Recovery of clean water
Wastewater system in Japan

Water & Waste Engineering (6)
2021/05/14

名古屋大学減災連携研究センター
Disaster Mitigation Research Center, NAGOYA UNIVERSITY

Japanese Experiences of Industrial Pollution

- Itai-itai disease(1912): River water pollution from mining, heavy metals such as cadmium
- Minamata disease(1956): Water pollution from plant, food containing methylmercury compounds
- Niigata Minamata disease(1965): Water pollution from plant, methlymercury compounds
- Yokkaichi asthma(1961): Air pollution from petrochemical plants, sulfur dioxide

Recovery of Clean Water; Laws, Regulations and Technology for Water Pollution Control

Minamata disease & Itai-Itai disease

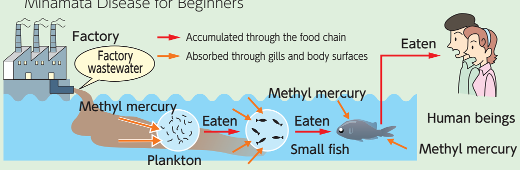
Minamata disease

Chisso Corporation Minamata Factory during the 1950s
Photo courtesy of the Minamata Disease Municipal Museum

The occurrence of Minamata disease was first confirmed in 1956. The disease was caused by methyl mercury discharged from a chemical factory (Chisso Corporation Minamata Factory) in Kumamoto Prefecture's Minamata City. Methyl mercury discharged into the sea was bioconcentrated in fish and shellfish through the food chain, damaging the health of those who ate contaminated seafood. Major symptoms of Minamata disease include sensory impairment of limbs, ataxia, constriction of the visual field, hearing impairment, and speech disorders. Some patients with severe symptoms became comatose and died.

Also, methyl mercury absorbed into a pregnant mother's body was sometimes incorporated through the umbilical cord into the fetus in her womb, resulting in the birth of a baby with congenital symptoms of Minamata disease (fetal Minamata disease patient). The total number of patients certified as suffering from Minamata disease was 2,275 as of October 2013. Similar health damage was also caused by organic mercury compounds discharged from Showa Denko's factory in the Agano River Basin in Niigata Prefecture (Niigata Minamata disease).

Source: Figure compiled from Kumamoto Prefecture, Knowledge of Minamata Disease for Beginners

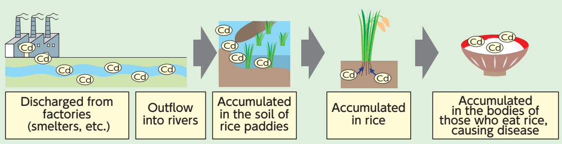


Itai-Itai disease

Cadmium discharged from the Kamioka Mine in Gifu Prefecture (Mitsui Mining & Smelting Co., Ltd.'s Kamioka Plant) contaminated rice paddies in the lower basin of the Jinzu River, causing disease among those who ate rice grown in the area. Itai-Itai disease is believed to have started around the Taisho period; it attracted public attention in 1955, when it was first reported in a newspaper.

Itai-Itai disease is caused by chronic cadmium poisoning, which initially damages kidneys and then causes osteomalacia (a disease that creates a defect in the system that hardens bones, preventing normal bone development). Symptoms of the disease include pain in the waist, shoulders, or knees. As the disease becomes more severe, the patient repeatedly breaks bones; eventually, the patient becomes incapable of moving around on his own due to pain felt throughout his entire body. The name of the disease is said to derive from the cry of pain ("Itai itai," meaning "It hurts" in Japanese) raised by the patient suffering from unendurable pain. A total of 196 patients were certified as suffering from Itai-itai disease between 1967, when the first Itai-itai disease patient was certified as such, and the end of 2011.

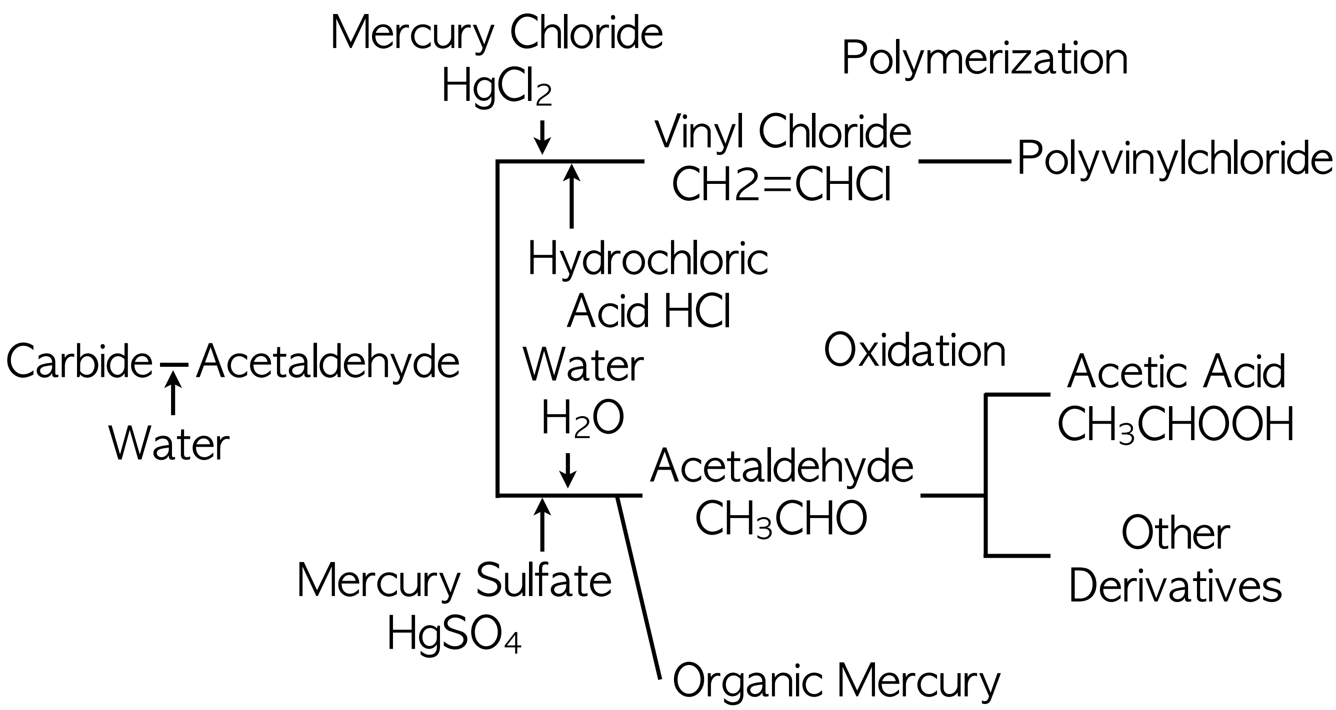
Source: Compiled from a figure on the website of the Toyama Prefectural Itai-Itai Disease Museum



Minamata Disease

- Establishment of Chisso Co. Ltd. and Outbreak of Minamata Disease
- Methylmercury compound
  - Entrance of the Minamata bay: 12.2 ppm
  - Seafood
  - 100% into the system through the intestines with oral intake.

Acetaldehyde manuracturing process using mercury



Itai-Itai Disease

- Jinzu river and Kamioka Mines
- Harmful heavy metals; Cadmium
  - heavy metals such as cadmium were deposited along the river bed and in the soil underlying rice patties
  - The heavy metals discharge from the Kamioka Mines
  - The cadmium dissolved in the agricultural water
  - the cadmium concentration in contaminated soil; 4.85ppm
  - the maximum concentration of cadmium in unpolished rice: 4.23ppm

Recovery of clean water; laws, regulations and technology for water pollution control

- **the historical background of water pollution and the conditions of under which the Minamata and Itai-itai diseases occurred are explained.**
- **the purpose of laws; to prevent water pollution**
- **more stringent prefectural standards, wastewater treatment systems and technologies for improving of water quality, and monitoring systems by telemeter.**

Water Pollution and its Control

Types of pollutant (1)

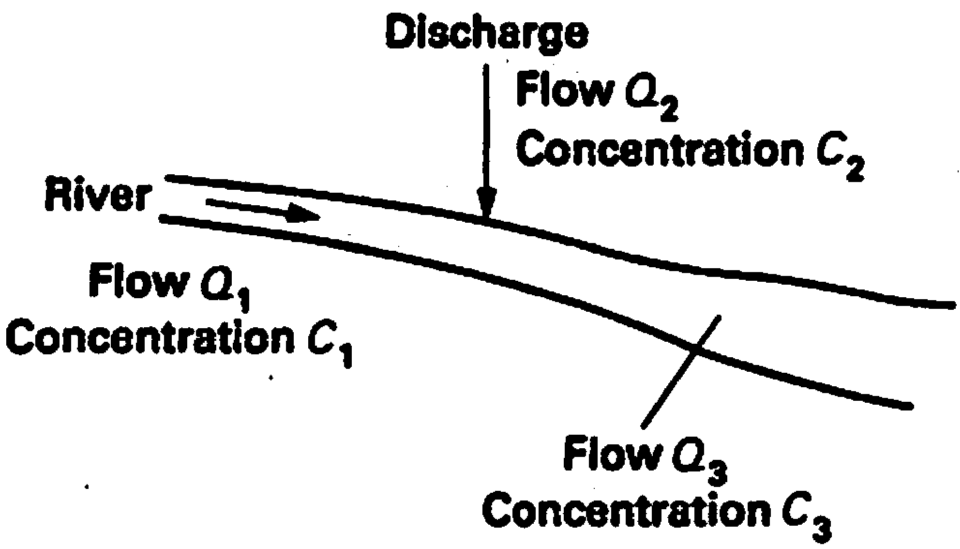
- Toxic compounds which result in the inhibition or destruction of biological activity in the water. Most of these materials originate from industrial discharges and would include heavy metals from metal finishing and plating operations, moth repellents from textile manufacture, herbicides and pesticides, etc. Some species of algae can release potent toxins and cases have been recorded where cattle have died after drinking water containing algal toxins.
- Anything which may affect the oxygen balance of the water

Water Pollution and its Control

Types of pollutant (2)

- Anything which may affect the oxygen balance of the water, including
  - ✓ substances which consume oxygen
  - ✓ substances which hinder oxygen transfer across the air-water interface
  - ✓ thermal pollution, which can upset the oxygen balance because the saturation DO concentration reduces with increasing temperature.
- Inert suspended or dissolved solids in high concentrations can cause problems, e.g. china-clay washings can blanket the bed of a stream preventing the growth of fish food and removing fish from the vicinity as effectively as a direct poison. The discharge of saline mine drainage water may render a river unsuitable for water-supply purposes.

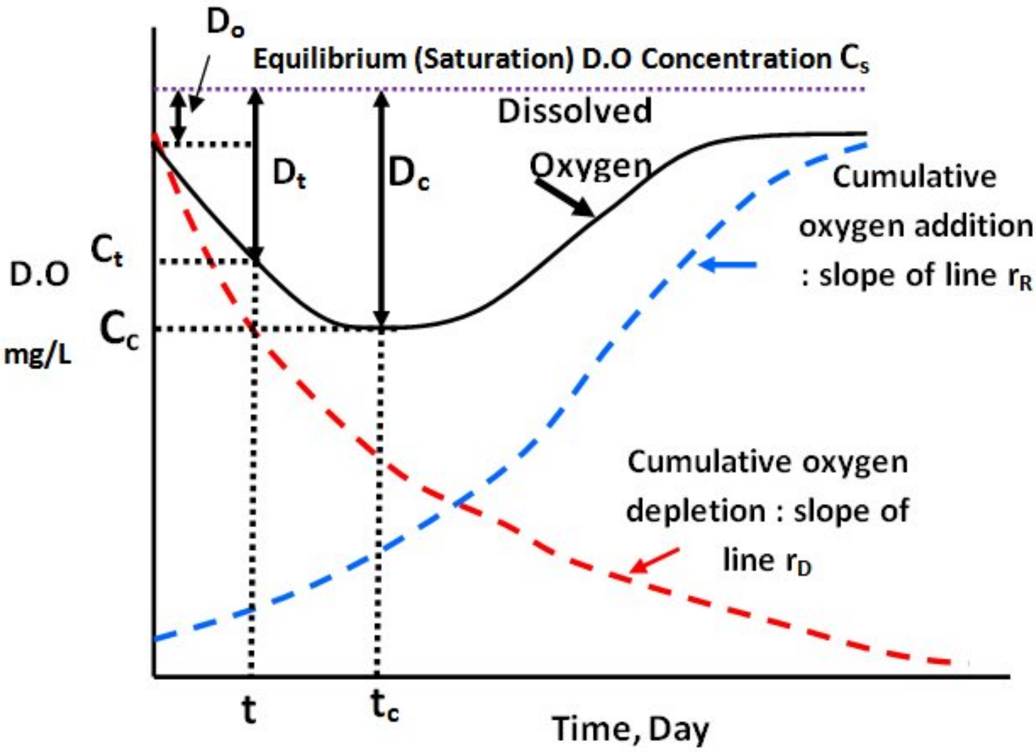
The mass balance concept in river pollution



DO sag curve

– If the stream is originally saturated with DO the BOD uptake curve for the mixture of effluent and stream water gives the cumulative deoxygenation of the stream. As soon as BOD begins to be exerted the DO falls below saturation and reaeration stars. With increasing saturation deficit the rate of reaeration increases until a critical point is reached where the rates of deoxygenation and reaeration are equal. At the critical point, minimum DO is reached and as further time passes the DO will increase

DO sag curve



Factors which may influence the DO sag

- The contribution of bottom muds to oxygen demand
- BOD addition in surface runoff
- removal of DO by diffusion into bottom mud to satisfy oxygen demand
- BOD addition by diffusion of soluble organics from bottom deposits
- removal of DO by purging action of gases released from bottom deposits
- addition of DO by photosynthetic activities of plants
- removal of DO by plants during night
- continuous redistribution of DO and BOD by longitudinal disperison

Some compounds toxic to fish

Material	*Occurrence*	*Approx. LD_{50} mg/l*
Acridine	Coal-tar wastes	0.7–1.0
Aldrin	Insecticide	0.02
Alkyl benzene sulphonate	Sewage effluent	3–12
Ammonia	Sewage effluent	2–3
Chloramine	Chlorinated effluents	0.06
Chlorine	Chlorinated effluents	0.05–0.2
Copper sulphate	Metal processing Algal control of reservoirs	0.1–2.0
Cyanide	Plating wastes	0.04–0.1
DDT	Insecticide	<0.1
Detergents, synthetic (packaged)	Sewage effluent	15–80
Fluoride	Aluminium smelting	2.5–6.0
Gammexane	Insecticide	0.035
Hydrogen sulphide	Bottom muds, sludge	0.5–1.0
Methyl mercaptan	Oil refineries Wood pulp processing	1.0
Naphthalene	Coal-tar wastes Gas liquor	10–20
Parathion	Insecticide	0.2
Potassium dichromate	Flow gauging	50–500
Silver nitrate	Photographic wastes	0.004
Zinc	Galvanizing Rayon manufacture	1–2

Note: These figures are intended only as a guide, the actual LD_{50} in any particular situation will depend on environmental factors, the species of fish involved and the duration of the exposure.

NAGOYA UNIVERSITY

Water quality classifications

River class	*Quality criteria*	*Remarks*	*Potential uses*
1A	DO >80% saturation BOD not >3 mg/l Ammonia not >0.4 mg/l Complies with A2 water Non-toxic to fish*	Average BOD not >1.5 mg/l No visible evidence of pollution	Potable supply Game fishery High amenity
1B	DO >60% saturation BOD not >5 mg/l Ammonia not >0.4 mg/l Complies with A2 water Non-toxic to fish*	Average BOD not >2 mg/l Average ammonia not >0.5 mg/l No visible evidence of pollution	As for 1A
2	DO >40% saturation BOD not >9 mg/l Complies with A3 water Non-toxic to fish*	Average BOD not >5 mg/l May be some colour and foam	Potable supply after advanced treatment Coarse fishery Moderate amenity
3	DO >10% saturation Not anaerobic BOD not >17 mg/l		Low grade supply Polluted to extent that fish are absent
4	DO <10% saturation Anaerobic at times		Grossly polluted Cause nuisance
X	DO >10% saturation		Insignificant waters Object is simply the prevention of nuisance

* European Inland Fisheries Advisory Commission (EIFAC) terms. A2 and A3 refer to treatment requirements under EC directive 76/464/EEC (Table 2.4).

Japanese effluent standards

Parameter (mg/l except where noted)	*National standard*	*Typical prefecture standard*
Health related parameters		
Cadmium	0.1	0.01
Cyanide	1.0	Not detectable
Organophosphorus compounds	1.0	Not detectable
Lead	1.0	0.1
Chromium (hexavalent)	0.5	0.05
Arsenic	0.5	0.05
Mercury	0.005	0.0005
Alkyl compounds	Not detectable	Not detectable
PCB	0.003	Not detectable
Environmentally related parameters		
BOD	160	25
SS	200	50
Phenol	5	0.5
Copper	3	1
Zinc	5	3
Iron (soluble)	10	5
Manganese (soluble)	10	5
Fluoride	15	10
Mineral oil	5	3
Fat	30	10
pH (units)	5.8–8.6	5.8–8.6
Coliforms (MPN/ml)	3000	3000

US minimum national standards for secondary wastewater treatment

Parameter	*30 day average*	*7 day average*
Five day BOD, most stringent of		
Effluent (mg/l)	30	45
Percentage removal	85	
Suspended solids, most stringent of		
Effluent (mg/l)	30	45
Percentage removal	85	
pH	Within range of 6.0 to 9.0 at all times	
Faecal coliforms (MPN/100 ml)	200	400

Wastewater

- Wastewater is the flow of used water from community.
- On an individual basis, each individual contributes approximately 260 to 560+ liters of water per day to a community's wastewater flow.
- Wastewater is actually 99.94% water by weight. The rest, that 0.06%, is material dissolved or suspended in the water.

Constituent	Abbreviation	Concentration(mg/L)
Biochemical oxygen demand	BOD5	100 - 300
Chemical oxygen demand	COD	250 - 1000
Total dissolved solids	TDS	200 - 1000
Suspended solids	SS	100-350
Total Kjeldahl nitrogen	TKN	20 -80
Total phosphorus as P	TP	5 -20

Wastewater Regulations in Japan

- Ministry of the Environment, Government of Japan established and revised the national effluent standards on October 21, 2015.
- The national effluent standards are uniformly applied in Japan. This standards has two categories: the standards for protecting human health (28items) and the standards for protecting the living environment (15 items).

The standards for protecting human health

Chemical	Permissible Limit	Chemical	Permissible Limit
Cadmium and its compounds	0.03mg Cd/L	cis-1,2-Dichloro ethylene	0.4 mg/L
Cyanide compounds	1 mg CN/L	1,1,1-Trichloro ethane	3 mg/L
Organic phosphorus compounds	1 mg/L	1,1,2-Trichloro ethane	0.06 mg/L
Lead and its compounds	0.1 mg Pb/L	1,3 Dichloropropene	0.02 mg/L
Hexavalent Chromium	0.5 mg Cr(VI)/L	Thiram	0.06 mg/L
Arsenic and its compounds	0.1 mg As/L	Simazine	0.03 mg/L
Mercury and its compounds	0.005 mg Hg/L	Thiobencarb	0.2 mg/L
Alkyl mercury compounds	Not detectable	Benzene	0.1 mg/L
PCBs	0.003 mg/L	Selenium and its compounds	0.1 mg Se/L
Trichloroethylene	0.1 mg/L	Boron and its compounds	10 mg B/L
Tetrachloroethylene	0.1 mg/L	Boron and its compounds(Coastal)	230 mg F/L
Dichloromethane	0.2 mg/L	Fluorine and its compounds	8 mg F/L
Carbon Tetrachloride	0.02 mg/L	Fluorine and its compounds(Coastal)	15 mg F/L
1,2-Dichloro ethane	0.04mg/L	Ammonia, Ammonium compounds, Nitrate and Nitrite compounds	100 mg/L
1,1-Dichloro ethylene	1 mg/L	1,4-Dioxane	0.5 mg/L

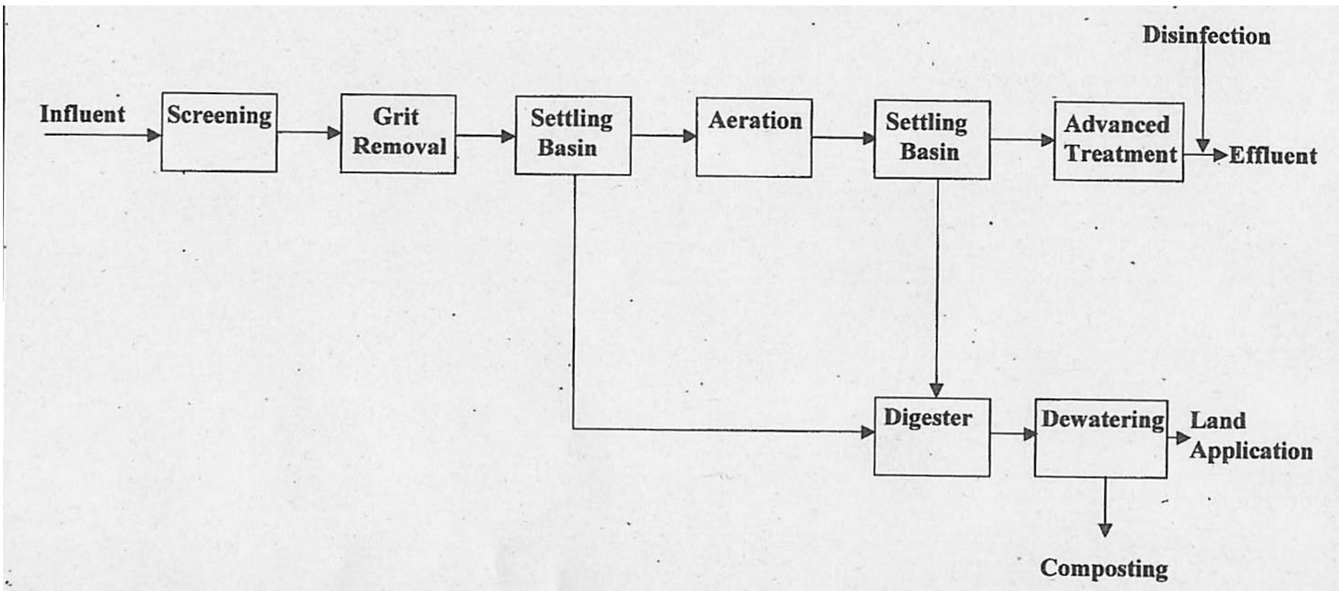
The standards for protecting living environment

Items	Permissible Limit	Items	Permissible Limit
Potential Hydrogen (pH)	5.8 - 8.6	Copper	3 mg/L
Potential Hydrogen (pH) (Coastal)	5.0 - 9.0	Zinc	2 mg/L
Biochemical Oxygen Demand (BOD)	160mg/L Daily Ave.120mg/L	Dissolved iron	10 mg/L
Chemical Oxygen Demand (COD)	160 mg/L Daily Ave.120mg/L	Dissolved manganese	10 mg/L
Suspended solids (SS)	200 mg/L Daily Ave.150mg/L	Chromium	2 mg/L
N-hexane Extracts (mineral oil)	5 mg/L	Coliform groups	Daily Ave. 3000/ cm3
N-hexane Extracts (animal and vegetable fats)	30 mg/L	Nitrogen	120 mg/L Daily Ave.60mg/L
Phenols	5 mg/L	Phosphorus	16 mg/L Daily Ave.8mg/L

Wastewater treatment

- Wastewater management is increasingly important as our water resources are stretched further and further as populations increase.
- Wastewater treatment process for treatment and for wastewater reclamation and reuse.
  1. Wastewater
  2. Pretreatment,
  3. Primary Sedimentation
  4. Biological Treatment
  5. Secondary Sedimentation
  6. Tertiary Treatment
  7. Disinfection
  8. Discharge Effluent

Primary, secondary, advanced treatment



Pretreatment (1)

- The initial stage in the treatment process (following collection and influent pumping) is primary treatment, which begins with preliminary treatment.
- Raw influent entering the treatment plant may contain many kinds of floating materials and settleable solids.
- The purpose of preliminary treatment is to protect plant equipment by removing these materials, which could cause clogs, jams or excessive wear to plant machinery.
- Pretreatment: Screening, Shredding, Grit Removal, Flow Measurement, Pre-aeration, Chemical Addition, Flow Equalization

Pretreatment (2)

- **Screening**
  - The purpose of screening in wastewater treatment is to remove large solids (such as rags, cans, rocks, branches, leaves, and roots) from the flow before the flow moves on to downstream processes.
- **Shredding**
  - As an alternative to screening, shredding can be used to reduce solids to a size that can enter the plant.
- **Grit Removal**
  - In cities with combined sewer systems, sand and silt may be carried in the sewage. The purpose of grit removal is to remove the heavy inorganic solids, which could cause excessive mechanical wear.

Pretreatment (3)

- **Flow Measurement**
  - Flow measurement is used throughout the treatment process to ensure the efficient operation of the treatment facility and to provide information (hydraulic and organic loading)
- **Pre-aeration**
  - Wastewater is aerated to achieve and maintain an aerobic state (freshening septic wastes), strip off hydrogen sulfide (reducing odors and corrosion), and agitate solids to release trapped gases (improving solids separation and settling).

Pretreatment (4)

- **Chemical Addition**
  - Chemical addition is made to the wastestream to reduce odors, neutralize acids or bases, reduce corrosion, reduce BOD5, improve solids and grease removal, reduce loading on the plant, and to aid subsequent processes.
  - Actual chemical use depends on the desired result.
- **Flow Equalization**
  - The purpose of flow equalization is to reduce or remove the wide swings in flow rates normally associated with wastewater treatment plant loadings.

Primary Sedimentation

– The purpose of primary sedimentation is to concentrate and remove settleable organic and floatable solids from wastewater.

- **Septic Tanks:** are prefabricated tanks serve as combined settling and skimming tanks, and as unheated-unmixed anaerobic digesters.
- **Tow-Story (Imhoff) Tank:** is similar to a septic tank in the removal of settleable solids and the anaerobic digestion of solids.
- **Plain Settling Tanks:** Sludge is removed from the tank for processing in other downstream treatment units.

Biological Treatment (1)

– Primary treatment unit processes remove only those pollutants that will either float or settle out by gravity. Thus, about 50% of the raw pollutant load still remains in the primary effluent.

– The main purpose of biological treatment is to provide BOD removal beyond what is achievable by primary treatment

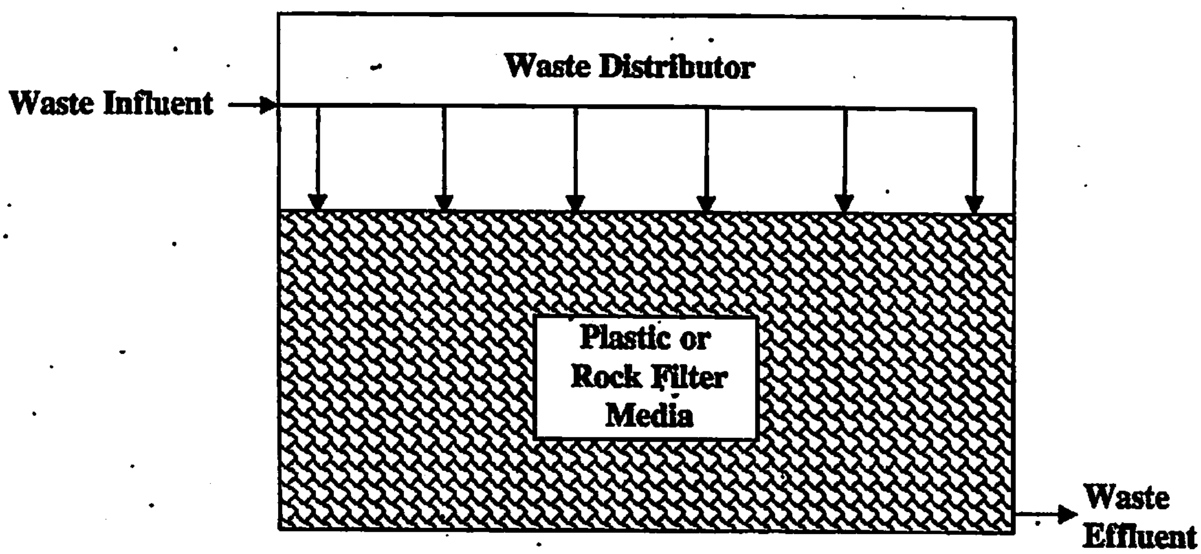
- **Secondary treatment**

– Secondary treatment refers to those treatment processes that use biological processes to convert <u>dissolved, suspended and colloidal organic wastes</u> to <u>more stable solids</u>, which can either be removed by settling or discharged to the environment without causing harm.

Biological Treatment (2)

- **Trickling Filters**
  - In most wastewater treatment systems, the trickling filter follows primary treatment and includes a secondary settling tank or clarifier. Trickling filters are widely used for the treatment of domestic and industrial wastes.
  - The trickling filter biological treatment process is a fixed film biological treatment method designed to remove BOD5 and suspended solids. It involves contact between wastewater that contains organic contaminants, and a population of microorganisms which are fixed or attached to the surface of filter media.

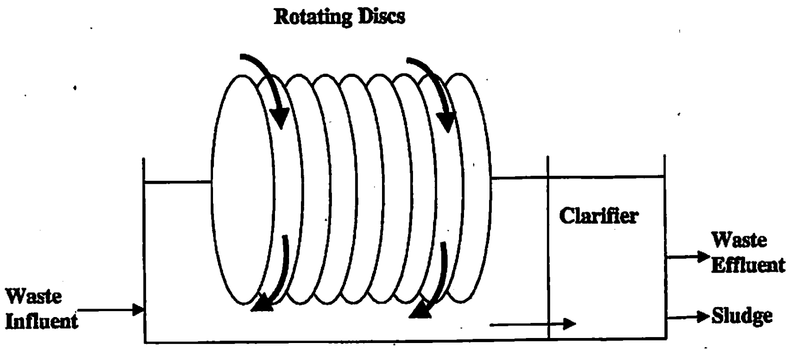
Trickling Filter



Biological Treatment (3)

Rotating Biological Contactors

- THe rotating biological contactor is a biological treatment system, a variation of the attached-growth idea provided by the trickling filter.



Biological Treatment (4)

Treatment Ponds/Lagoons

- **Ponds based on location and types of wastes received**
- Raw Sewage Stabilization Pond
  - ✓ Most common type of pond. Generally, raw sewage stabilization ponds are designed to provide a minimum of 45 days detention time.
- Oxidation Pond
  - ✓ An oxidation pond is normally designed using the same criteria as the stabilization pond. This type of pond provides biological treatment, additional settling, and some reduction in the number of fecal coliform present
- Polishing Pond
  - ✓ Polishing ponds remove additional BOD5, solids and fecal coliform, and some nutrients. They are designed to provide 1 to 3 days detention time.

Biological Treatment (5)

Treatment Ponds/Lagoons

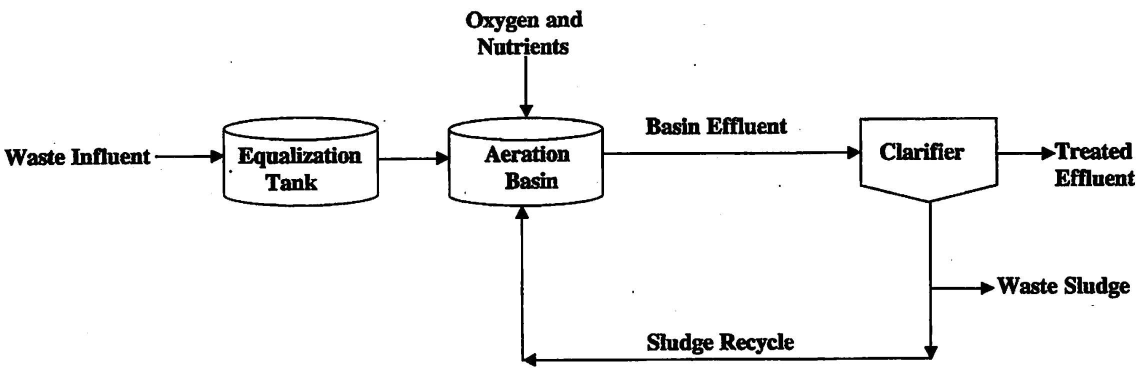
- **Ponds based on the type of processes occurring within**
- Aerobic Ponds
  - ✓ In aerobic ponds oxygen is present throughout the pond. All biological activity is aerobic decomposition.
- Anaerobic Ponds
  - ✓ Anaerobic ponds are normally used to treat high-strength industrial wastes. No oxygen is present in the pond and all biological activity is anaerobic decomposition.
- Facultative Pond
  - ✓ is the most common pond type. Oxygen is present in the upper portions of the pond and aerobic processes are occurring. No oxygen is present in the lower levels of the pond where occurring processes are anoxic and anaerobic.
- Aerated Pond
  - ✓ oxygen is provided through the use of mechanical or diffused air systems.

Biological Treatment (6)

Activated Sludge

- The activated sludge process is currently the most widely used biological treatment process, in the part because recirculation of the biomass (an integral part of the process) allows microorganisms to adapt to changes in wastewater composition by relatively short acclimation processes.
- The activated sludge process is designed to remove BOD5 and suspended matter through aerobic decomposition. Nitrogen and phosphorous may also be removed if process controls are properly adjusted.

Activated Sludge Process



©F. R. Spellman & N. E. Whiting, Water Pollution Control Technology, Government Institutes, 1999

Secondary Sedimentation

- Secondary sedimentation is an important part of the overall treatment process.
- Its importance can be illustrated in relation to the function it performs with and after the activated-sludge process.
- *How do we go about determining the solids concentration with in a secondary sedimentation tank?*
- In the first place, solids concentration can be assumed to be equal to the solids concentration in the aeration tank effluent. Additionally, solids concentrations can be determined in the laboratory using a core sample taken from the secondary clarifier. The secondary clarifier solids concentration can be calculated as an average of the secondary effluent suspended solids and the return activated sludge suspended solids concentration.

Final Sedimentation Tank Observations: Sludge Problems

- **Sludge bulking**
  - A bulking sludge is one that has poor settling characteristics and poor compactability.
- **Sludge solids washout**
- **Clumping**
- **Ashing**
- **Straggler floc**
- **Pin floc**

NAGOYA UNIVERSITY

Tertiary Treatment

- Advanced wastewater treatment refers to the addition of unit processes that remove more contaminants from wastewater than can usually be achieved by standard, conventional water pollution control technologies.
- **Tertiary treatment** suggests an additional step applied only after conventional primary and secondary wastewater processing. The simplest tertiary treatment is the addition of a special filtration unit process followed by chlorination with an extended contact time for removal of pathogens.
- **Advanced treatment** actually means any process or system that is used after conventional treatment, or to modify or replace one or more steps to remove refractory contaminants.