Al-Mustaqbal University
Department of Fuel and Energy Engineering Techniques
Second stage
Subject: Pollution
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Second semester

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Table 4.1. Wastewater treatment levels

Level	Removal
Preliminary	• Coarse suspended solids (larger material and sand)
Primary	• Settleable suspended solids • Particulate (suspended) BOD (associated to the organic matter component of the settleable suspended solids)
Secondary	• Particulate (suspended) BOD (associated to the particulate organic matter present in the raw sewage, or to the non settleable particulate organic matter, not removed in the possibly existing primary treatment) • Soluble BOD (associated to the organic matter in the form of dissolved solids)
Tertiary	• Nutrients • Pathogenic organisms • Non-biodegradable compounds • Metals • Inorganic dissolved solids • Remaining suspended solids

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The *removal efficiency* or in a treatment stage is given by the formula:

$$E = \frac{C_o - C_e}{C_o}.100 \qquad (4.1)$$

where:

E = removal efficiency (%)

C_o = influent concentration of the pollutant (mg/L)

C_e = effluent concentration of the pollutant (mg/L)

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4.2 WASTEWATER TREATMENT OPERATIONS, PROCESSES AND SYSTEMS

- **Physical unit operations:** treatment methods in which *physical forces* are predominant (e.g. screening, mixing, flocculation, sedimentation, flotation, filtration)

- **Chemical unit processes:** treatment methods in which the removal or the conversion of the contaminants occurs by the addition of *chemical products* or due to *chemical reactions* (e.g. precipitation, adsorption, disinfection).
- **Biological unit processes:** treatment methods in which the removal of the contaminants occurs by means of *biological activity* (e.g. carbonaceous organic matter removal, nitrification, denitrification)

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Table 4.3. Main mechanisms for the removal of pollutants in wastewater treatment

Pollutant	Subdivision	Main removal mechanisms	
Solids	Coarse solids (> ~1 cm)	*Screening*	Retention of the solids with dimensions greater than the spacing between the bars
	Suspended solids (> ~1 μm)	*Sedimentation*	Separation of the particles with a density greater than the sewage
	Dissolved solids (< ~1 μm)	*Adsorption*	Retention on the surface of biomass flocs or biofilms

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Organic matter	BOD in suspension (particulate BOD) (> ~1 μm)	*Sedimentation*	Separation of the particles with a density greater than the sewage
		Adsorption	Retention on the surface of biomass flocs or biofilms
		Hydrolysis	Conversion of the BOD in suspension into soluble BOD by means of enzymes, allowing its stabilisation
		Stabilisation	Utilisation by biomass as food, with conversion into gases, water and other inert compounds.
	Soluble BOD (< ~1 μm)	*Adsorption*	Retention on the surface of biomass flocs or biofilms
		Stabilisation	Utilisation by biomass as food, with conversion into gases, water and other inert compounds.

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Pathogens	Larger dimensions and/or with protective layer (protozoan cysts and helminth eggs)	*Sedimentation*	Separation of pathogens with larger dimensions and density greater than the sewage
		Filtration	Retention of pathogens in a filter medium with adequate pore size
	Lower dimensions (bacteria and viruses)	*Adverse environmental conditions*	Temperature, pH, lack of food, competition with other species, predation
		Ultraviolet radiation	Radiation from the sun or artificial
		Disinfection	Addition of a disinfecting agent, such as chlorine

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Pollutant	Subdivision	Main removal mechanisms	
Nitrogen	Organic nitrogen	*Ammonification*	Conversion of organic nitrogen into ammonia
	Ammonia	*Nitrification*	Conversion of ammonia into nitrite, and the nitrite into nitrate, by means of nitrifying bacteria
		Bacterial assimilation	Incorporation of ammonia into the composition of bacterial cells
		Stripping	Release of free ammonia (NH_3) into the atmosphere, under high pH conditions
		Break-point chlorination	Conversion of ammonia into chloramines, through the addition of chlorine
	Nitrate	*Denitrification*	Conversion of nitrate into molecular nitrogen (N_2), which escapes into the atmosphere, under anoxic conditions

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Phosphorus	Phosphate	*Bacterial assimilation*	Assimilation in excess of the phosphate from the liquid by phosphate accumulating organisms, which takes place when aerobic and anaerobic conditions are alternated
		Precipitation	Phosphorus precipitation under conditions of high pH, or through the addition of metallic salts
		Filtration	Retention of phosphorus-rich biomass, after stage of biological excessive P assimilation

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Table 4.4. Treatment operations, processes and systems commonly used for the removal of pollutants from domestic sewage

Pollutant	Operation, process or treatment system
Suspended solids	• Screening • Grit removal • Sedimentation • Land disposal
Biodegradable organic matter	• Stabilisation ponds and variants • Land disposal • Anaerobic reactors • Activated sludge and variants • Aerobic biofilm reactors
Pathogenic organisms	• Maturation ponds • Land disposal • Disinfection with chemical products • Disinfection with ultraviolet radiation • Membranes

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Pollutant	Operation, process or treatment system
Nitrogen	• Nitrification and biological • denitrification • Maturation and high-rate ponds • Land disposal • Physical–chemical processes
Phosphorus	• Biological removal • Maturation and high-rate ponds • Physical chemical processes