# Wastewater Characterization

DTU

Wastewater Characterization

DTU

**Prof. Mogens Henze**
**Technical University of Denmark**
**DENMARK**

ÉCOLE POLYTECHNIQUE MONTRÉAL

**Prof. Dr. Yves Comeau**
**Ecole Polytechnique Montreal**
**CANADA**

sponsored by
POWER.
K water
The Best Water Partner
UNESCO-IHE

# Wastewater Characterization

Professor Mogens Henze
Technical University of Denmark
Department of Environment & Resources

## Art, Science & Engineering

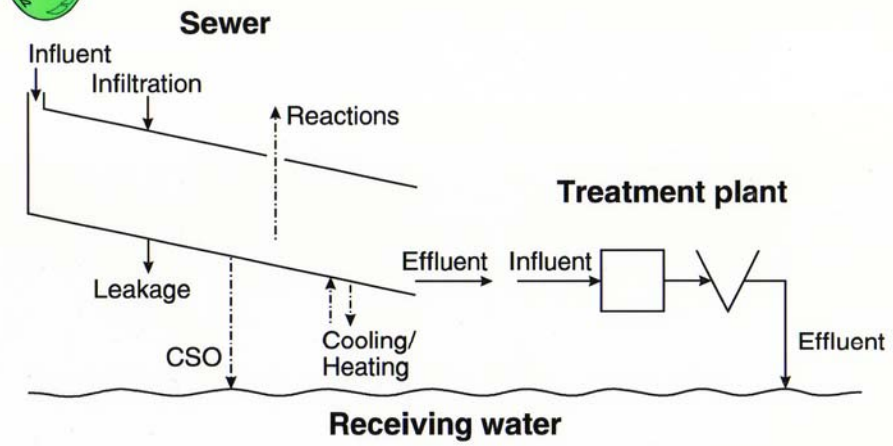
- Art is about guessing the correct solution
- Science is about producing tables in which we can find the right solution
- Engineering is about consulting the tables

(Poul Henningsen, Danish architect and writer)

## This is about engineering

- about consulting the tables

## 1. THE ORIGIN OF WASTEWATER



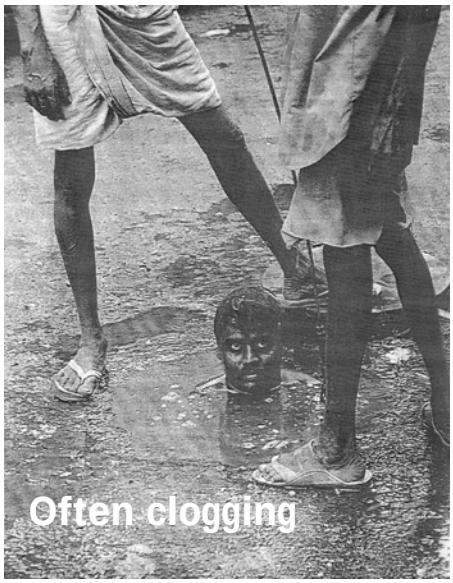
## What is going on in the sewer?

## What is going on in the sewer?

**Fermentation?**

**Oxidation?**

## What is going on in the sewer?






## Wastewater from the society

- Domestic wastewater
- Wastewater from institutions
- Industrial wastewater
- Infiltration into sewers
- Stormwater
- Leachate
- Septic tank wastewater

## Internally generated wastewater

- Thickener supernatant
- Digester supernatant
- Reject water from sludge dewatering
- Drainage water from sludge drying beds
- Filter wash water
- Equipment cleaning water



## Overview wastewater (1)

- Origin of wastewater
- Wastewater constituents
- BOD and COD
- Person equivalents and Person Load
- Important components
- Special components
- Microorganisms
- Special wastewaters and plant recycles
- Ratios

## Overview wastewater (2)

- Variations
- Flow
- Traditional wastes from households
- Wastewater design
- COD fractionation
- Wastewater fingerprint



## 2. WASTEWATER CONSTITUENTS

- Microorganisms
- Biodegradable organics
- Inert organic
- Nutrients
- Metals
- Other inorganic materials
- Thermal effects
- Odour (and taste)
- Radioactivity

## Organic pollution

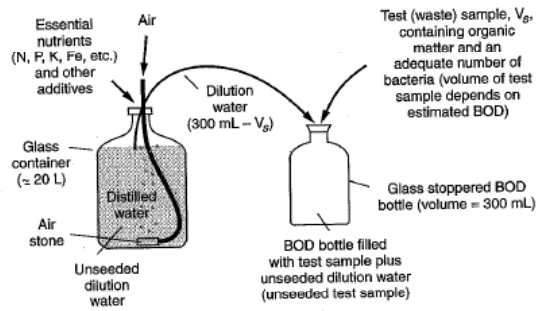
- Many compounds
- What is interesting
- Bulk parameters
  - COD
  - BOD
  - TOC



## 3. BOD/COD

- BOD is biodegradable organics during 5 days at 20 degr. C. Approx. 70% of biodegradable material in municipal wastewater is degraded.
- COD is chemical oxygen demand, measured by strong oxidation with dichromate, which oxidizes all organic compounds.

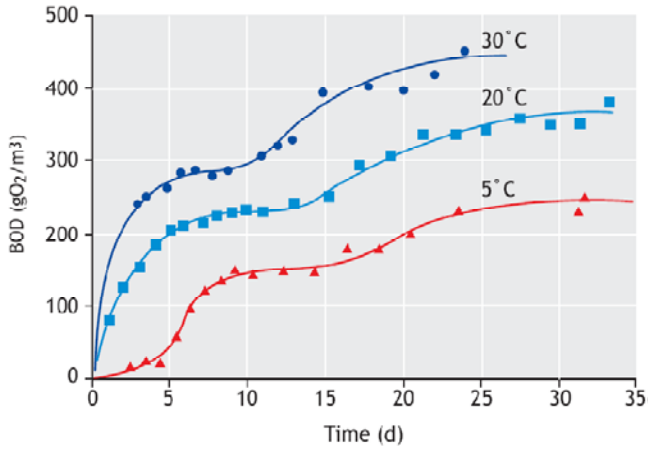
# BOD test



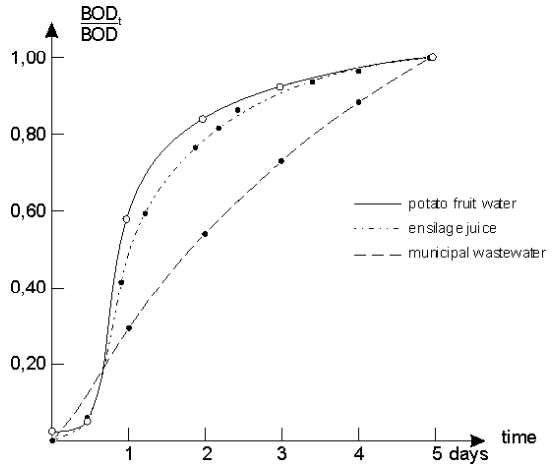

Source: Metcalf and Eddy, 2003



# BOD and temperature



# Industrial wastewater BOD






# COD calculation

- Carbon oxidised to carbon dioxide
- Ammonia nitrogen not oxidised
- Sulphide oxidised

1. Calculate level of oxidation
2. Calculate oxygen needed

## Level of oxidation

- Elements 0
- Hydrogen +1
- Oxygen ions -2
- Substances have total level equal to charge



## COD calculation

What is COD of ethanol, $C_2H_6O$ ?

$C_2H_6O + O_2 \rightarrow CO_2 + H_2O$

Balancing C

$C_2H_6O + O_2 \rightarrow 2CO_2 + H_2O$

Balancing O and $H_2O$

$C_2H_6O + 3O_2 \rightarrow 2CO_2 + 3H_2O$

46 g ethanol needs 96 g oxygen

COD is 96/46 = 2.09 /g ethanol

## Exercise 1: COD calculation

- *Calculate the COD of acetic acid, $CH_3COOH$*



## Exercise 1 Solution

- *Calculate the COD of acetic acid, $CH_3COOH$*

$CH_3COOH + 2O_2 \rightarrow 2CO_2 + 2H_2O$

*Molar weight of acetic acid is*
*12+1+1+1+12+16+16+1 = 60 g*

*60 g acetic acid needs 2·(16+16) = 64 g oxygen*

*COD is 64 g oxygen/60 g acetic acid*

*= 1.07 g oxygen/g acetid acid*

# 4. PERSON EQUIVALENTS AND PERSON LOAD

## Person Equivalent (PE)

- 1 PE = 60 g BOD/d
- 1 PE = 200 l /d



## Person Load

| | |
|---|---|
| BOD, g/person.d | 15-80 |
| COD, g/person.d | 25-200 |
| Nitrogen, g/person.d | 2-15 |
| Phosphorus, g/person.d | 1-3 |
| Wastewater, $m^3$/person.d | 0.005-0.4 |

## Exercise 2: Person Load

- Island with 240 people, all wastewater collected and the amount is 60 $m^3$/d and 18 kg BOD/d.
- What is the Person Load for wastewater and BOD?



## Exercise 2: Solution

- *The Person Load is (60 $m^3$/d) / 240 persons = 0.250 $m^3$/(capita·d)*
- *For BOD the Person Load is (18 kg BOD/d) / 240 persons = 75 g BOD/(capita · d)*

## Person Loads in various countries kg/(capita·y)

| | Brazil | Egypt | India | Turkey | US | Denmark | Germany |
|---|---|---|---|---|---|---|---|
| BOD | 20-25 | 10-15 | 10-15 | 10-15 | 30-35 | 20-25 | 20-25 |
| SS | 20-25 | 15-25 | | 15-25 | 30-35 | 30-35 | 30-35 |
| N-total | 3-5 | 3-5 | | 3-5 | 5-7 | 5-7 | 4-6 |
| P-total | 0.5-1 | 0.4-0.6 | | 0.4-06 | 0.8-1.2 | 0.8-1.2 | 0.7-1 |



## 5. IMPORTANT COMPONENTS

- Concentrations caused by
  - Pollution load to sewer
  - Water consumption
  - Dilution in sewer

## Typical content in raw municipal wastewater g/m³

| Parameter | High | Medium | Low |
|---|---|---|---|
| COD total | 1200 | 750 | 500 |
| COD soluble | 480 | 300 | 200 |
| BOD total | 560 | 350 | 230 |
| Total nitrogen | 100 | 60 | 30 |
| Ammonia N | 75 | 45 | 20 |
| Total P | 25 | 15 | 6 |
| SS | 600 | 400 | 250 |
| VSS | 480 | 320 | 200 |



## Nutrients content in raw municipal wastewater g/m³

| Parameter | High | Medium | Low |
|---|---|---|---|
| Total Nitrogen | 100 | 60 | 30 |
| Ammonia N | 75 | 45 | 20 |
| Nitrate + nitrite N | 0.5 | 0.2 | 0.1 |
| Organic N | 25 | 15 | 10 |
| Kjeldahl N | 100 | 60 | 30 |
| Total Phosphorus | 25 | 15 | 6 |
| O-phosphate P | 15 | 10 | 4 |
| Organic P | 10 | 5 | 2 |

## Medium concentrated municipal wastewater, soluble and suspended matter
## g/m$^3$

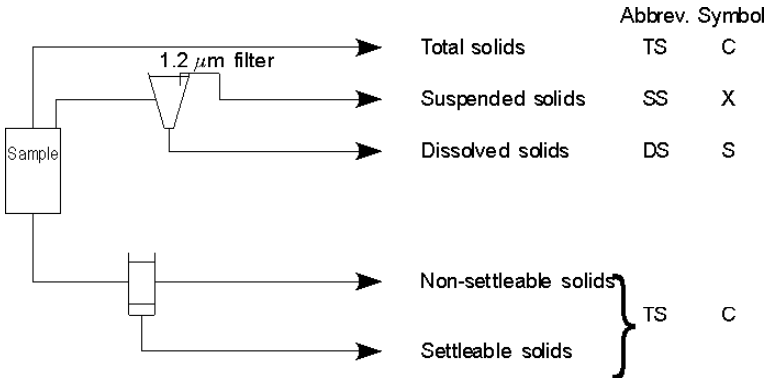
| Parameter | Soluble | Suspended | Total |
|---|---|---|---|
| COD total | 300 | 450 | 750 |
| BOD | 140 | 210 | 350 |
| Total Nitrogen | 50 | 10 | 60 |
| Total phosphorus | 11 | 4 | 15 |



## Medium concentrated municipal wastewater, biodegrable and inert matter
## g/m$^3$

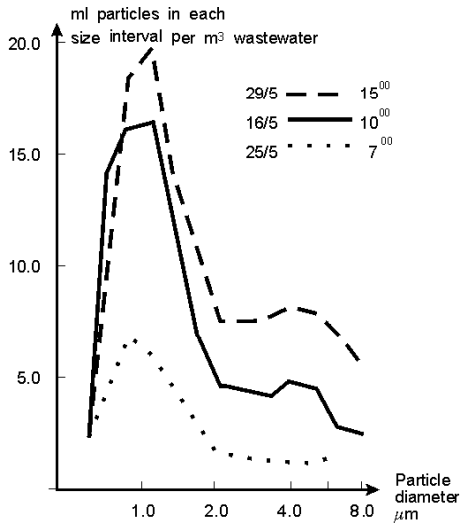
| Parameter | Biodegradable | Inert | Total |
|---|---|---|---|
| COD | 570 | 180 | 750 |
| COD soluble | 270 | 30 | 300 |
| COD suspend | 300 | 150 | 450 |
| BOD | 350 | 0 | 350 |
| Total N | 43 | 2 | 45 |
| Organic N | 13 | 2 | 15 |
| Total P | 14.7 | 0.3 | 15 |

# Suspended solids






# Particles fingerprint



# 6. SPECIAL COMPONENTS

## Metals in municipal wastewater (1) mg/m³

| | High | Medium | Low |
|---|---|---|---|
| Aluminum | 1000 | 600 | 350 |
| Cadmium | 4 | 2 | 1 |
| Chromium | 40 | 25 | 10 |
| Copper | 100 | 70 | 30 |
| Lead | 80 | 60 | 25 |
| Mercury | 3 | 2 | 1 |
| Nickel | 40 | 25 | 10 |
| Silver | 10 | 7 | 3 |
| Zinc | 300 | 200 | 100 |



## Metals in municipal wastewater (2) mg/m³

| Analysis parameter | Symbol | Unit[1)] | Wastewater type | | | |
|---|---|---|---|---|---|---|
| | | | Concentrated | Moderate | Diluted | Very diluted |
| Aluminium | $C_{Al}$ | mg Al/m³ | 1000 | 650 | 400 | 250 |
| Arsenic | $C_{As}$ | mg As/m³ | 5 | 3 | 2 | 1 |
| Cadmium | $C_{Cd}$ | mg Cd/m³ | 4 | 2 | 2 | 1 |
| Chromium | $C_{Cr}$ | mg Cr/m³ | 40 | 25 | 15 | 10 |
| Cobalt | $C_{Co}$ | mg Co/m³ | 2 | 1 | 1 | 0.5 |
| Copper | $C_{Cu}$ | mg Cu/m³ | 100 | 70 | 40 | 30 |
| Iron | $C_{Fe}$ | mg Fe/m³ | 1500 | 1000 | 600 | 400 |
| Lead | $C_{Pb}$ | mg Pb/m³ | 80 | 65 | 30 | 25 |
| Manganese | $C_{Mn}$ | mg Mn/m³ | 150 | 100 | 60 | 40 |
| Mercury | $C_{Hg}$ | mg Hg/m³ | 3 | 2 | 1 | 1 |
| Nickel | $C_{Ni}$ | mg Ni/m³ | 40 | 25 | 15 | 10 |
| Silver | $C_{Ag}$ | mg Ag/m³ | 10 | 7 | 4 | 3 |
| Zinc | $C_{Zn}$ | mg Zn/m³ | 300 | 200 | 130 | 80 |

[1)] mg/m³ = µg/l = ppb

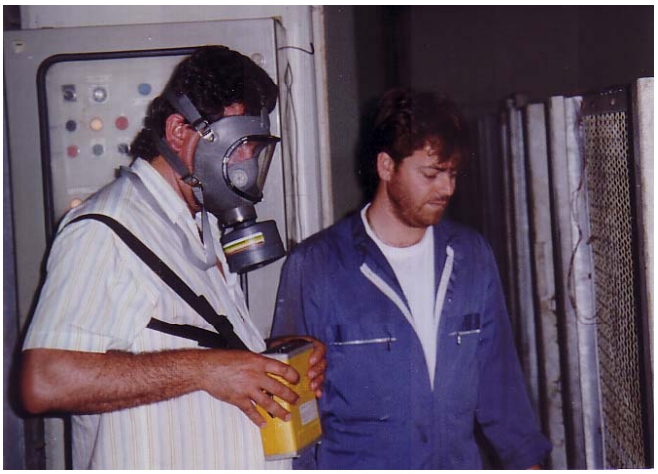
**Table 1.9**
Typical content of metals in domestic wastewater, data for example from /17/.

## Different parameters in municipal wastewater

| Parameter | High | Medium | Low | Unit |
|---|---|---|---|---|
| Absolute viscosity | 0.001 | 0.001 | 0.001 | kg/(m·s) |
| Surface tension | 50 | 55 | 60 | Dyn/cm$^2$ |
| Conductivity | 120 | 100 | 70 | mS/m |
| pH | 8.0 | 7.5 | 7.0 | - |
| Alkalinity | 7 | 4 | 1 | Eqv/m$^3$ |
| Sulphide | 10 | 0.5 | 0.1 | g S/m$^3$ |
| Cyanide | 0.05 | 0.03 | 0.02 | g /m$^3$ |



## Picture: $H_2S$ Measurement



## Wastewater components

| Analysis /matter | Symbol | Unit | Wastewater type | | | |
|---|---|---|---|---|---|---|
| | | | Concentrated | Moderate | Diluted | Very diluted |
| Suspended solids | $X_{SS}$ | g SS/m$^3$ | 450 | 300 | 190 | 120 |
| Suspended solids, volatile | $X_{VSS}$ | g VSS/m$^3$ | 320 | 210 | 140 | 80 |
| Precipitate after 2h | $X_{SS}$ | ml/l | 10 | 7 | 4 | 3 |
| Precipitate after 2h, suspended solids | $X_{SS}$ | g/m$^3$ | 320 | 210 | 140 | 80 |
| Precipitate suspended solids, volatile | $X_{VSS}$ | g/m$^3$ | 220 | 150 | 90 | 60 |
| Suspended solids after 2h | | g SS/m$^3$ | 130 | 90 | 50 | 40 |
| Coliform bacteria | | No./m$^3$ | $10^{12}$ | $10^{12}$ | $10^{12}$ | $10^{12}$ |
| Absolute viscosity | $\mu_a$ | kg/(m·s) | 0.001 | 0.001 | 0.001 | 0.001 |
| Surface tension | | dyn/cm$^2$ | 50 | 55 | 60 | 65 |
| Conductivity | | mS/m [1)] | 120 | 100 | 80 | 70 |
| pH | | - | 7-8 | 7-8 | 7-8 | 7-8 |
| Alkalinity | TAL | eqv/m$^3$ [2)] | 3-7 | 3-7 | 3-7 | 3-7 |
| Sulphide [3)] | | g S/m$^3$ | 0.100 | 0.100 | 0.100 | 0.100 |
| Cyanide | $C_{CN}$ | g/m$^3$ | 0.050 | 0.035 | 0.020 | 0.015 |
| Chloride [4)] | | g Cl/m$^3$ | 500 | 360 | 280 | 200 |
| Boron | | g B/m$^3$ | 1.0 | 0.7 | 0.4 | 0.3 |
| Temperature, summer [5)] | | °C | 20 | 18 | 15 | 15 |
| Temperature, winter [5)] | | °C | 8 | 8 | 8 | 8 |



## Personal care chemicals to domestic wastewater

**(Anna Ledin, E&R,DTU)**

## Sources to substances in wastewater- medicine
**(Anna Ledin, E&R,DTU)**

## Chemicals to domestic wastewater - detergents
**(Anna Ledin, E&R,DTU)**

## Chemicals to domestic wastewater

**(Anna Ledin, E&R,DTU)**

## Raw water: special substances

| Substance/ Group of substances | Typical concentration, µg/l | Where - from? | Effect |
|---|---|---|---|
| Metylenchloride | 10-50 | Solvents | Toxic(wwtp) |
| Nonylphenoles NPE | 10-50 | Detergent | Estrogene effect |
| LAS Linear Alkylbenzene Sulphonate | 5.000-10.000 | Detergents | Ecotoxic |
| Chloroform | 1-10 | Solvent | Toxic(wwtp) Cancer |
| Phtalates DEHP DOP | 100-200 100-500 | Plastics Paint | Estrogene effect |
| PAH Polyaromatic hydrocarbons | 0.5-2 | Tar | Ecotoxic Cancer |

# 7. MICROORGANISMS

Microorganisms in Wastewater (#/100 ml)

| | Raw sewage | Biol.treated |
|---|---|---|
| E.Coli | $10^7$ | $10^4$ |
| Cl.perfringens | $10^4$ | $3*10^2$ |
| Fecal streptococcae | $10^7$ | $10^4$ |
| Salmonella | 200 | 1 |
| Campylobacter | $5*10^4$ | $5*10^2$ |
| Listeria | $5*10^3$ | 50 |
| Staphyllococcus aureus | $5*10^4$ | $5*10^2$ |
| Coliphages | $10^5$ | $10^3$ |
| Giardia | $10^3$ | 20 |
| Roundworms | 10 | 0.1 |
| Enterovirus | 5000 | 500 |
| Rotavirus | 50 | 5 |
| Susp. matter (mg/100 ml) | 30 | 2 |



# Exercise 3: Bathing water

- *Bathing water quality limit is 1000 E.Coli per 100 ml of water. Calculate the needed dilution in the receiving water to reach the bathing water criteria for a wastewater of high microbial strength*

## Exercise 3: Solution

- *Bathing water criteria can be maximum 1000 E.Coli per 100 ml of water. Calculate the needed dilution in the receiving water to reach the bathing water criteria for a raw wastewater*
- *Answer:*
- *Dilution needed (Dn): 1000= $10^7$ /Dn*
- *Dn = $10^7$/1000 = $10^4$ = 10,000*



## 8. SPECIAL WASTEWATERS AND PLANT RECYCLES

- **Septic sludge: high COD, TN and sulphide**
- **Leachate: High soluble inert COD, high ammonia**
- **Digester supernatant: High TN, suspended solids and sulphide**
- **Reject water, sludge dewatering: High TN**
- **Filter wash water: High SS**

## Septic sludge
## g/m$^3$

| Compound | High | Low |
|---|---|---|
| BOD total | 30,000 | 2,000 |
| COD total | 90,000 | 6,000 |
| Total nitrogen | 1500 | 200 |
| Total phosphorus | 300 | 40 |
| Suspended solids | 100,000 | 7,000 |
| Hydrogen sulphide | 20 | 1 |



## Exercise 4: Septic sludge load

- *A septic tank truck with 20m$^3$ septic sludge containing 20 kg BOD/m$^3$, uses 1 hour to discharge its load directly into a wastewater treatment plant for 50,000 person equivalents of wastewater. The hourly wastewater flow in the plant is 1000 m$^3$ with a BOD concentration of 300 g BOD/m$^3$.*
- *What is the increase in BOD load during that hour?*

## Exercise 4
## Solution

- *Normal BOD load is (1000 $m^3$/h)·300 g BOD/ $m^3$= 300 kg BOD/h. The BOD load in the septic sludge is (20 $m^3$/h)·20 kg BOD/ $m^3$= 400 kg BOD/h. The per cent increase in BOD load is (400/300)100 = 133 %. It is obvious that such a load will influence the operation of the biological treatment. The need for oxygen supply in the aeration tank will be more than doubled during the period where the septic sludge is discharged into the plant.*



## Leachate
## g/$m^3$

| Compound | High | Low |
|---|---|---|
| BOD total | 12,000 | 300 |
| COD total | 16,000 | 1200 |
| Total nitrogen | 500 | 100 |
| Total phosphorus | 10 | 1 |
| Suspended solids | 500 | 20 |
| Hydrogen sulphide | 10 | 1 |

## Digester supernatant g/m$^3$

| Compound | High | Low |
|---|---|---|
| BOD total | 4000 | 300 |
| COD total | 9,000 | 700 |
| Total nitrogen | 800 | 120 |
| Total phosphorus | 300 | 15 |
| Suspended solids | 10,000 | 500 |
| Hydrogen sulphide | 20 | 2 |



## Exercise 5: Digester supernatant

- *A wastewater treatment plant receives 10,000 m$^3$/d of wastewater with 50 g Nitrogen/m3. During the 8 working hours at the plant it is assumed that the nitrogen load is 50% of the daily load. The plant has anaerobic digestion of sludge and the digester supernatant to 100 m$^3$/d with a content of 700 g Nitrogen/m$^3$*
- *What is the internal loading per day from the digester supernatant? What is the total nitrogen load during 4 working hours if the daily digester supernatant is recycled to the nitrification tank in that period. What is the nitrogen load outside the working hours?*

## Exercise 5: Solution

- *Digester supernatant nitrogen load is (100m$^3$/d)700 gN/m$^3$= 70 kg N/d. The nitrogen load from the influent wastewater is (10,000 m$^3$/d)50 gN/ m$^3$= 500 kg N/d. During the 8 working hours the load is 250 kgN or31.3 kgN/h.*
- *The internal nitrogen load is (70/500)100 = 14%. The load if recycled during4 working hours is 70/4 = 17.5 kgN/h. The total load in these hours will be 31.3 + 17.5 = 48.8 kgN/h. During the night the load is 250/16 = 15.6 kgN/h. The uneven distribution between night and day can create problems for the nitrification process. A result is often breakthrough of ammonia during the high load period in the working hours.*



## Reject water from sludge dewatering g/m$^3$

| Compound | High | Low |
|---|---|---|
| BOD total | 1500 | 300 |
| COD total | 4,000 | 800 |
| Total nitrogen | 500 | 100 |
| Total phosphorus | 20 | 5 |
| Suspended solids | 1000 | 100 |
| Hydrogen sulphide | 20 | 0.2 |

# Filter wash water
# g/m$^3$

| Compound | High | Low |
|---|---|---|
| BOD total | 400 | 50 |
| COD total | 1500 | 300 |
| Total nitrogen | 100 | 25 |
| Total phosphorus | 50 | 5 |
| Suspended solids | 1500 | 300 |
| Hydrogen sulphide | 0.1 | 0.01 |



# 9. RATIOS

- Ratios influence treatment options
  - Low COD/BOD means easy removal of organics
  - High COD/TN good for denitrification
  - High VSS/SS good for sludge digestion
  - Low VFA/COD bad for biological P-removal
- Strange ratios?
  - Industrial wastewater influence?
  - Analytical errors?

## Ratios in municipal wastewater

| Ratio | High | Medium | Low |
|---|---|---|---|
| COD/BOD | 2.5-3.5 | 2.0-2.5 | 1.5-2.0 |
| VFA/COD | 0.12-0.08 | 0.08-0.04 | 0.04-0.02 |
| COD/TN | 12-16 | 8-12 | 6-8 |
| BOD/TN | 10-7 | 4-7 | 2-4 |
| COD/TP | 45-60 | 35-45 | 20-35 |
| COD/VSS | 1.6-2.0 | 1.4-1.6 | 1.2-1.4 |
| VSS/SS | 0.8-0.9 | 0.6-0.8 | 0.4-0.6 |



## Exercise 6: Ratios in wastewater

- *A wastewater has the following composition in g/m$^3$*
  - *BOD 400*
  - *COD 300*
  - *SS 350*
  - *VSS 280*
  - *Total Nitrogen (TN) 65*
- *What are the ratios for COD/BOD and BOD/TN ?*
- *Are there anomalies in this wastewater analysis?*

## Exercise 6: Solution

- *The ratios are COD/BOD = 300/400 = 0.75, BOD/TN = 400/65 = 6.2.*
- *The COD/BOD ratio is strange. Variations of 1.5 - 3.5 is reasonable. Since BOD measures a fraction of the organic matter, COD must be higher than BOD. One of the two analytical results must be wrong. Since the BOD/TN ratio is within the expected range, the BOD value is most probably correct. Thus the COD value must be due to an analytical error.*

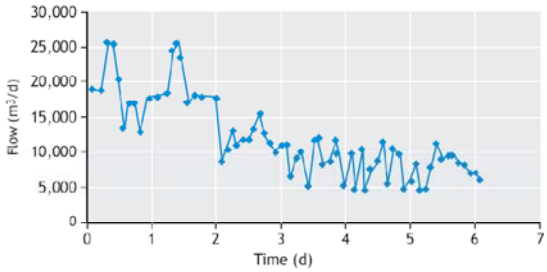


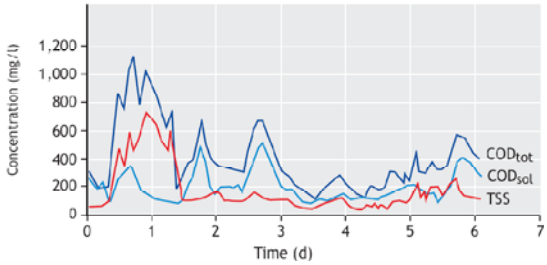
## 10. VARIATIONS

- **Wastewater flow varies**
- **Substance concentrations vary**
- **Temperature vary**

- **Everything varies – it is frustrating**

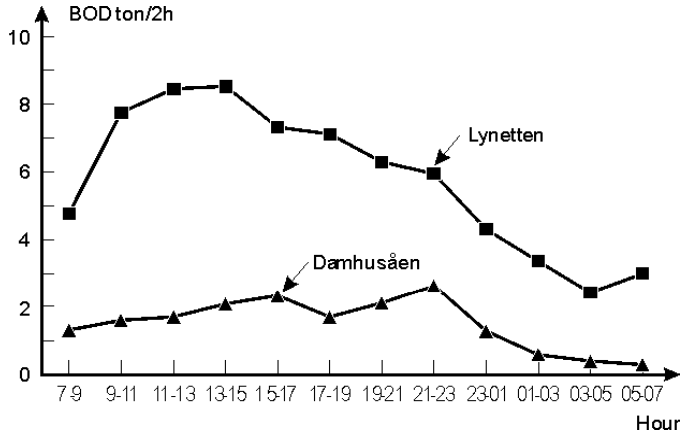
# Variations in flow COD and SS



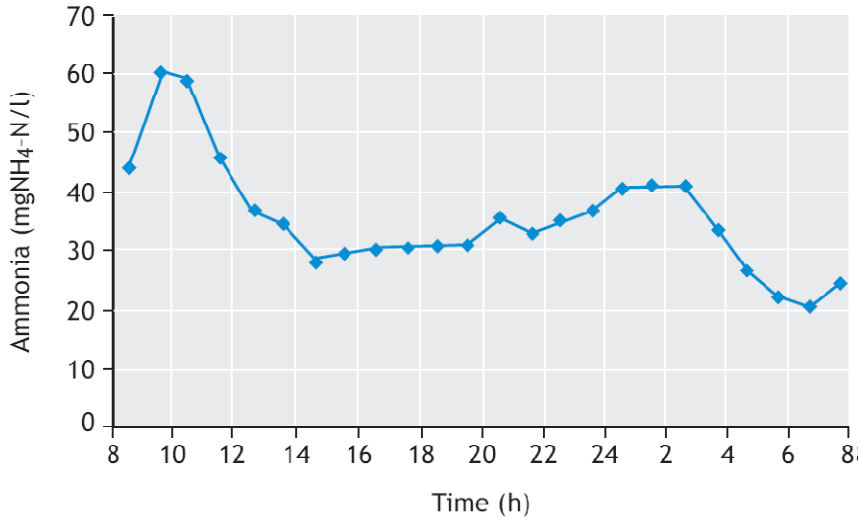






# Diurnal variations in BOD load

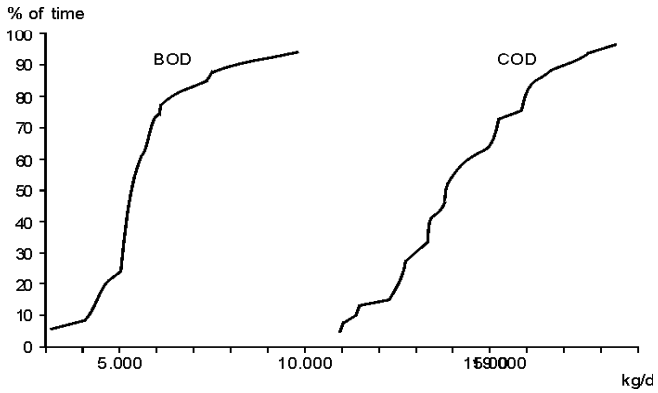


## Ammonia in influent to Galindo WWTP, Spain






## Statistical variations in BOD and COD



## Wastewater is difficult to control

## Sampling of wastewater

- The variations in time for flow and components makes wastewater sampling troublesome
- Analytical results for components will vary considerably with the chosen sampling procedure
- Floatable materials (oil and grease) and heavy components (sand and grit) are the most difficult ones to get reliable sampling results from

## Sampling principles

- Various sampling principles
  - Grab sample (one sample collected in a bucket submerged) (very restricted information)
  - Time proportional sample (can be OK for only small variations in components concentrations)
  - Flow proportional sample (most correct result, but floating and sinking materials might be underestimated)
  - 24 hour variations in concentrations
  - Week samples (time or flow proportional)

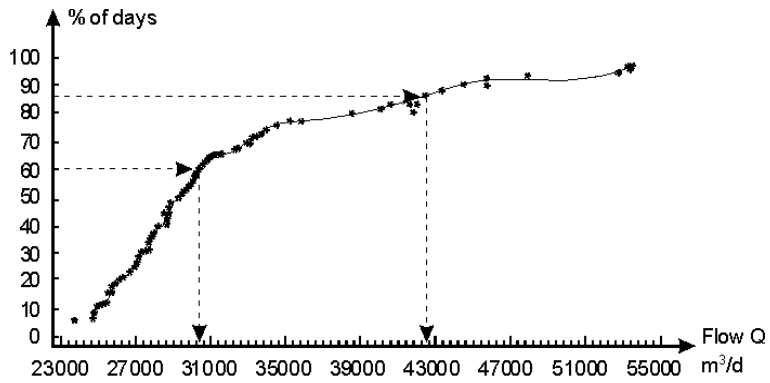
Pablo Picasso: Painting

El Guardia de las instalaciones de aguas pollutantes ?

(1875?)

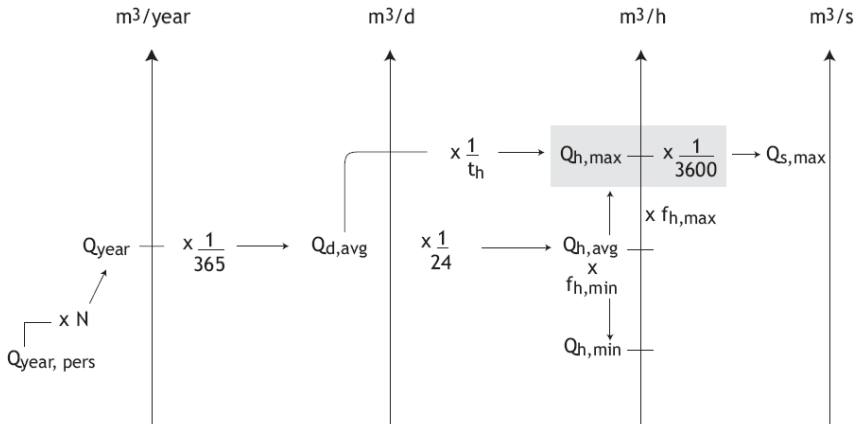
# 11. FLOW + INDUSTRY + INSTITUTIONS

## Influent wastewater variations






## Design values for municipal wastewater



## Wastewater design flow

- $Q_{d,av}$ is calculated as wastewater flow per year divided by 365
- $Q_{h,max}$ is maximum hourly flow
- $f_{h,max}$ is maximum hourly constant (1.3-2.4 depending on size of city)
- $t_{h,d}$ is the hourly factor (the number of hours the average daily flow can be distributed over to find the maximum hourly flow (10-18 hours depending on size of city)



## Exercise 7: Wastewater design flow

- *Wastewater flow to a planned wastewater treatment plant is 70,000 $m^3$/d. The hourly factor, th,d is 16.*

*Questions:*

- *What is the person equivalent to that plant based on flow?*
- *What is the yearly wastewater flow?*
- *What is the maximum hourly wastewater flow?*

## Exercise 7: Solution

- *Person equivalent is (70,000 $m^3$/d)/0.2 $m^3$/d = 350,000 person equivalent.*
- *Yearly wastewater flow is 70,000 ·365 = 25.55 mill $m^3$/y.*
- *The maximun hourly flow is (70,000 $m^3$/d) / 16 h/d = 4375 $m^3$/h.*



## HOUSEHOLDS

### Traditional wastewater load originating from households kg/y

| | Toilet total (urine) | Kitchen | Bath/ laundry | Total |
|---|---|---|---|---|
| BOD | 9.1 (1.8) | 11 | 1.8 | 21.9 |
| COD | 27.5 (5.5) | 5.5 | 16 | 49 |
| Nitrogen | 4.4 (4.0) | 0.3 | 0.4 | 5.1 |
| Phosphorus | 0.7 (0.5) | 0.07 | 0.1 | 0.87 |
| Potassium | 1.3 (0.9) | 0.15 | 0.15 | 1.6 |

## How to change the waste flows?

Reduction of generated wastes
or
Diversion of certain wastes



## Options for changes in wastewater

- Toilet waste separated (night soil, compost toilets, septic tanks)
- Urine separation
- Kitchen waste (Clean-tech cooking: Half can be transferred to the solid waste fraction)
- Laundry and bath wastewater reused for toilet flushing
- Garbage grinders

# 13. WASTEWATER DESIGN

- Minimizing waste loads to wastewater
  - Toilet separation, clean-tech cooking
- Maximizing waste loads to wastewater
  - Garbage grinders



# Reduced waste load to wastewater g/(capita·d)

| Technology | Traditional | Toilet separation | Clean-tech cooking |
|---|---|---|---|
| COD | 130 | 55 | 32 |
| BOD | 60 | 35 | 20 |
| Nitrogen | 13 | 2 | 1.5 |
| Phosphorus | 2.5 | 0.5 | 0.4 |

## Pollutant concentration with reduced waste load to wastewater
## g/m$^3$

| Wastewater production | 250 l/(c·d) | 160 l/(c·d) | 80 l/(c·d) |
|---|---|---|---|
| COD | 130 | 200 | 400 |
| BOD | 80 | 125 | 250 |
| Nitrogen | 6 | 9 | 19 |
| Phosphorus | 1.6 | 2.5 | 5 |



## Effluent guidelines in g/m$^3$ ?

## Problem with reduced water consumption

## Pollutant concentration with maximum waste load to wastewater
## g/m$^3$

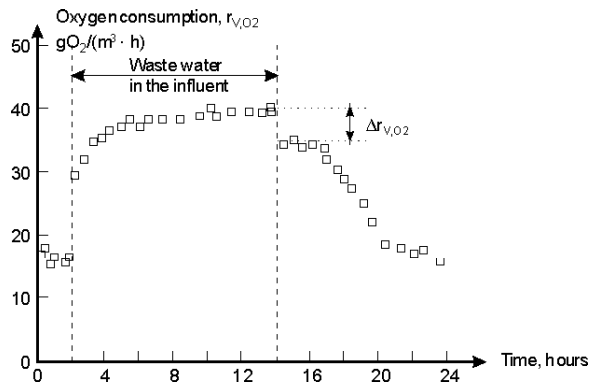
| Wastewater production | 250 l/(c·d) | 160 l/(c·d) | 80 l/(c·d) |
|---|---|---|---|
| COD | 880 | 1375 | 2750 |
| BOD | 360 | 565 | 1125 |
| Nitrogen | 59 | 92 | 184 |
| Phosphorus | 11 | 17 | 35 |



## Grey and black wastewater, concentrations
## g/m$^3$

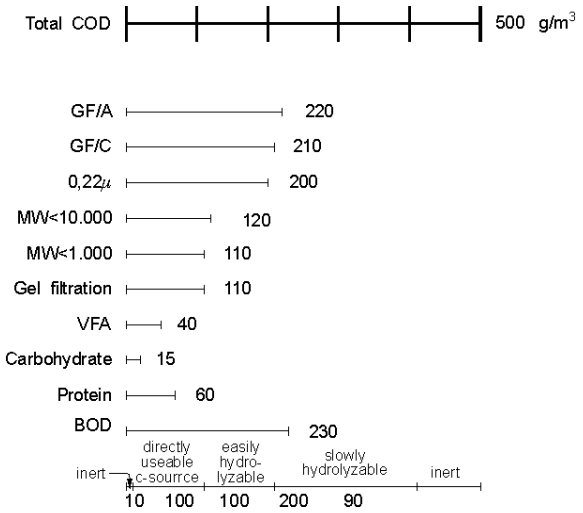
| Compound | Grey high | Grey low | Black high | Black low |
|---|---|---|---|---|
| BOD | 400 | 100 | 600 | 300 |
| COD | 700 | 200 | 1500 | 900 |
| Total N | 30 | 8 | 300 | 100 |
| Total P | 7 | 2 | 40 | 20 |
| Potassium | 6 | 2 | 90 | 40 |

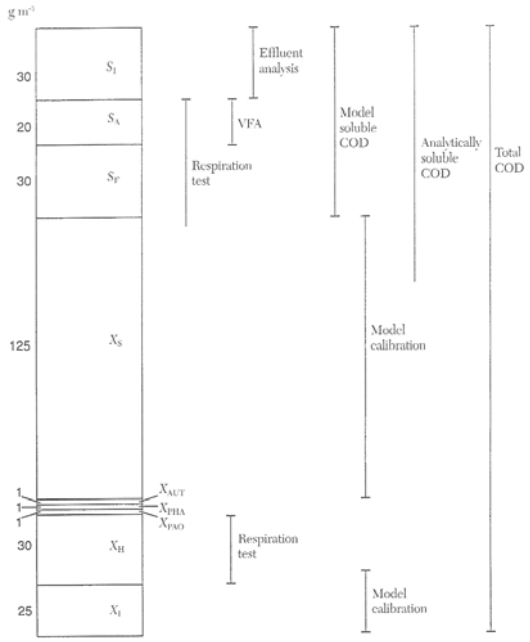
# 14. COD FRACTIONATION






# COD fractionation





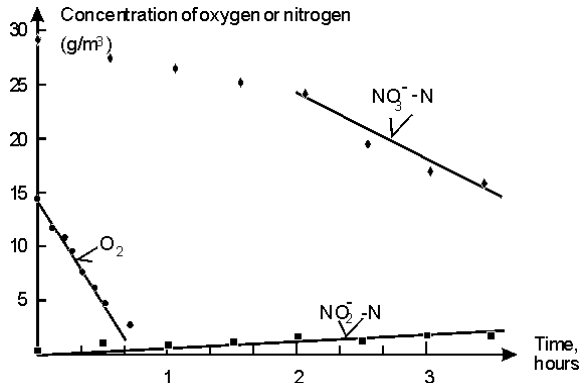

## COD fractionation

$X_S$ is found by modelling using oxygen uptake rate measurements

$X_I$ is found by modelling with sludge production



# Oxygen utilization rate (OUR) and Nitrate utilization rate (NUR)



## 3.15 WASTEWATER FINGERPRINT

**Show me your wastewater and I will tell you who you are…**



## Fingerprint? Information on….

- Sex
- Drugs
- Coloured hair
- Lice
- Steak maniac
- Work away from home
- Environmental concious
- Pregnant
- Alcoholic

## FAQ to a wastewater professor

- Does wastewater have conscience?
- Is wastewater evil?
- Does wastewater have a soul?



## FGA (Frequently Given Answers) from a wastewater professor

- Does wastewater have conscience?
  - No, it resembles mankind
- Is wastewater evil?
  - No
- Does wastewater have a soul?
  - May be, research not yet finished

# But…



# Wastewater is a resource

- It contains
  - Water
  - Nitrogen
  - Phosphorus
  - Potassium
  - Energy
  - Chemicals for wastewater treatment
  - Metals