Wastewater Engineering

Class 1 Introduction

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- **学时数： 32 学时 (16 Times)**

  （Week 1: 7th Sep.– Week 8: 6th Nov.）

❖ **Exam：6th Nov.**

Detailed schedule

Week 1	9.7 (Tue)	Introduction I	
	9.10 (Thur)	Introduction II	
Week 2	9.14 (Tue)	Introduction III	
	9.17 (Thur)	Reading + Presenting	
Week 3	9.21 (Tue)	Self - study	Mid-autumn Day
	9.24 (Thur)	Flow equalization	
Week 4	9.28 (Tue)	Screens	
	9.30 (Thur)	Grit removal	
Week 5	10.10 (Sun)	Presentation	**10.10**
	10.7 (Thur)	Self - study	National Day
Week 6	10.12 (Tue)	Primary sedimentation	
	10.14 (Thur)	Reactor engineering	
Week 7	10.19 (Tue)	Activated sludge system	
	10.21 (Thur)	Aeration	
Week 8	10.26 (Tue)	Final clarifier	
	10.28 (Thur)	**EXAM - PAPER**	**31st Oct**

Exam

- **Attendance 10%**
- **WWTP case related PPT 40%**
- **Paper 50%**

Why?

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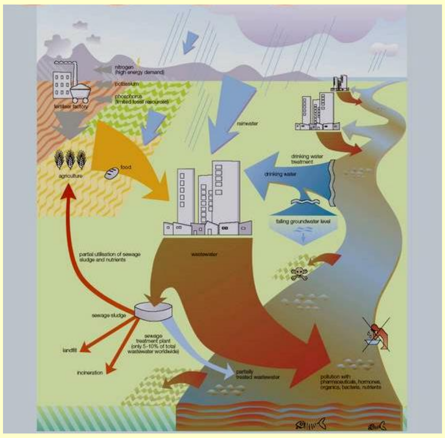

Schematic diagram of a wastewater management infrastructure (1)

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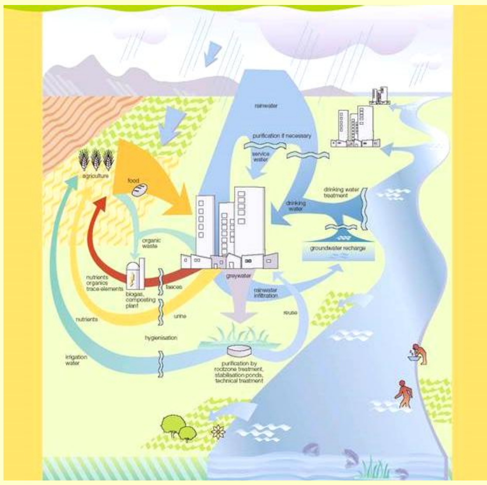

Schematic diagram of a wastewater management infrastructure (2)

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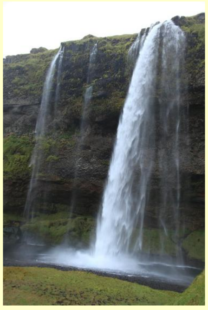

How to solve?

Learn from this course

Goal of this course

This course train future environmental engineers to understand, apply and design processes that reduce environmental damage. It covers fundamental knowledge of (1) wastewater characteristics, (2) wastewater treatment, principles and applications.

Textbooks:

1. Wastewater Engineering - Treatment and Reuse, Metcalf & Eddy, 4th Edition McGraw Hill 2003
2. Biological Wastewater Treatment Principles, Modeling and Design, M. Henze, M. C. M. van Loosdrecht, G. A. Ekama, and D. Brdjanovic, IWA Publishing, 2008
3. Biological Wastewater Treatment 2nd Edition, Grady, C. P. L, G. T. Daigger and H. C. Lim, Marcel Dekker, 1999

Course Content

Class	Title
1	Introduction
2	Flow and Its Equalization
3	Screening
4	Grit Removal
5	Primary Sedimentation
6	Activated Sludge Systems Basics
7	Aeration
8	Final Clarification Principle

Wastewater Characteristics

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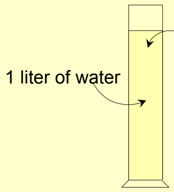
The units used in wastewater measurement

The most important concentration unit is in mg per liter, **mg/l**



The concentration of sugar in this sweetened water is 10 **mg/l**

Since 1 liter of water weights about 1000 g or 1000,000 mg, then 10 mg of sug in 1,000,000 mg of water can be expressed as 10/1,000,000 **parts per million**, or **ppm** by weight or simply ppm, so **ppm = mg/l**

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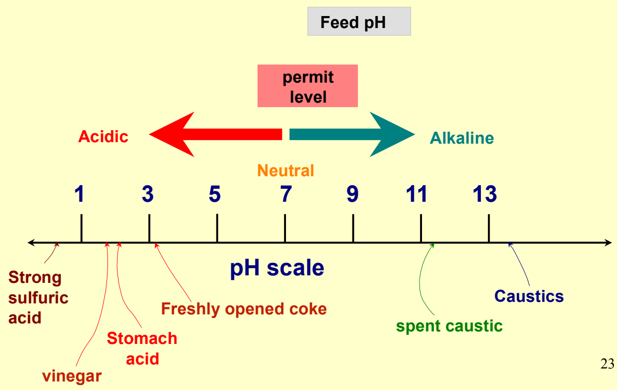
pH

A parameter to gauge the acidic or alkaline nature of the wastewater

$$pH = -\log_{10}[H^+]$$



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- PH range suitable for the existence of most biological life is quite narrow and critical, typically 6 to 9.
- Wastewater with an extreme concentration of hydrogen ion is difficult to treat by biological means.
- For treated effluents discharged to the environment the allowable pH range usually varies from 6.5 to 8.5.

Typical meter used for the measurement of pH and specific ion concentrations

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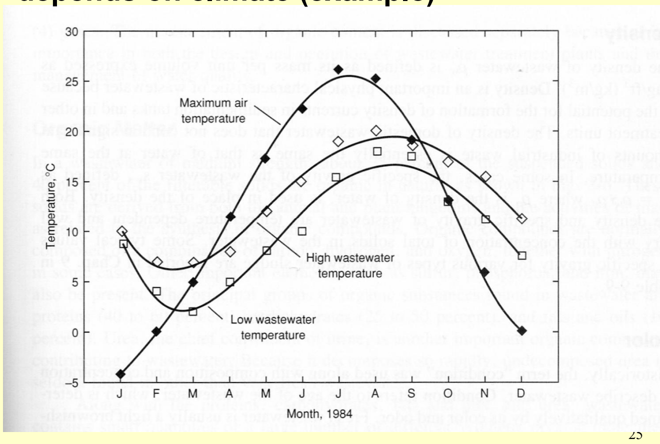
Temperature: wastewater temperature depends on climate (example)



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25 - 35℃	Optimum temperatures for bacterial activity
Higher than 50 ℃	Aerobic digestion and nitrification stops
Lower than 15 ℃	Methane-producing bacteria quite inactive
At 2 ℃	Chemoheterotrophic bacteria acting on carbonaceous material become essentially dormant

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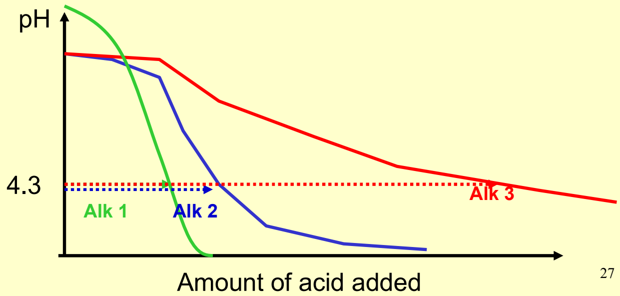
Alkalinity: Acid neutralizing capacity of a water sample. Measured as how much standard acid to add to lower the pH of the sample from ambient to pH of 4.3.

So if the pH of the sample is less than 4.3, the alkalinity would be zero. Other than this fact, the alkalinity does not relate to the pH of the sample.



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- Alkalinity is determined by titrating against a standard acid; the results are expressed in terms of calcium carbonate, mg/L as $CaCO_3$.
- Alkalinity is contributed mainly by the HCO_3^-, CO_3^{2-}, OH^- and by other minor ions such as, phosphate, borate, silicate. It is important parameter used in judging the pH change from biological activities.

$$\text{Alk, eq/m}^3 = \text{meq/L} = [HCO_3^-] + 2\,[CO_3^{2-}] + [OH^-] - [H^+] \quad (2\text{–}34)$$

The corresponding expression in terms of equivalents is

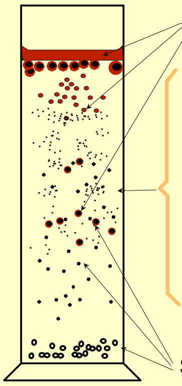
$$\text{Alk, eq/m}^3 = (HCO_3^-) + (CO_3^{2-}) + (OH^-) - (H^+) \quad (2\text{–}35)$$

In practice, alkalinity is expressed in terms of calcium carbonate. To convert from meq/L to mg/L as $CaCO_3$, it is helpful to remember that

$$\text{Milliequivalent mass of } CaCO_3 = \frac{100\ \text{mg/mmole}}{2\ \text{meq/mmole}} \quad (2\text{–}36)$$
$$= 50\ \text{mg/meq}$$

Thus 3 meq/L of alkalinity would be expressed as 150 mg/L as $CaCO_3$.

$$\text{Alkalinity, Alk as } CaCO_3 = \frac{3.0\ \text{meq}}{\text{L}} \times \frac{50\ \text{mg } CaCO_3}{\text{meq } CaCO_3}$$
$$= 150\ \text{mg/L as } CaCO_3$$



Oil : free oil, emulsified oil droplets

Soluble organics: oxygenates, aromatics, phenolics, solvents and other additives

Nitrogen compounds: ammonia, CN, amines

Sulfur compounds: sulfides, mercaptans, polysulfide,

Salts: Ballast water, cooling tower, desalter

Soluble metals: catalysts, corrosion products, additives, tank bottoms

Solids: settlable solids, oil-coated solids, grit, colloids, coke fines, lime solids

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How do we measure complex organic molecules in wastewater?

1. There are thousands of unknown organic compounds in most wastewater samples. One can not use modern instruments to measure all of them. (We can only get less than 15% of the molecules quantified in refinery wastewaters).

2. We use "**lump**" parameters in estimating the organic concentration in wastewater.

TOC, COD, BOD

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- TOC, Total Organic Carbon – measure the amount of carbon C molecules in organic compounds. This parameter will provide the estimate of organic carbon concentration but will not provide you with low "polluting" or how "toxic" these molecules are.
- COD, Chemical Oxygen Demand – instead of measuring carbon, here we measure the amount of oxygen required to oxidize the organic molecules to CO_2, H_2O, SO_4. This parameter will provide you with the polluting potential of the organics in the sample.
- BOD, Biological Oxygen Demand – this measurement provides us with a biodegradable portion of the COD in the wastewater. This will give the real potential polluting strength of the wastewater.

Total Organic Carbon (TOC)

- A measure of the total organic material in the sample
- Will not detect inorganics (e.g. H_2S)
- Does not indicate biodegradability or oxygen requirements

Compound	Formula	MW	Carbon Wt.	TOC (g/g)
benzene	C_6H_6	78	12*6 = 72	0.923
DEA	$C_4H_{11}O_2N$	105	12*4 = 48	0.457
sulfide	HS^-	33	12*0 = 0	0.00

Chemical Oxygen Demand. The COD test is used to measure the content of organic matter of both wastewater and natural waters. The oxygen equivalent of the organic matter that can be oxidized is measured by using a strong chemical oxidizing agent in an acidic medium. Potassium dichromate has been found to be excellent for this purpose. The test must be performed at an elevated temperature. A catalyst (silver sulfate) is required to aid the oxidation of certain classes of organic compounds. Since some inorganic compounds interfere with the test, care must be taken to eliminate them. The principal reaction using dichromate as the oxidizing agent may be represented in a general way by the following unbalanced equation:

$$\text{Organic matter } (C_aH_bO_c) + Cr_2O_7^{-2} + H^+ \xrightarrow[\text{heat}]{\text{catalyst}} Cr^{+3} + CO_2 + H_2O \quad (3\text{-}23)$$

$C_{10}H_{19}O_3N$ is often used to represent the biodegradable organic matter in wastewater.

- **Chemical Oxygen Demand (COD)**
  - O_2 req. for oxidation of organics
  - Oxidize carbonaceous matter with a strong oxidant (e.g., hot dichromate sol. with sulfuric acid)

$$C_nH_aO_b + \underset{\text{Dichromate}}{cCr_2O_7^{2-}} + \underset{H_2SO_4}{8cH^+} \xrightarrow[\text{Catalyst silver sulfate}]{\text{Heat}} nCO_2 + \frac{a+8c}{2}H_2O + 2cCr^{3+}$$

$$c = \frac{2n}{3} + \frac{a}{6} - \frac{b}{3}$$

  - Reduction of O_2
    - $4e^- + 4H^+ + O_2 \rightarrow 2H_2O$
    - 1 mole of O_2 (32 g) = $4e^-$ equivalents
    - 1 g COD = 1 g O_2 = 1/8 electron equiv.
  - NH_3 not oxidized
  - Aromatic hydrocarbons and pyridenes are not oxidized.

Chemical Oxygen Demand (COD)

(sulfide, ferrous iron, thiosulfate, nitrite)

- Theoretical COD calculation:

(benzene)

$$C_6H_6 + 7½\ O_2 \longrightarrow 6\ CO_2 + 3\ H_2O$$

MW=78 MW=32

$$\text{Th COD} = \frac{7\frac{1}{2} \times 32}{78} = 3.08 \text{ mg COD/mg benzene}$$

Chemical Type	COD (mg COD/mg compound)
Carbohydrates	1 - 1.2
Proteins	1.8
Oil and Grease	3
short-chain carboxylic acids	2

Theoretical Oxygen Demand (ThOD)

1. Carbonaceous demand: C → CO_2; N → NH_3
2. Nitrogenous demand: NH_3 → HNO_2; HNO_2 → HNO_3
3. ThOD = ΣO_2 req. in steps 1& 2

Ex. Glycine, $CH_2(NH_2)COOH$

1. Carbonaceous demand

$$CH_2(NH_2)COOH + 1.5O_2 \rightarrow 2CO_2 + H_2O + NH_3$$

2. Nitrogenous demand

$$NH_3 + 1.5O_2 \rightarrow HNO_2 + H_2O$$

$$HNO_2 + 0.5O_2 \rightarrow HNO_3$$

3. ThOD = [1.5 + (1.5+0.5)] mol O_2/mol glycine
   = 3.5 × 32 g O_2/mol = 112 g O_2/mol

- **Biological Oxygen Demand (BOD)**
  - O_2 req. for microbial decomposition
  - Inadequate to assess the electron donor capacity; after 5 days, still some biodegradable matters exist.
  - Carbonaceous BOD - aerobic heterotrophs
    - Decompose organic molecules to minerals and residues
    - Obtain their cell carbon from the organic material
  - Nitrogenous BOD
    - Caused strictly by obligate aerobic chemo-autotrophs
    - Character of nitrifiers
      - DO < 2 mg/L action slow; DO < 0.5 mg/L action ceases
      - Optimum pH: 8.3
      - More sensitive than heterotrophs to toxins
      - Slow growers

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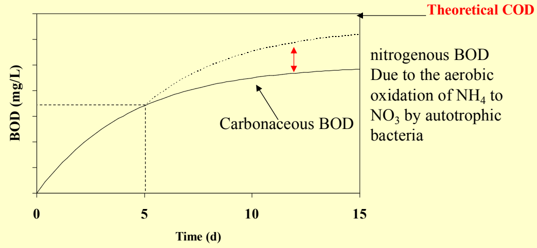
Biological Oxygen Demand (BOD)

- Estimate of oxygen required to biodegrade organic material
- Typical duration of test is 5 days (BOD5)



- Requires acclimated seed (TSS is seed for effluent samples)
- The test not only detect the O_2 requirement for organic degradation, respiration of the biosoilds in the sample also adds to BOD

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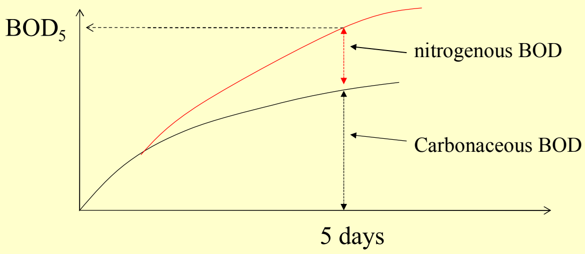
Carbonaceous Biological Oxygen Demand (cBOD)

- Sometimes, mostly in biological effluent samples, the nitrification can happen significantly before 5 days.



- The ammonia in the BOD bottle can be in the original sample, or in the analytical dilution water specified by the Standard method.

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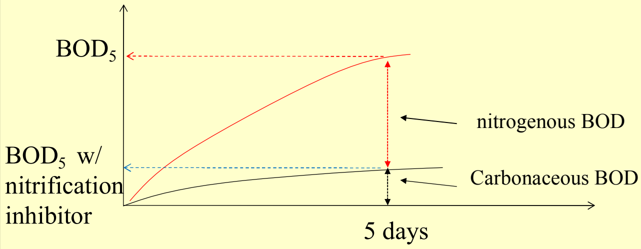
Carbonaceous Biological Oxygen Demand (cBOD)

- In some cases, the nBOD can be significantly higher than the cBOD



- In order to obtain the original intend of the test, nitrification inhibitor is added in the test to eliminate nBOD
- The resulting BOD_5 is termed cBOD

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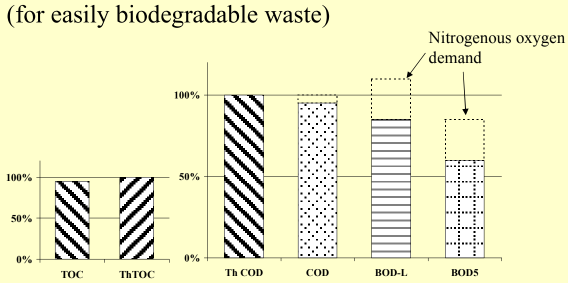
Comparison of TOC, COD, & BOD

- Rule of thumb: BOD5 / COD = 0.5 to 0.7 (for easily biodegradable waste)



- BOD/TOC and BOD/COD ratios change with degree of treatment

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BOD_5/COD - 0.4 ~ 0.8

BOD_5/TOC - 1.0 ~ 1.6

BOD_5/COD □ 0.6 : can be decomposed completely

BOD_5/COD □ 0.2 : cannot be decomposed easily

BOD_5/COD □ 0 : has toxic materials

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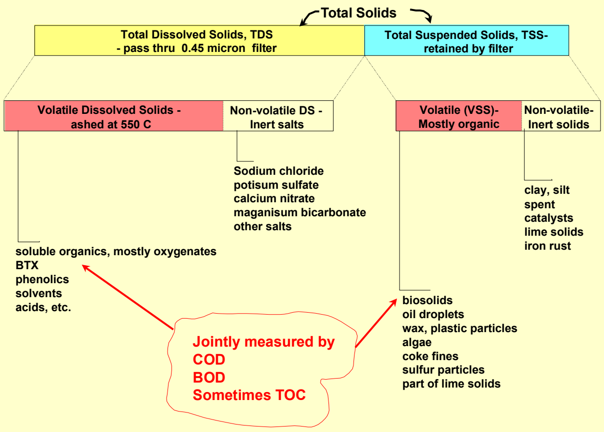
Schematics of Distribution of "SOLIDS" in Wastewater Samples



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Total Dissolved Solids (TDS)

- Definition: the solids contained in the filtrate that passes through a filter with a nominal pore size of 2µm or less are classified as dissolved.
- Traditionally, it is used for quantifying the dissolved salts contents of water sample. Organic material will show up in the test.

Types of Water/Wastewater	TDS (mg/l)
Tap Water	350 - 500
Water Start to Taste Bad	1,000 – 2,000
Seawater	25,000 – 30,000
Refinery Wastewater	1,000 – 6,000
Norco Chemical Wastewater	20,000 – 40,000
CS Metals Wastewater	30,000 – 100,000

- Max TDS biological system can tolerate:
  - Reported range, 10,000 - 40,000 mg/l.
- What is measured as TDS is comprised of colloidal (0.001-1 µm) and dissolved solids
- TDS concentration shock is more damage to bio-activity than high salt concentration
- Solids/liquid separation becomes difficult as TDS increases
- Conductivity measurement can be used to estimate TDS

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Total Suspended Solids (TSS)

- The amount of suspended matter that retained by a standard fiber glass filter paper and dried at 103 C.
- Turbidity measurement (light scattered by particles in water) may or may not be correlated with TSS analysis. However, sonification/turbidity measurement has been shown to correlate with biotreated effluent TSS well.
- For sample with high TDS concentration, sometimes the dissolved salts may be retained in the filter paper, which causes erroneous TSS results.
- It is important to note the pore size of the filter paper used, when comparing reported TSS values.

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Ammonia Is Regulated

- It is toxic to certain species of fish at elevated pH.

- It will deplete dissolved oxygen in the receiving streams to cause stress to aquatic animals.

- It will enrich the receiving waters (lakes) to produce algae or aquatic plants growth, making "pee soup" or "choking" the water way.

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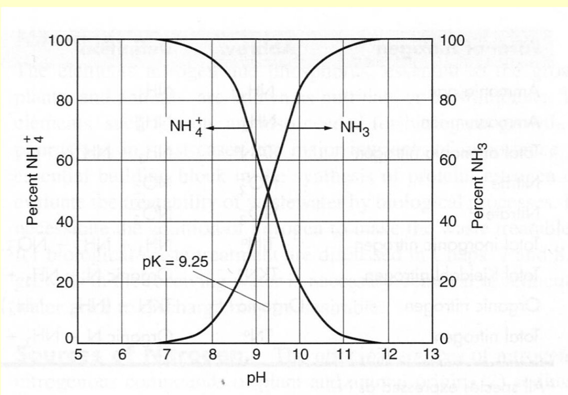
Ammonia / Ammonium Relationship depends on pH

$$NH_3 + H^+ \longrightarrow NH_4^+$$



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Nitrogen-Containing Compounds

Organic Nitrogen	Ammonia	Nitrite	Nitrate
•protein •urea •biomass •amines	$\bullet NH_3$ $\bullet NH_4^+$	$\bullet NO_2^-$	$\bullet NO_3^-$

Total Nitrogen

Total Kjeldahl Nitrogen

Ammonia

Nitrite + Nitrate

- In biotreaters:

Organic Nitrogen → Ammonia

Ammonia or Organic-N → Biomass-N

Nitrite or Nitrate → Biomass-N

Biomass-N → Ammonia + Organic-N

- In nitrifying biotreaters:

Ammonia → Nitrite or Nitrate

- In anoxic zones:

Nitrate → Nitrite → N_2

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Phosphorous

In wastewater the P species consist of : Orthophosphate, polyphosphate and organic phosphate. 4 to 14 mg/L as P

1. Ortho-phosphate: PO_4^{-3}, HPO_4^{-2}, $H_2PO_4^{-1}$ and H_3PO_4

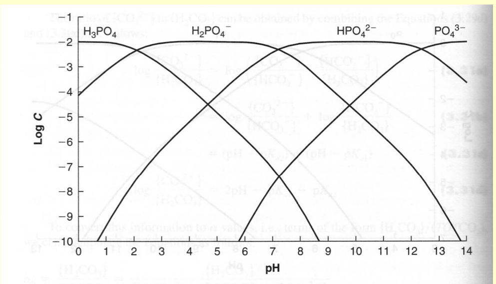

Figure 3.16 Distribution of phosphate species as a function of pH for a system containing 10^{-2} *M TOTPO*$_4$. Phosphoric acid is a triprotic acid with $pK_{a1} = 2.16$, $pK_{a2} = 7.20$, and $pK_{a3} = 12.35$.

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What do environmental engineering do?

Regulations

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About 1900 to the early 1970s

- The removal of colloidal, suspended and floatable material;
- The treatment of biodegradable organics
- The elimination of pathogenic organisms

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The early 1970s to about 1980

Based primarily on aesthetic and environmental concerns

- The reduction of biological oxygen demand (BOD), total suspended solids (TSS) and pathogenic organisms at a higher levels;
- Removal of nutrients, such as nitrogen and phosphorus;

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Since 1980

- Emphasis has shifted to the definition and removal of constituents that may cause long-term health effects and environmental impacts.

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HOMEWORK

- Regulations in your country & one of the developed country
- Comparision?

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《城镇污水处理厂污染物排放标准》GB 18918－2002

GB18918-2002

表 1　基本控制项目最高允许排放浓度（日均值）　　单位　mg/L

序号	基本控制项目		一级标准		二级标准	三级标准
			A 标准	B 标准		
1	化学需氧量（COD）		50	60	100	120①
2	生化需氧量（BOD_5）		10	20	30	60①
3	悬浮物（SS）		10	20	30	50
4	动植物油		1	3	5	20
5	石油类		1	3	5	15
6	阴离子表面活性剂		0. 5	1	2	5
7	总氮 （以 N 计）		15	20	－	－
8	氨氮（以 N 计）②		5（8）	8（15）	25（30）	－
9	总磷（以 P 计）	2005 年 12 月 31 日前建设的	1	1. 5	3	5
		2006 年 1 月 1 日起建设的	0. 5	1	3	5
10	色度（稀释倍数）		30	30	40	50
11	pH		6-9			
12	粪大肠菌群数（个/L）		10^3	10^4	10^4	－

注：①下列情况下按去除率指标执行：当进水 COD 大于 350mg/L 时，去除率应大于 60%；

BOD 大于 160mg/L 时，去除率应大于 50%。

②括号外数值为水温>12℃ 时的控制指标，括号内数值为水温≤12℃ 时的控制指标。

《城镇污水处理厂污染物排放标准》GB 18918－2002

表 2　部分一类污染物最高允许排放浓度（日均值）　单位　mg/L

序号	项目	标准值
1	总汞	0. 001
2	烷基汞	不得检出
3	总镉	0. 01
4	总铬	0. 1
5	六价铬	0. 05
6	总砷	0. 1
7	总铅	0. 1

《城镇污水处理厂污染物排放标准》GB 18918－2002

表 3　选择控制项目最高允许排放浓度（日均值）　　单位　mg/L

序号	选择控制项目	标准值	序号	选择控制项目	标准值
1	总镍	0. 05	23	三氯乙烯	0. 3
2	总铍	0. 002	24	四氯乙稀	0. 1
3	总银	0. 1	25	苯	0. 1
4	总铜	0. 5	26	甲苯	0. 1
5	总锌	1. 0	27	邻-二甲苯	0. 4
6	总锰	2. 0	28	对-二甲苯	0. 4
7	总硒	0. 1	29	间-二甲苯	0. 4
8	苯并(a)芘	0. 00003	30	乙苯	0. 4
9	挥发酚	0. 5	31	氯苯	0. 3
10	总氰化物	0. 5	32	1, 4-二氯苯	0. 4
11	硫化物	1. 0	33	1, 2-二氯苯	1. 0
12	甲醛	1. 0	34	对硝基氯苯	0. 5
13	苯胺类	0. 5	35	2, 4-二硝基氯苯	0. 5
14	总硝基化合物	2. 0	36	苯酚	0. 3
15	有机磷农药（以 P 计）	0. 5	37	间-甲酚	0. 1
16	马拉硫磷	1. 0	38	2, 4-二氯酚	0. 6
17	乐果	0. 5	39	2, 4, 6 –三氯酚	0. 6
18	对硫磷	0. 05	40	邻苯二甲酸二丁酯	0. 1
19	甲基对硫磷	0. 2	41	邻苯二甲酸二辛酯	0. 1
20	五氯酚	0. 5	42	丙烯晴	2. 0
21	三氯甲烷	0. 3	43	可吸附有机卤化物（AOX 以 CL 计）	1. 0
22	四氯化碳	0. 03			

《城镇污水处理厂污染物排放标准》GB 18918－2002

城镇污水处理厂废气的排放标准值按表 4 的规定执行。

表 4　厂界（防护带边缘）废气排放最高允许浓度　　单位　mg/m^3

序号	控制项目	一级标准	二级标准	三级标准
1	氨	1. 0	1. 5	4. 0
2	硫化氢	0. 03	0. 06	0. 32
3	臭气浓度（无量纲）	10	20	60
4	甲烷（厂区最高体积浓度 %）	0. 5	1	1

4. 2. 3 取样与监测

4. 2. 3. 1 氨、硫化氢、臭气浓度监测点设于城镇污水处理厂厂界或防护带边缘的浓度最高点；甲烷监测点设于厂区内浓度最高点。

4. 2. 3. 2 监测点的布置方法与采样方法按 GB16297 中附录 C 和 HJ/T55 的有关规定执行。

4. 2. 3. 3 采样频率，每 2h 采样一次，共采集 4 次，取其最大测定值。

4. 2. 3. 4 监测分析方法按表 8 执行。

《城镇污水处理厂污染物排放标准》GB 18918－2002

4.3 污泥控制标准

4. 3. 1 城镇污水处理厂的污泥应进行稳定化处理，稳定化处理后应达到表 5 的规定。

表 5　污泥稳定化控制指标

稳定化方法	控制项目	控制指标
厌氧消化	有机物降解率（%）	>40
好氧消化	有机物降解率（%）	>40
好氧堆肥	含水率（%）	<65
	有机物降解率（%）	>50
	蠕虫卵死亡率（%）	>95
	粪大肠菌群菌值	>0. 01

4. 3. 2 城镇污水处理厂的污泥应进行污泥脱水处理，脱水后污泥含水率应小于 80%。

4. 3. 3 处理后的污泥进行填埋处理时，应达到安全填埋的相关环境保护要求。

4. 3. 4 处理后的污泥农用时，其污染物含量应满足表 6 的要求。其施用条件须符合 GB4284 的有关规定。

《城镇污水处理厂污染物排放标准》GB 18918－2002

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表 6　污泥农用时污染物控制标准限值

序号	控制项目	最高允许含量（mg/kg 干污泥）	
		在酸性土壤上（pH<6. 5）	在中性和碱性土壤上（pH>=6. 5）
1	总镉	5	20
2	总汞	5	15
3	总铅	300	1000
4	总铬	600	1000
5	总砷	75	75
6	总镍	100	200
7	总锌	2000	3000
8	总铜	800	1500
9	硼	150	150
10	石油类	3000	3000
11	苯并(a)芘	3	3
12	多氯代二苯并二噁英/多氯代二苯并呋喃（PCDD/PCDF 单位:ng 毒性单位/kg 干污泥）	100	100
13	可吸附有机卤化物（AOX）（以 Cl 计）	500	500
14	多氯联苯（PCB）	0. 2	0. 2

4. 3. 5 取样与监测

4. 3. 5. 1 取样方法，采用多点取样，样品应有代表性，样品重量不小于 1kg。

4. 3. 5. 2 监测分析方法按表 9 执行。

4. 4 城镇污水处理厂噪声控制按 GB12348 执行。

《城镇污水处理厂污染物排放标准》GB 18918－2002

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表 7　水污染物监测分析方法

序号	控制项目	测　定　方　法	测定下限（mg/L）	方法来源
1	化学需氧量(COD)	重铬酸盐法	30	GB11914－89
2	生化需氧量(BOD)	稀释与接种法	2	GB7488－87
3	悬浮物(SS)	重量法		GB11901－89
4	动植物油	红外光度法	0.1	GB/T16488－1996
5	石油类	红外光度法	0.1	GB/T16488－1996
6	阴离子表面活性剂	亚甲蓝分光光度法	0.05	GB7494－87
7	总氮	碱性过硫酸钾-消解紫外分光光度法	0.05	GB11894－89
8	氨氮	蒸馏和滴定法	0.2	GB7478－87
9	总磷	钼酸铵分光光度法	0.01	GB11893－89
10	色　度	稀释倍数法		GB11903－89
11	pH 值	玻璃电极法		GB6920－86
12	粪大肠菌群数	多管发酵法		1）
13	总　汞	冷原子吸收分光光度法	0.0001	GB7468－87
		双硫腙分光光度法	0.002	GB7469－87
14	烷基汞	气相色谱法	10ng/L	GB/T14204－93
15	总　镉	原子吸收分光光度法（螯合萃取法）	0.001	GB7475－87
		双硫腙分光光度法	0.001	GB7471－87
16	总　铬	高锰酸钾氧化－二苯碳酰二肼分光光度法	0.004	GB7466－87
17	六价铬	二苯碳酰二肼分光光度法	0.004	GB7467－87
18	总　砷	二乙基二硫代氨基甲酸银分光光度法	0.007	GB7485－87
19	总　铅	原子吸收分光光度法（螯合萃取法）	0.01	GB7475－87
		双硫腙分光光度法	0.01	GB7470－87
20	总　镍	火焰原子吸收分光光度法	0.05	GB11912－89
		丁二酮肟分光光度法	0.25	GB11910－89
21	总　铍	活性炭吸附－铬天青 S 光度法		1）
22	总　银	火焰原子吸收分光光度法	0.03	GB11907－89
		镉试剂 2B 分光光度法	0.01	GB11908－89
23	总　铜	原子吸收分光光度法	0.01	GB7475－87
		二乙基二硫氨基甲酸钠分光光度法	0.01	GB7474－87
24	总　锌	原子吸收分光光度法	0.05	GB7475－87
		双硫腙分光光度法	0.005	GB7472－87
25	总　锰	火焰原子吸收分光光度法	0.01	GB11911－89
		高碘酸钾分光光度法	0.02	GB11906－89
26	总硒	2,3－二氨基萘荧光法	0.25μg/L	GB11902－89
27	苯并(a)芘	高压液相色谱法	0.001μg/L	GB13198－91
		乙酰化滤纸层析荧光分光光度法	0.004μg/L	GB11895－89
28	挥发酚	蒸馏后 4-氨基安替比林分光光度法	0.002	GB7490－87
29	总氰化物	硝酸银滴定法	0.25	GB7486－87
		异烟酸-吡唑啉酮比色法	0.004	GB7486－87
		吡啶-巴比妥酸比色法	0.002	GB7486－87
30	硫化物	亚甲基蓝分光光度法	0.005	GB/T16489－1996
		直接显色分光光度法	0.004	GB/T17133－1997
31	甲醛	乙酰丙酮分光光度法	0.05	GB13197－91
32	苯胺类	N－(1-萘基)乙二胺偶氮分光光度法	0.03	GB11889－89
33	总硝基化合物	气相色谱法	5μg/L	GB4919－85
34	有机磷农药（以 P 计）	气相色谱法	0.5μg/L	GB13192－91

《城镇污水处理厂污染物排放标准》GB 18918－2002

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续表

序号	控制项目	测定方法	测定下限（mg/L）	方法来源
35	马拉硫磷	气相色谱法	0.64μg/L	GB13192－91
36	乐　果	气相色谱法	0.57μg/L	GB13192－91
37	对硫磷	气相色谱法	0.54μg/L	GB13192－91
38	甲基对硫磷	气相色谱法	0.42μg/L	GB13192－91
39	五氯酚	气相色谱法	0.04μg/L	GB8972－88
		藏红 T 分光光度法	0.01	GB9803－88
40	三氯甲烷	顶空气相色谱法	0.30μg/L	GB/T17130－1997
41	四氯化碳	顶空气相色谱法	0.05μg/L	GB/T17130－1997
42	三氯乙烯	顶空气相色谱法	0.50μg/L	GB/T17130－1997
43	四氯乙烯	顶空气相色谱法	0.2μg/L	GB/T17130－1997
44	苯	气相色谱法	0.05	GB11890－89
45	甲　苯	气相色谱法	0.05	GB11890－89
46	邻－二甲苯	气相色谱法	0.05	GB11890－89
47	对－二甲苯	气相色谱法	0.05	GB11890－89
48	间－二甲苯	气相色谱法	0.05	GB11890－89
49	乙　苯	气相色谱法	0.05	GB11890－89
50	氯　苯	气相色谱法		HJ/T74－2001
51	1,4 二氯苯	气相色谱法	0.005	GB/T17131－1997
52	1,2 二氯苯	气相色谱法	0.002	GB/T17131－1997
53	对硝基氯苯	气相色谱法		GB13194－91
54	2,4-二硝基氯苯	气相色谱法		GB13194－91
55	苯　酚	液相色谱法	1.0μg/L	1）
56	间－甲酚	液相色谱法	0.8μg/L	1）
57	2,4-二氯酚	液相色谱法	1.1μg/L	1）
58	2,4,6-三氯酚	液相色谱法	0.8μg/L	1）
59	邻苯二甲酸二丁酯	气相、液相色谱法		HJ/T72－2001
60	邻苯二甲酸二辛酯	气相、液相色谱法		HJ/T72－2001
61	丙烯腈	气相色谱法		HJ/T73－2001
62	可吸附有机卤化物（AOX）（以 Cl 计）	微库仑法	10μg/L	GB/T 15959－1995
		离子色谱法		HJ/T 83-2001

注：暂采用下列方法，待国家方法标准发布后，执行国家标准。

1）《水和废水监测分析方法（第三版、第四版）》　中国环境科学出版社

《城镇污水处理厂污染物排放标准》GB 18918－2002

表 8　大气污染物监测分析方法

序号	控制项目	测定方法	方法来源
1	氨	次氯酸钠-水杨酸分光光度法	GB/T14679-93
2	硫化氢	气相色谱法	GB/T14678-93
3	臭气浓度	三点比较式臭袋法	GB/T14675-93
4	甲烷	气相色谱法	CJ/T3037-95

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表 9　污泥特性及污染物监测分析方法

序号	控制项目	测定方法	方法来源
1	污泥含水率	烘干法	1）
2	有机质	重铬酸钾法	1）
3	蛔虫卵死亡率	显微镜法	GB7959-87
4	粪大肠菌群菌值	发酵法	GB7959-87
5	总镉	石墨炉原子吸收分光光度法	GB/T17141-1997
6	总汞	冷原子吸收分光光度法	GB/T17136-1997
7	总铅	石墨炉原子吸收分光光度法	GB/T17141-1997
8	总铬	火焰原子吸收分光光度法	GB/T17137-1997
9	总砷	硼氢化钾-硝酸银分光光度法	GB/T17135-1997
10	硼	姜黄素比色法	2）
11	矿物油	红外分光光度法	2）
12	苯并（a）芘	气相色谱法	2）
13	总铜	火焰原子吸收分光光度法	GB/T17138-1997
14	总锌	火焰原子吸收分光光度法	GB/T17138-1997
15	总镍	火焰原子吸收分光光度法	GB/T17139-1997
16	多氯代二苯并二噁英/多氯代二苯并呋喃（PCDD/PCDF）	同位素稀释高分辨毛细管气相色谱/高分辨质谱法	HJ/T 77-2001
17	可吸附有机卤化物（AOX）		待定
18	多氯联苯（PCB）	气相色谱法	待定

注：暂采用下列方法，待国家方法标准发布后，执行国家标准。

1）《城镇垃圾农用监测分析方法》

2）《农用污泥监测分析方法》

Characteristics of municipal wastewaters

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Typical Composition of Raw Domestic Wastewater US Data

	Concentration		
	Weak	Medium	Strong
Solids, total (TS), mg/L	350	720	1200
Total dissolved (TDS), mg/L	250	500	850
Total suspended (TSS), mg/L	100	200	350
Settleable solids, mg/L	5	10	20
BOD_5, mg/L	110	220	400
TOC, mg/L	80	160	290
COD, mg/L	250	500	1000
Nitrogen (total as N), mg/L	20	40	85
Organic, mg/L	8	14	35
Free ammonia, mg/L	12	25	50
Nitrites + nitrates, mg/L	0	0	0
Phosphorus (total as P), mg/L	4	8	15
Organic, mg/L	1	3	5
Inorganic, mg/L	3	5	10
Chlorides, mg/L	30	50	100
Sulfate, mg/L	20	30	50
Alkalinity, mg/L as $CaCO_3$	50	100	200
Grease, mg/L	50	100	150
Total coliform, no/100 mL	10^6~10^7	10^7~10^8	10^7~10^9

EU Data

Table 3.6 Typical composition of raw municipal wastewater with minor contributions of industrial wastewater

Parameter	High	Medium	Low
COD total	1,200	750	500
COD soluble	480	300	200
COD suspended	720	450	300
BOD	560	350	230
VFA (as acetate)	80	30	10
N total	100	60	30
Ammonia-N	75	45	20
P total	25	15	6
Ortho-P	15	10	4
TSS	600	400	250
VSS	480	320	200

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Minimum National Standards for Secondary Treatment

Parameters	Units	30-day ave. conc.	7-day ave. conc.
BOD_5	mg/L	30	45
Suspended solids	mg/L	30[a]	45
Hydrogen-ion conc.	pH units	6~9[b]	6~9[b]
Carbonaceous BOD_5[c]	mg/L	25	40

[a] Average removal □ 85%
[b] Only enforced if caused by industrial wastewater or by in-plant chemical addition
[c] May be substituted for BOD_5 at the option of the NPDES permitting authority

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Example discharge Standards based on water quality concerns

Parameters	Units	30-day ave. conc.
BOD_5	mg/L	10
Suspended solids	mg/L	10
Hydrogen-ion conc.	pH units	6~9
Ammonium- Nitrogen	mg/L	1 / 5[a]

[a]. Summer liimit is 1 mg/L and winter limit is 5 mg/L

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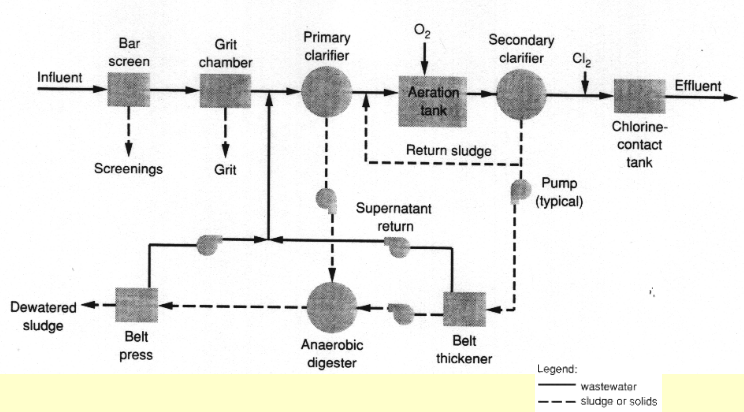
Activate Sludge Process



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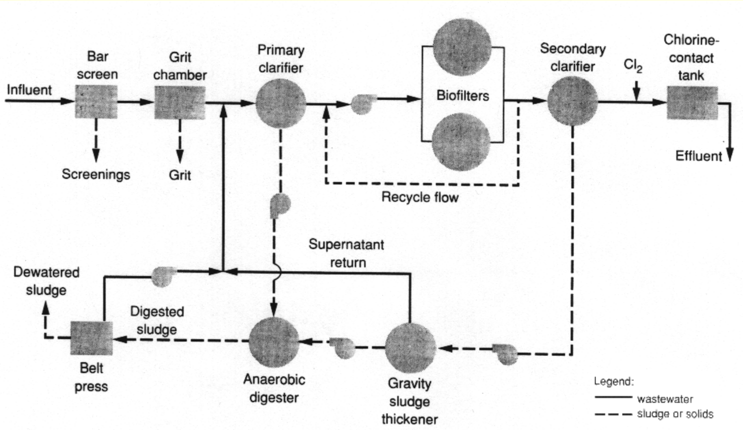
Trickling Filter



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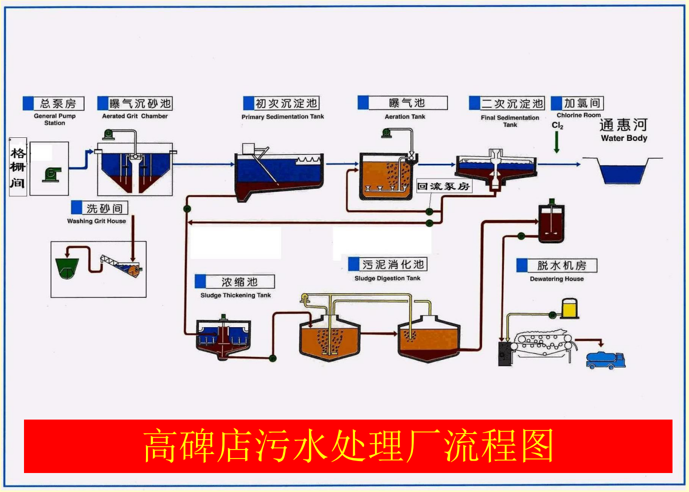

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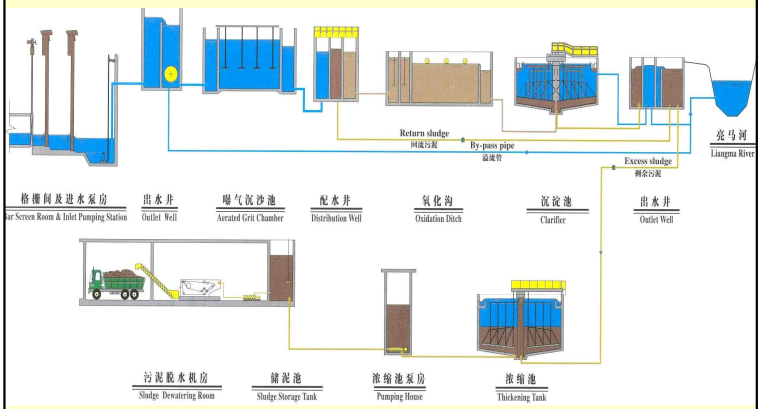

酒仙桥污水处理厂工艺流程

Treatment level	Description
Preliminary	Removal of wastewater constituents such as rags, sticks, floatables, grit, and grease that may cause maintenance or operational problems with the treatment operations, processes, and ancillary systems
Primary	Removal of a portion of the suspended solids and organic matter from the wastewater
Advanced primary	Enhanced removal of suspended solids and organic matter from the wastewater. Typically accomplished by chemical addition or filtration
Secondary	Removal of biodegradable organic matter (in solution or suspension) and suspended solids. Disinfection is also typically included in the definition of conventional secondary treatment
Secondary with nutrient removal	Removal of biodegradable organics, suspended solids, and nutrients (nitrogen, phosphorus, or both nitrogen and phosphorus)
Tertiary	Removal of residual suspended solids (after secondary treatment), usually by granular medium filtration or microscreens. Disinfection is also typically a part of tertiary treatment. Nutrient removal is often included in this definition
Advanced	Removal of dissolved and suspended materials remaining after normal biological treatment when required for various water reuse applications

[a] Adapted, in part, from Crites and Tchobanoglous (1998).

Wastewater Treatment Processes

- Suspended solids
  - Screening and comminution
  - Grit removal
  - Sedimentation
  - Filtration
  - Flotation
  - Chemical polymer addition
  - Coagulation/sedimentation
  - Natural systems (land treatment)
- Volatile organics
  - Air stripping
  - Off gas treatment
  - Carbon adsorption

Wastewater Treatment Processes - continued

- Biodegradable organics
  - Activated sludge variations
  - Fixed-film reactor: trickling filters
  - Fixed-film reactor: rotating biological contactors
  - Lagoon variations
  - Intermittent sand filtration
  - Physical-chemical systems
  - Natural systems
- Pathogens
  - Chlorination/hypochlorination
  - Bromine chloride
  - Ozonation
  - UV radiation
  - Natural systems

Wastewater Treatment Processes - continued

- Nitrogen - nutrient
  - Suspended-growth nitrification/denitrification
  - Fixed-film nitrification/denitrification
  - Ammonia stripping
  - Ion exchange
  - Breakpoint chlorination
  - Natural systems
- Phosphorus - nutrient
  - Metal-salt addition
  - Lime coagulation/sedimentation
  - Biological phosphorus removal
  - Biological-chemical phosphorus removal
  - Natural systems
- Nitrogen and phosphorus - nutrients
  - Biological nutrient removal

Sludge Processing/Disposal Methods

- Thickening
  - Gravity thickening
  - Flotation
  - Centrifugation
  - Gravity belt thickening
  - Rotary drum thickening
- Stabilization
  - Lime stabilization
  - Heat treatment
  - Anaerobic digestions
  - Aerobic digestion
  - Composting
- Conditioning
  - Chemical conditioning
  - Heat treatment

Sludge Processing/Disposal Methods

- Disinfection
  - Pasteurization
  - Long-term storage
- Dewatering
  - Vacuum filter
  - Centrifuge
  - Belt press filter
  - Filter press
  - Sludge drying beds
  - Lagoons
- Thermal reduction
  - Multiple hearth incineration
  - Fluidized bed incineration
  - Wet air oxidation
  - Vertical deep well extractor
- Ultimate disposal
  - Land application
  - Distribution and marketing
  - Landfill
  - Lagooning
  - Chemical fixation

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Process Selection

- Needs theoretical knowledge and practical experience
- Principal elements of process analysis
  - Development of the process flow diagram
  - Establishment of process design criteria and sizing treatment units
  - Preparation of solids balances
  - Evaluation of the hydraulic requirements (hydraulic profile)
  - Site layout considerations

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Treatment Efficiency

Treatment units	BOD	COD	SS	P	Org-N	NH_3-N
Bar racks	0	0	0	0	0	0
Grit chambers	0~5	0~5	0~10	0	0	0
Primary sedimentation	30~40	30~40	50~65	10~20	10~20	0
Activated sludge	80~95	80~85	80~90	10~20	15~50	8~15
Trickling filters						
High rate, rock media	65~80	60~80	60~85	8~12	15~50	8~15
Super rate, plastic media	65~85	65~85	65~85	8~12	15~50	8~15
Rotating biological contactors (RBCs)	80~85	80~85	80~85	10~25	15~50	8~15
Chlorination	0	0	0	0	0	0

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Wastewater Treatment Plant Design

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Design Considerations

- Cost - initial and annual O&M costs
  - Order of magnitude estimates for conceptual planning
  - Budget estimates (during preliminary design stage)
  - Definitive estimates derived from detailed quantity takeoffs of completed plans and specifications
- Environmental - environmental impact statement
- Equipment availability
- Personnel requirements
- Energy and resource requirements

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Project Management

- **Facilities planning**: define problems, identify design year needs (usually > 20 years), define/develop/analyze alternative treatment/disposal systems, select plan, and outline an implementation plan (financial arrangements and schedule)
- **Design**: conceptual, preliminary, and final design with field testing for design criterion development
- **Value engineering**: intensive review of a project by experts (1/3 and 2/3 of the project schedule)
- **Construction**: ease of integration of new facilities into existing sites, clarity of presentation, spec of high quality materials of construction, timely completion of work, and minimum changes
- **Startup and Operation**: O&M manual

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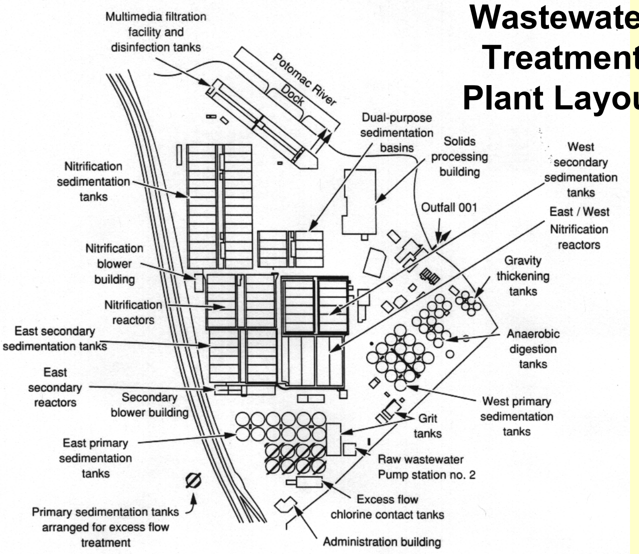
Wastewater Treatment Plant Layout



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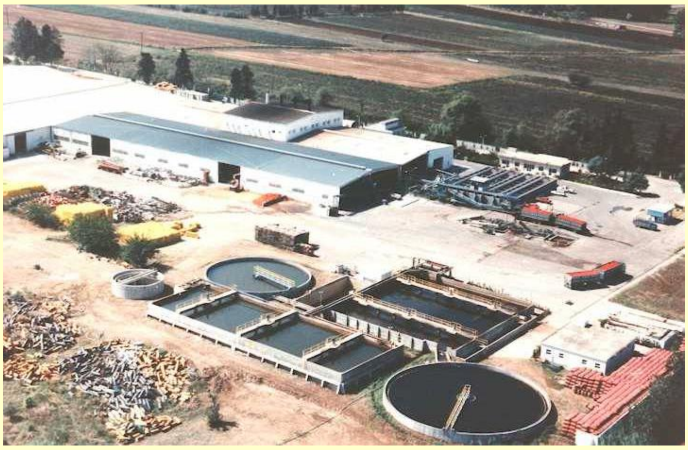

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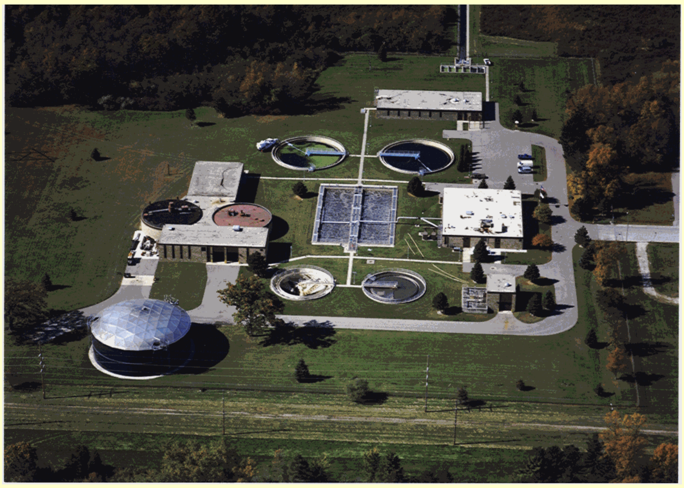

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