For Environmental Seminar in EiMAS

Introduction of water pollution control

March 11, 2011

Japan Environmental Management Association for Industry (JEMAI)

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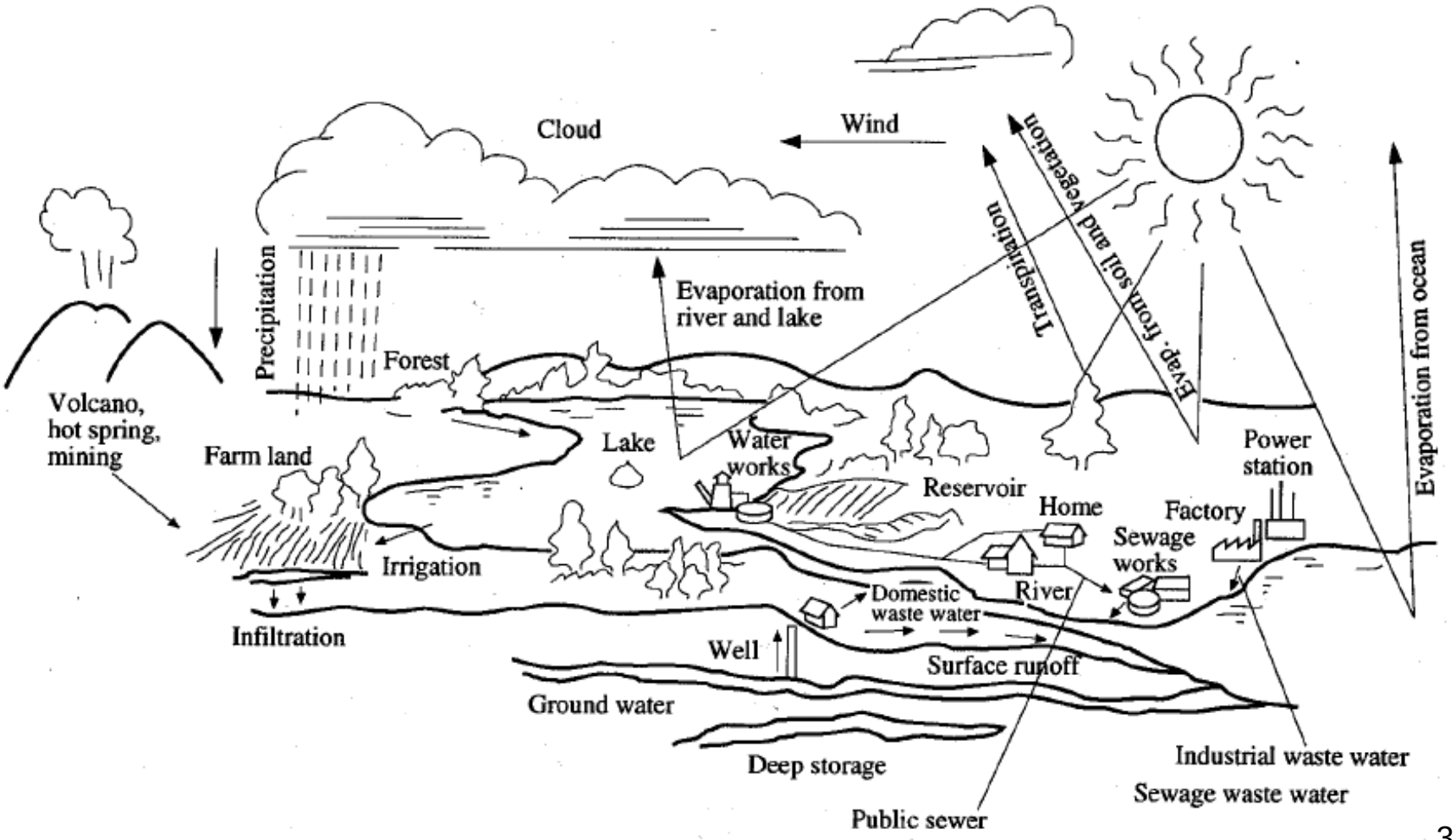
Water circulation in nature



Water balance in the earth

	$km^3=10^9m^3$	%
Saline water :		
Sea	1349929000	97.50
Brackish water lake	94000	0.007
Fresh water :		
Ice	24230000	1.75
Fresh water lake	125000	0.009
River	1200	0.0001
Soil water	25000	0.002
Underground water		
(shallow layer)	4500000	0.72
(deep layer)	5600000	
Water vapor	12600	0.001
Biological water	1200	0.0001
	1384518000 km^3	

(from Han'ya-Otake : Environmental Graphic Book of Japan (1978))

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Classification of Water Pollutants and Their Characteristics (1/2)

Kind of pollution	Water quality index (item of measurement)	Polluting material	Main polluting source	Characteristic of pollution and other notes	Main treating method
Organic matter	BOD, COD, TOC, Ignition loss	Starch, sugar, protein, oil and fat ; petroleum, synthetic organic chemicals	Industry (almost all industries; especially, food processing, pulp, petroleum, chemical, fermentation) ; livestock raising ; urban sewage; domestic waste water, human manure	As a whole, organic matter is decomposed by being eaten by aerobic microorganisms ; at this moment, dissolved oxygen is consumed and it sometimes results oxygen deficiency of aquatic zone	Biological treatment (activated sludge process, etc.)
Muddiness	Suspended solid (SS) Turbidity	Inorganic SS, Organic SS	Industry (especially, ceramics, paper, pulp, food processing, stonequarrying, mining), construction works, natural phenomena (flood)	Little effect at low pollution; breathing trouble for fish and interference for photosynthesis of aquatic plants at high pollution	Filtration, Sedimentation separation
Oil	Hexane extractable matter, carbon tetrachloride extractable	Mineral oil	1) Mineral oil (petrochemical; machinery, iron and steel; oil leakage from ship)	Accidental big pollution is caused by wreckage of oil tanker	Oil-water separation (pressurized flotation); biological treatment
		Vegetable and animal oil and fat	2) Biological oil and fat (food, oil & fat industry, urban sewage, human manure)		
Acid and alkali	pH	Sulfuric acid , hydro chloric acid, calcium hydroxide, caustic soda	Electroplating, inorganic industry, iron and steel mill, leather manufacture		Neutralization
Toxic substance (inorganic)	1) Heavy metal ion	Hg, Cd, Pb, Cr, Zn, Cu, As, etc.	Metal mining, electroplating, inorganic chem., glass, organic synthesis (catalyst)	It is sometimes concentrated in a specific internal organ when it is ingested; and it is also concentrated through food chain	Precipitation, Coagulation, Ion-exchange
	2) Non-metals (cyanide, fluorine, etc.)		1) Cyanide (Electroplating, synthetic chemistry) 2) Fluoride (aluminum, glass, chemical fertilizer)		Cyanide: alkaline oxidation Fluorine etc.: chemical reactions

Classification of Water Pollutants and Their Characteristics (2/2)

Kind of pollution	Water quality index (item of measurement)	Polluting material	Main polluting source	Characteristic of pollution and other notes	Main treating method
Toxic substance (organic)	Organic phosphorus, organochlorine compound, organometallic compound	Organophosphorus pesticide, DDT, BHC, PCB, trichloroethylene, etc.	Pesticide, Industrial chemical, plasticizer, plastic monomer, organic solvents for electronic industry		Adsorption
Nutrient	Nitrogen compounds (NH_4^-, NO_2^-, NO_3^-, organic and total nitrogen); phosphoric acid	Protein, chemical fertilizer, synthetic detergent	Urban sewage, human manure and other domestic wastes, organic detergent, agriculture, livestock raising, industry (food processing & chemical industry etc.)	It causes the eutrophication of aquatic area (especially, lakes and closed bay)	Nitrogen: biological denitrification Phosphorus: coagulation
Color	Color	Pigment and dyestuff; lignin, humic acid, melanine	Industry (pulp, dyeing of fabric and leather, food processing); urban sewage		Adsorption
Offensive odor	Odor (olfactometric measure) gas chromatography	Phenol, ammonia, sulfur dioxide, amines, lower fatty acids, mercaptan	Industry (chemistry, petroleum refinery, food, leather); sewage, human manure	12 chemical substances are specified in Offensive Odor Control Law.	
Heat	Water temperature	Cooling water	Thermal power station, oil refinery, pulp mill, steel mill, chemical ind.		
Pollution of bottom sediment	Solution test Biotic test	Org. & inorg. mud; Heavy metals, residual pesticide, PCB	Flooding of earth & sand industry, domestic waste		Dredging
Microbes	Coliform bacteria test & other microbiological test	Coliform and pathogenic bacteria	Urban sewage, human manure, livestock raising		Sterilization
Soluble inorganic substance	Electric conductivity, evaporation residue, hardness test	Various inorganic ions	Elution of soil and rock, inorganic chemical indust, ceramics, mining	"Hard water" is a kind of natural water containing inorganic salts such as bicarbonates of Ca and Mg.	Ion exchange

Characteristics of waste water of main industries

(1) Food Industry

① High concentration of organic matters
② High concentration of semi-solid waste and floating substances
③ Big seasonal fluctuations
④ Large volume of washing water (hot and cold) for hygienic reason.
⑤ No harmful substances such as heavy metals.
⑥ High contents of oil, nitrogen and phosphorus.
⑦ Starch and brewage production release particularly high BOD.
⑧ Sludge from waste water treatment is changed to manure and forage.

(2) Textile Industry

① Composition is much different between natural and synthetic textile.
② Wool industry discharges high conc. of BOD, fat and alkaline matters.
③ Dye industry discharges various pollutants such as dyes, auxiliary additives and other chemicals.
④ Quality and quantity of waste water fluctuates according to seasons and fashion.

(3) Pulp and Paper Industry

① Typical industries which consume large volume of water.
② Pulp industry discharges all contents of natural plants except cellulose and also discharges chemicals used to take out cellulose from natural plants.
③ Pollution load of waste water is high.
④ Waste water contains very high concentration of COD and coloration.
⑤ Waste water from paper industry contains large volume of floating matters including fine fiber, paper and various fillers.

(4) Petroleum refining Industry

① Main component of pollutants is oil spilled as emulsion state.
② Waste water contains malodorous substances such as hydrogen sulfide, other sulfides, ammonia, mercaptan and phenols etc.

(5) Petrochemical Industry

① Waste water contains hydrocarbons, various organic compounds and catalysts.
② Content of pollutants varies largely according to the type of products.

(6) Iron and steel Industry

① Typical industries which consume large volume of water.
② Waste water from the cooling and cleaning process for coke oven contains ammonia, cyanide, phenols etc.
③ Waste water from dust collecting process of each furnace contains suspended solids (coke dust and ore).
④ Waste water from pickling process contains acid, iron and oil.
⑤ Majority of waste water is cooling water and recent built steel mill recycles more than 90% of industrial water.

Water pollution from other human activities

(1) Construction Works

① Incidental pollution during progress of construction and pollution caused by the change in natural condition as a result of construction works.
② The latter is more serious
③ Construction works for a dam, river improvement, port facilities, creation and reclamation of land and gravel gathering from river-bed are enumerated as examples of above-mentioned case.

(2) Various tertiary Industries

① Typical sources are cleaning and laundries, hotels, printings, hospitals, laboratories and research institutes, transportations and so on.
② Waste water from increased peoples daily life.
③ Oil tankers may cause water pollution in coastal regions discharging cleaning waste water tanks.

(3) Errors, Accidents and Disasters

① Accidental damage to public sewage works or drainage of industrial effluent and erroneous operations of these facilities cause water pollution.
② Pollution of a ocean due to oil resulting from collision of tankers.

Classification of water pollutants by their physical and Chemical properties

(1) Suspended Solid (Abbreviated as “SS”)

① This causes what is called the “turbidity of water”.

② In general suspended solids are defined as those having a diameter of over 1 μ (micron).

③ Inorganic SS comes from waster water of cement industry and mines, while organic SS comes from those of municipal sewage and kraft pulp factories as examples.

(2) Organic Matter

① Organic matter is measured as “BOD” or “COD” and extract with n-hexane.

② Organic matters consumes dissolved oxygen in water and eventually destroys ecosystem of hydrosphere.

③ Emission sources are municipal waste water and industrial waste water such as those from food processing, chemical, pulp and leather industries.

(3) Inorganic Matter

① Inorganic matter comprises acids, alkalis, various salts, metals etc.

② Sources are mining, chemical, pulp, electroplating, ceramics and other industries.

(4) Inorganic and Organic Toxic Substances

Toxic substances are defined as chemical substances even traces of which adversely affect health of human body.

① Inorganic toxic substances

metallic ones: cadmium, lead, hexavalent chromium, mercury, etc

non-metallic ones: cyanide, arsenic

② Organic toxic substances

Many synthetic substances are developed and using and in some case containing phosphorus, chlorine, mercury etc..

(5) Oil and Fat (Hexane Extracts)

① Vegetable oil, animal fat are found in municipal waste water and in waste water from food, oil and fat processing industries etc.

② Mineral oils are found in waste water from oil drilling, petroleum refining, petrochemical, iron and steel making and other industries.

③ Mineral oils are found in waste water from ships.

(6) Nutrients (Nitrogen compounds and Phosphates)

① Salts such as nitrogen compounds and phosphates (NH_4^+, NO_2^-, NO_3^- and PO_4^{3-}) exist in small quantities even in natural clean water. These substances are ingested by organisms as nutrient salts.

② When their quantities exceed certain concentration, eutrophication in waters occurs.

③ These substances are discharged from municipal waste water, surplus of fertilizers, some industrial waste water and synthetic detergents.

(7) Sulfur Compounds

① Hydrogen sulfide (H_2S) is formed in municipal waste water, nightsoil, waste water from digesting processing of pulp and from gas plant.

② Hydrogen sulfide has offensive odor and corrodes facilities and buildings because of its strong reducing power.

③ Sulfur oxides (SOx) are main pollutants in sir and one source of acid rain.

(8) Coloring and Offensive Odor Substances

① Though coloring or offensive odor substances are not so serious, they affect living environment of people.

② These substances are found in waste water from dyeing, chemical, agricultural products processing, marine produc processins etc..

(9) Coliform Bacteria

① Coliform bacteria has not any pathogenic nature.
② Coliform bacteria is used as index to measure pollution by nightsoil.

(10) Radioactive Substances

① Hospitals and research institutes are sources of radioactive substances such as isotopes.
② Nuclear fuel treatment plants and nuclear power plants are also sources.

(11) Warm and Hot Waste Waters

① Source of warm and hot waste water is cooling water from factories and thermal power plants.
② They may change environment of waters and affect regional ecosystem.

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Chemical composition of river water in Japan and world

		Japan	World
Total evaporation residue		74.8 mg/*l*	100 mg/*l*
Sodium	(Na^+)	9.4%	5.79%
Potassium	(K^+)	1.68	2.12
Magnesium	(Mg^{2+})	2.70	3.41
Calcium	(Ca^{2+})	12.5	20.39
Chloride	(Cl^-)	8.21	5.68
Sulfate	(SO_4^{2-})	14.77	12.14
Carbonate	(CO_3^{2-})	21.6	35.15
Soluble silica	(SiO_2)	26.84	11.67
Nitrate nitrogen	(NO_3^--N)	1.63	0.6

Composition of sea water

Unit: 1/1kg-sea water

Ion	g	Ion	g
Sodium ion (Na^+)	10.65	Chlorine ion (Cl^-)	18.98
Potassium ion (K^+)	0.38	Bromide ion (Br^-)	0.065
Magnesium ion (Mg^{2+})	1.27	Sulfate ion (SO_4^{2-})	2.65
Calcium ion (Ca^{2+})	0.40	Bicarbonate ion (HCO_3^-)	0.14
Strontium ion (Sr^{2+})	0.008	Boric acid (H_3BO_3)	0.026

Substances designated as hazardous for human health in Japanese Water Pollution Control regulations and their properties

	Environ-mental standard (mg/*l*)	Emission standard (mg/*l*)	Main effects on human health	Main emission sources	Main treating methods	Notes
Cadmium (Cd)	0.01	0.1	Disorder of kidney, loss of calcium balance, osteomalacia	Electroplating, pigment, battery, copper & zinc mine	Precipitating with hydroxide (pH 10.5 or higher)	Cause of itai-itai disease is said osteomalacia resulted from Ca-balance disorder coming from Cd polluted rice.
Cyanide (CN)	N.D.	1.0	Toxic to breathing, combine with hemoglobin & stop its oxygen-carrying ability & suffocate	Electroplating, coke-oven (town gas & steel mill), chemical ind. (acrylonitrile, etc.)	Alkali chlorination (two-staged oxidation with hypochlorite)	Massive death of fish occurred by discharge of cyanide to river.
Organic phosphorus	-	1.0	Toxic to nervous system (obstacle to cholin-esterase activity)	Organo-phosphorus pesticides		"Organic phosphorus" means 4 kinds of designated pesticides : parathion, methyl parathion, methyl demetone & EPN.
Lead (Pb)	0.01	1.0	Anemia (low blood-pigment, whole body disorder, lead-poisoning)	Lead battery, pigment, paint, glazing for pottery, printing, plumber, electroplating	Precipitation with hydroxide (pH 9.5- 10 — be careful at narrow opt. pH range)	Lead poisoning is a well known professional disease from ancient time. Regulated by Lead Poisoning Control Act (Ministry of Labor)
Hexavalent chromium	0.05	0.5	External injury for skin & digestive organs, damage to nasal septum	Electroplating, chemical industry (pigment, anticorrosive, etc.)	After reducing to trivalent chromium (Cr-III) precipitate with hydroxide (for reduction, metal iron, Fe-II, sulfite or electrolytic reduction ; optimum pH for precipitation is 8)	Chromium exists as trivalent or hexavalent. Trivalent has only a weak toxicity.
Arsenic (As)	0.01	0.5	Sediment of pigment on skin, disorder of liver, skin cancer	Chemical & semi conductor industries, mining	Co-precipitation with iron compound as hydroxide	Various vernacular diseases are found in the world caused by arsenic poisoning.
Total mercury (Hg)	0.0005	0.005	Disorder of kidney, inorganic Hg is apt to change organic in the natural environment	Thermometer & other meters, fluorescent light, amalgam (dental & other uses), chemical industry (catalyst), dry battery, chloroalkali industry (Hg-electrolysis process), pesticide pharmaceuticals	Precipitation with sulfide.(After-treatment is demanded such as absorption since the regulation is very strict).Organomercury is decomposed by oxidation with chlorine and then precipitated.	Minamata disease is said to be caused by toxicity of alkyl mercury which is discharged from a chemical factory to sea and concentrated into fish body.
Alkyl mercury	N.D.	N.D.	Cerebral palsy, trembling of limbs, oral disorder, ataxia, defect in visual field			
PCB (poly chlorinated biphenyl)	N.D.	0.003	Sediment of black pigment on skin, chloracne, disorder of liver	Transformer oil, capacitor oil, heat medium, carbonless copying paper		PCB oil poisoning case occurred by eating rice contaminated with PCB which had been used as a heating medium.

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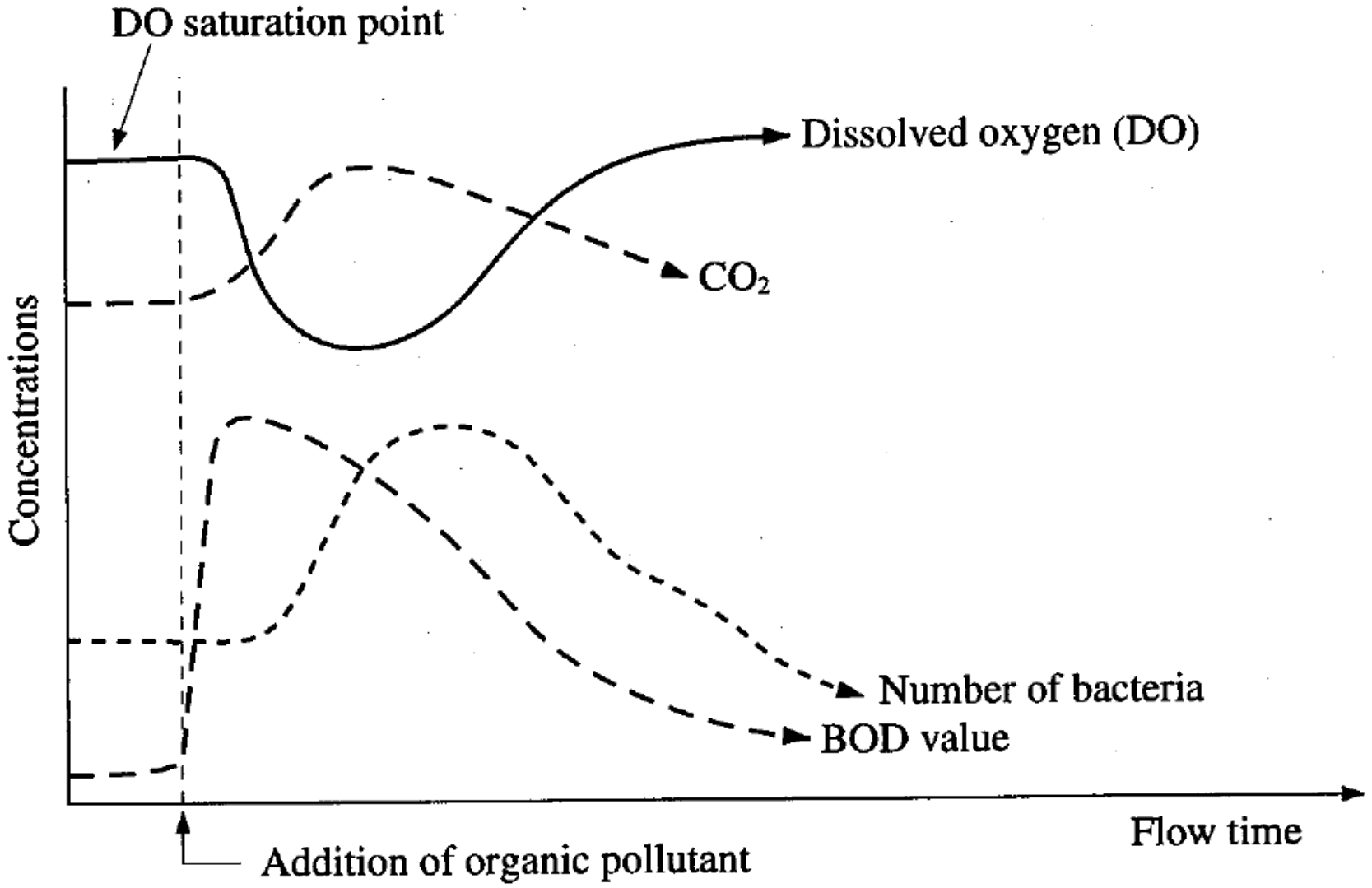
11. Combination of aerobic and anaerobic waste water treatment

Material concentration and bacterial number in a polluted river



Pollution loading amount by types of industry

Unit: ton/year

Code for type of industry	pH		BOD	COD	SS	Hexane extract (oil content)	Phospho-rus com-pound	Nitrogen compound
	Acid	Alkali						
Type of industry	204984	33926	411521	1802837	4926294	244407	4873	50134
Food processing industry	2589	1471	66664	68755	33416	2692	66	2327
Textile industry	1527	1406	30436	17477	27397	19771	42	291
Pulp and paper making industries	6366	199	209669	512241	519360	457	27	110
Chemical industry	119062	11973	81154	1041808	231285	9812	3078	41195
Leather industry	0	53	1171	585	1902	88	0	9
Ceramic and quarrying industries	4244	1987	448	1119	474921	435	346	114
Iron and steel industries	10925	3787	2132	65307	3520119	35231	21	546
Nonferrous metal industry	46300	4058	551	2880	48107	239	10	160
Metal processing industry	4477	56	1005	1122	5012	143	4	46
Gas supply industry	0	2	1302	2503	265	727	0	1403

Pollution loading per output for major industries

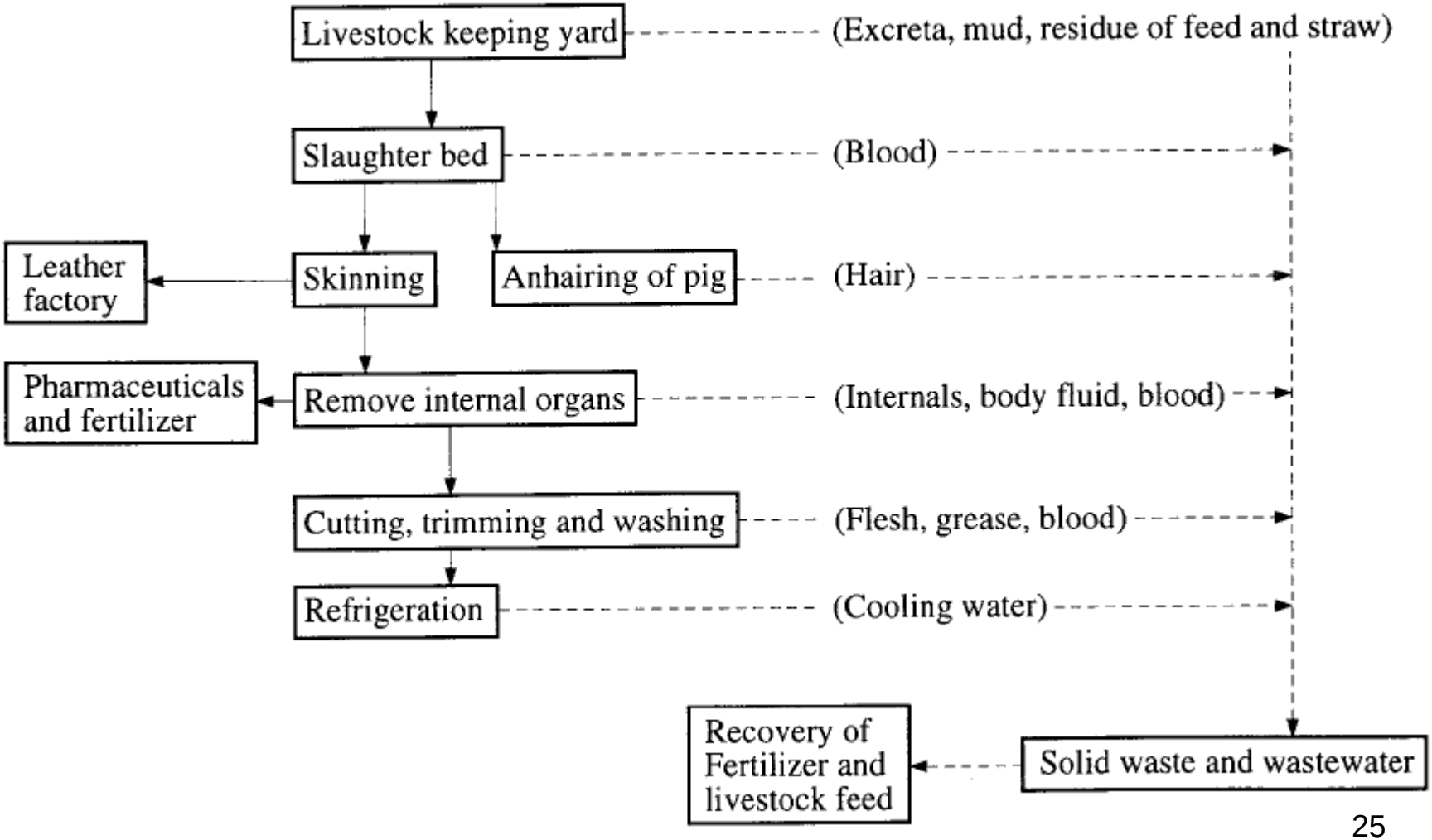
Unit: kg/one million yen

	BOD	COD	Suspended solid (SS)	Total nitrogen	Total phos-phorus
Food processing industry	181	165	79	90	1.5
Textile industry	426	402	122	46	3.4
Pulp and paper industries	897	1110	1820	46	3.0
Inorganic chemical industry	53	218	174	98	1.1
Organic chemical industry	1150	578	236	75	1.7
Petroleum and coal industries	22	23	33	3.2	0.2
Leather industry	443	620	874	91	2.8

Unit pollution load for stock-farming (cattles and pigs)

Item	Cattle	Pig
Water quantity (*l*/head·day)	45 - 135	13.5
BOD (g/head·day)	640	200
COD (g/head·day)	530	130
SS (g/head·day)	3000	770
Total nitrogen (g/head·day)	378	40
Total phosphorus (g/head·day)	56	25

Flow of slaughterhouse waste and waste water



Analysis of waste water from slaughterhouse

Analyzer	pH	Evaporation residue (mg/*l*)	Ignition loss (mg/*l*)	Ignition residue (mg/*l*)	Suspended solids (mg/*l*)	COD (mg/*l*)	BOD (mg/*l*)	Ammoniacal nitrogen (mg/*l*)	Albuminoid nitrogen (mg/*l*)
Watanabe	7.3	1386	1115	271	538	290	892	36	53
Takahashi et al.	7.0	1220	915	305	479	112	830	38	49
Itoh et al.	6.3 - 6.6	2690	2330	360	2370	397	1720	-	-

Pollution loading of domestic waste water

Unit: g/day・person

	Human excrement	Other domestic waste water	Total
BOD	13	31	44
COD	6.5	15.5	22
Suspended solid	10	30	40
Total nitrogen	9	3	12
Total phosphorus	0.57	0.83	1.4

(Survey by the Ministry of Construction)

Examples of calculations for the degree of pollution and population equivalent for organic industrial waste water

	Quantity of waste water	BOD (ppm)	BOD pollution load (kg/day)	Population (× 10000 persons)*
Alcohol manufacturing plant	370	30000	11100	22
Beer brewery	2000	500	1000	2
Yeast raising plant	100	7500	750	1.5
Pulp plant	50000	700	35000	70
Wool processing plant	1000	2500	2500	5
Leather factory	250	2000	500	1

* BOD load is 50g/day/person

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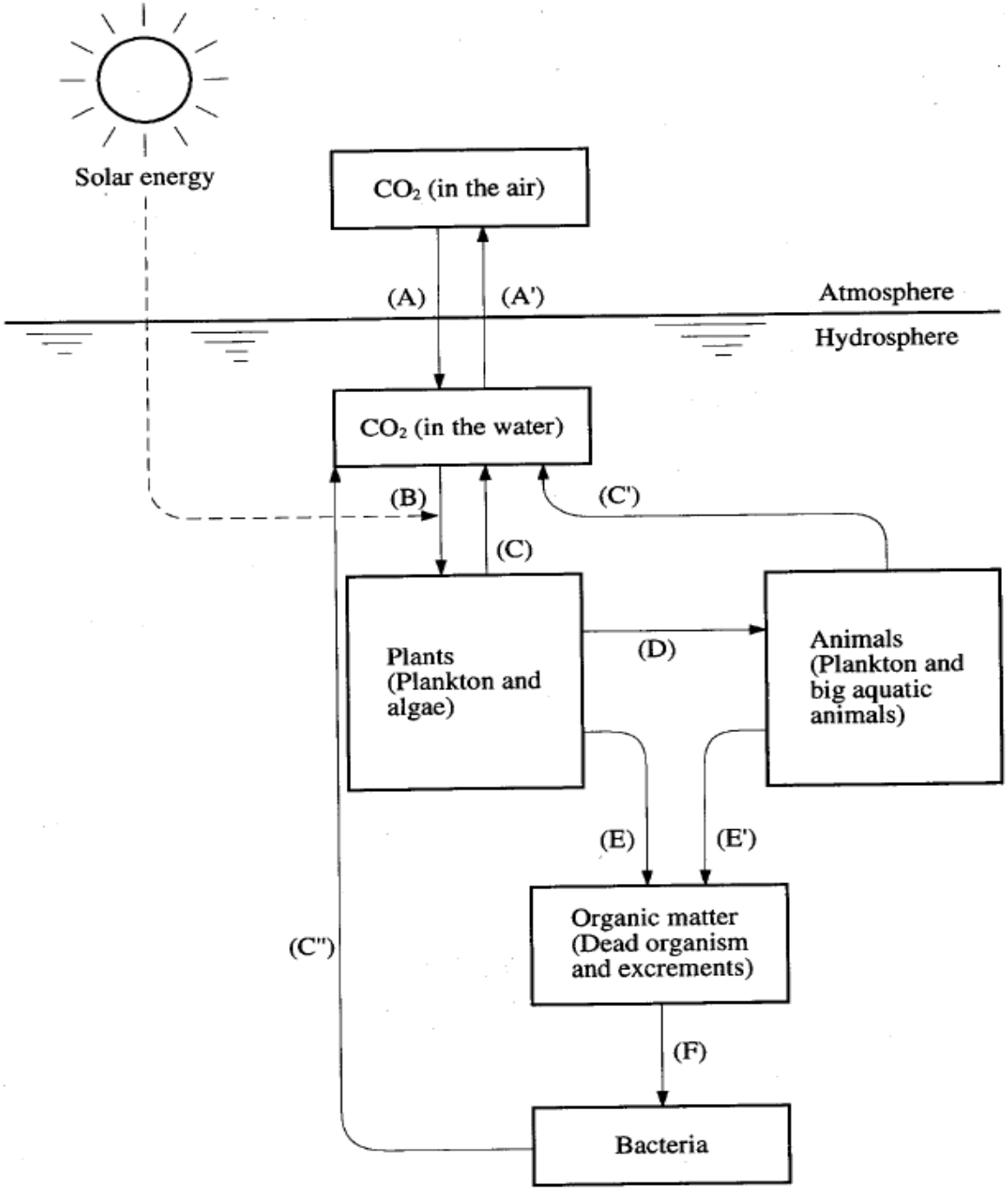
Material cycle in the aquatic zone-cycle of carbon compounds(organic substances)



【Legend】

(A),(A')	:	Intake of CO_2 from atmospheric air. CO_2 equilibrium is established between air and water.
(B)	:	Photosynthesis (CO_2 assimilation) by phytoplanktons and green algae taking place only in the water region the sunshine can reach (primary production).
(C),(C'),(C")	:	Releasing of CO_2 as a result of respiratory action of vegetables, animals and bacteria.
(D)	:	Intake by animals (secondary and tertiary productions).
(E),(E')	:	Isolation of organ ic substances as a result of death, excretion, secretion and exuviation of animals and vegetables.
(F)	:	Intake of organic substances by bacteria.

Solubility of oxygen in fresh water and sea water

Unit: mg/L

Temperature	Pure water	Seawater
0°C	14.6	11.3
5	12.8	10.0
10	11.3	9.0
15	10.2	8.1
20	9.2	7.4
25	8.4	6.7
30	7.6	6.1

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Prediction of changes of waters

- Factors affecting to growth of Phytoplankton
  1. Load of nutritive salts（N, P）
  2. Avairable light intensity
  3. Raised water temperature
- Feature of Closing Water Area
  1. Long term stay of pollutants
  2. Generation of malti layer in summer

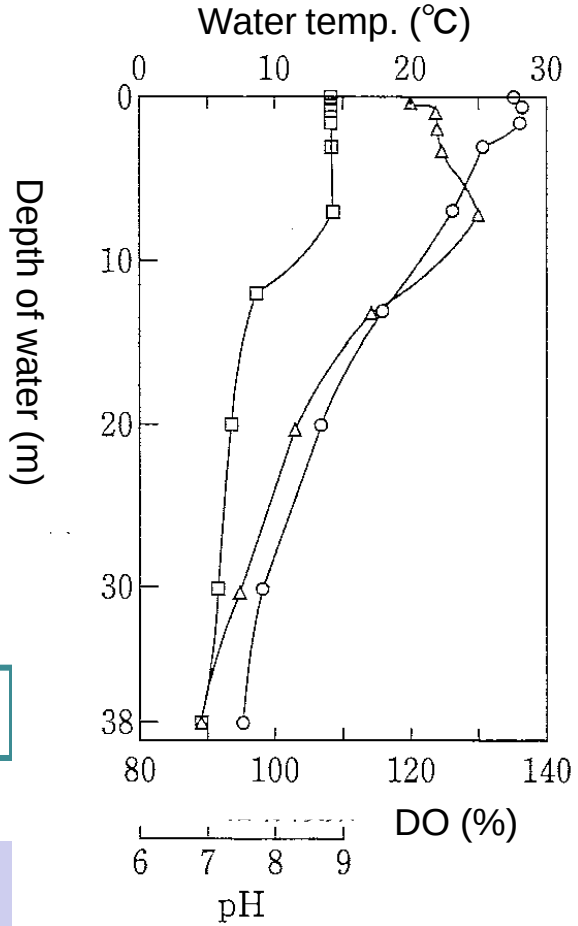
Phytoplankton, nutritive salts
→ passive as dynamics

Wayer temperature, conc.of salts, fishues
→ active as dynamics

Three dimensional model of ecosystem

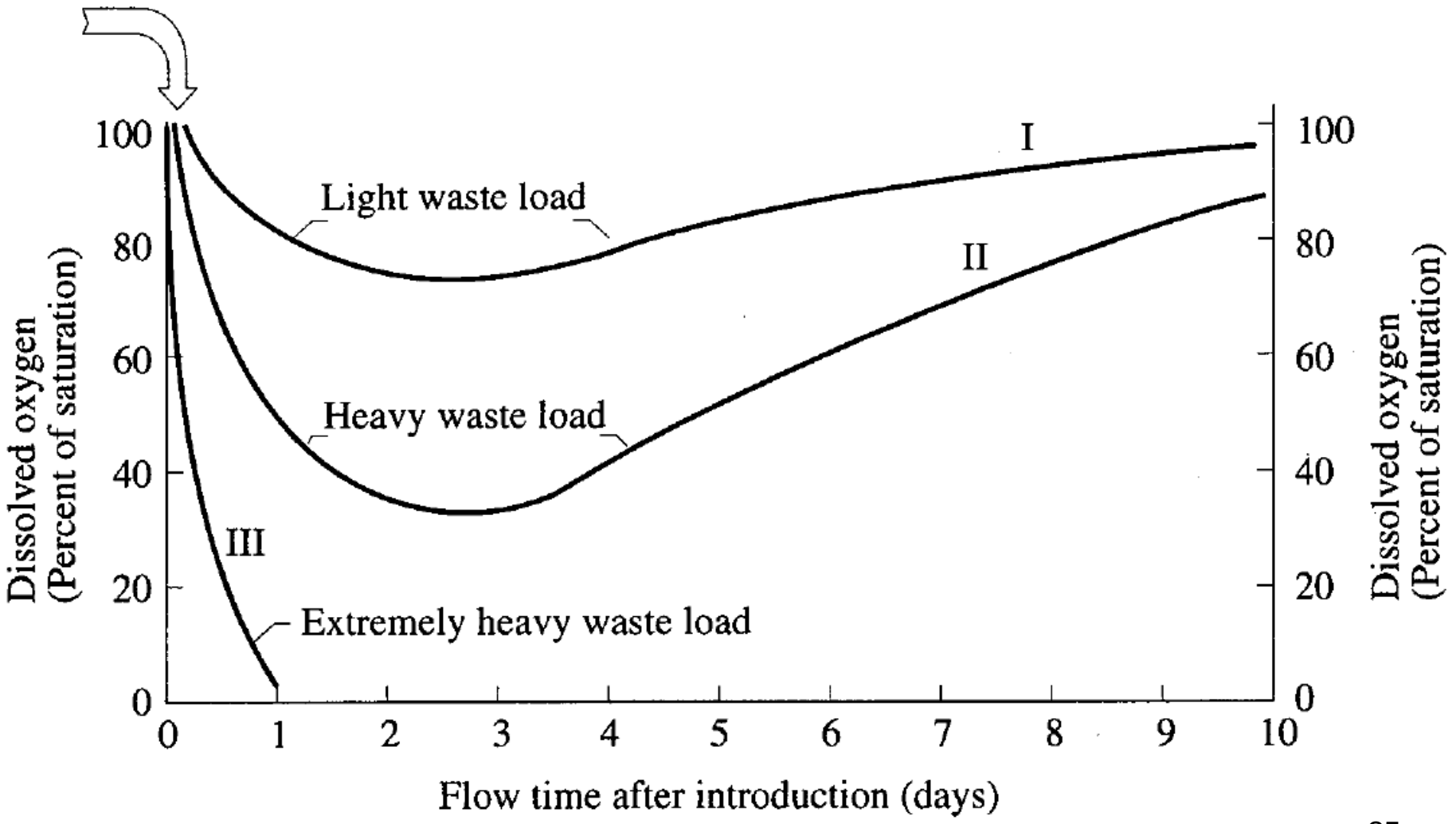
（Consist of passive factors as dynamics）

Surface ：Growth of Phytoplankton
(inner production of COD)
Lower layer ：Ristriction of DO supply (poor O_2 conc.)
Bottom sludge ：Anaerobic→Generation of sludge,
re-dissolution of nutritive salts

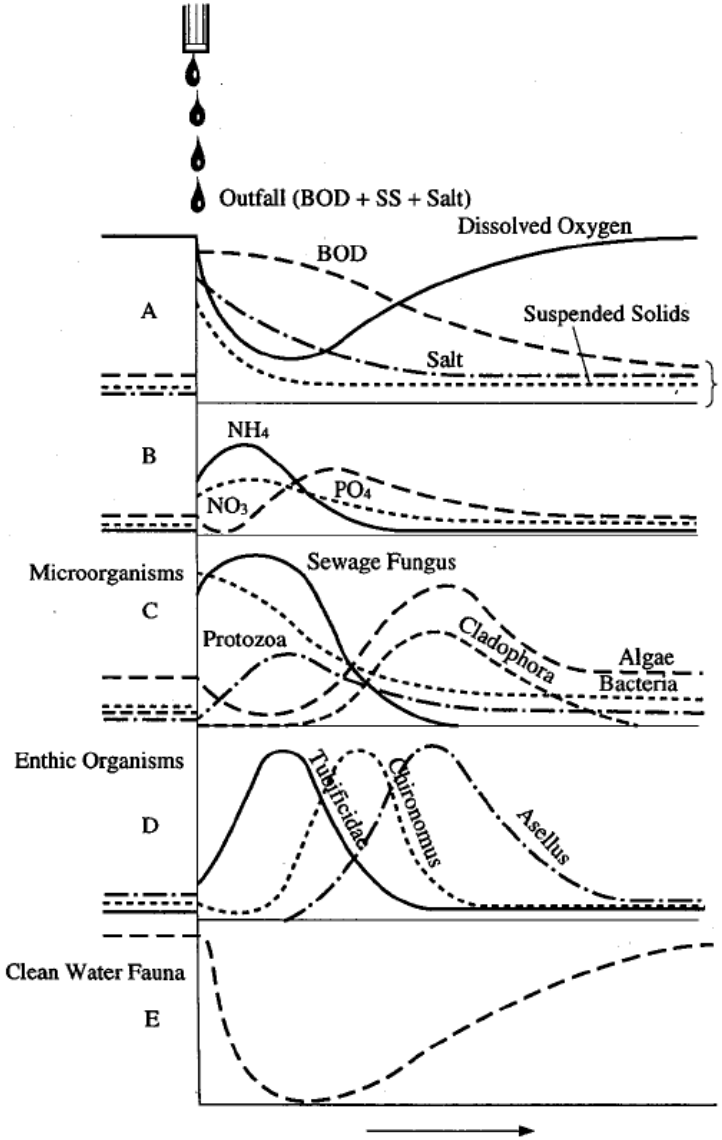


Ex.: Biwa lake in Japan in summer, 1970
Water temp. (○), DO (△), pH (□)

Concentration change of dissolved oxygen



Change of biota in river when organic pollutants are introduced (Hynes,1960)



Outfall : Introduction of pollutants into a river

Amount of organic substances, represented in BOD value, decreases as a result of dilution, diffusion and aerobic bacterial digestion.

SS and Salt decrease through dilution and diffusion.

Oxygen is consumed when organic substances are decomposed by action of aerobic bacteria. As the decomposition subsides, dissolution of oxygen into water from the atmospheric air exceeds its consumption, ultimately restoring the original saturated level (Oxygen sag curve).

NH_4 and NO_3 : NH_4 increases temporarily as a result of aerobic degradation of nitrogen-containing organic substances, and decreases again through intake by vegetables or oxidation to NO_3 by the action of nitrification bacteria. Accordingly, the peak of NO_3 appears slightly later.

PO_4 : This is released by aerobic digestion of phosphorus-containing organic substances, but decreases immediately through dilution and other processes.

Microorganisms : Sewage fungi begin to grow first, followed by protozoas. Multiplication of cladophoras and other algae occurs later. All these finally begin to decrease after each peak. Bacteria entered together with the sewage water continue to decrease monotonically.

Benthic organisms : Tubificidae, chironomus, asellus and other sewage organisms begin to grow successively, and then decrease.

The clean water fauna cannot exist for some time after the sewage is introduced. They begin to grow again as water quality is restored.

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LC_{50} values of various Fishes

Unit: ppm

Fish (mean body-weight) / Toxic subst.	Freshwater fishes					Seawater fishes		
	Orange-red medaka (killifish) (0.35g)	Guppy (0.14g)	Carp (0.41g)	Goldfish (2.8g)	Rainbow trout (0.39g)	Seawater acclimatized rainbow trout (0.36g)	Gobies (0.09g)	Emerald damselfish (1.56g)
$HgCl_2$ (as Hg)	0.74	0.38	0.47	0.48	0.49	3.2	2.6	1.3
$ZnSO_4$ (as Zn)	18	11	20	26	1.1	95	46	13
KCN (as CN)	0.43	0.43	0.33	0.55	0.09	0.40	0.33	0.15
NH_4Cl (as N)	76	98	53	90	16	91	34	12
Acetic acid	11000	8800	7700	8400	8400	14000	12000	13000
Phenol	25	50	47	34	15	24	17	18
Tannic acid	140	66	46	24	8.4	—	—	—
ABS*	56	46	38	43	20	5.2	5.8	5.4
Parathion	3.5	1.9	2.7	4.0	2.2	2.0	0.01	0.08
PCP* (Na salt)	0.40	0.86	0.18	0.37	0.16	1.3	0.52	0.06

(K. Tabata, 1972)

Test conditions : i) Temperature : 25°C; (Rainbow trout : 12-13°C)
ii) pH : KCN, acetic acid, tannic acid : 7.0 (freshwater), 8.0 (seawater)
NH_4Cl : 8.0 (freshwater and seawater)
* ABS (Alkylbenzenesulfonate)
PCP (Pentachlorophenol)

Substances designated as hazardous for human health in Japanese

	Environ-mental standard (mg/*l*)	Emission standard (mg/*l*)	Main effects on human health	Main emission sources	Main treating methods	Notes
Cadmium (Cd)	0.01	0.1	Disorder of kidney, loss of calcium balance, osteomalacia	Electroplating, pigment, battery, copper & zinc mine	Precipitating with hydroxide (pH 10.5 or higher)	Cause of itai-itai disease is said osteomalacia resulted from Ca-balance disorder coming from Cd polluted rice.
Cyanide (CN)	N.D.	1.0	Toxic to breathing, combine with hemoglobin & stop its oxygen-carrying ability & suffocate	Electroplating, coke-oven (town gas & steel mill), chemical ind. (acrylonitrile, etc.)	Alkali chlorination (two-staged oxidation with hypochlorite)	Massive death of fish occurred by discharge of cyanide to river.
Organic phosphorus	-	1.0	Toxic to nervous system (obstacle to cholin-esterase activity)	Organo-phosphorus pesticides		"Organic phosphorus" means 4 kinds of designated pesticides : parathion, methyl parathion, methyl demetone & EPN.
Lead (Pb)	0.01	1.0	Anemia (low blood-pigment, whole body disorder, lead-poisoning)	Lead battery, pigment, paint, glazing for pottery, printing, plumber, electroplating	Precipitation with hydroxide (pH 9.5- 10 — be careful at narrow opt. pH range)	Lead poisoning is a well known professional disease from ancient time. Regulated by Lead Poisoning Control Act (Ministry of Labor)
Hexavalent chromium	0.05	0.5	External injury for skin & digestive organs, damage to nasal septum	Electroplating, chemical industry (pigment, anticorrosive, etc.)	After reducing to trivalent chromium (Cr-III) precipitate with hydroxide (for reduction, metal iron, Fe-II, sulfite or electrolytic reduction ; optimum pH for precipitation is 8)	Chromium exists as trivalent or hexavalent. Trivalent has only a weak toxicity.
Arsenic (As)	0.01	0.5	Sediment of pigment on skin, disorder of liver, skin cancer	Chemical & semi conductor industries, mining	Co-precipitation with iron compound as hydroxide	Various vernacular diseases are found in the world caused by arsenic poisoning.
Total mercury (Hg)	0.0005	0.005	Disorder of kidney, inorganic Hg is apt to change organic in the natural environment	Thermometer & other meters, fluorescent light, amalgam (dental & other uses), chemical industry (catalyst), dry battery, chloroalkali industry (Hg-electrolysis process), pesticide pharmaceuticals	Precipitation with sulfide.(After-treatment is demanded such as absorption since the regulation is very strict).Organomercury is decomposed by oxidation with chlorine and then precipitated.	Minamata disease is said to be caused by toxicity of alkyl mercury which is discharged from a chemical factory to sea and concentrated into fish body.
Alkyl mercury	N.D.	N.D.	Cerebral palsy, trembling of limbs, oral disorder, ataxia, defect in visual field			
PCB (poly chlorinated biphenyl)	N.D.	0.003	Sediment of black pigment on skin, chloracne, disorder of liver	Transformer oil, capacitor oil, heat medium, carbonless copying paper		PCB oil poisoning case occurred by eating rice contaminated with PCB which had been used as a heating medium.

Relationship between growth of rice crop and nitrogen content in irrigation water (tested by Tokyo Metropolitan Agriculture Laboratory)

Effect on the growth and crop	Total nitrogen content
1. No effect	Under 1 ppm
2. Excess growth, but only a small effect	1 - 3 ppm
3. Too much growth, sometimes causes crop decrease	3 - 5 ppm
4. Crop decrease	5 - 10 ppm
5. Serious crop decrease	Over 10 ppm

Rice crop and COD in the irrigated water (tested by Aichi prefectural agricultural laboratory)

COD	0	6	8	15	20
Crop index	100	100	95	90	80

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City water Quality Standard

Water quality standard (law)	Water quality standard value (ministerial ordinace)	
To be free of organisms or substances contaminated, or not suspected to be contaminated by pathogenic organisms	Nitrogen (ammonia)	—
	Nitrogen (nitrite)	Under 10 mg/*l*
	Nitrogen (nitrate)	Under 10 mg/*l*
	Chloride ion	Under 200 mg/*l*
	COD-Mn	Under 10 mg/*l*
	Bacteria	Under 100 per colony consisting of test water of 1 m*l*
	Coliform group bacteria	Should not be detected.
To be free of toxic substances such as cyanides, mercury, etc.	Cyanides	Should not be detected.
	Mercury	Should not be detected.
	Organic phosphorus	Should not be detected.
Not to contain copper, iron, fluoride, phenol, etc. exceeding their allowable limit	Copper	Under 1.0 mg/*l*
	Iron	Under 0.3 mg/*l*
	Manganese	Under 0.3 mg/*l*
	Zinc	Under 1.0 mg/*l*
	Lead	Under 0.1 mg/*l*
	Hexavalent chromium	Under 0.05 mg/*l*
	Arsenic	Under 0.05 mg/*l*
	Fluoride	Under 0.8 mg/*l*
	Cadmium	Under 0.01 mg/*l*
	Calcium, magnesium, etc. (Hardness)	Under 300 mg/*l*
	Phenols	Under 0.005 mg/*l* as phenol
	Anionic surfactants	Under 0.5 mg/*l*
	Evaporation residue	Under 500 mg/*l*
To be free of abnormal acidity or alkalinity	Concentration of hydrogen ion	pH value: over 5.8 and under 8.6
To be free from abnormal odor except the ordor of disinfectant	Odor	Not to be abnormal
	Taste	Not to be abnormal
External appearance should be colorless and transparent	Color	Under 5 degree
	Turbidity	Under 2 degree

Quality standard for agricultural water

Item	Quality standard
pH	6.0 - 7.5
COD	Under 6 ppm
SS	Under 100 ppm
Dissolved oxygen	Higher than 5 ppm
Total nitrogen	Under 1 ppm
Electric conductivity	Under 0.3 mS/cm
As	Under 0.05 ppm
Zn	Under 0.5 ppm
Cu	Under 0.02 ppm

Requirements for the quality of industrial water

Quality \ Use	Problem	Boiler	Processing and cleaning of products	Cooling	Control of temperature and humidity
Turbidity	Corrosion and scale	Under 5°	Under 5°	Under 10°	Under 5°
Electric conductivity		Under 10 ppm		Under 150 mho	Under 150 mho
Chlorine ion				Under 15 ppm	Under 15 ppm
pH		Under 7.0	6.0 - 8.5	Under 7.5	Under 7.5
M alkalinity	Scale			Under 50 ppm	Under 50 ppm
Total hardness		Under 50 ppm		Under 50 ppm	Under 50 ppm
Evaporation residue		Under 100 ppm	Under 100 ppm		
Silica		Under 10 - 15 ppm			
Chromaticity	Discoloration and scale		Under 10°		
Total iron			Under 0.5 ppm	Under 0.5 ppm	Under 0.5 ppm
Manganese			Under 0.1 ppm		
Ammonium ion	Slime		Under 1 ppm	Under 1 ppm	Under 1 ppm
BOD			Under 1 ppm	Under 1 ppm	Under 1 ppm
COD		Under 2 ppm	Under 2 ppm	Under 2 ppm	Under 2 ppm
ABS	Foam		Under 0.5 ppm		Under 0.5 ppm

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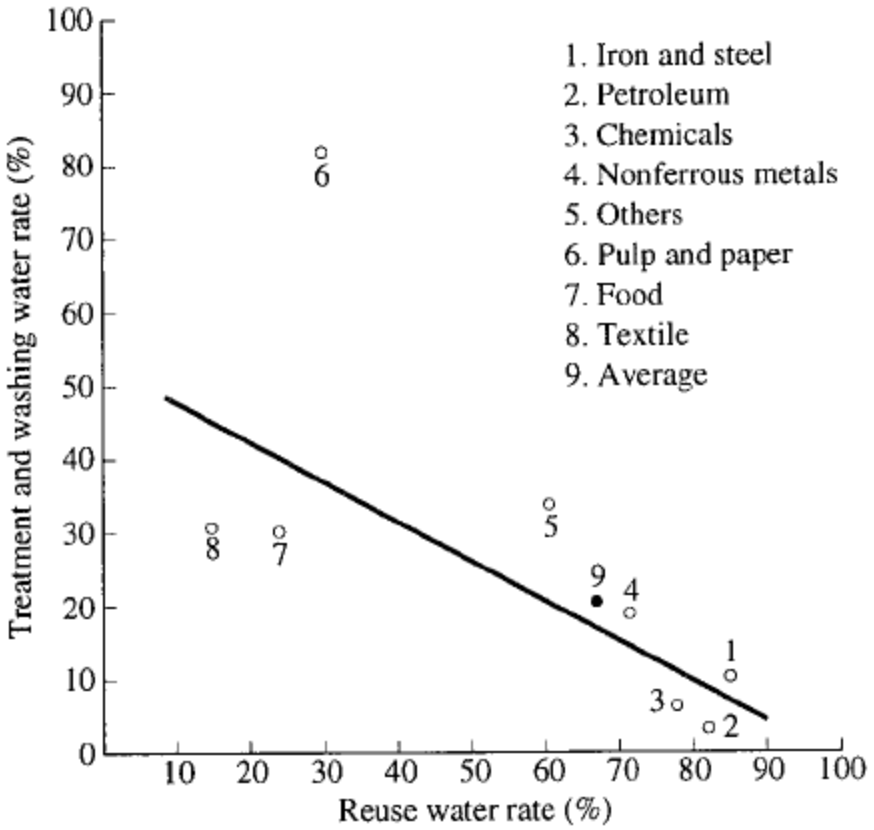
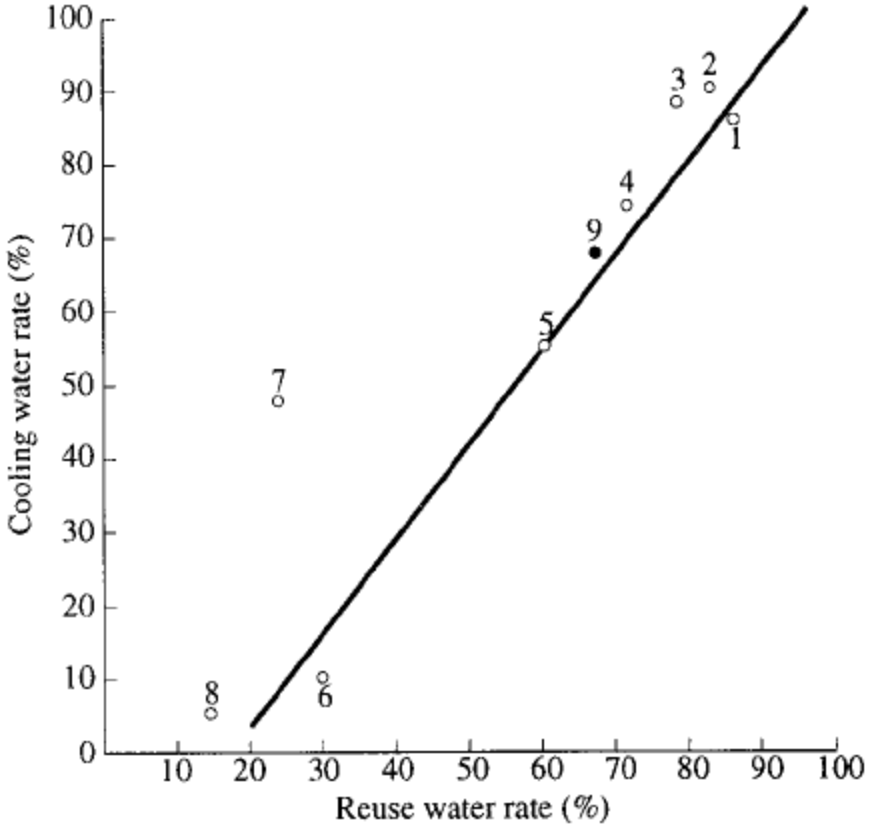
Reuse rate of industrial water

Industry	Reuse rate (%)	Cooling water rate (%)	Treatment and washing water rate (%)
1. Iron and steel	84.8	85.4	9.8
2. Petroleum	82.0	90.1	2.8
3. Chemicals	77.8	87.2	5.9
4. Nonferrous metals	71.2	73.5	18.7
5. Others	60.0	77.1	33.5
6. Pulp and paper	29.8	9.9	82.1
7. Food	24.1	48.0	30.4
8. Textiles	15.3	5.0	29.7
9. Average	67.0	67.6	20.76

Reuse rate of industrial water





Reuse of used and/or waste water

Save water
- Narrow sense “save water”
- Reuse of water

Narrow sense

Well management of industrial water and exclusion of useless use of water

- measure of daily use
- Establish of std. operation procedure (SOP)

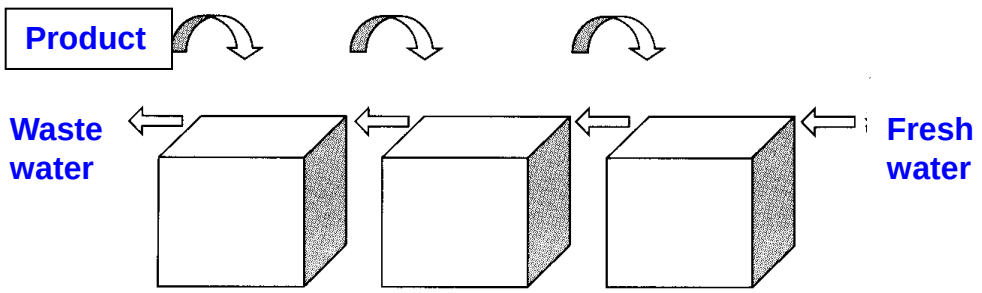
→ Improvement of awareness of employees

① **Decrease of excess water**

Automatic water supply equipment (Hand washing, Toilet etc)

② **Counter Current Decantation**

Bottle washing in food industry
Surface treatment in iron industry
Enough cleaness with little water



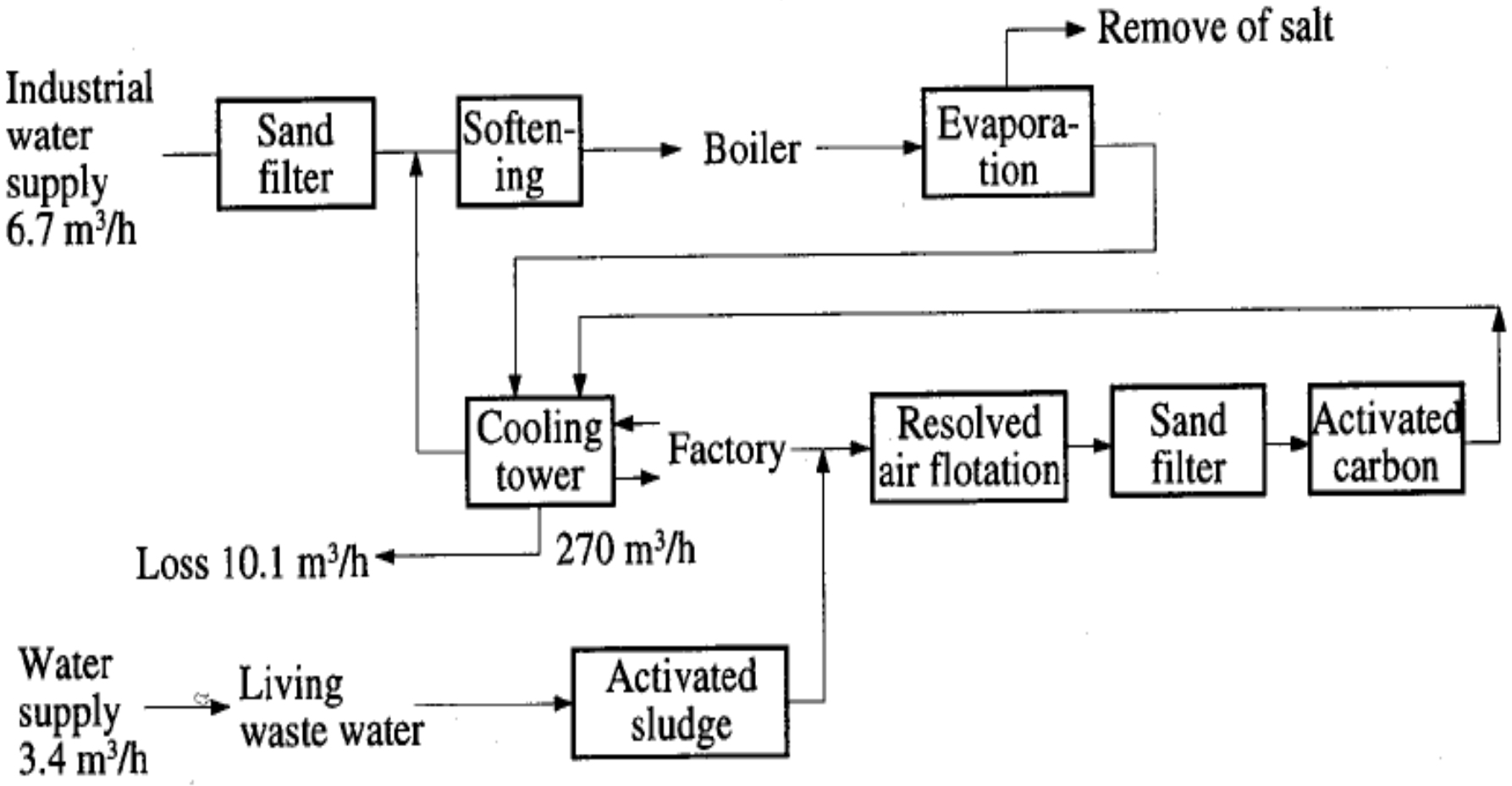
③ **Local circulation**

Circulation within a machine

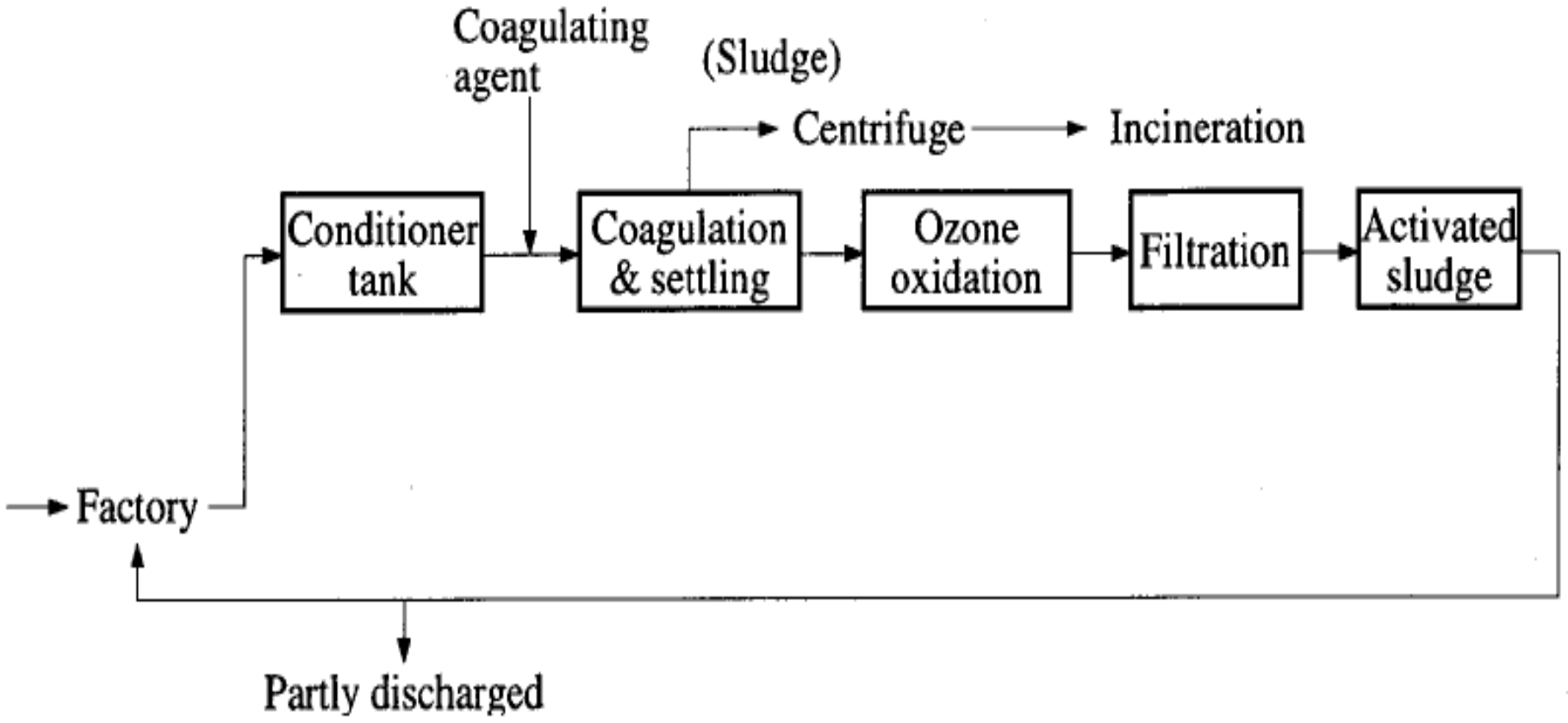
④ **High pressure water cleaning machine**

Small diameter of spray nozzle
Increase water pressure

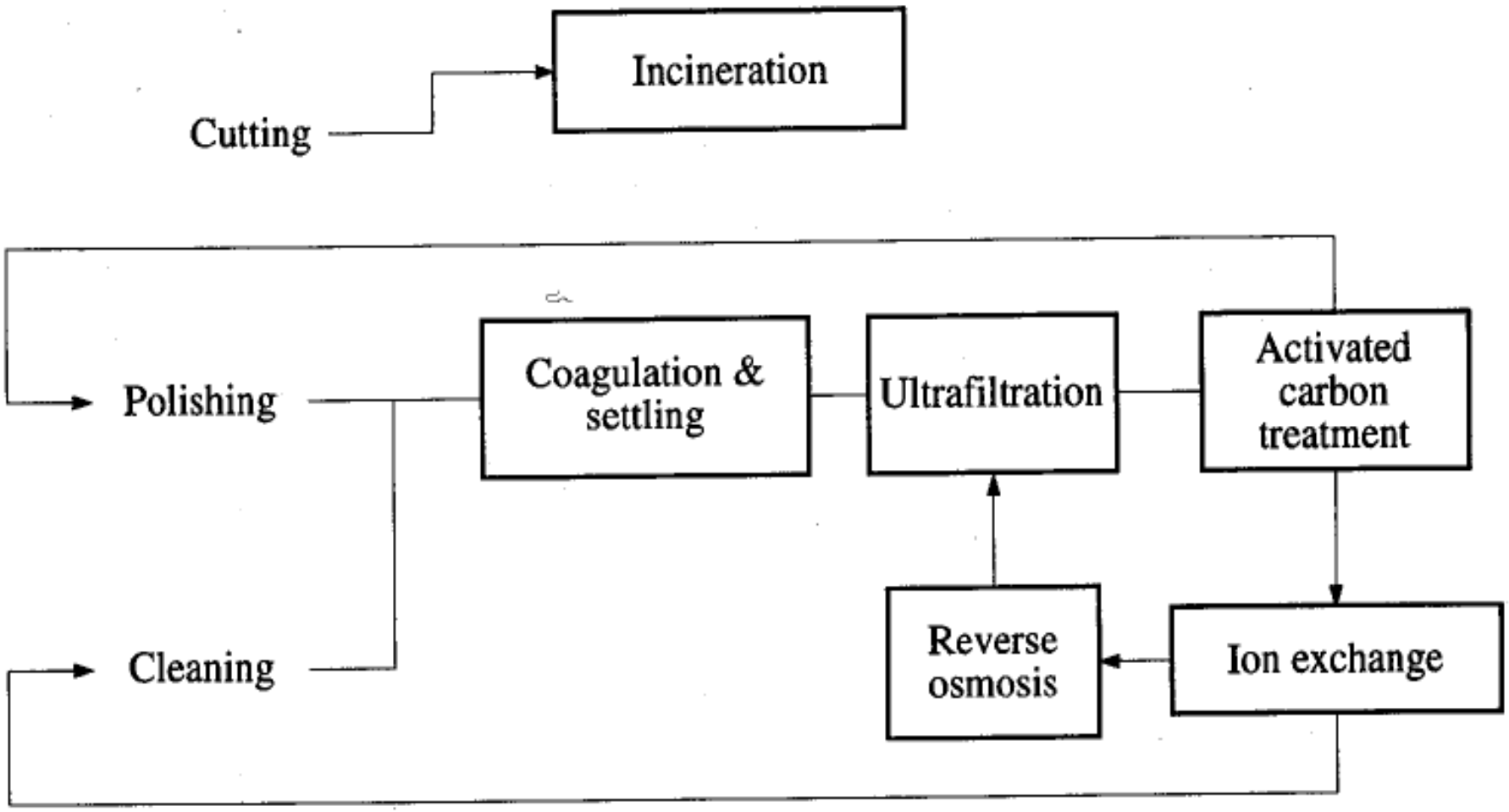
Closed system of a rubber processing factory (A company)



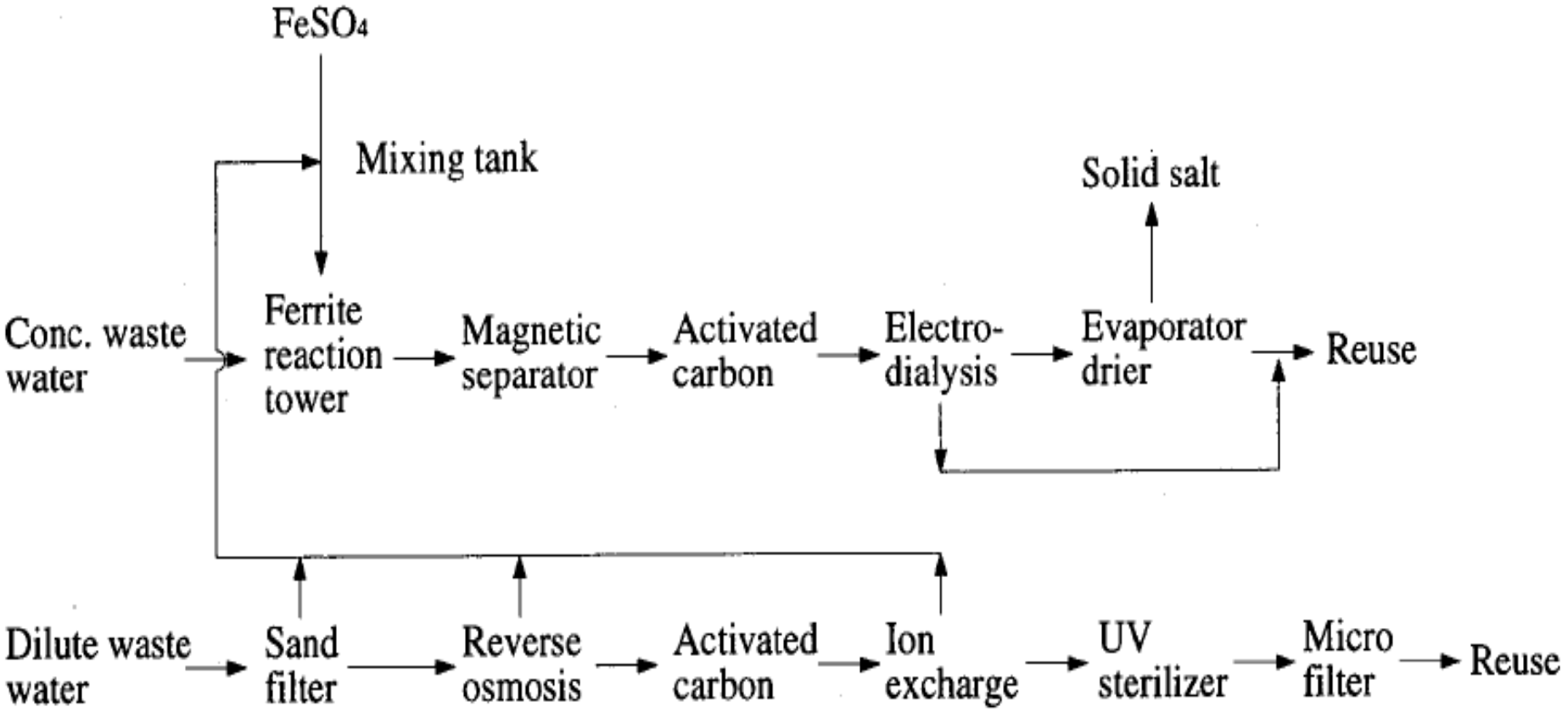
Closed system of a shipbuilding yard (B company)



Closed system of a lens factory (C company)



Water recycling system of an electric company (D company)



Waste water treatment by ferrite process

Heavy metal ion	Before treatment	After treatment
Cu	9500 mg/*l*	0.5 mg/*l*
Ni	20300 mg/*l*	0.5 mg/*l*
Sn	4000 mg/*l*	10 mg/*l*
Pb	6800 mg/*l*	0.1 mg/*l*
Cr (VI)	2000 mg/*l*	0.1 mg/*l*
Cd	1800 mg/*l*	0.1 mg/*l*
Fe	2%	1%
Hg	3000 mg/*l*	ND

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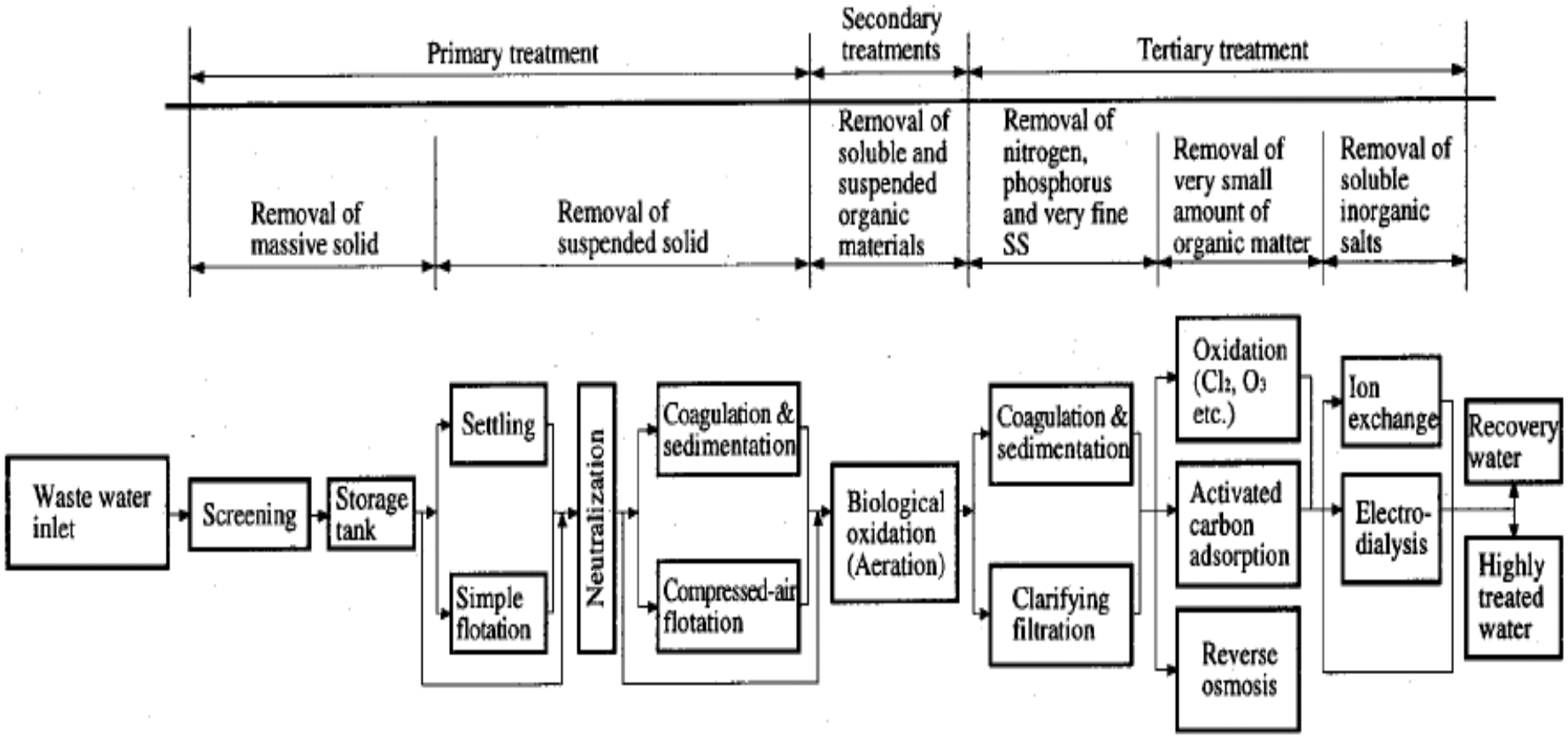
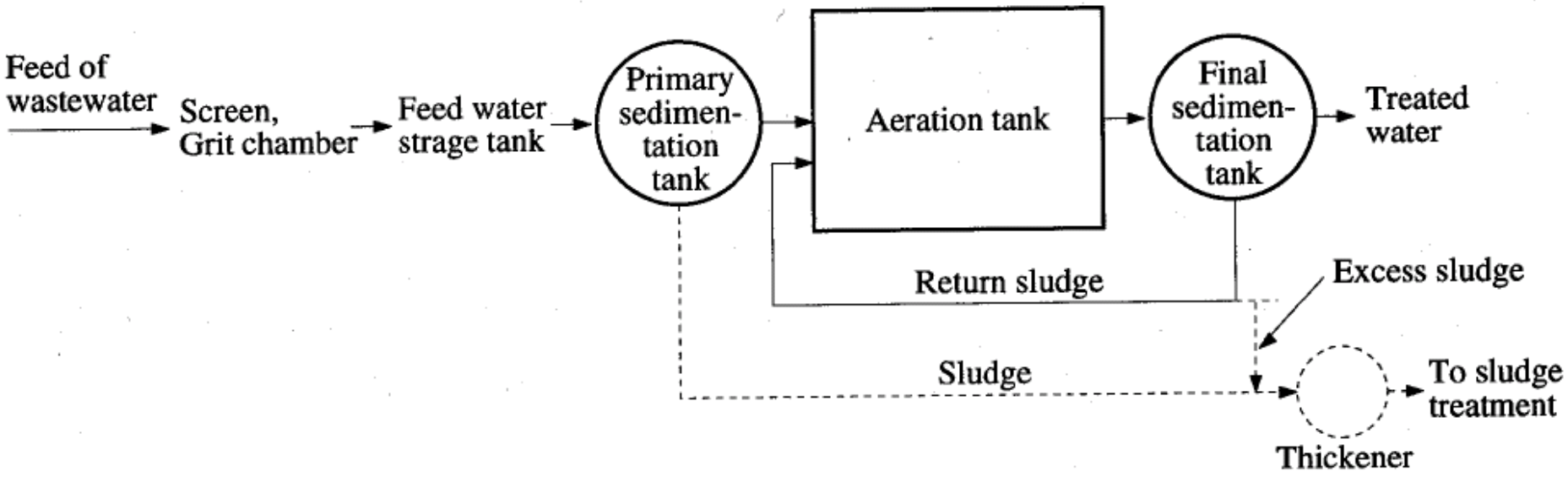
Waste water treatments

1st step (primary)	Remove of SS	Screening, Sedimentation
2nd step (secondary)	Remove of organic substance	Activated sludge Trickling filter Rotary disc Lagoon
	Remove of inorganic substance	Neutralization Oxidation Reduction Ion flotation
3rd step (tertiary)	Remove of N and P	Dephosphorization Denitrification
	Remove of colloid	Ultrafiltration
	Remove of trace elements	Activated carbon adsorption Ion exchange Electrodialysis Reverse osmosis Ultrafiltration Evaporation

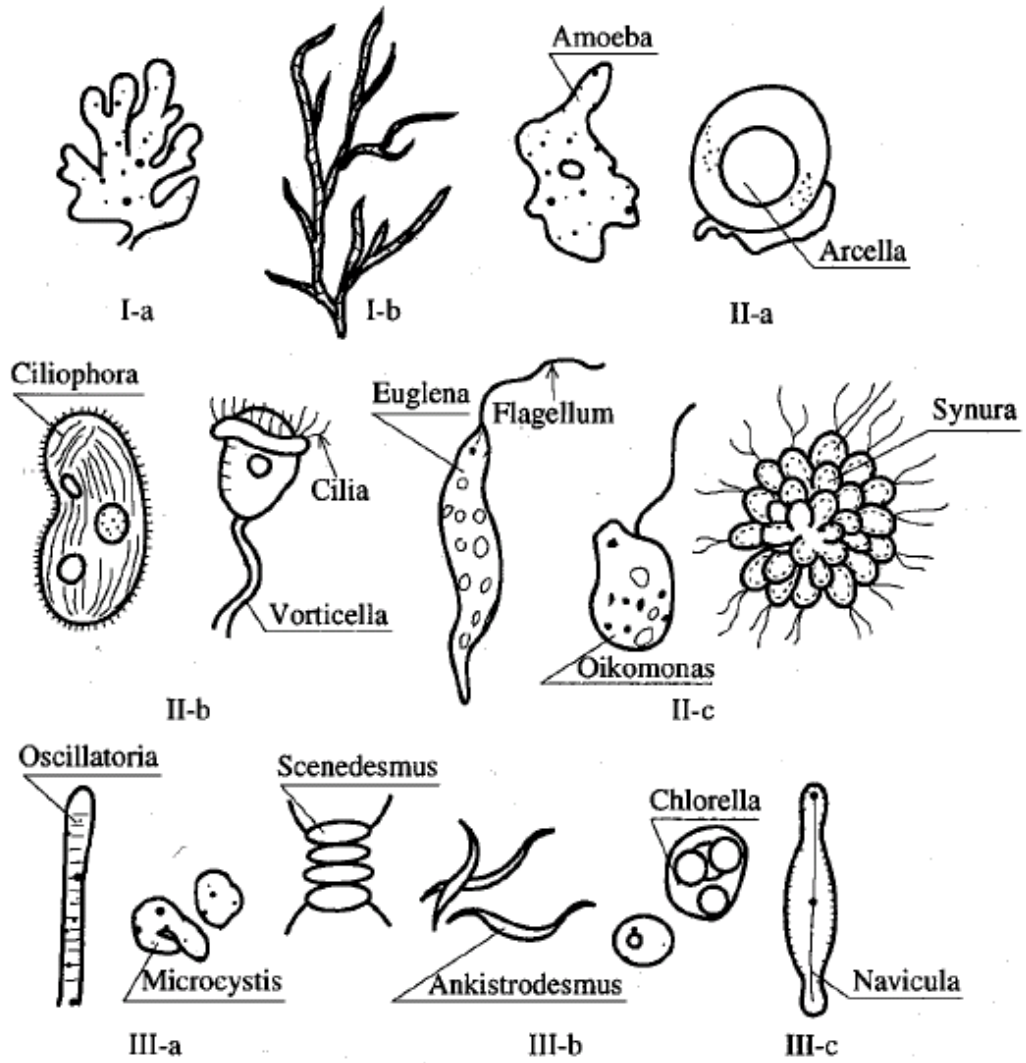
Outline of waste water treatment process



Flowsheet of standard activated sludge process

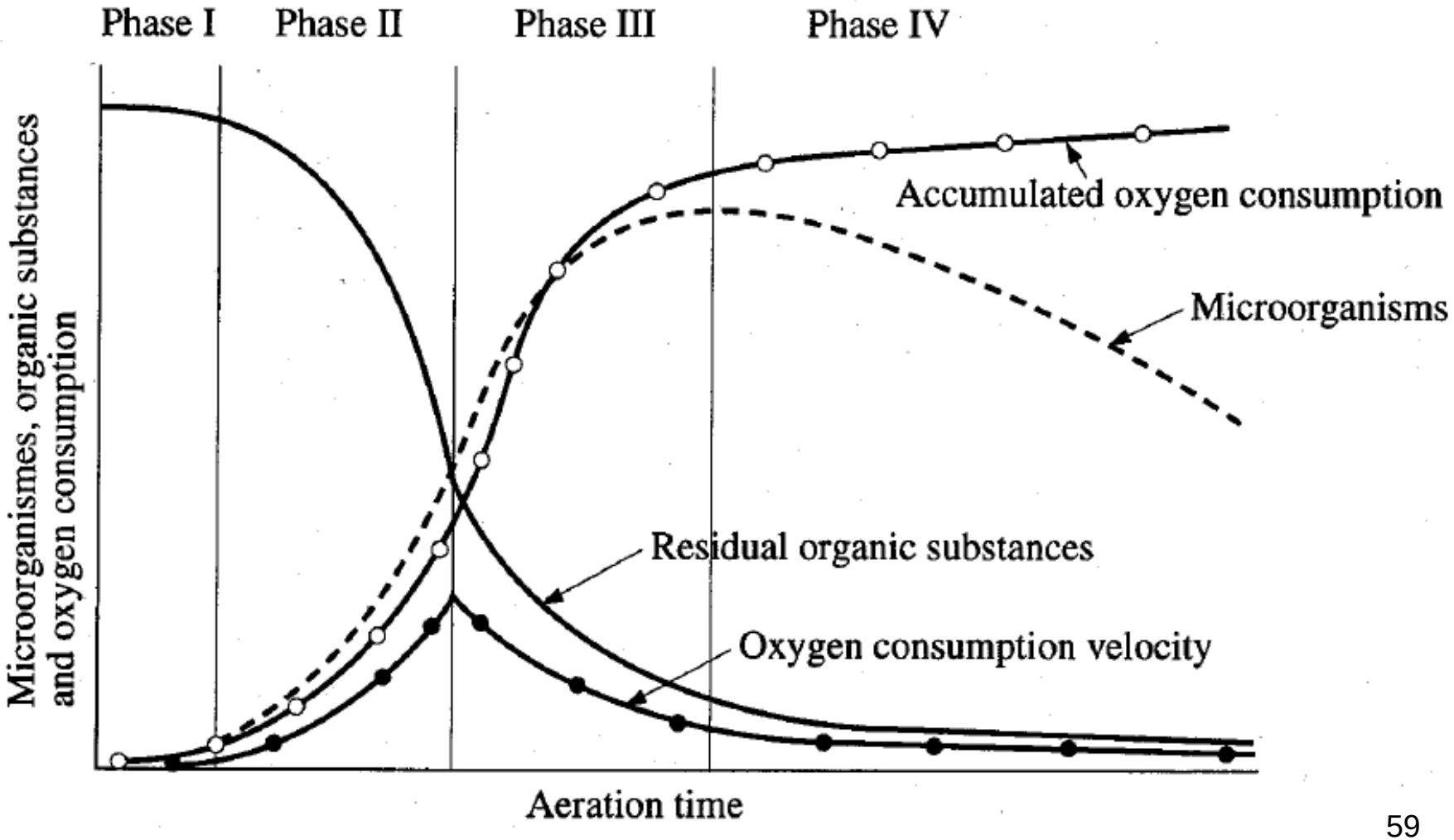


Organisms living in waste water

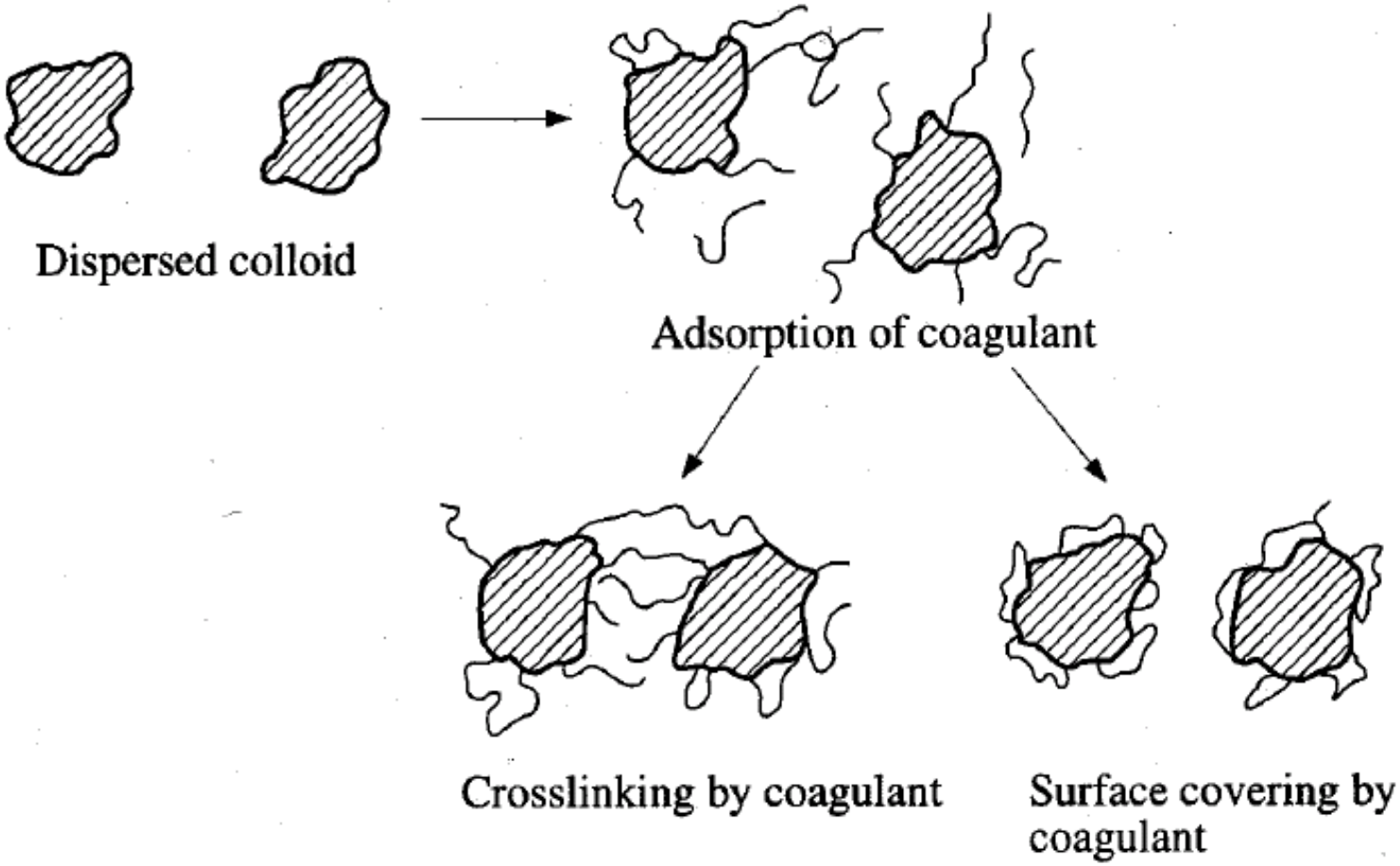


I. Bacteria (a. Zooglea b. Sphaerotilus)
II. Protozoa (a. Amebas b. Trichina c. Mastigote)
III. Algae (a. Blue-green algae b. Green algae c. Diatom)

Decomposition of organic substances and growth of microorganisms



Crosslinking by highmolecular coagulant and redispersion



Typical Highmolecular Coagulants

Ionic nature	Composition	
Anionic	(1) Sodium polyacrylate	$\left(-CH_2-\underset{\underset{COONa}{|}}{CH}-\right)_n$
	(2) Partially hydrolyzed polyacrylamide	$\left(-CH_2-\underset{\underset{CONH_2}{|}}{CH}-\right)_3\left(CH_2-\underset{\underset{COONa}{|}}{CH}-\right)_n$
Cationic	(1) Polyaminoalkylacrylamide	$(-CH_2-\underset{\underset{CONHR_1N^{\oplus}<^{R_2}_{R_3}\ HX^{\ominus}}{|}}{CH}-)_n$
	(2) Polyaminoalkyl methacrylate	$-CH_2-\underset{\underset{COOR_1N^{\oplus}<^{R_2}_{R_3}\ HX^{\ominus}}{|}}{\overset{\overset{CH_3}{|}}{C}H}-$ R: Alkyl X: Cl, SO_4
	(3) Polyethylene-imine	$(-CH_2CH_2NH)_n$
Nonionic	(1) Polyacrylamide	$\left(-CH_2-\underset{\underset{CONH_2}{|}}{CH}-\right)_n$
	(2) Polyethylene oxide	$(-CH_2\cdot CH_2O-)_n$

Filtration

Kinds and Types of Clarifying Filters

Kind	Type	Example of Application
Granular bed filtration	Slow and rapid gravity filters, Slow and rapid pressure filters, Multi-layer rapid filter, Movable bed, continuous rapid filters	Rapid filters are most commonly used for the treatment of supply and waste water.
Filter aid filtration	Filter comprising a layer of diatomaceous earth or other filter aids coated on a cloth or other supports	Circulating clarification of swimming pool water
Direct filtration	Filter and micro-strainer comprising porous ceramics, sintered metal, wire gauze or cloth	Clarification of suspensions of comparatively high con-centrations

Comparison of the Performances of Various Dewatering Equipments

Item \ Type	Vacuum filter	Filter press	Filter press with squeezer	Centrifugal filter
Feed method	Continuous	Batch	Batch	Continuous
Dewatering system	Vacuum filtration (0.3 - 0.6 kg/cm^2)	Pressure filtration (3 - 7 kg/cm^2)	Feed by pressure (3 - 5 kg/cm^2) Squeeze (10 - 20 kg/cm^2)	Centrifugal force : 1500 - 4500 G
Attachments	Vacuum pump, Controller	Sludge feed pump, Compressor, Controller	Sludge pump, Pressure water pump, Compressor, Controller	Controller
Control	Full-automatic operation possible	Full-automatic operation possible. (Semi-automatic operation is common).	Full-automatic operation possible.	Full-automatic operation possible.
Capacity per de watering area	Large	Small	Large	Large
Water content of cake (%)	65 - 75%	60 - 65%	45 - 55%	70 - 85%
Recovery rate of solid substance	Over 85%	Over 98%	Over 98%	Over 90%
Running cost	Medium	High	High	High
Initial cost	Low	Medium	Large	Low
Remarks	Dewatering performance largely depends on the condition of the sludge.	(1) Available capacity is up to 250 m^2 in filtration area. (2) One cycle requires 1.5 - 2.5 hrs.	(1) Available capacity is up to 200 m^2 in filtration area. (2) One cycle requires 10 - 25 min.	(1) Requires pretreatment, and high molecular coagulant is much used. (2) Widely used in small sewage treatment plants. (3) Screw decanter type is mainly used.

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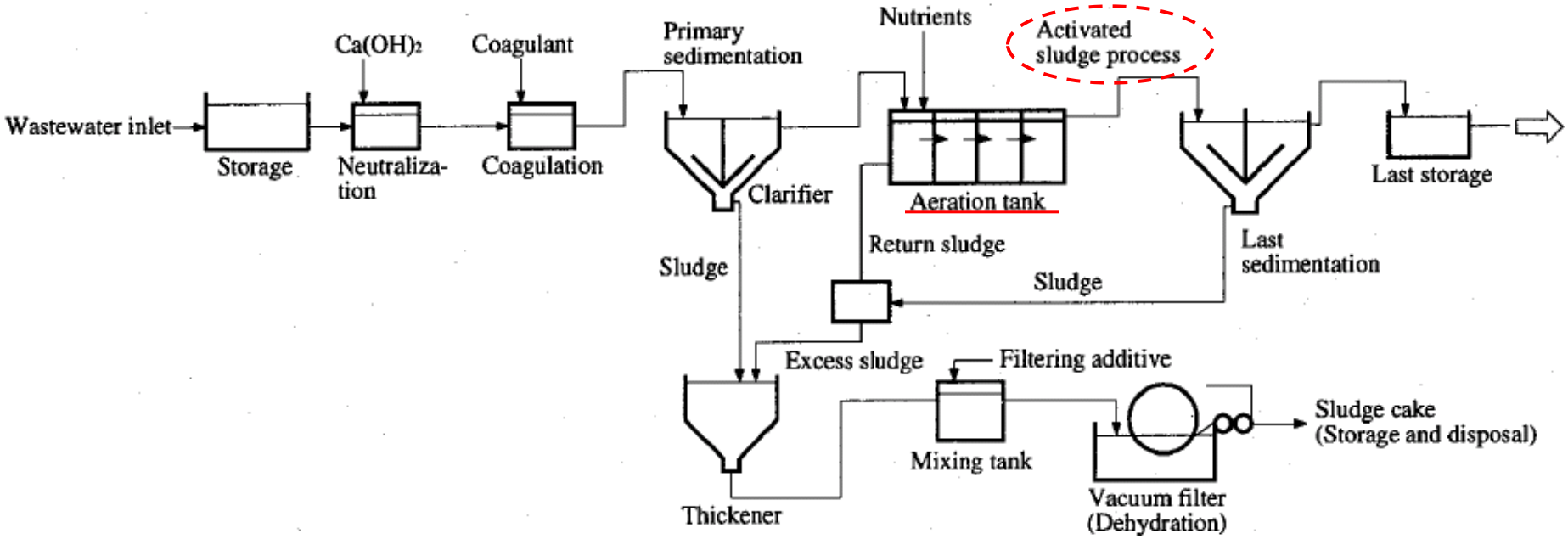
1. Water circulation and balance in the earth
2. Water pollutants and their characteristics and sources
3. Water composition and water quality standards
4. Concentration of pollutants of waste water from different sources
5. Carbon cycle in aquatic zone
6. Change of concentration of water indexes
7. Toxicity of water pollutants
8. Quality standards of water
9. Countermeasures for reuse of waste water
10. Theory of waste water treatment by activated sludge
11. Combination of aerobic and anaerobic waste water treatment

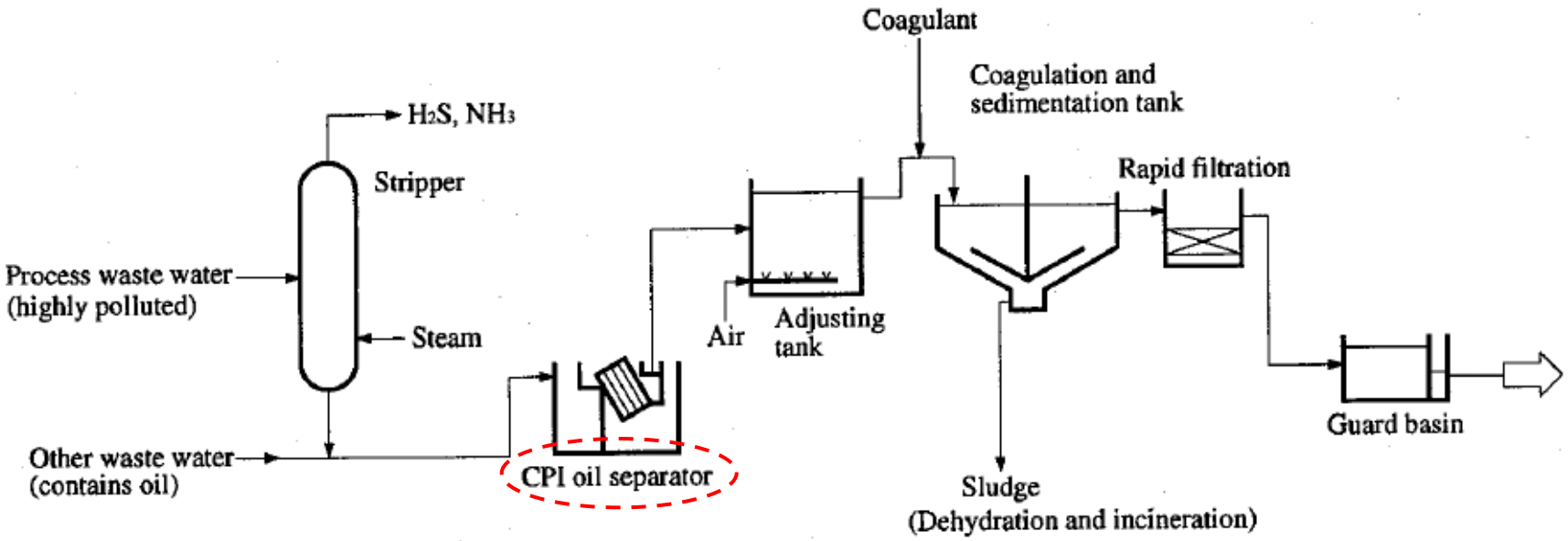
Examples of waste water treatment (1/4)

Chemical industry (Waste water contains various organic compounds, heavy metals used as catalyst, acid and alkali)



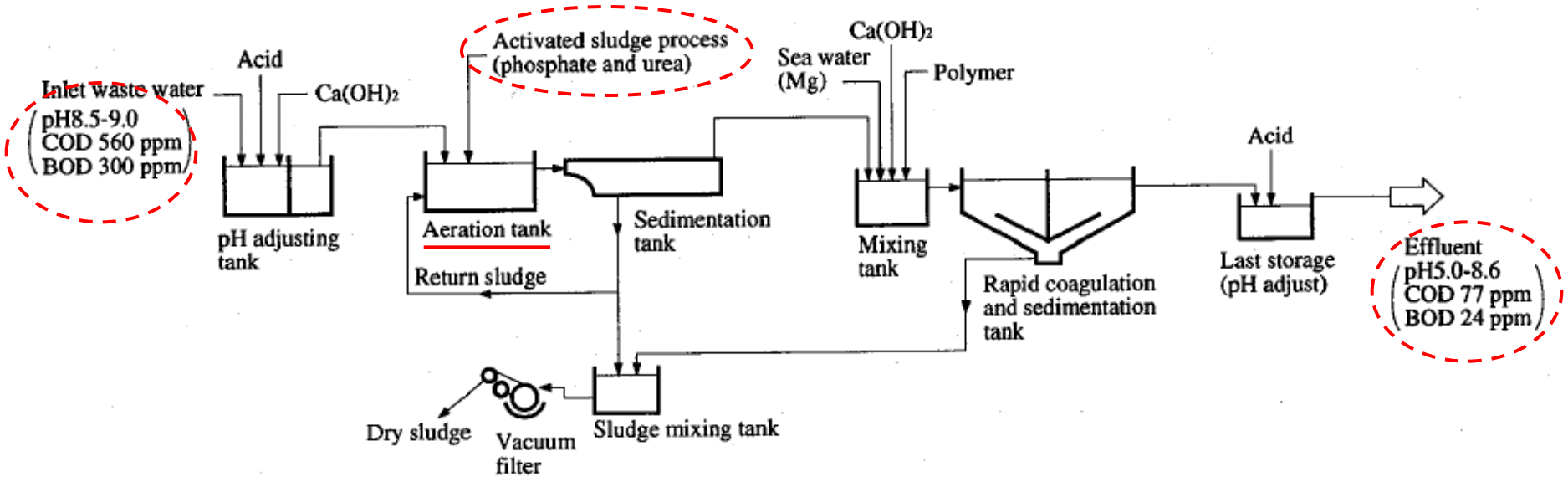
Examples of waste water treatment (2/4)

Petroleum refinery

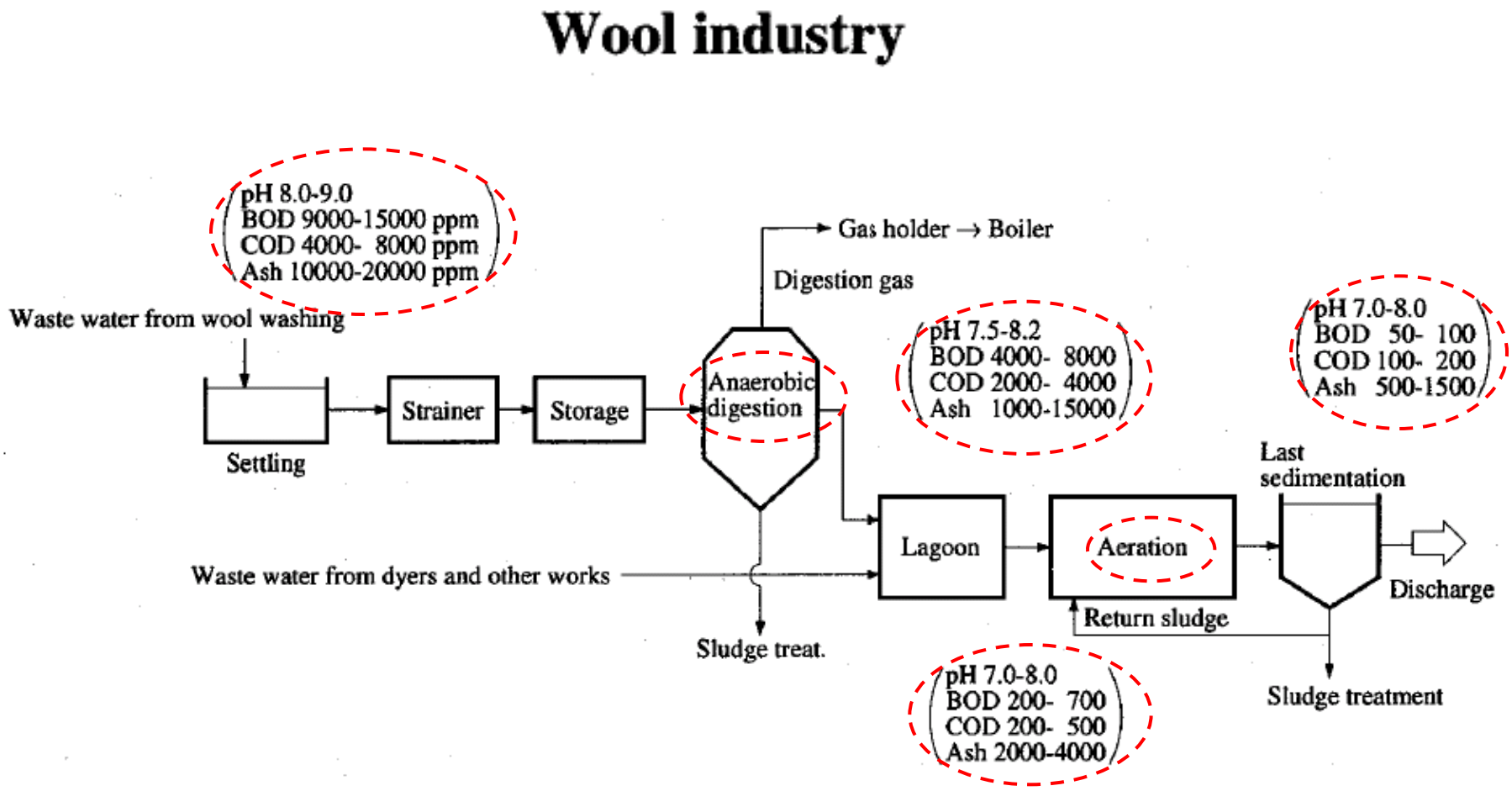


Examples of waste water treatment (3/4)

Pulp industry



Examples of waste water treatment (4/4)



Thank you for your attention !!