Lecture 1: (100 min)

Industrial Waste:
Characteristics & Regulatory Requirements

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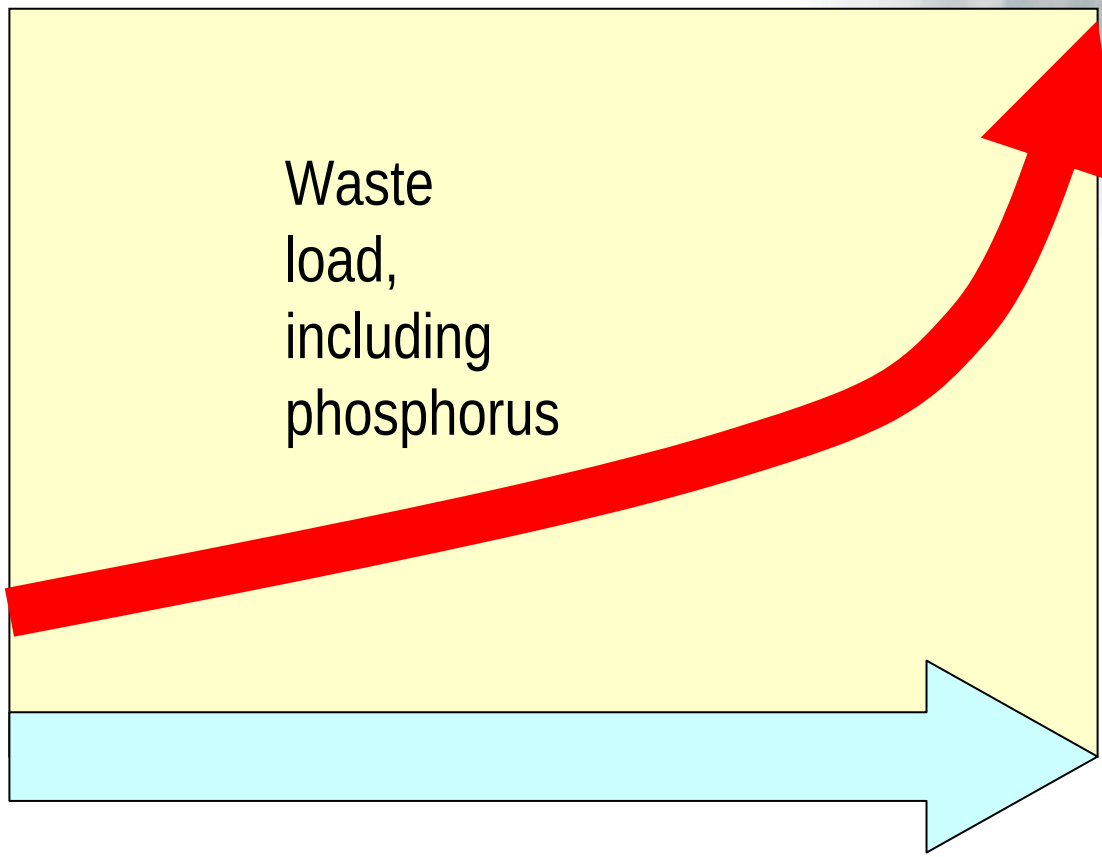
Presentation menu

- Introduction to industrial waste management
- Wastewater characterization
- Regulatory requirements
- Exercise 1
- Q&A

Megatrends in environmental management

- **Climate-change centric**
  - Reduction of greenhouse gas emission
  - Renewable and alternative energy
  - Hydrogen economy
  - Carbon sink
- **Resource recovery**
  - Reclamation, reuse, recycle, reengineering
  - Biogas generation
- **Environmental health**
  - Ecosystem perspective
  - Green technology
- **Deep-ecology**
  - Life style and philosophy
  - Green consumerism

The waste stream

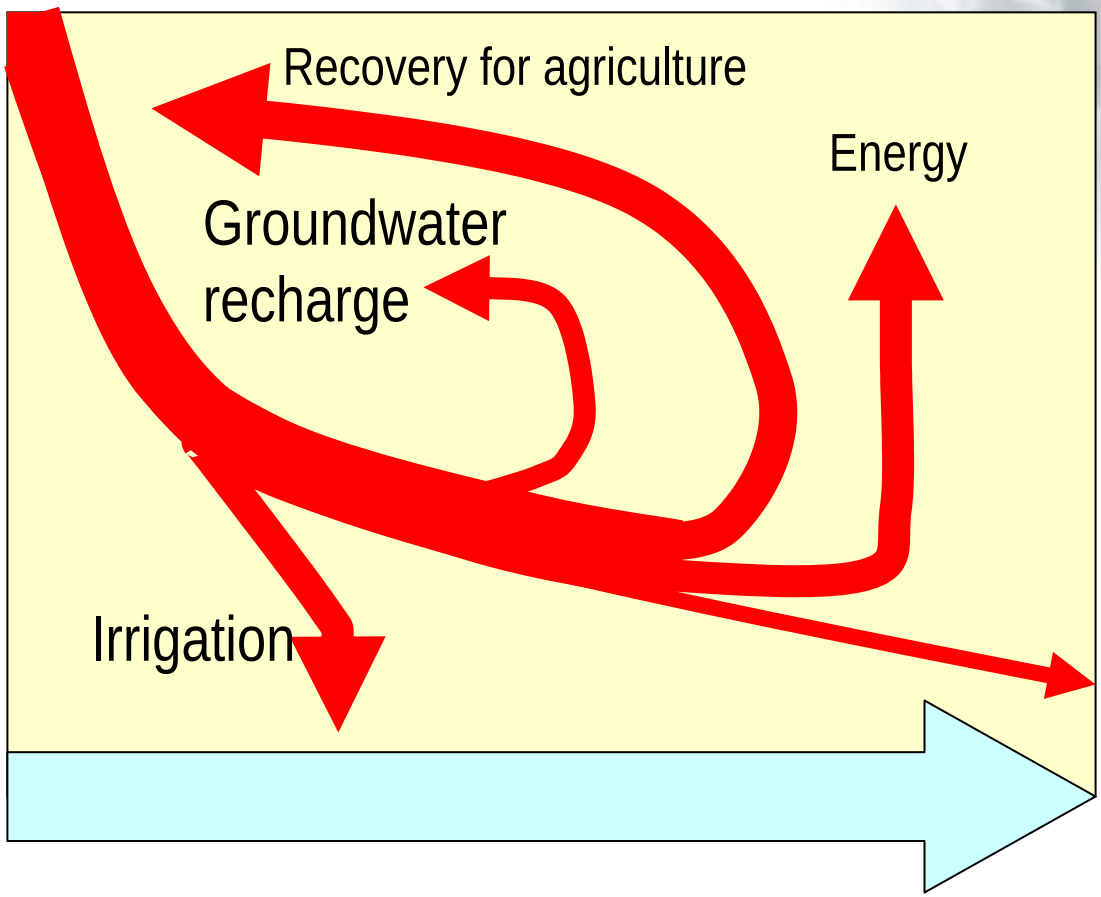


Upstream
Of rivers etc

Estuary,
Ocean, etc

The waste streams (?)

Waste load, including phosphorus



Upstream
Of rivers etc

Downstream,
Estuary,
Ocean, etc

Dependent on
- Waste composition
- Volume
- Technology
- Policy
- Cost
- Market
- Sustainability

Definition of “Wastewater”?

- “Waste” or “resource”?
- Cost of wastewater treatment?
- Cost of advanced treatment?
- What actually the “waste”?
- Waste characterization?
- What can be recovered & reused?
- Recycle?
- Expectation?

Used water
Black water

New definition

Definition of “Waste”?

- Unwanted, useless, dangerous, pollutants etc.

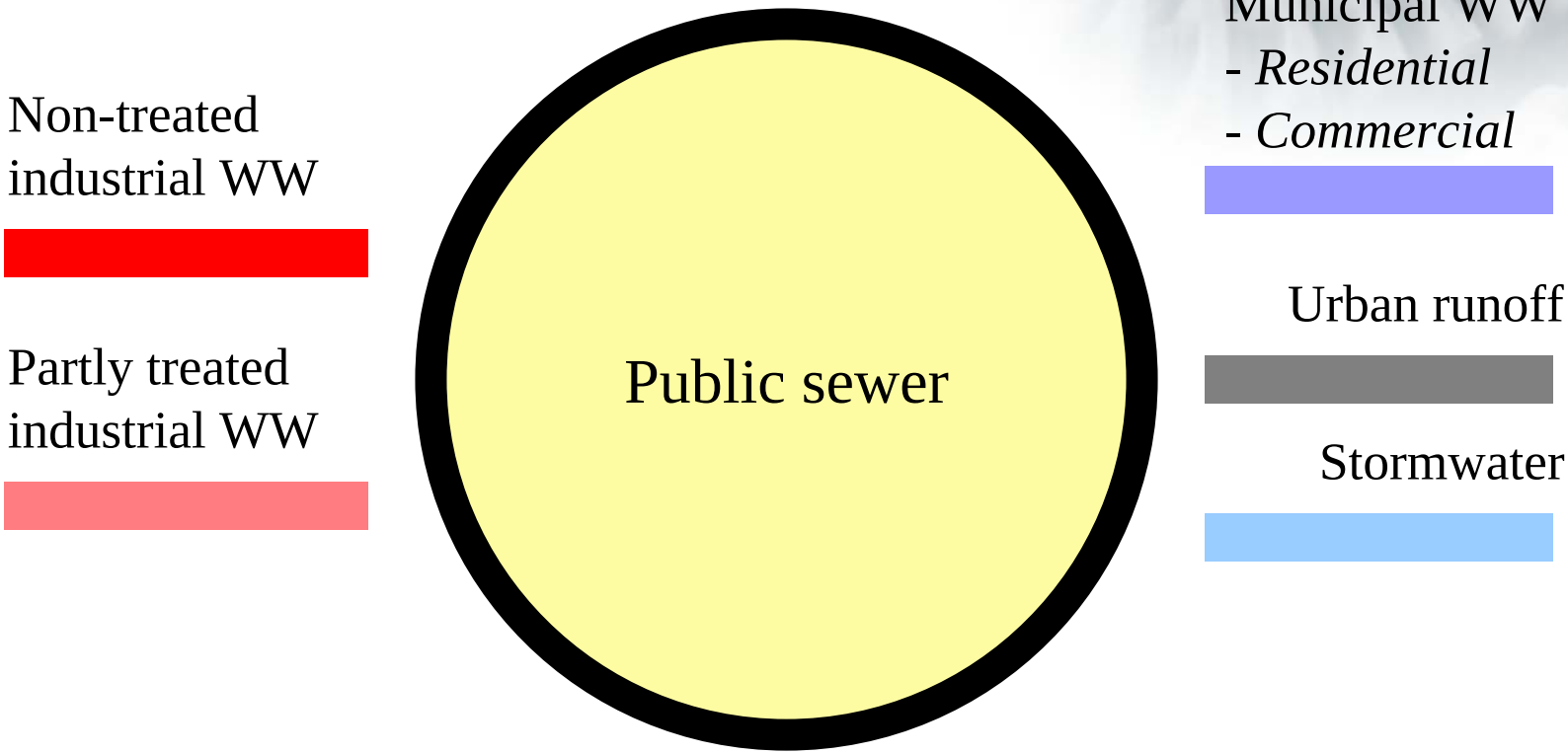
Definition of “Resource”?

- Wanted, useful, saleable, etc.

Sewerage system and facilities

- Sewage = municipal wastewater
- Sewerage = the system of sewage management (includes collection, treatment, disposal)
- Sewer = the collection pipe of sewage
- Sewerage facilities (US, Japan, Sweden) includes sewage, industrial wastewater and stormwater

Sewerage system and facilities
(Combined system)



Wastewater characterization

- Municipal wastewater
- Industrial wastewater
- Combined wastewater
- Combined wastewater and stormwater

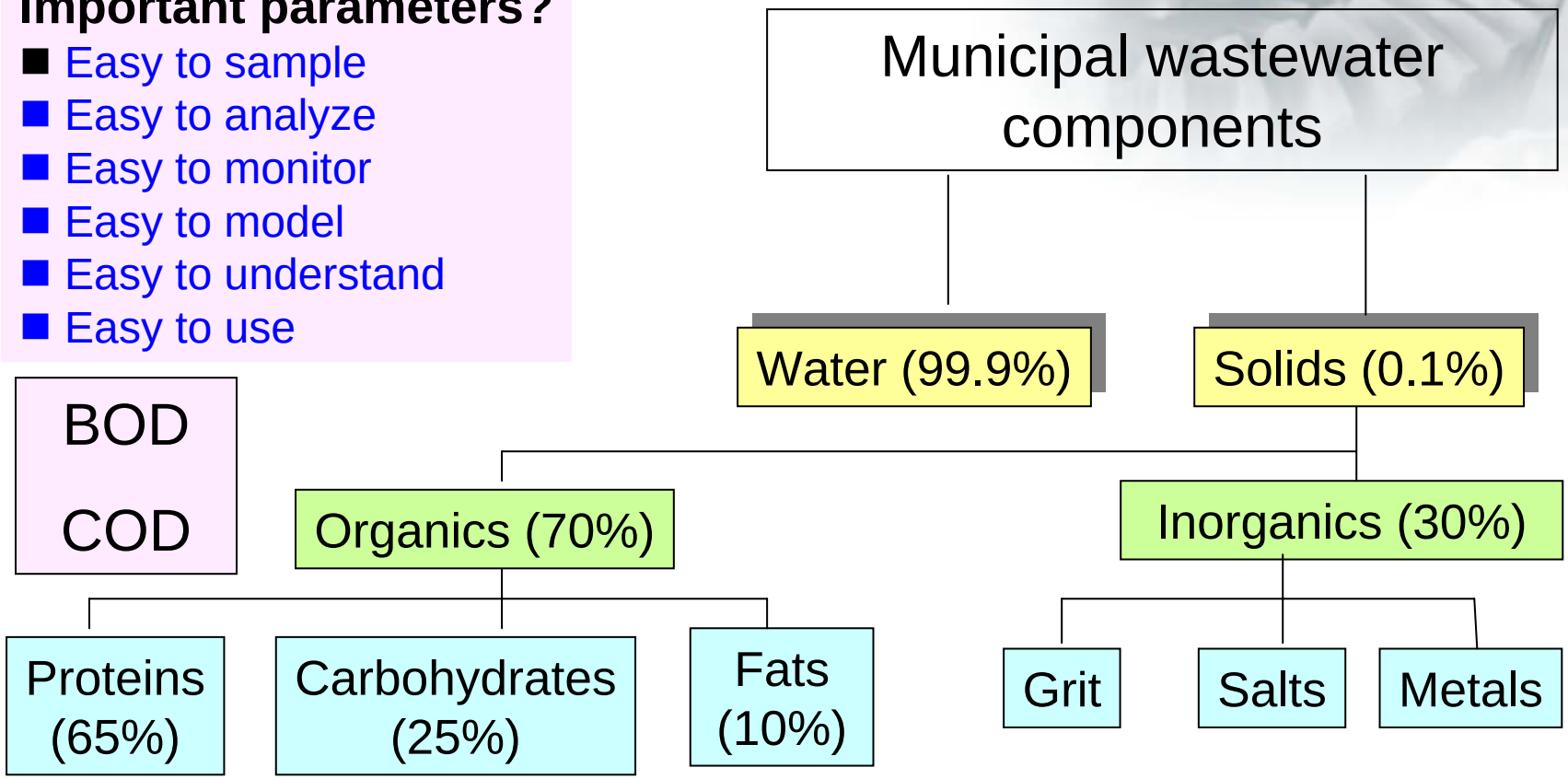
Objectives of characterization

- To determine the components of the wastewater
- To identify the treatment systems suitable to achieve the treatment objectives
- To optimize the operating system

Characterization

Important parameters?

- Easy to sample
- Easy to analyze
- Easy to monitor
- Easy to model
- Easy to understand
- Easy to use



Undesirable components

- Soluble organic causing depletion of DO
- Suspended solids
- Priority pollutants (in Malaysia: scheduled wastes)
- Heavy metals, cyanide, toxic organics
- Color and turbidity
- Nitrogen and phosphorus
- Refractory substances resistant to biodegradation
- Oil and floating materials
- Volatile materials
- Aquatic toxicity

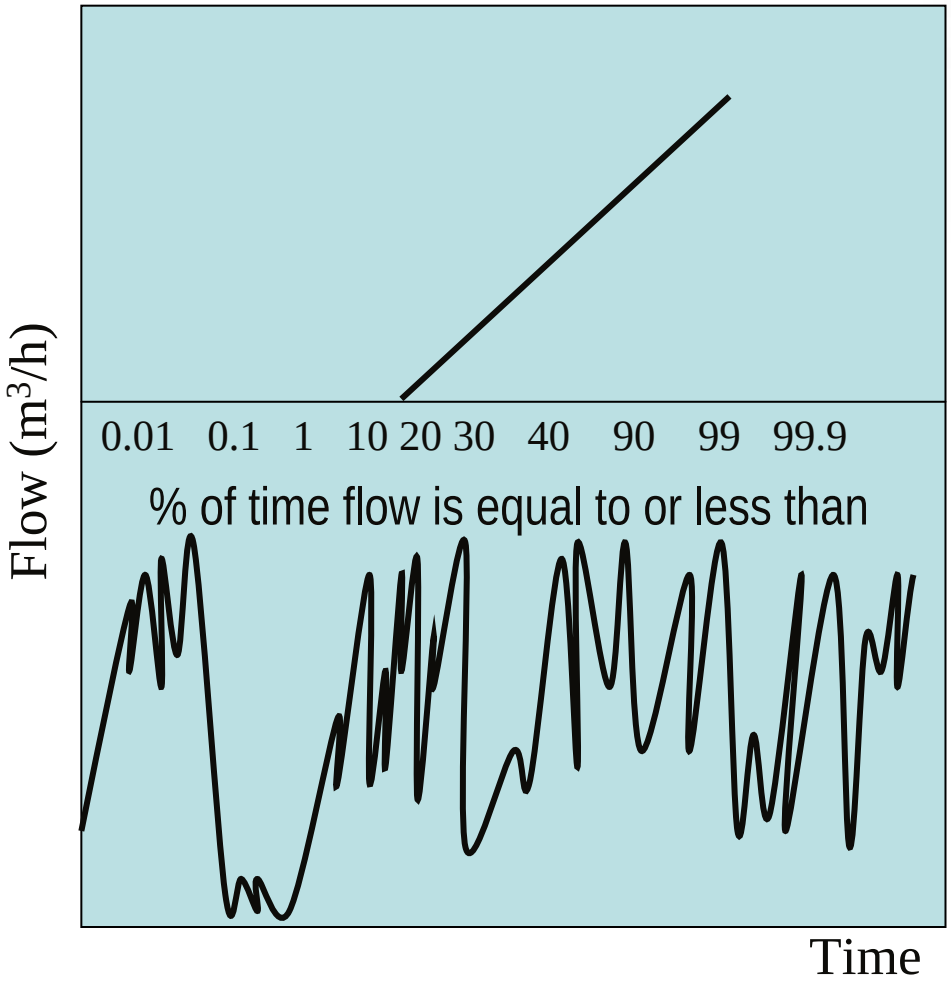
Sources and Characteristics

- Volume and strength of pollution of industrial wastewater – in units of production
- Example: m^3/ton of palm oil
- Example: kg BOD / tonne of palm oil
- Statistical variation on waste flow depends on the
  - *diversity of products manufactured*
  - *process operations generating waste*
  - *batch or continuous types*

Note:

- Ton = 2000 lb
- Tonne = 1000 kg

Sources and Characteristics



Variation in flow from a batch operation

Variation in flow & waste characteristics for some industrial wastes

Waste	Flow, gal/product % frequency			BOD, lb/product % frequency			SS, gal/product % frequency		
	10	50	90	10	50	90	10	50	90
Pulp & paper*	11,000	43,000	74,000	17	58	110	26	105	400
Paper board*	7,500	11,000	27,500	10	28	46	25	48	66
Slaughter house**	165	800	4,300	3.8	13	44	3	10	31
Brewery	130	370	600	1	2	44	0.25	1.2	2.5
Tannery†	4.2	9	13.6	575	975	1400	600	1900	3200

*Tons paper production; **1000 lb live weight kill; †mg/l

General procedure to develop wastewater characterization

- Develop a sewer map (to locate sampling points)
- Establish sampling and analysis schedule
- Develop a flow-and-material-balance diagram
- Establish statistical variation in significant waste characteristics


The concrete lined channel, choked with rubbish and green with algae, typified the degeneration of urban rivers when the photograph was taken, in the early 1990s. (The Lower Lea Project)

Exercise 1: Wastewater design

UTM is planning to use treated sewage for landscaping irrigation.

a) Suggest a conceptual design for a sewage treatment plant.

b) PE = 10,000. Calculate the organic and hydraulic loading for the treatment plant

Estimation of organics

- BOD_5 at 20^oC
- COD test (potassium permanganate)
- COD test (potassium dichromate)
- Total organic carbon
- Total oxygen demand

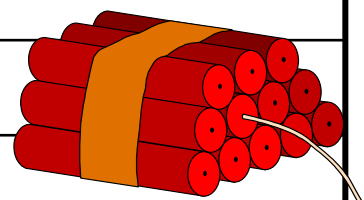
Analysis for organics in sewage

Parameters	Names	Raw sewage
COD_p	COD (potassium permanganate alkaline)	180
BOD_5	5-day BOD	280
BOD_7	7-day BOD	320
BOD_∞	Total BOD	400
COD	COD (potassium dichromate)	600
S_s	Easily biodegradable matters	60
X_s	Slowly biodegradable matters	200
TOC	Total organic carbon (800^{o}C)	200

Note: All units are mg/l

Wastewater components

POLLUTANTS	REUSE POTENTIALS
Organics	Soil conditioners
	Substrate for microorganisms
	Resins
	Biopolymers
	Biogas
Nutrients	Fertilizers
Heavy metals	Recycle
Endocrine disrupters	??
Persistent organics	??



Waste characterization

Conventional methods	ASM methods
BOD COD	Oxygen utilization rate Nitrogen utilization rate Phosphorus utilization rate
Suspended solids	
Pathogens	ACTIVATED SLUDGE MODELS - ASM 1 (1987) - ASM 2 (1987) - ASM 3 (1999) RIVER MODELS (2005) ANAEROBIC MODELS (2007)
Nitrite	
Nitrate	
Phorphorus	
Heavy metals	

Activated sludge models

Key reserachers/principals

- Mogens Henze (Denmark)
- Peter Vanrollegham (Belgium/Canada)
- Takashi Mino (Japan)
- Mark van Loosdrecht (the Netherlands)
- Willi Gujer (Switzerland)
- Leslie Grady (USA)
- Tom Matsuo (Japan)
- G. v. Marais (South Africa)
- Gustaf Olsson (Sweden)

THIRD SCHEDULE OF THE ENVIRONMENTAL QUALITY ACT, 1974
ENVIRONMENTAL QUALITY (SEWAGE AND INDUSTRIAL EFFLUENTS) REGULATIONS, 1979

PARAMETER LIMITS OF EFFLUENT OF STANDARDS "A" AND "B"

Parameter	Unit	Standard	
		A	B
Temperature	^{o}C	40	40
pH Value	-	6.0 – 9.0	5.5-9.0
BOD_5 at $20^{0}C$	mg/L	20	50
COD	mg/L	50	100
Suspended solids	mg/L	50	100
Mercury	mg/L	0.005	0.05
Cadmium	mg/L	0.01	0.02
Chromium, Hexavalent	mg/L	0.05	0.05
Arsenic	mg/L	0.05	0.10
Cyanide	mg/L	0.05	0.10

THIRD SCHEDULE OF THE ENVIRONMENTAL QUALITY ACT, 1974
ENVIRONMENTAL QUALITY (SEWAGE AND INDUSTRIAL EFFLUENTS) REGULATIONS, 1979

PARAMETER LIMITS OF EFFLUENT OF STANDARDS A AND B

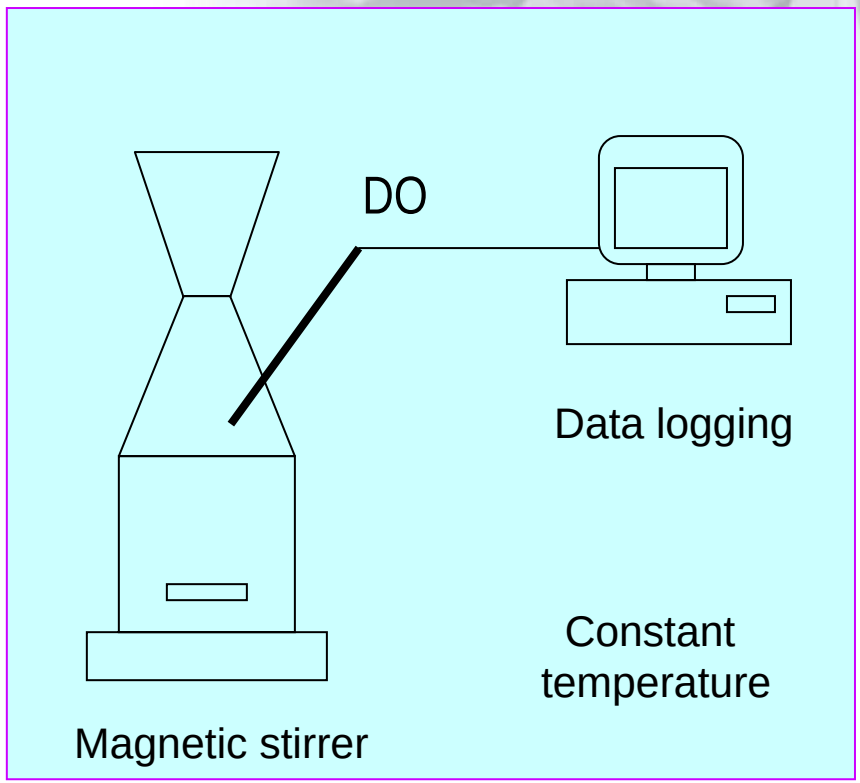
Parameter	Unit	Standard	
		A	B
Lead	mg/L	0.10	0.5
Chromium, Trivalent	mg/L	0.20	1.0
Copper	mg/L	0.20	1.0
Manganese	mg/L	0.20	1.0
Nickel	mg/L	0.20	1.0
Tin	mg/L	0.20	1.0
Zinc	mg/L	1.0	1.0
Boron	mg/L	1.0	4.0
Iron (Fe)	mg/L	1.0	5.0
Phenol	mg/L	0.001	1.0
Free Chlorine	mg/L	1.0	2.0
Sulphide	mg/L	0.50	0.50
Oil and Grease	mg/L	Not Detectable	10.0

Characteristics of Waters and Wastewaters

Characteristic	River Water	Drinking Water	Raw Sewage	Sewage Effluent
pH	x	x	x	x
Temperature	x	x	x	
Colour	x	x		
Turbidity	x	x		
Taste		x		
Odour	x	x		
Total Solids	x	x		
Settleable solids			x	
Suspended solids	x		x	x
Conductivity	x	x		
Radioactivity	x	x		
Alkalinity	x	x	x	x
Acidity	x	x	x	x
Hardness	x	x		
DO	x	x		
BOD	x		x	x
PV, COD or TOC	x		x	x
Organic Nitrogen			x	x

Wastewater Characterization using Respirometric Analysis

- Use respirometer
- Based on respiration rate
- Principle: Utilized DO is directly to:
  - biomass growth
  - substrate removal
- Gives detailed information on the composition of wastewater
- Use COD fractionation
- Respiration rate is an important indicator of process condition
- Applications:
  - biokinetic parameters
  - biodegradation rate
  - modeling
  - process control



Waste characterization

IWA Activated Sludge Model 1 (1987)

COD Fractionation

- Readily biodegradable substrate, S_s
- Slowly biodegradable substrate, X_s
- Inert soluble organic matter, S_I
- Inert suspended organic matter, X_I

COD Total = $S_S + S_I + X_S + X_I$

Wastewater Characterization

IWA Activated Sludge Model 2 (1995)

COD Fractionation

- Fermentation products (acetate), S_A
- Readily biodegradable substrate, S_F
- Inert soluble non-biodegradable matter, S_I
- Inert suspended non-biodegradable matter, X_I
- $S_S = S_F + S_A$
- Heterotrophic biomass, X_H
- Phosphorus-accumulating organisms, X_{PAO}
- Organic storage products of PAO, X_{PHA}
- Autotrophic, nitrifying biomass, X_{AUT}

$$\text{COD Total} = S_A + S_F + S_I + X_I + X_S + X_H + X_{PAO} + X_{PHA} + X_{AUT}$$

Wastewater Characterization

COD Substrate

Substrates	Models	
	ASM1	ASM2
Parameters	S_S	S_F
		S_A
	X_S	X_S
		X_{PHA}

Wastewater Characterization

Biomass

Biomass	Models	
	ASM1	ASM2
Parameters	Heterotrophic	Heterotrophic, X_H
	Autotrophic	Autotrophic, X_{AUT}
		Phosphorus accumulating organisms, X_{PAO}

Wastewater characterization

Activated sludge model 1 (1987)

Total Nitrogen Fractionation

- Total Kjeldahl nitrogen, C_{TKN}
- Particulate Kjeldahl nitrogen, X_{TKN}
- Soluble Kjeldahl nitrogen, S_{TKN}
- Soluble nitrate plus nitrite, S_{NO3}

$$\text{Total N} = C_{TKN} + S_{NO3}$$
$$= X_{TKN} + S_{TKN} + S_{NO3}$$

Wastewater characterization

Activated sludge models 1 & 2

Nitrogen compounds	Models	
	ASM1	ASM2
Parameters	S_{NH4}, S_{NO3}	S_{NH4}, S_{NO3}, S_{N2}
	S_{ND}	Organic nitrogen included as a fraction of COD

S_{N2} = Dissolved dinitrogen

Wastewater characterization

Activated sludge model 2 (1995)

Total Phosphorus Fractionation

- Dissolved inorganic orthophosphate, S_{PO4}
- Dissolved inorganic polyphosphate, S_{P-P}
- Dissolved organic phosphorus, $S_{org.P}$
- Suspended organic phosphorus, $X_{org.P}$

Total P = S_{PO4} + S_{P-P} + $S_{org.P}$ + $X_{org.P}$

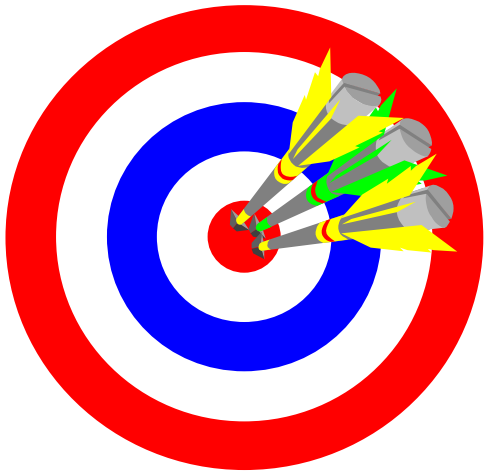
Wastewater characterization

Activated sludge models 1 & 2

Phosphorus compounds	Models	
	ASM1	ASM2
Parameters	Not available	S_{PO4}, X_{PP}
		Organic phosphorus included as a fraction of COD

S_{PO4} = phosphate, X_{PP} = poly-phosphate

What can be used / reused?

Organics	COD Fractionation
 IWA Activated Sludge Model 2 (1995)	•Fermentation products (acetate), S_A •Readily biodegradable substrate, S_F •Inert soluble non-biodegradable matter, S_I •Inert suspended non-biodegradable matter, X_I •Slowly biodegradable substrate, S_A •Heterotrophic biomass, X_H •Phosphorus-accumulating organisms, X_{PAO} •Organic storage products of PAO, X_{PHA} •Autotrophic, nitrifying biomass, X_{AUT}

What can be recycled?

COD Fractionation

- Fermentation products (acetate), S_A
- Readily biodegradable substrate, S_F
- Inert soluble non-biodegradable matter, S_I
- Inert suspended non-biodegradable matter, X_I

- Slowly biodegradable substrate, S_A
- Heterotrophic biomass, X_H
- Phosphorus-accumulating organisms, X_{PAO}
- Organic storage products of PAO, X_{PHA}
- Autotrophic, nitrifying biomass, X_{AUT}