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INDUSTRIAL WASTEWATER TREATMENT TECHNOLOGIES

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Industrial Wastewaters (IWW) means the water or liquid that carries waste from industrial or processes, if it is distinct from domestic wastewater.

Desalination plant

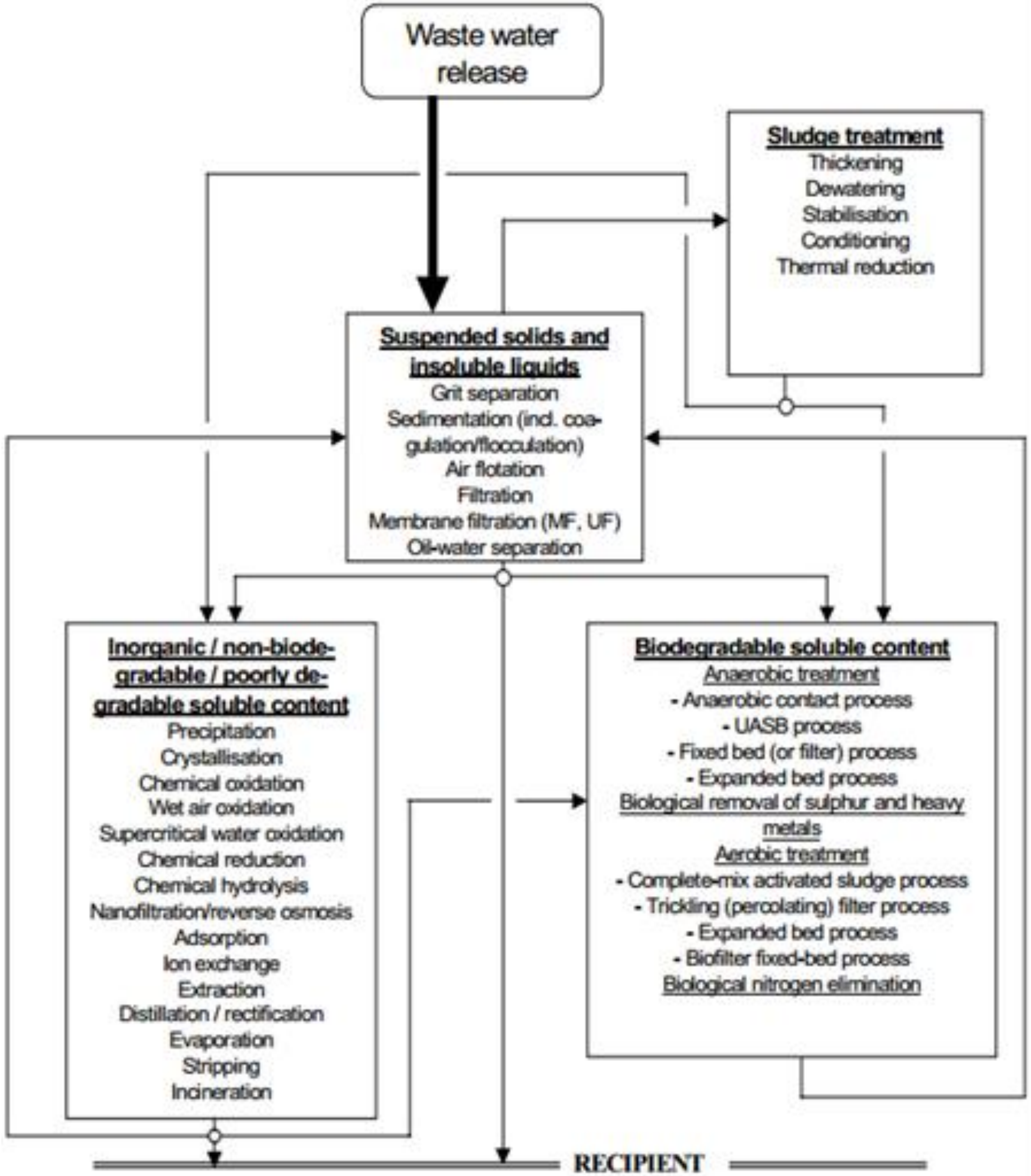
"Rambla Morales desalination plant (Almería - Spain)" by David Martínez Vicente from Flickr licensed under CC BY 2.0

IWW may result from any process or activity of industry which uses water as a reactant or for transportation of heat or materials.

Characteristics of wastewater from industrial sources vary with the type and the size of the facility and the on-site treatment methods, if any. Because of this variation, it is often difficult to define typical operating conditions for industrial activities.

Options available for the treatment of IWW are summarized briefly in next figure. To introduce in a logical order in the description of treatment techniques, the relationship between pollutants and respective typical treatment technology is taken as reference.

1. **Removal of suspended solids and insoluble liquids**
2. **Removal of inorganic, non-biodegradable or poorly degradable soluble content**
3. **Removal of biodegradable soluble content**



Range of wastewater treatments in relation to type of contaminants. Source: BREF

http://eippcb.jrc.ec.europa.eu/reference/

3.1. CLASSIFICATION OF INDUSTRIAL EFFLUENTS

CLASSIFICATION OF EFFLUENTS FROM TYPICAL INDUSTRIAL FACILITIES

- Industrial effluents with **organic** compounds
  - Pulp and paper mills
  - Sugar factories
  - Slaughterhouses
  - Leather tanneries
  - Canneries (vegetables, meat, fish, ...)
  - Dairies (milk, cheese, butter,... production)
  - Fermentation industries (alcohol, yeasts,... production)
  - Food-processing industries (oils and others)
  - Soft drink industries
  - Laundries

- Industrial effluents with **organic** and **inorganic** compounds
  - Oil refineries and petrochemical industries
  - Coke production
  - Textile industries
  - Chemical industries
- Industrial effluents containing **inorganic** compounds
  - Metal processing industries
  - Salt and mineral mining industries
  - Production of chemical inorganic compounds
- Industrial effluents containing **suspended solids**
  - Coal and mineral washing processes
  - Marble and other products' cutting and polishing
  - Steel hot-rolling and continuous smelting
- Industrial effluents from activities with **refrigeration systems**
  - Thermal power plants and nuclear power plants

COMPOSITION OF EFFLUENTS FROM TYPICAL INDUSTRIAL FACILITIES

- **Paper mills**
  - Color
  - Suspended and settleable material
  - BOD_5
  - Occasionally (the pH)
- **Leather tanning industry**
  - Alkalinity
  - Suspended materials and settleable materials
  - BOD_5
  - Sulfur
  - Chromium
- **Oil refineries**
  - Oils
  - BOD_5
  - Phenols
  - Ammonia
  - Sulfur
- **Siderurgy**
  - Phenols
  - Tars
  - Cyanides
  - BOD_5
  - Sulfur
  - Suspended solids
  - pH
  - Iron
  - Oils and fats

3.2. SPECIFIC TREATMENT PROCESSES

Due to the characteristics of the process specific waste, there is not a standard design to treat all IWW. Each facility requires a **design specific to the process** at hand.

Chemical operations, in conjunction with various physical operations (settling, coagulation-flocculation, grease and oil removal,…), have been developed for the treatment of industrial wastewater.

- **Chemical precipitation**
- **Chemical neutralization**
- **Oxidation and reduction processes**

3.2.1. Chemical precipitation

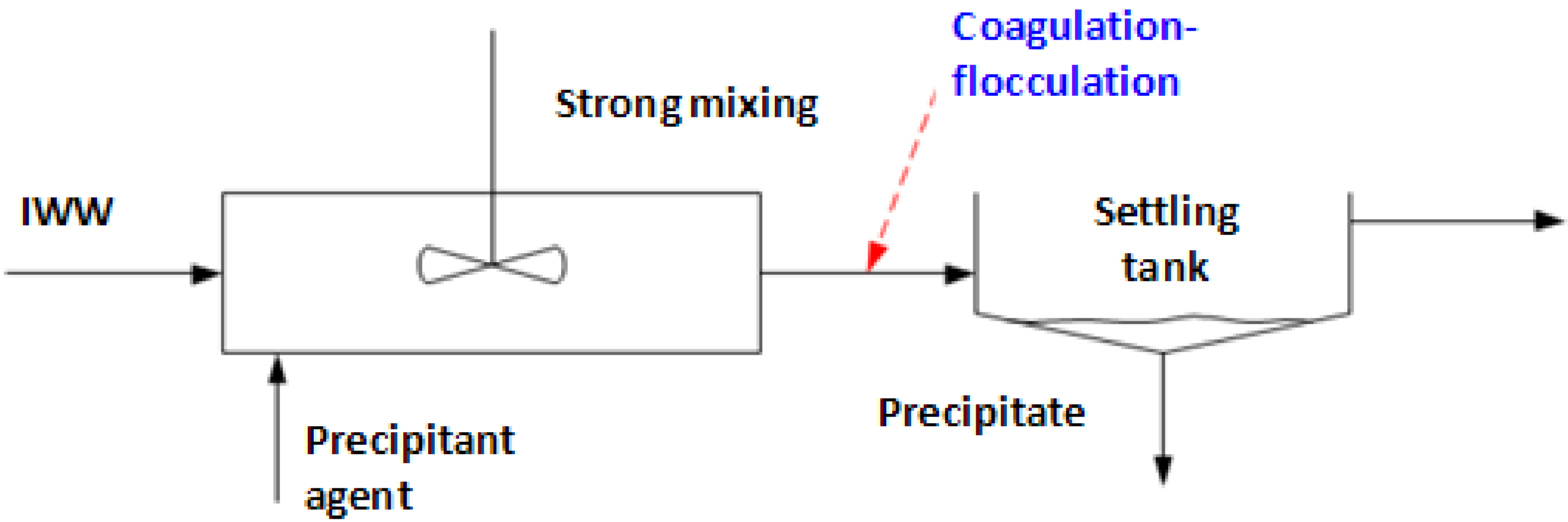
Chemical precipitation consists in adding chemicals to form particulates from dissolved solids and facilitate their removal by sedimentation.

Applications

- Removal of phosphorous
- Removal of heavy metals. Heavy metals can be precipitated as metal hydroxides through the addition of lime ($Ca(OH)_2$) or caustic soda (NaOH)

$$Cu^{2+} + 2\,NaOH \rightarrow Cu(OH)_2 + 2\,Na^{+}$$
$$Cu^{2+} + Ca(OH)_2 \rightarrow Cu(OH)_2 + Ca^{2+}$$

- Removal or reduction of hardness



Chemical Precipitation Diagram by E. Sáez de Cámara

It consists of one or two stirred **mixing tanks**, where the precipitant agents are added, a **sedimentation tank** to separate the precipitates and storage tanks for the chemical agents.

If precipitates are colloids a coagulation-flocculation unit must be required.

3.2.2. Neutralization

Removal of excess acidity or alkalinity by treatment with a chemical of the opposite composition is termed **neutralization**.

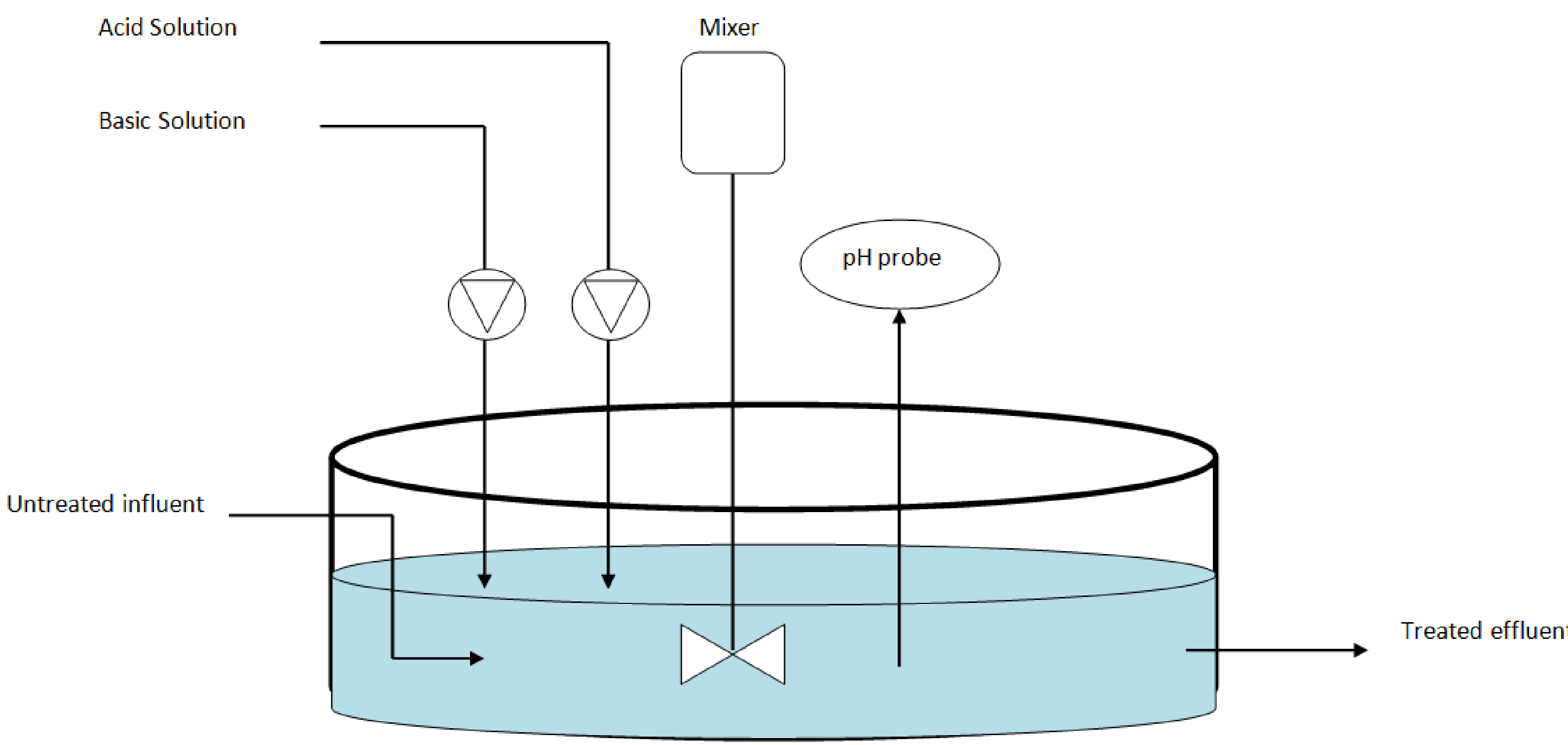
Applications

pH adjustment is required to:

- Fulfill the discharge limit requirements
- Optimize operating range for other treatment processes such as biological degradation
- Control the aggressiveness of IWW with respect to corrosion

- **Acidic waters** can be neutralized with a number of basic chemicals.
  - Caustic soda (NaOH)
  - Lime ($Ca(OH)_2$)
  - Sodium carbonate (Na_2CO_3)
  - Sodium bicarbonate ($NaHCO_3$)
  - Ammonia (NH_3)

- **Alkaline waters** are less problematic than acidic waters but nevertheless often require a treatment.
  - Combustion gases
  - Concentrate acids such as sulfuric acid (H_2SO_4), clorhidric acid (HCl), nitric acid (HNO_3) or phosphoric acid (H_3PO_4)
  - Carbon dioxide (CO_2)

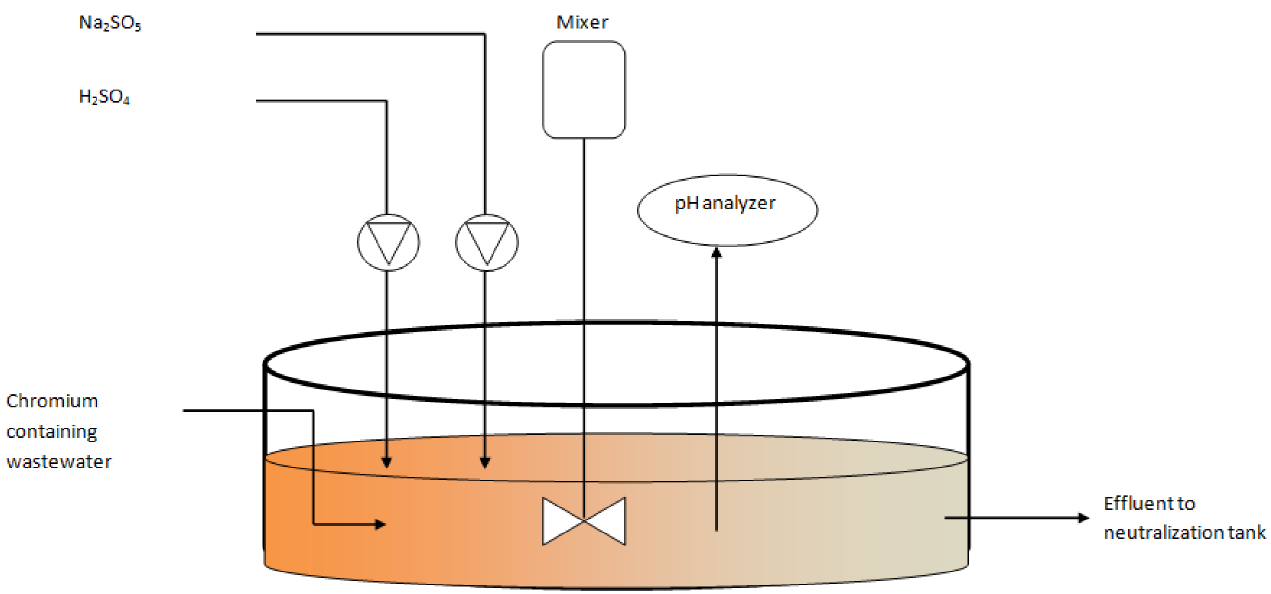


Neutralization process

Neutralization process diagram by E. De la Torre

3.2.3. Redox processes

Chemical oxidation or **chemical reduction** involves use of oxidants or reductants to bring about a change in the chemical composition of a compound or group of compounds to less harmful or hazardous compounds.



Reduction of Chromium (Reaction Tank)

Reduction of Chromium process diagram by E. De la Torre

In the reaction tank:

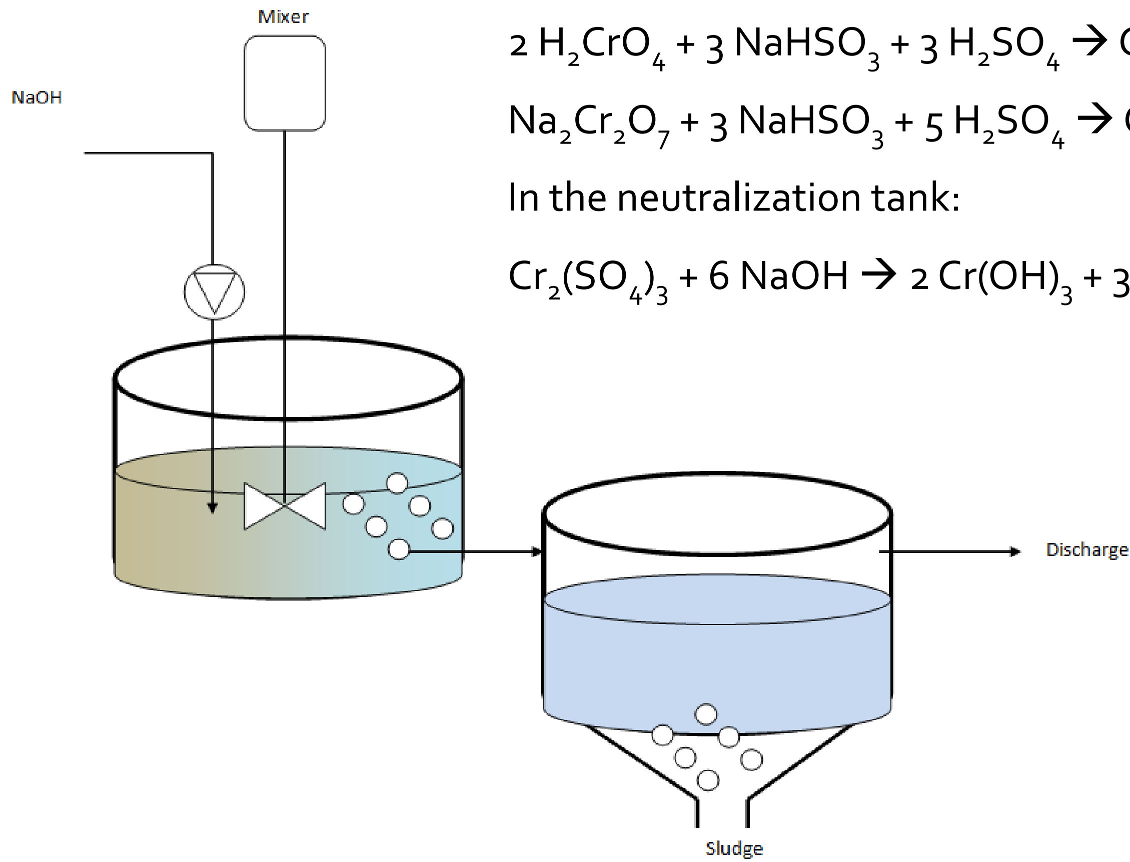
$Na_2S_2O_5 + H_2O \rightarrow 2\ NaHSO_3$

$2\ H_2CrO_4 + 3\ NaHSO_3 + 3\ H_2SO_4 \rightarrow Cr_2(SO_4)_3 + 3\ NaHSO_4 + 5\ H_2O$

$Na_2Cr_2O_7 + 3\ NaHSO_3 + 5\ H_2SO_4 \rightarrow Cr_2(SO_4)_3 + 5\ NaHSO_4 + 4\ H_2O$

In the neutralization tank:

$Cr_2(SO_4)_3 + 6\ NaOH \rightarrow 2\ Cr(OH)_3 + 3\ Na_2SO_4$



Reduction of Chromium (Neutralization and Settling Tank)

Reduction of Chromium process diagram by E. De la Torre

INDUSTRIAL OXIDATIONS

Chemical oxidizing agents: ozone (O_3), hydrogen peroxide (H_2O_2), permanganate (MnO_4) and chlorine (Cl_2).

Applications

- Disinfection
- Oxidation of iron and manganese
- Control of odorous compounds
- Removal of ammonia.

INDUSTRIAL REDUCTIONS

Chemical reductants: ferrous sulfate ($FeSO_4$), sodium bicarbonate ($NaHSO_3$) and sulfur dioxide (SO_2)

Application

- Removal of metals. Chemical reduction of normally results in products (hydroxides and sulfides) that be treated more easily in downstream treatment facilities such as chemical precipitation.

In considering the application of the chemical processes to be discussed in this section, it is important to note that one of the inherent disadvantages associated with most chemical unit processes, as compared with physical or biological unit operations, is that they are **additive processes**.

In chemical processes something is added to the wastewater to achieve the removal of something else. As a result, there is always a net increase in dissolved constituents in the wastewater.

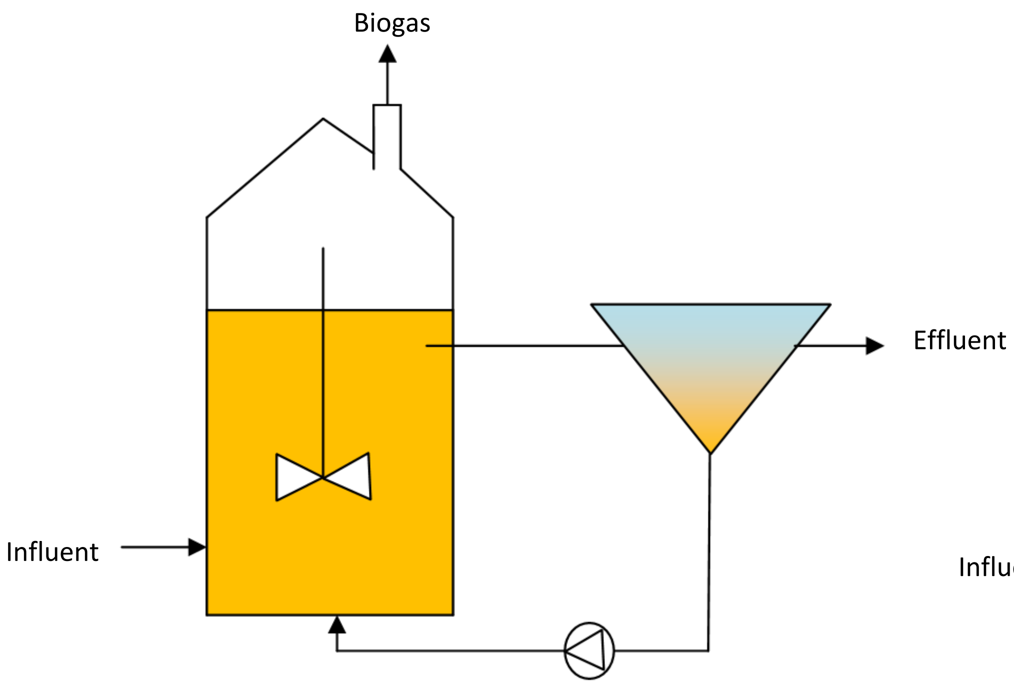
3.2.4. Biological anaerobic treatment

Anaerobic biological processes are very attractive for wastewaters with a high organic load and a constant quality.

Applications. Wastewaters from ...

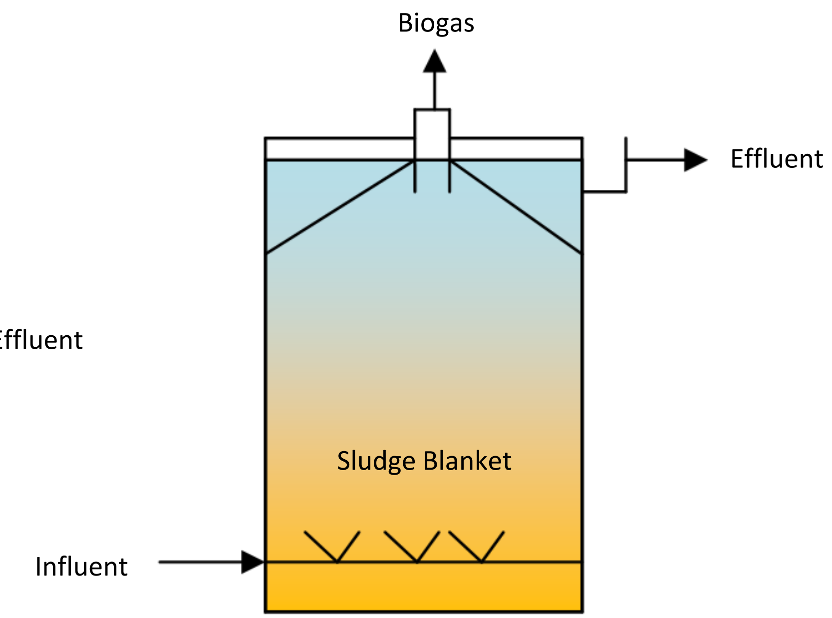
- Breweries
- Alcohol distillation
- Food processing
- Dairy and cheese processing
- Sugar processing
- Slaughterhouses
- Meatpacking industry

It has become increasingly important in recent years.



Anaerobic contact reactor

by E. De la Torre



Upflow reactor

by E. De la Torre

BIODEGRADABILITY

- **BOD/COD** **≥ 0.5** IWW **easily** treatable by biological means.
- **BOD/COD** **< 0.3** IWW is **partially** treatable by biological means and acclimated microorganisms may be required.
- **BOD/COD** **< 0.1** Biological treatment is very unlikely to be of benefit.

Non-biodegradable or hardly biodegradable compounds may affect biological treatment because they are resistant to biodegradation (recalcitrant) and, they inhibit the metabolic pathways and growth of microorganisms, consequently, hampering the degradation of easily biodegradable compounds

ANAEROBIC PROCESSES *vs* AEROBIC PROCESSES

- **Low amount of sludge**. Anaerobic processes result in lower biomass production, thus, sludge processing and disposal costs are reduced greatly. However, this implies **more start-up time** to develop necessary biomass.
- **Low energy consumption** because there is no energy need for air or oxygen supply to the reactor, but only for efficient stirring.
- **Production of an energy-rich gas**. Methane, can be recovered and be used as a low-quality fuel.
- The excess sludge produced from anaerobic processes is **stable**, whereas the sludge from aerobic process is unstable (high potential for putrefaction and the production of odors).