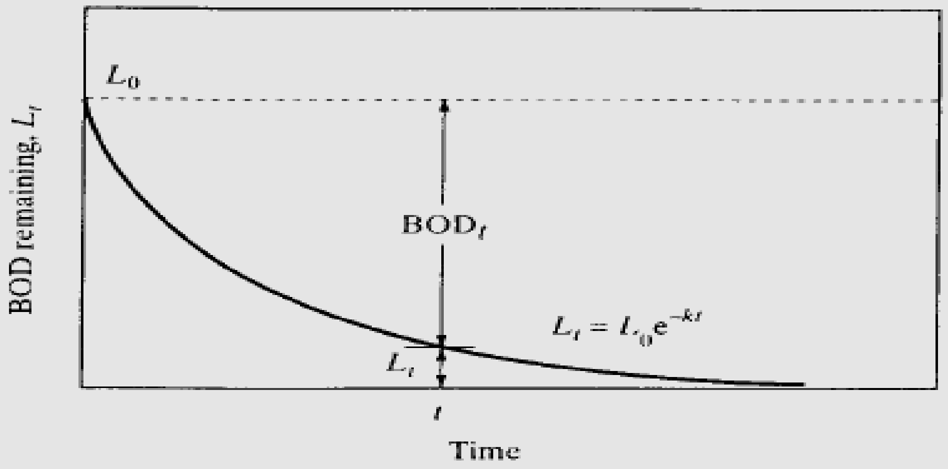
$$\frac{dL_t}{dt} = -kL_t$$

$$L_t = L_0 e^{-kt}$$

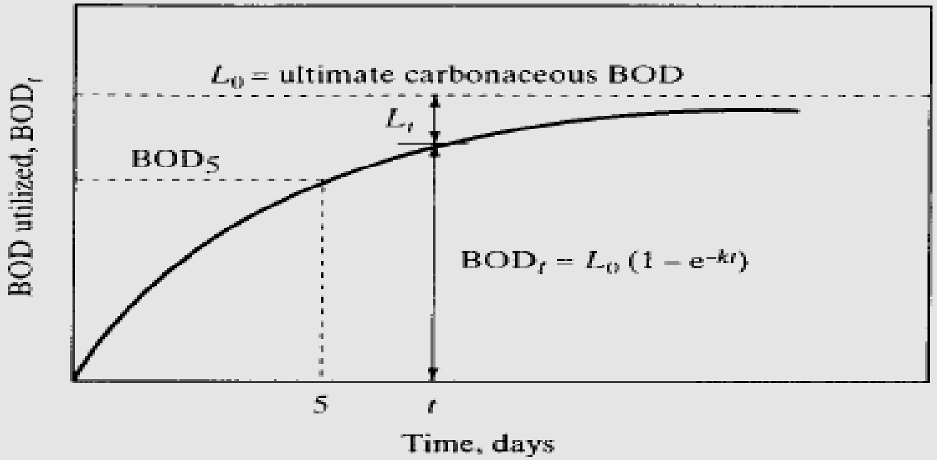
$$L_0 = BOD_t + L_t$$

$$BOD_t = L_0 (1 - e^{-kt})$$

$$k = K \ln 10 = 2.303 K$$

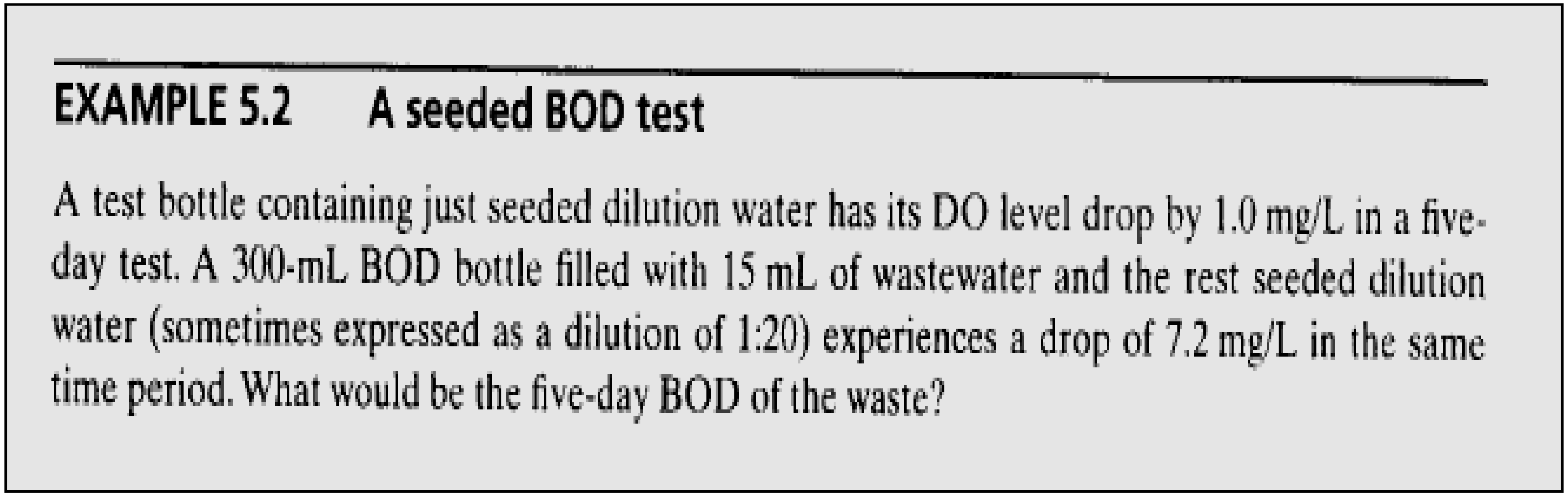


(*a*) BOD remaining



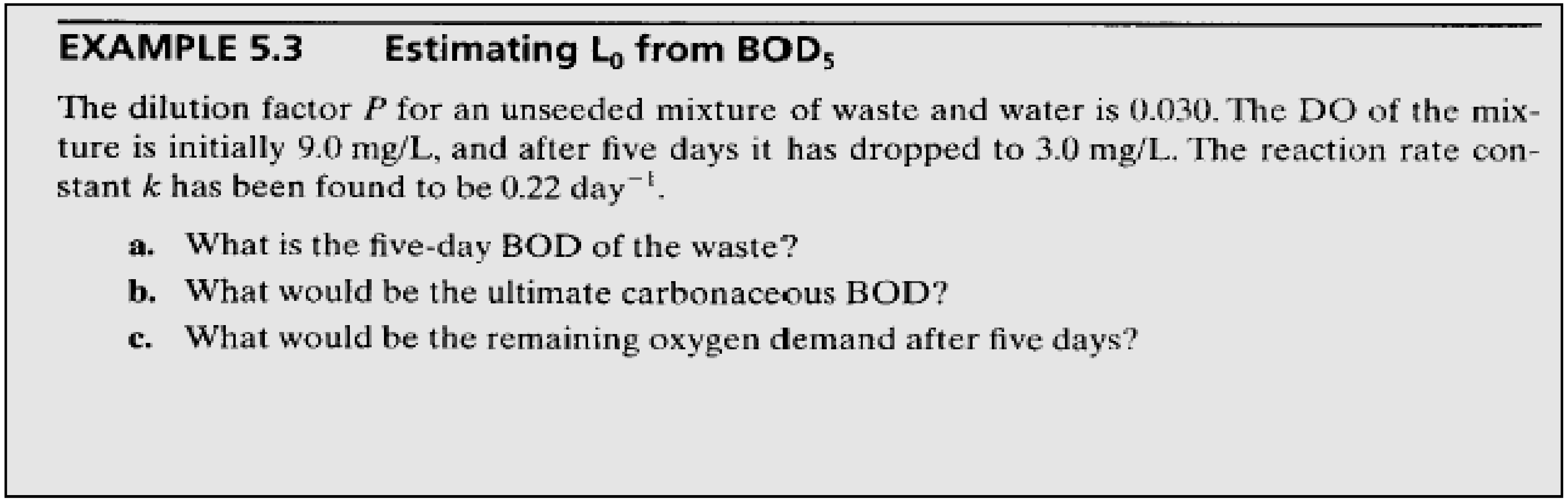
(*b*) BOD utilized

FIGURE 5.11 Idealized carbonaceous oxygen demand: (*a*) The BOD remaining as a function of time, and (*b*) the oxygen already consumed as a function of time.



EXAMPLE 5.2 A seeded BOD test

A test bottle containing just seeded dilution water has its DO level drop by 1.0 mg/L in a five-day test. A 300-mL BOD bottle filled with 15 mL of wastewater and the rest seeded dilution water (sometimes expressed as a dilution of 1:20) experiences a drop of 7.2 mg/L in the same time period. What would be the five-day BOD of the waste?



EXAMPLE 5.3 Estimating L_0 from BOD_5

The dilution factor P for an unseeded mixture of waste and water is 0.030. The DO of the mixture is initially 9.0 mg/L, and after five days it has dropped to 3.0 mg/L. The reaction rate constant k has been found to be 0.22 day^{-1}.

a. What is the five-day BOD of the waste?

b. What would be the ultimate carbonaceous BOD?

c. What would be the remaining oxygen demand after five days?

The BOD reaction rate constant k

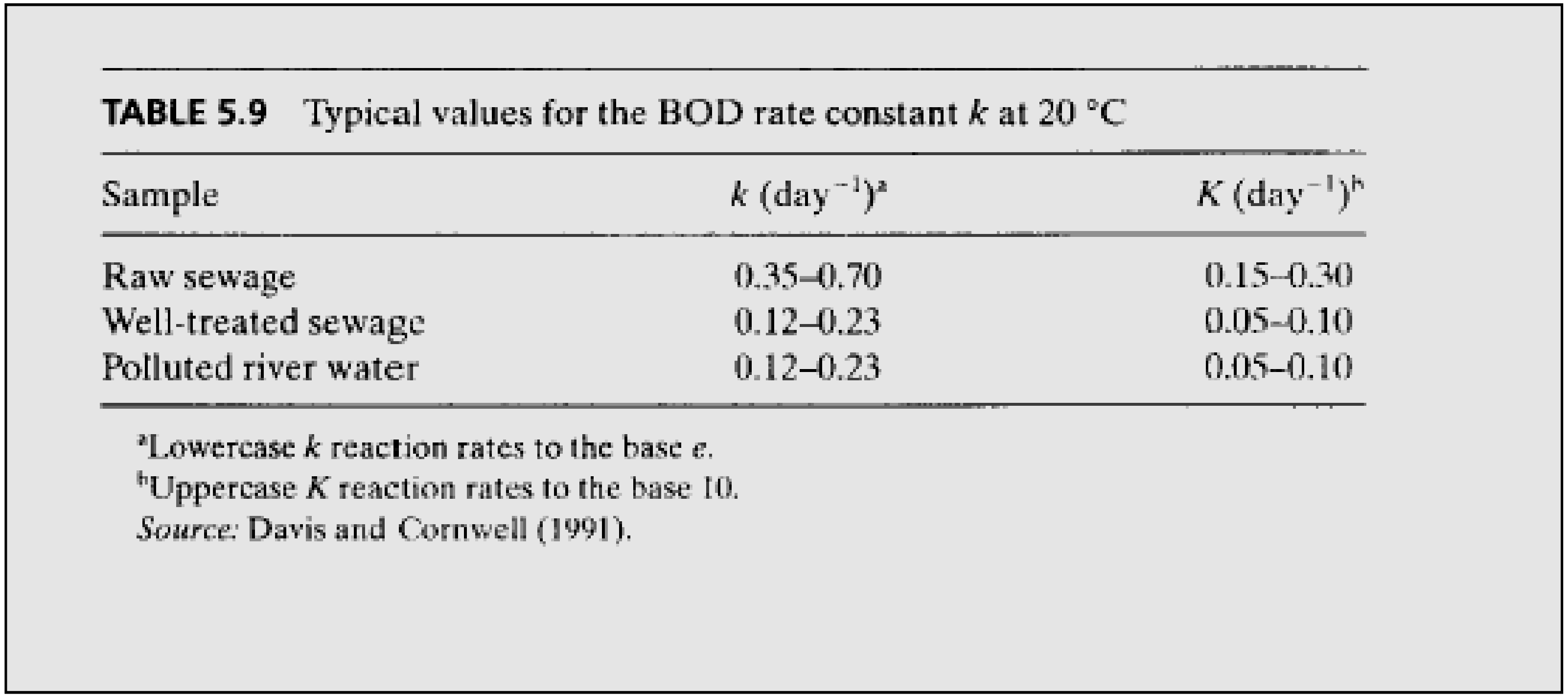


TABLE 5.9 Typical values for the BOD rate constant *k* at 20 °C

Sample	k (day^{-1})[a]	K (day^{-1})[b]
Raw sewage	0.35–0.70	0.15–0.30
Well-treated sewage	0.12–0.23	0.05–0.10
Polluted river water	0.12–0.23	0.05–0.10

[a] Lowercase *k* reaction rates to the base *e*.

[b] Uppercase *K* reaction rates to the base 10.

Source: Davis and Cornwell (1991).

$$k_T = k_{20}\theta^{(T-20)}$$

TABLE 22–1

BOD measurable with various dilutions of samples

Using percent mixtures		By direct pipeting into 300–ml bottles	
% mixture	Range of BOD	ml	Range of BOD
0.01	20,000–70,000	0.02	30,000–105,000
0.02	10,000–35,000	0.05	12,000–42,000
0.05	4,000–14,000	0.10	6,000–21,000
0.1	2,000–7,000	0.20	3,000–10,500
0.2	1,000–3,500	0.50	1,200–4,200
0.5	400–1,400	1.0	600–2,100
1.0	200–700	2.0	300–1,050
2.0	100–350	5.0	120–420
5.0	40–140	10.0	60–210
10.0	20–70	20.0	30–105
20.0	10–35	50.0	12–42
50.0	4–14	100	6–21
100	0–7	300	0–7

TABLE 22–2

Significance of reaction rate constant *k* upon BOD

Time days	Percent of total BOD exerted				
	k = 0.05	*k* = 0.10	*k* = 0.15	*k* = 0.20	*k* = 0.25
1	11	21	29	37	44
2	21	37	50	60	68
3	29	50	64	75	82
4	37	60	75	84	90
5	44	68	82	90	94
6	50	75	87	94	97
7	55	80	91	96	98
10	68	90	97	99	99+
20	90	99	99+	99+	99+

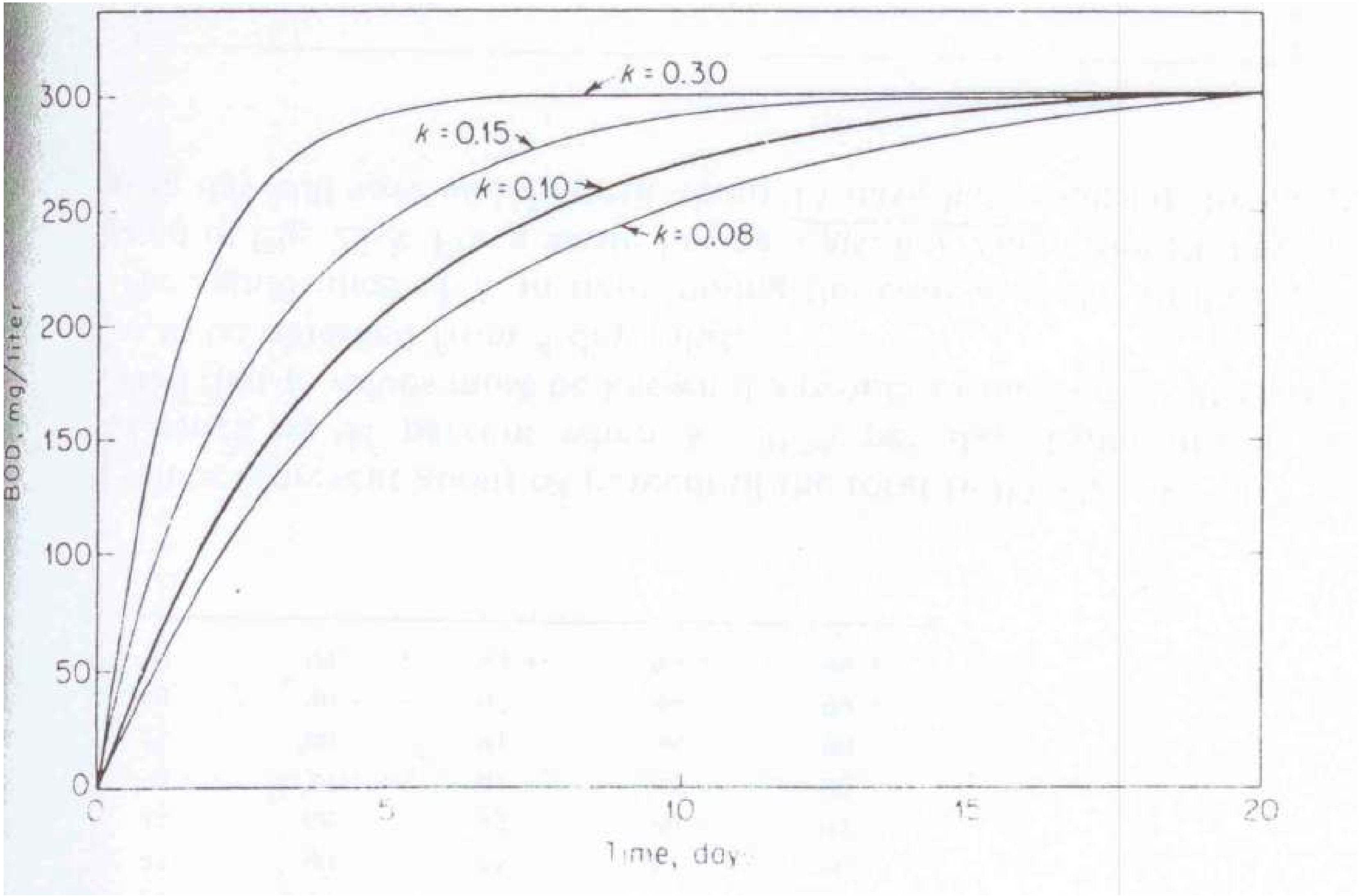


FIGURE 22-3

Effect of rate constant *k* on BOD (for a given *L* value)

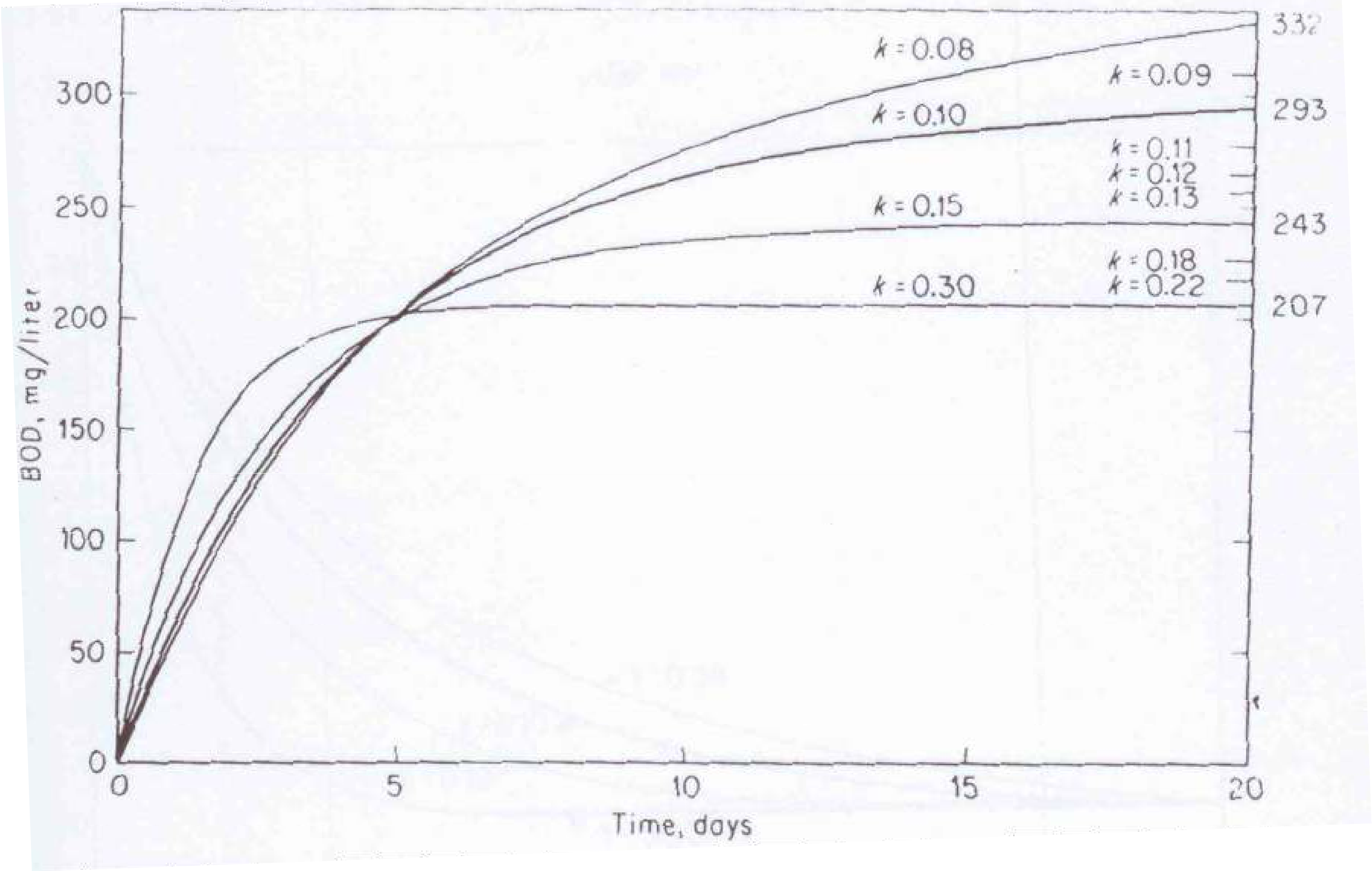
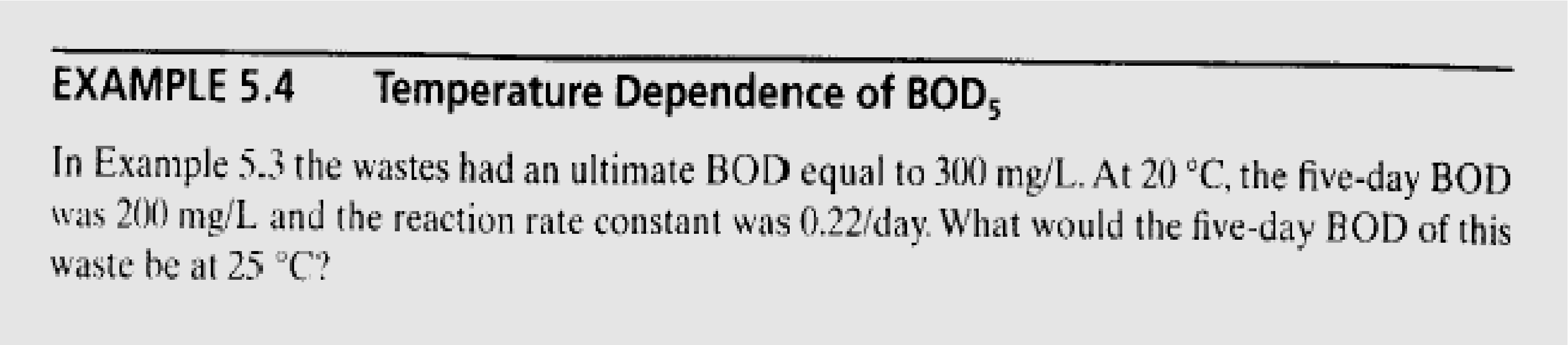


FIGURE 22-4

Effect of rate constant *k* on ultimate BOD (based on assumed 5-day Bod of 200mg/l).



EXAMPLE 5.4 Temperature Dependence of BOD_5

In Example 5.3 the wastes had an ultimate BOD equal to 300 mg/L. At 20 °C, the five-day BOD was 200 mg/L and the reaction rate constant was 0.22/day. What would the five-day BOD of this waste be at 25 °C?

Nitrification

- $2NH_3 + 3O_2 \xrightarrow[\textit{Nitrosomonas}]{} 2NO_2^- + 2H^+ + 2H_2O$

- $2NO_2^- + O_2 \xrightarrow[\textit{Nitrobacter}]{} 2NO_3^-$

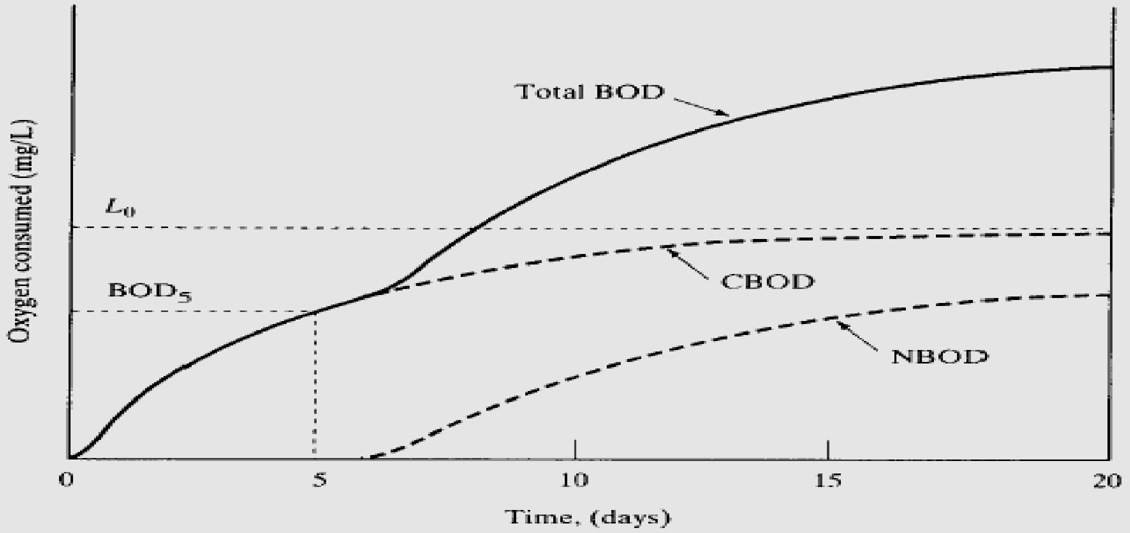


FIGURE 5.13 Illustrating the carbonaceous and nitrogenous biochemical oxygen demand. Total BOD is the sum of the two.

Nitrifying bacteria do not exert an appreciable demand for oxygen until about 8 to 10 days have elasped in regular BOD test.

- serious error into BOD measurement
- BOD_5 ➔ the basis for 5-day incubation period chosen

-in untreated domestic wastewater/the effluent from biological treatment units

- inhibiting agent (2-chloro 6-(trichloro methyl)pyridine , TCMP)
- How about algal growth? → 정확한 BOD 측정의 어려움

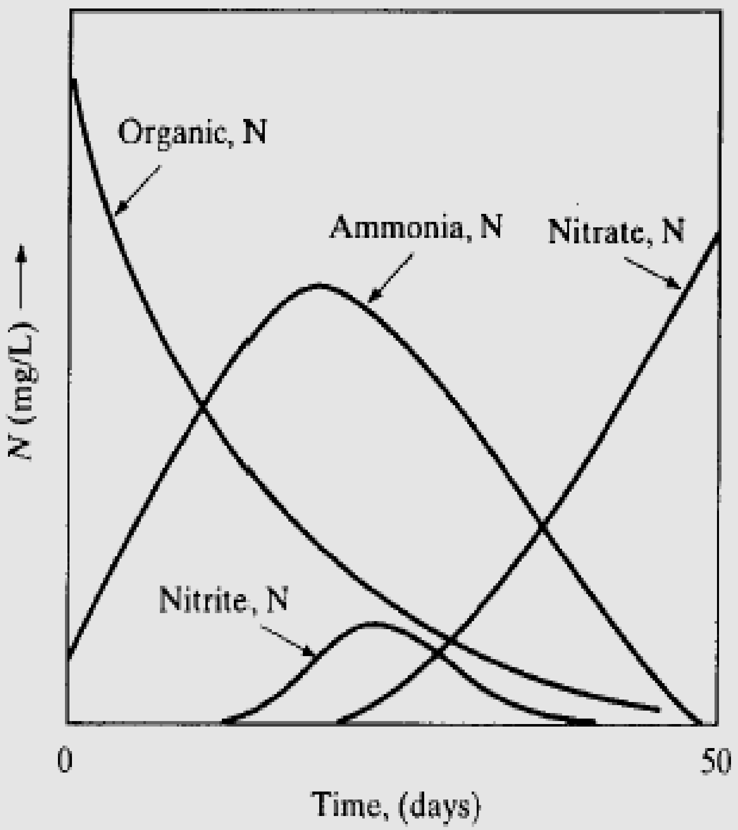
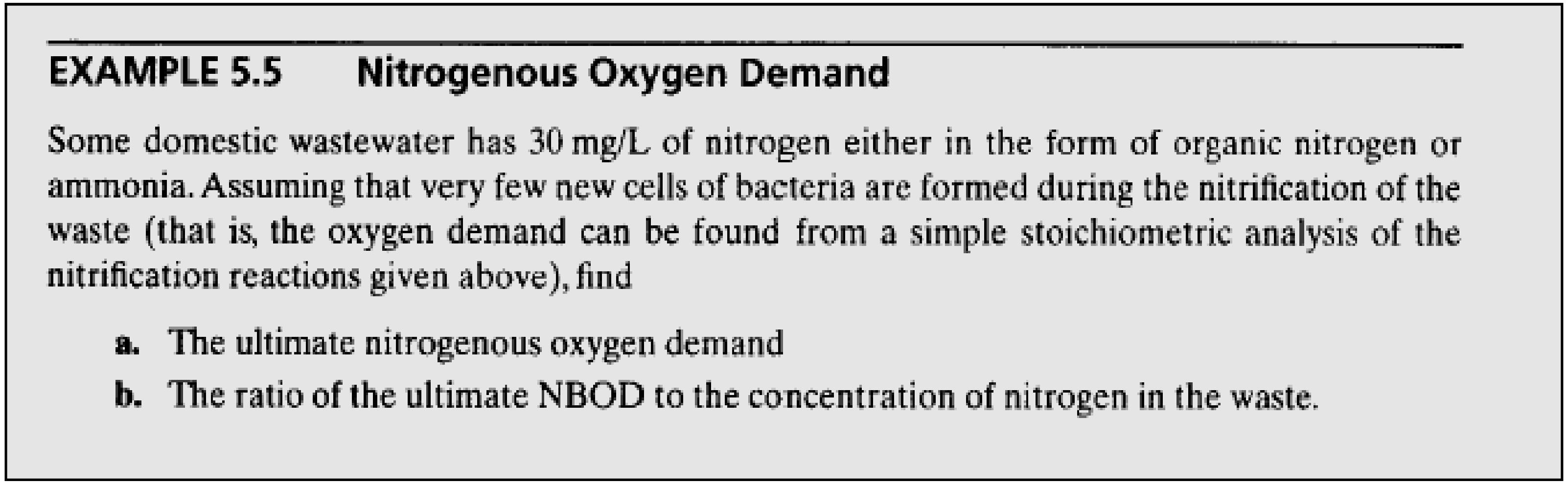


FIGURE 5.12 Changes in nitrogen forms in polluted water under aerobic conditions. (*Source*: Sawyer and McCarty, *Chemistry for Environmental Engineers*, 4th ed., © 1994. Reprinted by permission of McGraw-Hill, Inc.)



EXAMPLE 5.5 Nitrogenous Oxygen Demand

Some domestic wastewater has 30 mg/L of nitrogen either in the form of organic nitrogen or ammonia. Assuming that very few new cells of bacteria are formed during the nitrification of the waste (that is, the oxygen demand can be found from a simple stoichiometric analysis of the nitrification reactions given above), find

a. The ultimate nitrogenous oxygen demand

b. The ratio of the ultimate NBOD to the concentration of nitrogen in the waste.

5-day BOD Test; BOD_5

: The total amount of oxygen consumed by microorganisms during the first five days of biodegradation at 20 C

$$BOD_5 = \frac{DOi - DOf}{P}$$

$$P = the \ dilution \ fraction = \frac{volume \ of \ wastewater}{volume \ of \ wastewater \ plus \ dilution \ water}$$

DO_i =*the initial dissolved oxygen (DO) of the diluted wastewater*

DO_f= *the final DO of the diluted wastewater, 5 days later*

Rate of Biochemical Oxidations

BOD reaction rate constant ~ 0.1day^{-1} at 20℃
polluted river waters and domestic wastes in the United States and England.

the analysis of industrial wastes ➔ the use of synthetic dilution waters
→ K values considerably in excess of 0.10 day^{-1}
an appreciable variation for different waste materials
K values for effluents from biological waste treatment
~ significantly lower than that of the raw waters.

Table 22.2 Figure 22-3 & Figure 22-4

=> ① the nature of the organic matter
② the ability of the microrganism present to utilize the organic matter

~ varies greatly in chemical character and availability to micro organism

~ readily available

~ must await nydrolytic action and diffusion

~ colloidal and coarse suspension

~ the most important factor in controlling the rate of the reaction

glucose K ~ high

more complex material K ~ low

(lignin)

lag period ~ particularly those containing organic compounds of synthetic origin

seeding ; a properly acclimated seed is needed, ~ lack of proper enzyme system

Discrepancy between L values and theoretical oxygen demand values.

total BOD = theoretical oxygen demand (?)
(L)

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$
180 192

If glucose 300 mg/L → BOD 320mg/L 예상
실제 250~285 20 day
85% of the theoretical amount

(part of organic matter is converted to cell tissue)
(Living bacteria serve as food material)
(a non biodegradable matter)

Discrepancy between observed rates and 1st order rates.

Carbonaceous BOD → two phases (Fig 2-22)

~ the secondary action of protozoa

1~2 days ~ rapid consumption by bacteria

of soluble organic material

30~50% is oxidized

the remainder is converted to bacterial cells plateau ~ a reduced rate of oxidation occurs

~ endogenous respiration phase of bacterial metabiolism

-> BOD data

-> However, do not invalidate the use of “first-order” kinetics

within a day or two a secondary rise in the rate of oxidation occurs and is attributed to a rise in the population of protozoa.

Application of BOD data

~ application in environmental engineering pratice

~ water criteria

~ Stream pollution control

Chemical Oxygen Demand; CODcr

~ a measure of the oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant.

물속의 유기물이 정해진 농도의 산화제에 의해 산화될 때 소모되는 산소의 양

~ dichromate reflux method

95~100% of the theoretical value

~ pyridine

~ volatile organic acids.

~ Ammonia(?)

~ always CODcr > BODs

~ Advantage vs. Disadvantage ; COD Analysis

Open reflux method ~ popular

Closed reflux method ~ economical

화학적 산소요구량 (COD)

- 물속에 있는 유기물을 강한 산화제를 이용하여 산화 가능한 유기물을 화학적으로 산화시킨 후 소모된 산소 요구량 산정

  유기물 + $Cr_2O_7^{2-}$ + H^+

  Cr^{3+} + CO_2 + H_2O

- 미생물의 성장에 유해한 독성물질이 함유되어 있는 산업폐수나 도시하수 중 유기물의 측정에 사용됨
- 일반적으로 COD > BOD : 생물학적으로 산화되는 화합물보다 화학적으로 산화되는 화합물이 더 많기 때문
- 3시간 정도에 측정이 가능해 BOD가 5일인 것에 비해 유용한 경우가 많다.

$K_2Cr_2O_7$

Organic decompostion by Potassium Chromate

$$C_6H_{12}O_6 + \boxed{4\ K_2Cr_2O_7} + 16\ H_2SO_4 \rightarrow 4\ Cr_2(SO_4)_3 + 4\ K_2SO_4 + 6\ CO_2 + 22\ H_2O$$

oxidant

(Measurement of Excess Oxidizing Agent)

FAS (Ferrous Ammonium Sulfate)에 의한 중크롬산의 환원

$Fe(NH_4)_2(SO_4)_2 \cdot 6H_2O$

$$Cr_2O_7^{2-} + 14H^+ + 6Fe^{2+} \dashrightarrow 2Cr^{3+} + 6Fe^{3+} + 7H_2O$$

reductant

$$CH_2O + O_2 \rightarrow CO_2 + H_2O$$

$$C_6H_{12}O_6 + \boxed{6O_2} \rightarrow 6CO_2 + 6H_2O$$

p.547

$$CnHaObNc + dCr_2O_7^{2-} + (8d + c)H^+ \xrightarrow[\Delta]{} nCO_2 + \frac{a + 8d - 3c}{2} H_2O + cNH_4^+ + 2dCr^{3+}$$

$$d = (2n/3 + a/6 + b/3 + c/2)$$

Indicator

~ a very marked change in ORP occurs at titration

~ Ferroin (ferrous 1, 10-phenanthroline)

 ~ a very sharp brown color change

Alternative Procedure for Low COD samples

~ accurate and precise for 50 mg/L or greater

for more dilute samples ➔ preferred for a diluted dichromate solution

~ maintain the volume of conc H_2SO_4 to volume of sample plus dichromate solution (1:1)

if it is smaller,

if it is larger,

Methods to Reduce Haz Waste Generation

~ COD test generate a large volume of liquid haz waste

~ spent sol’m must be stored, packaged, and disposed into approved haz waste storage sites.

~ close-reflux method

(smaller sample and reagent volumes)

~ Use lower ferrous ammonium sulfate titrant

~ colorimetric method rather than volumetric titration

Cr(Ⅳ)(orange) ---→ Cr(Ⅲ) Blue

Open Method		Closed Method
Sample 양	50	10
$K_2Cr_2O_7$	10	5
H_2SO_4	30 $\left(\frac{N}{40}\right)$	15
FAS	0.25	0.025
	“페로인” 녹색 -> 적갈색	

Interference by chloride (Cl^-)

$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$ E° = 1.33V

$Cl_{2(aq)} + 2e^- \rightarrow 2Cl^-$ E° = 1.39V

$6Cl^- \rightarrow 3Cl_{2(aq)} + 6e^-$ E° = -1.39V

$6Cl^- + Cr_2O_7^{2-} + 14H^+ \rightarrow 3Cl_2 + 2Cr^{3+} + 7H_2O$ E° = -0.06V

$E<0 \quad E = E° - \frac{RT}{nF}\ \ell nQ$

$E° = \frac{2.3RT}{nF}\ \log Q$ T = 273 + 100 (100℃)

$\fallingdotseq 0.012 \log Q$ R = 1.98Cal deg^{-1} mol^{-1}

F = 23060 Cal vol^{-1}

Q = 10^{-5} n = 6

$$Q = \frac{[Cl_2]^3[Cr^{3+}]^2}{[Cl^-]^6[Cr_2O_7^{2-}][H^+]^{14}} = 10^{-5}$$

$$[H+] = H_2SO_4\ 27\ mL \times 36N \times \frac{[H^+]/M}{H_2SO_4/N} \times \frac{1}{62mL} \fallingdotseq 15.68M$$

$$[Cr_2O_7^{2-}] = (0.25eq/L) \times 10mL \times (mole/3eq)(\frac{1}{62mL}) = 0.0134M$$

평형점에서 75% 의 중크롬산이 남는다고 가정하면

$[Cr_2O_7^{2-}]= 0.0134 \times 0.75M = 0.01M$ $[Cr^{3+}] = 0.01 \times 2M$

$$\frac{[Cl_2]}{[Cl^-]^2} \fallingdotseq 311562$$

* 중크롬산보다 환원전위가 큰 물질은 환원형
" 낮은 " 산화형으로.

Calculation

COD as mg O2/L = $\frac{(A-B)\times M\times 8000}{50mL\ sample}$

A : mL FAS used for blank

B : mL FAS used for sample

M : FAS의 molarity

FAS titrant – 0.25M

NV = N′V′

$$N = \frac{N'V'}{V}$$

$6O_2 : 4K_2Cr_2O_7$

$K_2Cr_2O_7 : 6Fe2+ \equiv 6FAS$

$$4\times\frac{1}{24}=\frac{1}{6}$$

$$\frac{1}{4}\ O_2 : \frac{1}{6}\ K_2Cr_2O_7$$

$$\frac{1}{6}\ K_2Cr_2O_7 : Fe^{2+}$$

$$= (A\text{-}B)\cdot M \times \frac{1}{4} \times 32 \times \left(\frac{1000L}{50mL}\right)$$

$$= \frac{(A-B)\cdot M\cdot 8000}{50mL\ sample}$$

Open Reflux acid

- principle ~ by a boiling mixture of chromic and sulfuric acid
  ~ 2h reflux time
  ~ titrate with FAS $FeSO_4(NH_4)_2\ SO_4 \cdot 6H_2O$
- Titration – ferroin indicator
  1.485g 1.10 phenanthroline monohydrate 695 mg $FeSO_4$
  -> 100mL

take end point blue green to reddish brown

Interferences and Limitations

Volatile straight-chain aliphatic compounds

- ➔ volatiles organics are present in the vapor phase
- ➔ add Ag_2SO_4 (“as a catalyst”)

  Ag^+이 용존하면 $KMnO_4$용액과 반응하여 오차!!

However, $$Ag_2SO_4 + \begin{matrix} Cl\text{-} \\ Br\text{-} \\ I\text{-} \end{matrix} \longrightarrow \text{precipitate} \left(\begin{matrix} AgX \\ AgCl \\ AgBr \\ AgI \end{matrix} \right.$$

➔ $HgSO_4$를 첨가!!!(Cl^-와 complexation)

➔ NO_2^- exerts a COD 1.1 mg O_2/mg NO_2^- - N

$$= \frac{16 \leftarrow \frac{1}{2}O_2}{14 \nwarrow NO_2\text{-}N}$$

$$NO_2^- + \frac{1}{2}O_2 \dashrightarrow NO_3^-$$

46 : 16

add 10mg sulfamic acid for each mg NO_2^- - N

-Fe^{2+} , S^{2-}, manganous manganese

~ 방해물질

COD_{Mn}

원리 : 산성조건(황산)에서 과망간산칼륨($KMnO_4$)를 이용하여 유기물을 분해, 소비된 과망간산칼륨으로 부터 이에 상응하는 산소의 양을 측정.

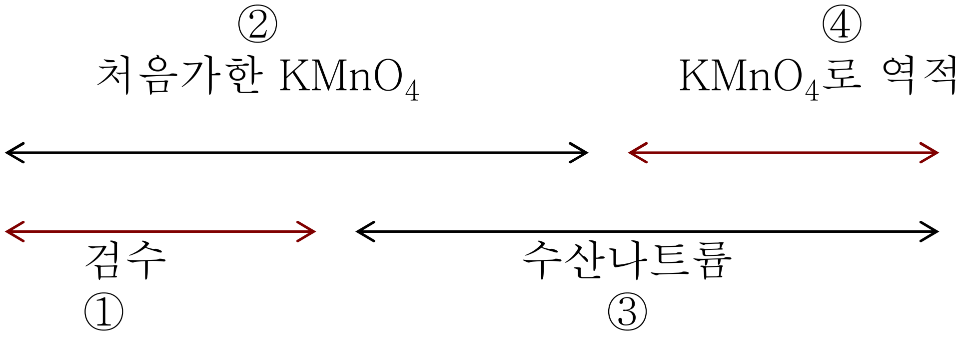
산성용액

$MnO_4^- + 8H^+ + 5e \rightleftarrows Mn^{2+} + 4H_2O$

$2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \rightleftarrows 2Mn^{2+} + 10CO_2 + 8H_2O$

과잉의 $C_2O_4^{2-}$를 과망간산칼륨의 표준용액으로 역적정

COO$^-$
|
COO$^-$



계산방법

(0.025 × 8)

$$\text{COD(mg/L)} = (b\text{-}a) \cdot f \cdot \frac{1000}{V} \cdot 0.2$$

a ; 바탕시험 적정에 소비된 0.025N $\left(\frac{1}{40}\right)$KMnO4 (㎖)

b ; 시료의 적정에 소비된 " (㎖)

f ; 0.025N $KMnO_4$ 역가

V ; 시료의 양

$NV = N'V'$ $\frac{1}{8} = 0.125$ N

$\frac{1}{40} = 0.025$ N

(주의사항)

① 30분 가열반응 후 과망간산 칼륨이 양 50~70% 남도록

Cf. CODcr과 비교!

② 염소이온에 대한 황산은 당량은 0.9g

200mg Ag_2SO_4

Cl^- Ag_2SO_4

200mg

MW 35.5

312

$2Cl^- + Ag_2SO_4 \rightarrow 2AgCl + SO_4^{2-}$

③ 적정시 온도의 유지(60~80%)

$KMnO_4$의 용액자기분해

④ 무색 → 엷은 홍색

$C_6H_{12}O_6 + 6H_2O \rightarrow 6CO_2 + 24H^+ + 24e^- \times 5$

$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O \times 24$

$5C_6H_{12}O_6 + 30H_2O \rightarrow 30CO_2 + 120H^+ + 120e^-$

$24MnO_4^- + 192H^+ + 120e^- \rightarrow 24Mn^{2+} + 96H_2O$

$5\ C_6H_{12}O_6 + 24MnO_4^- + 30H_2O + 192H^+$

$\rightarrow 30CO_2 + 96H_2O + 24Mn^{2+} + 120H^+$

$-24 + 192 = +48 + 120$

$168 = 168$