

Environmental Technology

Practice 1. Waste codification

1. Determine the LER code for the following wastes

a) Industrial waste by sector

1. Red mud from the production of aluminum from bauxite. The sludge contains hazardous substances.
2. Sand and clay wastes generated in the processing of non-metalliferous minerals. No hazardous substances were detected.
3. Manure from livestock to be treated off-site
4. Milk unsuitable for consumption or processing, from a dairy processing plant.
5. Wastes of Cr, As and Cu salts used as wood preservatives
6. Sludge contaminated with ink from a paper recycling process.
7. Liquid effluent from a tanning process containing chromium
8. Effluent with hydrocarbons at alkaline pH, from the cleaning of tanks in an oil refinery
9. Wastes with arsenic generated in a chemical industry during the synthesis of mineral acids
10. Non-halogenated organic solvents used in the cleaning of equipment in a chemical industry for the synthesis of organic basic products
11. Water-based paint expired, from a paint factory. The paint contains substances considered hazardous.
12. Out-of-spec toner that is discarded at the manufacturing site. The toner contains hazardous substances.
13. Waste of photographic processing or development with organic solvents
14. Fly ashes from a coal-fired power plant
15. Sand from a fluidized bed combustion system
16. Steel chips containing oil from machining operations. Lubricating oil used in machining operations is a hazardous substance.
17. Machining sludges derived from the cutting of pieces containing dangerous substances

b) chapters 13-15

1. Engine oil from a car
2. Solvent (benzene)
3. Metal containers generated in a company of surface painting (the containers contain traces of paint with dangerous substances).
4. Laboratory wastes contaminated with various substances (gloves, filter paper, ...)
5. Paper and cardboard packaging
6. Plastic containers
7. Wooden containers
8. Metal containers

c) Chapter 16

1. Automotive antifreeze liquid (with ethylene glycol)
2. Battery of a car

d) Chapters 17-19

1. Mixture of bricks and concrete from the construction of a building
2. Wood wastes from construction or demolition works.
3. Sanitary waste contaminated with human pathogens

4. Precipitation sludge generated in the treatment of an industrial residual effluent containing chromium
5. Leachate from a hazardous waste safety deposit

e) Urban or urban-like waste (Chapter 20)

1. Fluorescent tubes
2. Selective waste collection: Paper and cardboard
3. Selective waste collection: Glass
4. Selective waste collection: Plastics
5. Selective waste collection: Metals
6. WEEE with toxic heavy metals (Pb and Cr).

2. Determine the hazardous or non-hazardous waste label


Hazardous wastes

1. Spent solvent, contaminated with paint, generated in the cleaning of the painting system in an automobile factory. The solvent is going to be recovered and recycled.
2. Electrical and electronic apparatus (WEEE) generated in the University. WEEE may contain hazardous substances, such as metals: copper and mercury. WEEE are intended for temporary storage before being subjected to a non-specified treatment or recovery process.
3. Waste toner, generated in the university, and delivered to a manager for recovery. Toner is considered hazardous waste due to its content in solvents and other organic compounds, which are irritant and toxic to the environment
4. Fluorescent tubes generated in the UVigo, they are stored before treatment and elimination
5. Contaminated soil with dangerous organic compounds, from an industrial area with an oil refinery. The soil was contaminated due to accidental spills or bad practices in waste management. It is intended for temporary storage before disposal.

Non-hazardous waste

1. Wooden pallets from a store of construction materials
2. Paper and cardboard from the packaging of food products from a supermarket.
3. Tires from a car workshop.
4. Plastic film used as packaging in a paint factory
5. Waste Electrical and Electronic Equipment (WEEE)

Model label for hazardous waste

WASTE: HALOGENATED SOLVENT	
LER CODE: 14 06 03	HAZARDOUS PROP.: HP3 + HP5
PRODUTOR: productur's name ADDRESS: Generation or storage place PHONE: Productur's phone	
Packing date: 11/09/2017	
	
FLAMMABLE	TOXIC

Model label for non-hazardous waste

WASTE: GLASS
LER CODE: 20 01 02
PRODUTOR: productur's name ADDRESS: Generation or storage place PHONE: Productur's phone
Packing date: 11/09/2017

WASTE:

ELW CODE:

HAZARDOUS PROP.:

PRODUCTOR: Owner's name

ADDRESS: Generation or storage location

PHONE: Owner's phone

Packing date:

WASTE:

ELW CODE:

PRODUCTOR: Owner's name

ADDRESS: Generation or storage place

PHONE: Owner's phone

Packing date:

GHS Pictograms

HP1 Explosive



HP2 Oxidizing



HP3 Flammable



HP4 Irritant



HP5 Harmful



HP6 Acute Toxicity



HP7 Carcinogenic



HP8 Corrosive



HP9 Infectious



HP10 Toxic for reproduction



HP11 Mutagenic



HP12 Release of an acute toxic gas



HP13 Sensitizing



HP14 Ecotoxic



HP15 Waste capable of exhibiting a hazardous property listed above not directly displayed by the original waste

GASES



PRACTICE 2: Removal of colored compounds in solution by adsorption of immobilized activated carbon.**Stage 1: Immobilization of activated carbon in alginate****1. Introduction**

Activated carbon is an absorbent widely used in many industrial processes, mainly due to its ability to retain large amounts of a variety of compounds such as organics, inorganic anions and metals. The adsorption capacity of the activated carbon is related to its specific surface area. Due to its microporous structure, the specific surface area of the activated carbon ranges from 500 to 3000 m²/g. Active carbon is available in granular or powder form. In general, the adsorption is faster when using finer activated carbon. However, such small particles are difficult to retain, and they tend to leave the system with the fluid, blocking membranes and filtration systems. The immobilization of the activated carbon in calcium alginate retains the fine particles of the activated carbon and may overcome the operational problems.

2. Objective

The objective of this practice is the immobilization of powdered activated carbon in calcium alginate. The particles of immobilized activated carbon will be used in the second stage of this practice for the removal of a colored compound in water using the adsorption capacity of the carbon.

3. Working plan

The immobilization of the activated carbon requires the preparation of two solutions/suspensions:

- a) Dissolve 2 g of sodium alginate in 100 mL of water. When dissolved, add 2 g of activated carbon and mix thoroughly.
- b) Prepare 250 mL of calcium chloride 0.58 molar.

The suspension of activated carbon in alginate is dropped through a syringe into the calcium chloride solution. The alginate forms a precipitate with calcium forming calcium alginate beads. The activated carbon is trapped inside the beads.

Recover all the alginate beads in a flask with enough calcium chloride solution to cover all the particles, and store it in the fridge until use in the second part of the practice.

Materials	Reagents
1 peristaltic pump or syringe	DI water
1 baker 250 mL	Sodium alginate
1 baker 500 mL	Activated carbon in powder
1 Magnetic stirrer	Calcium chloride, 0.58 molar

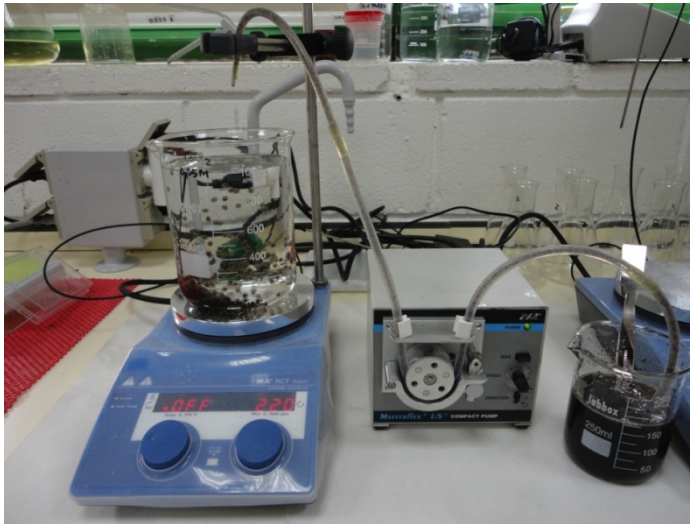


Figure 1. Formation of the alginate beads using a peristaltic pump

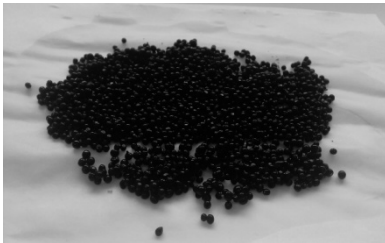


Figure 2. Alginate beads with activated carbon

PRACTICE 3: Removal of colored compounds in solution by adsorption on immobilized activated carbon.

Stage 2: Adsorption of colored compounds on activated carbon

1. Introduction

Activated carbon is a widely used adsorbent in industrial processes for the retention of organic and inorganic compounds from aqueous effluents. The removal of those organic or inorganic compounds improve the quality of the effluent and avoid the emission of contaminants to the environment.

The activated carbon is a cheap and ready available adsorbent. This is why it is commonly used in many industrial processes. However, the fine particles of the activated carbon make difficult the retention and separation of the carbon from the liquid effluent. This disadvantage can be avoided by immobilization of the carbon in alginate as in this lab practice.

2. Objective

The objective of this practice is the determination of the adsorption capacity of the activated carbon for the retention of colored compounds from a residual effluent from a winery facility.

3. Working plan

The absorption capacity of the activated carbon is determined in this lab practice with two experiments and reported in the table. 1 g of activated carbon is added to 50 mL of the colored effluent and the absorbance at 420 and 520 nm is measured at the beginning of the test and after 30 min. Test 2 uses 50 mL of alginate beads (they contain 1 g of activated carbon) and 50 mL of the colored effluent. The absorbance of the liquid is measured 6 times along the contact time, from 0 min to 30 min as it is described in the table 1.

Table 1. Test conditions and measurements

	Test 1: Activated carbon		Test 2: Immobilized activated carbon	
Colored effluent	50 mL		50 mL	
Activated carbon	1 g of activated carbon		50 mL of alginate beads ⁽¹⁾	
Measurement ⁽²⁾	Abs @ 420 nm	Abs @ 520 nm	Abs @ 420 nm	Abs @ 520 nm
0 min				
5 min	-----	-----		
10 min	-----	-----		
15 min	-----	-----		
20 min	-----	-----		
30 min				

⁽¹⁾ 50 mL of alginate beads contains 1 g of activated carbon.

Abs: measurement of absorbance of the colored liquid at 420 and 520 nm in a spectrophotometer.

Calculations

The concentration of the colored substance in the liquid is determined from the absorbance measurements and the so-called coloration index (CI) using the following equations.

Calculation of the coloration index: $CI = ABS @ 420 + ABS @ 520$

Calculation of the concentration: $Colored\ Subs. (mg/L) = 19.466 \cdot CI - 0.2238$

The equation that combines the CI and the concentration of the colored substance was obtained from the following figure. Various solutions of the colored substance were prepared and measured for the absorbance. Plotting the concentration of the solutions versus the CI, a linear dependence between the concentration and the CI was observed.

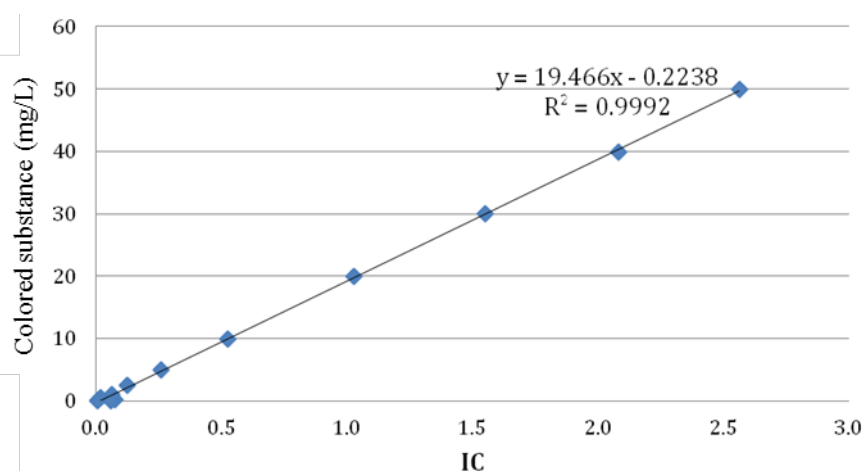


Figure 1. Linear dependence between the colored substance concentration and coloration index.

Activities

Based on the experimental data, determine:

1. The kinetic study for the adsorption of the colored substance (expressed in ppm or mg/L) on the activated carbon during the test.
2. Determine the absorption capacity (q) of the colored substance on activated carbon during the test.
3. Answer the following questions:
 - a. What time did the activated carbon reach the adsorption equilibrium?
 - b. What is the absorption capacity (q) in the equilibrium?

PRACTICE 4: COAGULATION-FLOCCULATION.

1. INTRODUCTION

Groundwater and surface water contain both dissolved and suspended particles. Coagulation and flocculation are used to separate the suspended solids portion from the water.

Suspended particles vary in source, charge, particle size, shape, and density. Correct application of coagulation and flocculation depends upon these factors. Suspended solids in water have a negative charge and since they have the same type of surface charge, they repel each other when they come close together. Therefore, suspended solids will remain in suspension and will not clump together and settle out of the water, unless proper coagulation and flocculation is used.

Coagulation and flocculation occurs in successive steps, allowing particle collision and growth of floc. This is then followed by sedimentation. If coagulation is incomplete, flocculation step will be unsuccessful, and if flocculation is incomplete, sedimentation will be unsuccessful.

Coagulant chemicals with charges opposite those of the suspended solids are added to the water to neutralize the negative charges on non-settable solids (such as clay and color-producing organic substances).

Once the charge is neutralized, the small suspended particles are capable of sticking together. These slightly larger particles are called microflocs, and are not visible to the naked eye. Water surrounding the newly formed microflocs should be clear. If not, coagulation and some of the particles charge have not been neutralized. More coagulant chemicals may need to be added.

A high-energy, rapid-mix to properly disperse coagulant and promote particle collisions is needed to achieve good coagulation. Over-mixing does not affect coagulation, but insufficient mixing will leave this step incomplete. Contact time in the rapid-mix chamber is typically 1 to 3 minutes.

Flocculation, a gentle mixing stage, increases the particle size from submicroscopic microfloc to visible suspended particles. Microfloc particles collide, causing them to bond to produce larger, visible flocs called pinflocs. Floc size continues to build with additional collisions and interaction with added inorganic polymers (coagulant) or organic polymers. Macroflocs are formed and high molecular weight polymers, called coagulant aids, may be added to help bridge, bind, and strengthen the floc, add weight, and increase settling rate. Once floc has reached its optimum size and strength, water is ready for sedimentation.

Design contact times for flocculation range from 15 or 20 minutes to an hour or more, and flocculation requires careful attention to the mixing velocity and amount of mix energy. To prevent floc from tearing apart or shearing, the mixing velocity and energy are usually tapered off as the size of floc increases. Once flocs are torn apart, it is difficult to get them to reform to their optimum size and strength. The amount of operator control available in flocculation is highly dependent upon the type and design of the equipment.

2. OBJECTIVE

The objective of this practice is to determine the best coagulant, its dose and the optimum pH for the coagulation of a wastewater specimen.

3. MATERIAL AND REAGENTS

To develop this practice, the following material will be used:

Labware	Chemicals
1 Flocculator 4-6 positions	Wastewater
3 250 ml beakers	Ferric Sulfate (30 g / l)
3 25ml measuring cylinders	Ferric Chloride (30 g / l)
2 Pasteur pipette	Aluminum Chloride (30 g / l)
1 chronometer	HCl _(aq)
pH indicator paper	NH ₃ _(aq)

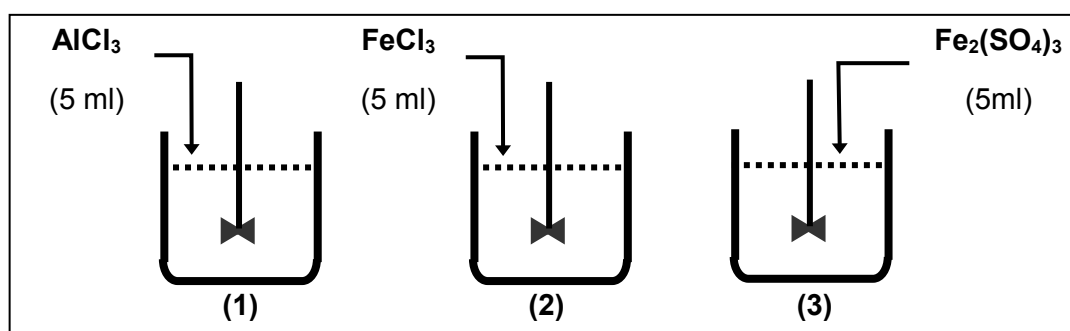
4. EXPERIMENTAL PROCEDURE

The tests to be carried out are planned following the methodology proposed by W. W. ECKENFELDER, which consists of the following stages:

1. Selection of the best coagulant at a previously established pH
2. Optimization of the pH value for the coagulant selected in stage 1
3. Optimization of the coagulant dose under the pH conditions established in stage 2

Stage 1. Selection of the best coagulant at a previously established pH.

The practice begins by pouring 200 ml of wastewater into each of the 3 beakers and measuring its pH. Next, the coagulants to be studied are selected and the same coagulant dose (5 ml) is added simultaneously to each of the beakers.



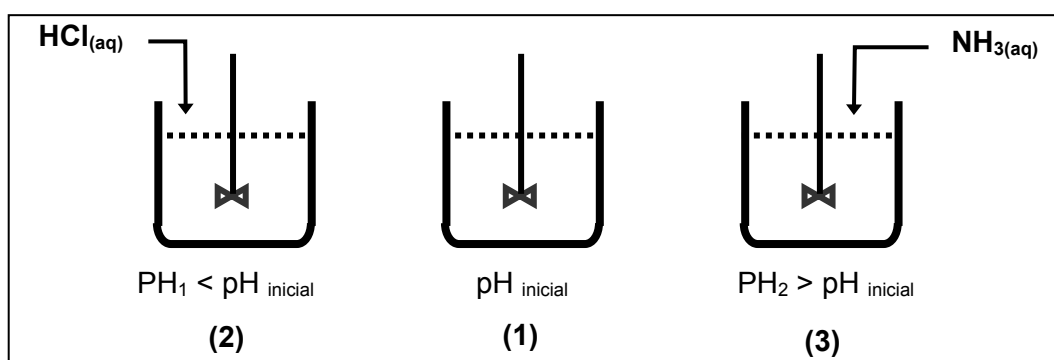
The content of each beaker is stirred for 1 minute at 100 rpm. to homogenize the mixture and cause coagulation, and for 3 minutes at 50 rpm. to get the possible flocculation. After that time, stirring is stopped and the settling of the formed flocs occurs.

Finally, the best coagulant is selected by visual evaluation, that is, depending on the formation of flocs, their size and abundance, the clarity of the water at the end of the process and the speed of the sedimentation process.

Stage 2. Optimization of the pH value for the coagulant selected in stage 1

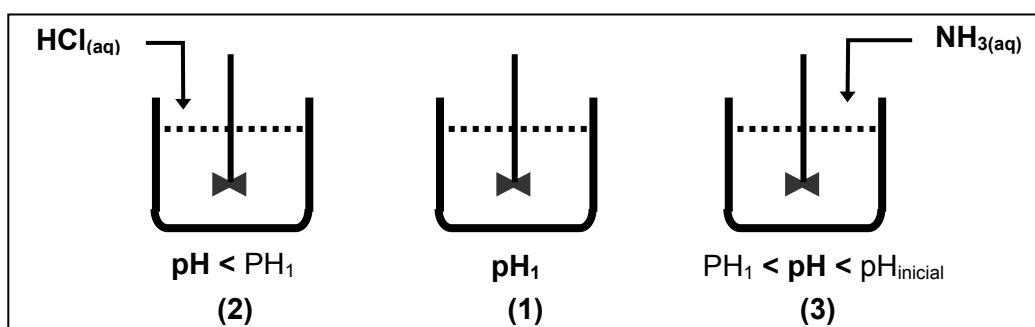
After emptying, in the corresponding waste container, the contents of the beakers, washing them and drying them properly, a second series of experiences will be carried out in order to estimate the optimum pH.

For this purpose, 200 ml of wastewater are poured into each of the beakers and the pH is measured. Next, $\text{HCl}_{(\text{aq})}$ is added to one of the beakers until a pH of substantially less than the initial is achieved, while $\text{NH}_3_{(\text{aq})}$ is added to another of the vessels until a pH is greater than the initial.



Once the working pH is established, 5 ml of the coagulant selected in stage 1 are added simultaneously to each of the beakers. The resulting mixture is stirred for 3 minutes, at 100 rpm., and for 12 minutes, at 50 rpm. After that time the stirring stops and the sedimentation process begins. By visual evaluation of the process, it is determined for which of the 3 pH values the process is better and then the previous experience is repeated for other pH values.

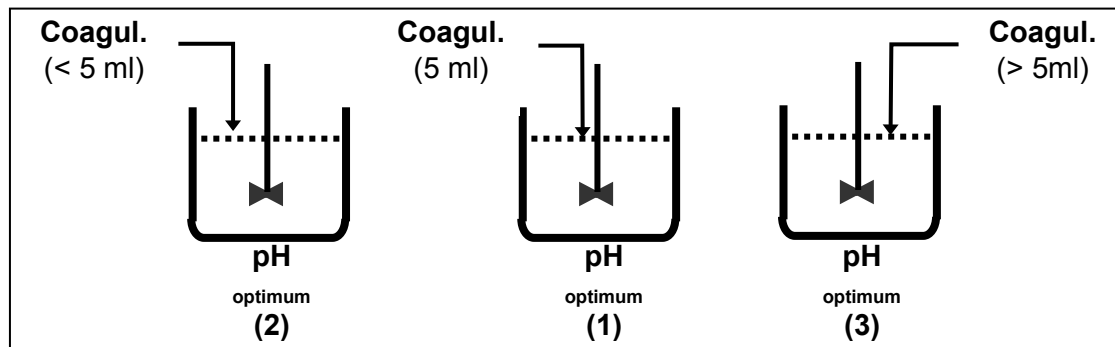
Thus, for example, if pH_1 were the best one, we would proceed as follows:



The experience is repeated as many times as necessary, until the optimum pH value is achieved. At that time the contents of the beakers are emptied into the waste container, they are washed, dried and the third part of the practice begins.

Stage 3. Optimization of the coagulant dose under the pH conditions established in stage 2

To carry out this stage, three 200 ml samples of wastewater are taken, the pH is adjusted to the optimum value (stage 2) and a different coagulant dose is added to each vessel.

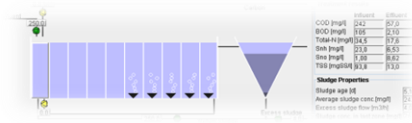


The mixture is stirred for 3 minutes, at 100 rpm., to achieve coagulation and for 12 minutes, at 50 rpm, to achieve flocculation. The formed flocs are allowed to settle, and it is determined which of the three doses is the one that leads to better results.

The experience is repeated with other doses of coagulant until the optimum value is obtained. At that time, the material used is cleaned and collected and the practice is terminated.

Practice 6

JASS (Java Activated Sludge process Simulator)



Introduction.

JASS (Java Activated Sludge Process Simulator) is a free on-line simulator developed at the University of Uppsala (Sweden). This program simulates the biological water treatment by integrating the equations that describe microbial growth, consumption of organic matter, oxygen and other factors involved in the biological processes. The more factors and variables are considered in the model, the more real the model is, but more complex too.

The simulator includes 4 modes of operation/control:

- Pre_denit_10
- Benchmark
- BioP
- Post_denit_10

Features of JASS:

This is a dynamic simulator, the variables vary along time, until the system reach the steady state. The user can modify some variables or characteristics of the plant, and analyze the system response. The default time unit is 0.01 h (36 s).

The simulator program runs in JAVA, and it is available at:

http://www.it.uu.se/research/project/jass/newJASS/jass4/jass_3.1_en.html

If your computer system blocks Java from running, add this address “<http://www.it.uu.se>” to the list of exception sites in java security configuration, be sure that you tick the “activate java content in browser”.

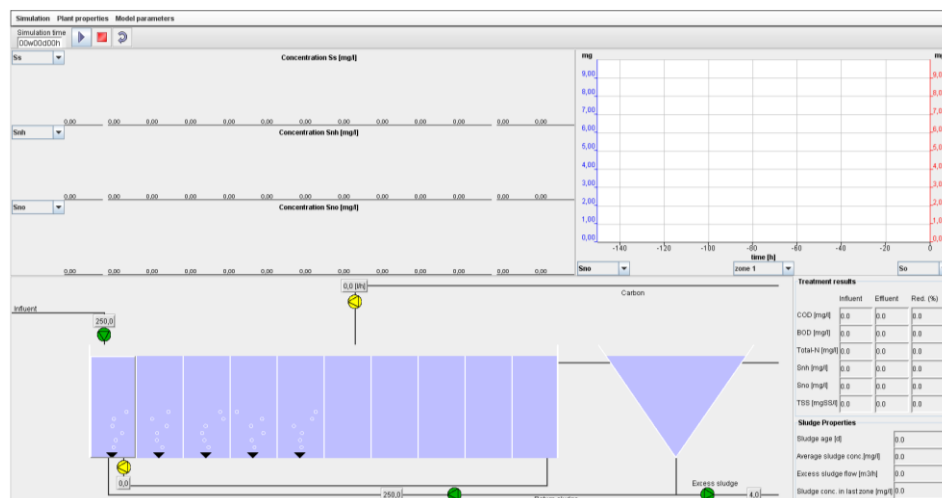


Figure 1. JASS simulator



Figure 2. JASS basic counter and controls: start, stop and reset (in that order). The stop button pauses the simulation. It will continue at the same time when the start button is clicked again. The reset button resets the system to the initial conditions.

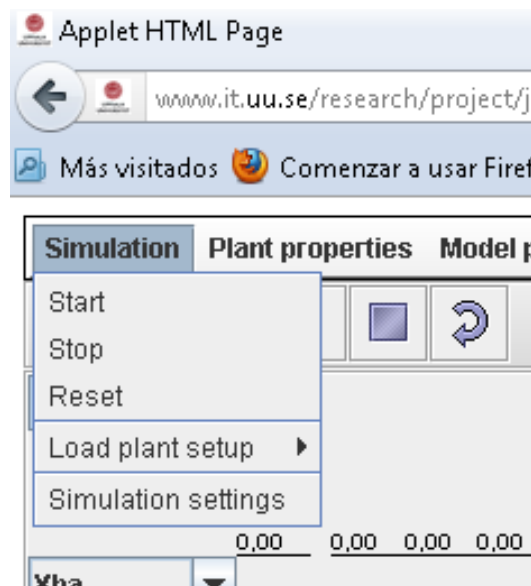


Figure 3. Simulator main menu with the basic controls from Figure 2, choice of the four possible plant designs and simulation speed.

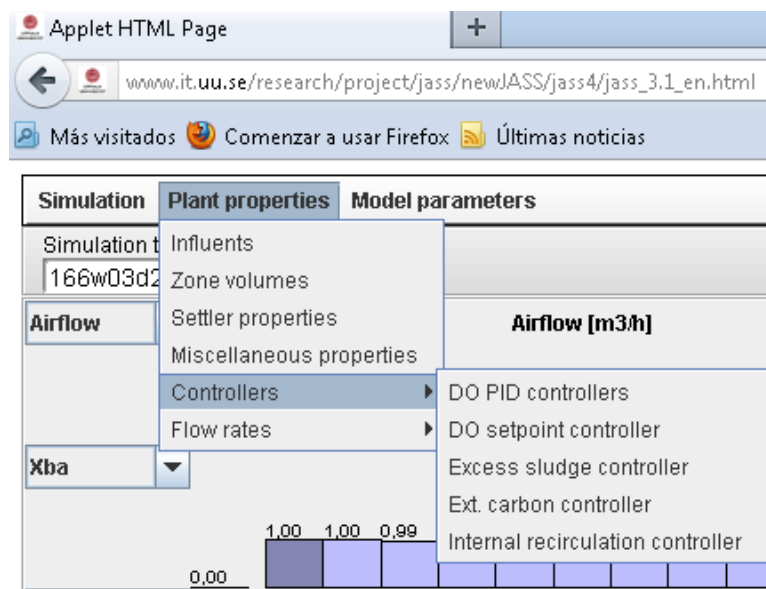


Figure 4. Menu with plant properties: characteristics of influent, volumes of biological reactor zones, sedimentation properties, external carbon source concentration, dissolved oxygen controllers, excess sludge, recirculation,...

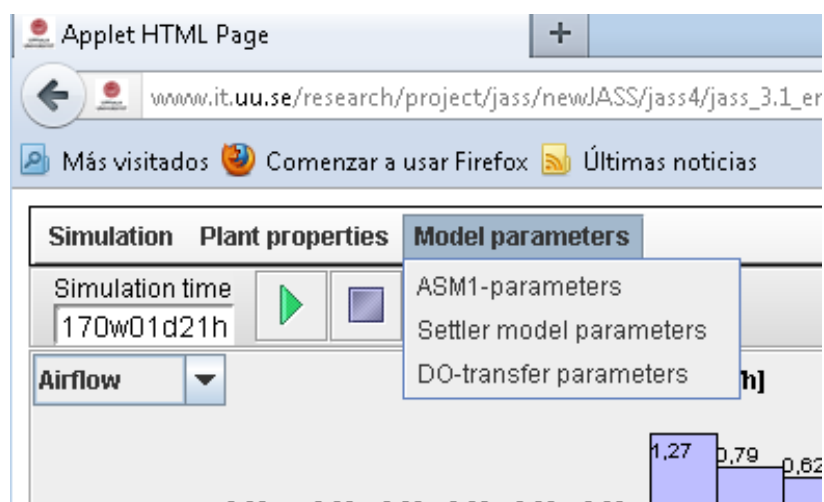


Figure 5. Menu of basic parameters of the model (list in Table 1). They should not be modified except for advanced users.

Table 1. Process parameters (in mg/L). Parameters modifiable or to be monitored for simulation processes. The parameters in bold are the main parameters.

Abbreviation	Description
Xbh	Biomass of heterotrophic microorganisms
Xba	Biomass of autotrophic microorganisms
Snh	Nitrogen as ammonium ($\text{NH}_4\text{-NH}_3$)
Sno	Nitrogen as nitrate (NO_3^-) and nitrite (NO_2^-)
So	Disolved oxygen
Ss	Organic matter, easily bidegradable
Xs	Oraganic matter, non-biodegradable
Xi	Organic matter, inert as particles
Xnd	Organic nitrogen, biodegradable as particles
Snd	Organic nitrogen, soluble, biodegradable
Si	Organic matter, soluble, inert

JASS Exercises

Write down everything you do with the simulator and the results you get. At the end you should make a report of your results and conclusions. You can use tables with the data from JASS, figures, screen captures, etc., to support your comments and conclusions. This report can be done during the simulation. It is recommended not to exceed 2 pages.

Exercises with JASS: Pre-Denitrification Process:

1. Start up the simulator. Basic controls.

Start the program and modify the design of the plant. Select pre_denit_10. Select the following variables in the upper left control panel: Air flow, ammonium (Snh) and nitrate (Sno).

Make sure that the influent reaches 250 m³/h, the internal recirculation is 0 and the excess sludge is 4 m³/h.

Check that the level of dissolved oxygen (So) in the aerated zones of the reactor is 2 mg/L and 0 in the other zones.

Start the simulator and let it get the steady state, then check the values of:

- Ammonium in the effluent: (mg/L)
- Nitrate in the effluent: (mg/L)
- Nitrate in the last anoxic zone: (mg/L)

Compare the values with your peers to be sure that everyone is doing the simulation in the same way. If so, move to the next exercise.

2. Study of the effect of the amount of incoming organic matter.

In post-denitrification mode (first aerated zones and then non-aerated zones) you have to modify the input of easily biodegradable organic matter (Ss), from the initial value 80 mg/L to 20 mg/L, in intervals of 20 units (80, 60, 40, 20 mg/L). This variation simulates a reduction in the amount of organic matter in the influent, somewhat similar to what happens when it rains, although in this case we will not modify the incoming flow. Start the simulator and wait until the steady state. Observe and write down the changes in total nitrogen, ammonium and nitrate concentrations in the effluent. What process, nitrification or denitrification, is more affected by the reduction of organic matter in the influent?

The operation problem you found in the previous paragraph has an easy solution. One option to achieve good denitrification when there is not enough easily degradable organic matter, is the addition of a carbon source (ethanol, methanol, etc.). So, when there is not enough organic matter, which zone of the bioreactor has to be supplemented with an external source of carbon?

Add 5, 10 and 15 L/h of methanol (denoted as "carbon" in the simulator) and write down the total nitrogen, ammonium and nitrate in the effluent. Check if the addition of methanol has an effect on the microbiological community in the reactor (Xbh and Xba) for each methanol addition.

3. Study of the effect of sludge flow.

The amount of biomass (microorganisms) in the reactor has a decisive influence on the biodegradation process. In order to maintain an appropriate concentration of biomass in the bioreactor, the sludge from the settling unit is recirculated to the bioreactor, except a fraction (the excess sludge) that is sent to the sludge treatment. You are going to study the effect of the excess of sludge in the biological treatment.

Refresh the JASS to set all the variables to the initial value. Then, increase the flow of the excess of sludge from 4 L/h to 8 L/h in intervals of 1 unit. In the last value, you are reaching the wash-out of the bioreactor, all the biomass is removed from the bioreactor because you are removing more biomass than it is produced. Do not worry, this is a simulator.

Refresh the JASS again and now reduce the flow of the excess of sludge from 4 L/h to 0.5 L/h (4, 3, 2, 1 and 0.5 L/h). Analyze the concentration of nitrogen (ammonium, nitrate,...) in the effluent. Pay attention to the sludge age (in the lower right corner). What happens with the characteristics of sludge when reducing the flow of the excess of sludge?

Take a look at the settling unit when the flow of the excess of sludge is 0.5 L/h. As you can see, the settling unit is filled with sludge.

4. Additional exercise.

You have multiple possibilities to test. Select a variable and study the effect on the system: recirculation, addition of external source of carbon, temperature, inflow, outflow,... Study the effect of two or more variables at a time to maximize the removal of nitrogen from the effluent. Analyze your results and try to explain what happens in the system.

Practice 6

Life Cycle Assessment - Product

PVC bottle (32 g)

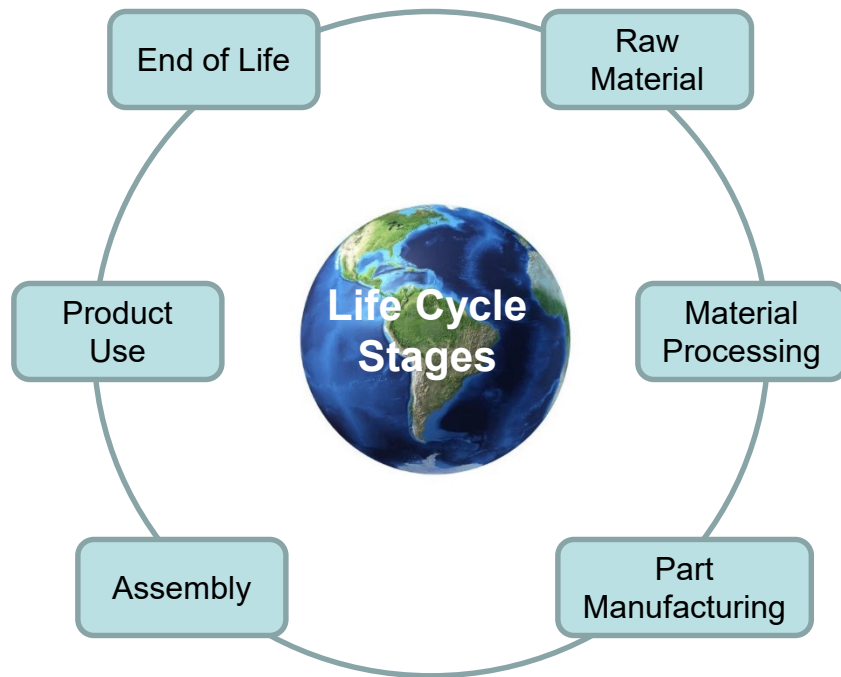
PET bottle (25 g)

Functional unit

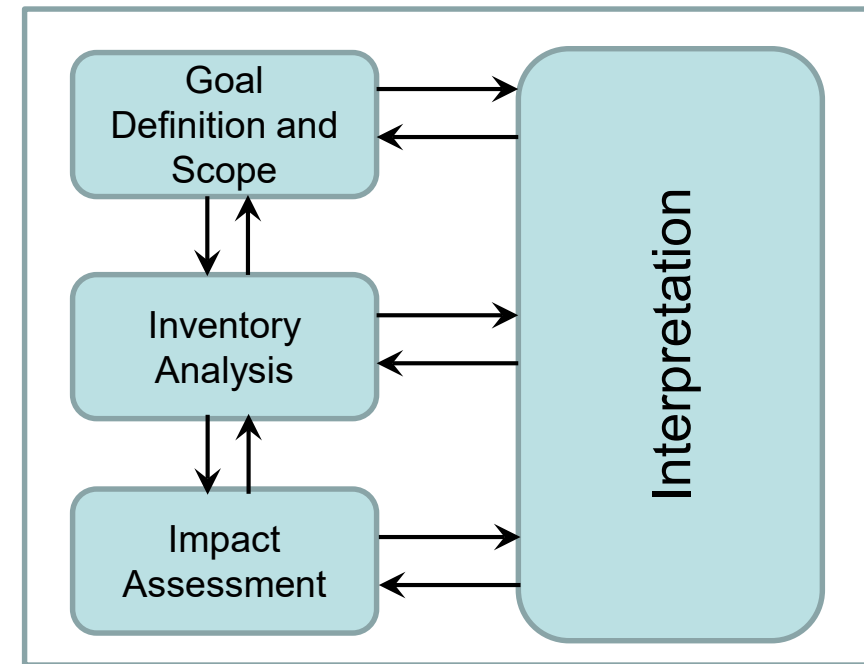
Life Cycle Assessment

Definition - ISO 14040:2006

The technique for determining the environmental aspects and potential impacts associated with a product: compiling the inventory of the relevant inputs and outputs of the system; evaluating the potential environmental impacts associated with these inputs and outputs; and interpreting the results of the inventory and impact phases in relation to the objectives of the study

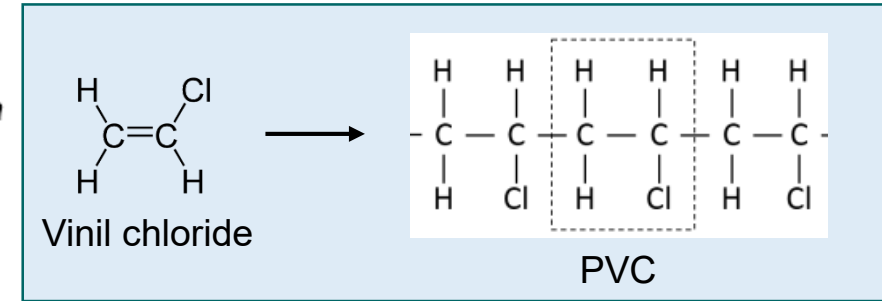
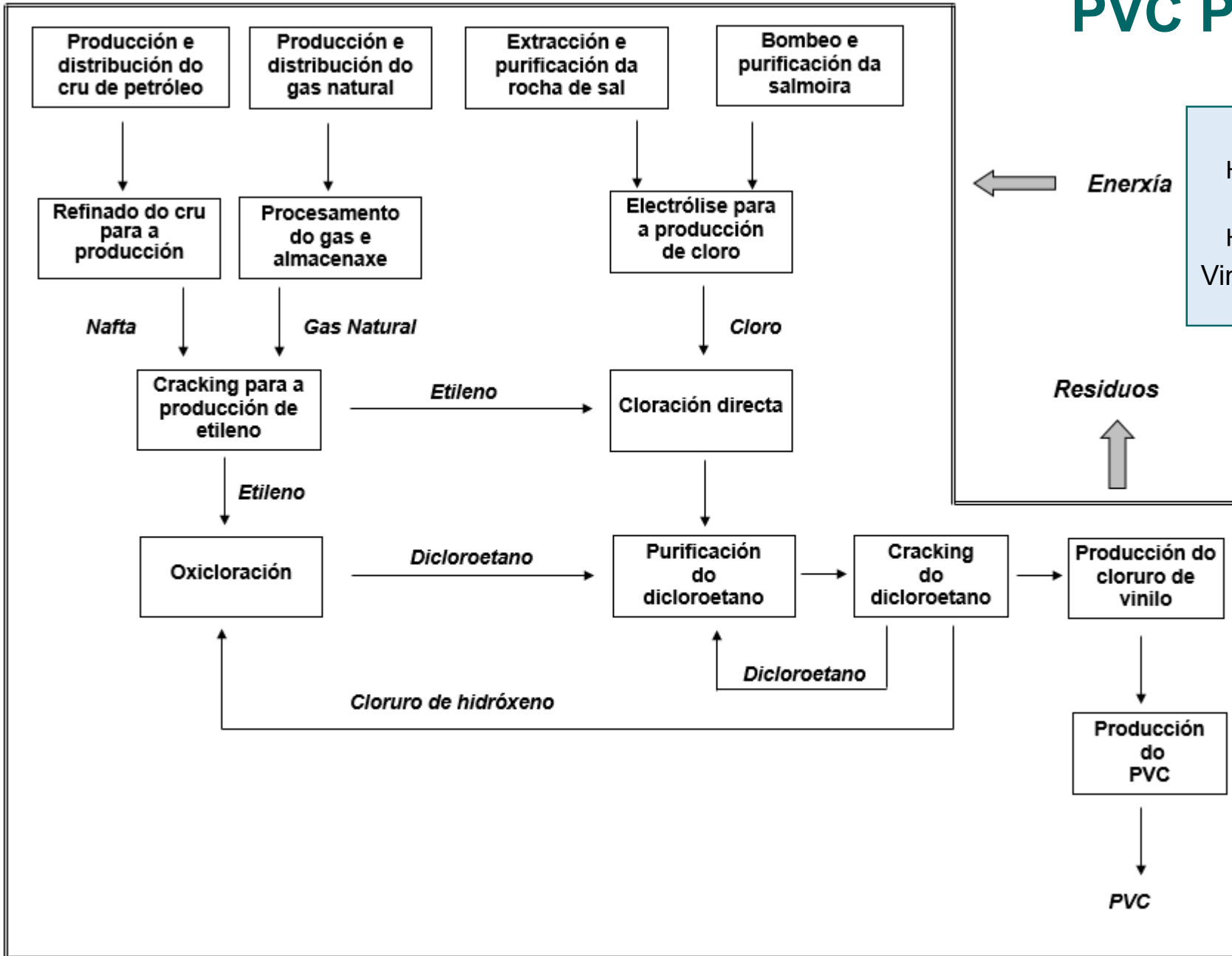


Life cycle stages



LCA stages

PVC Production



System boundaries
(raw material - manufacturing)

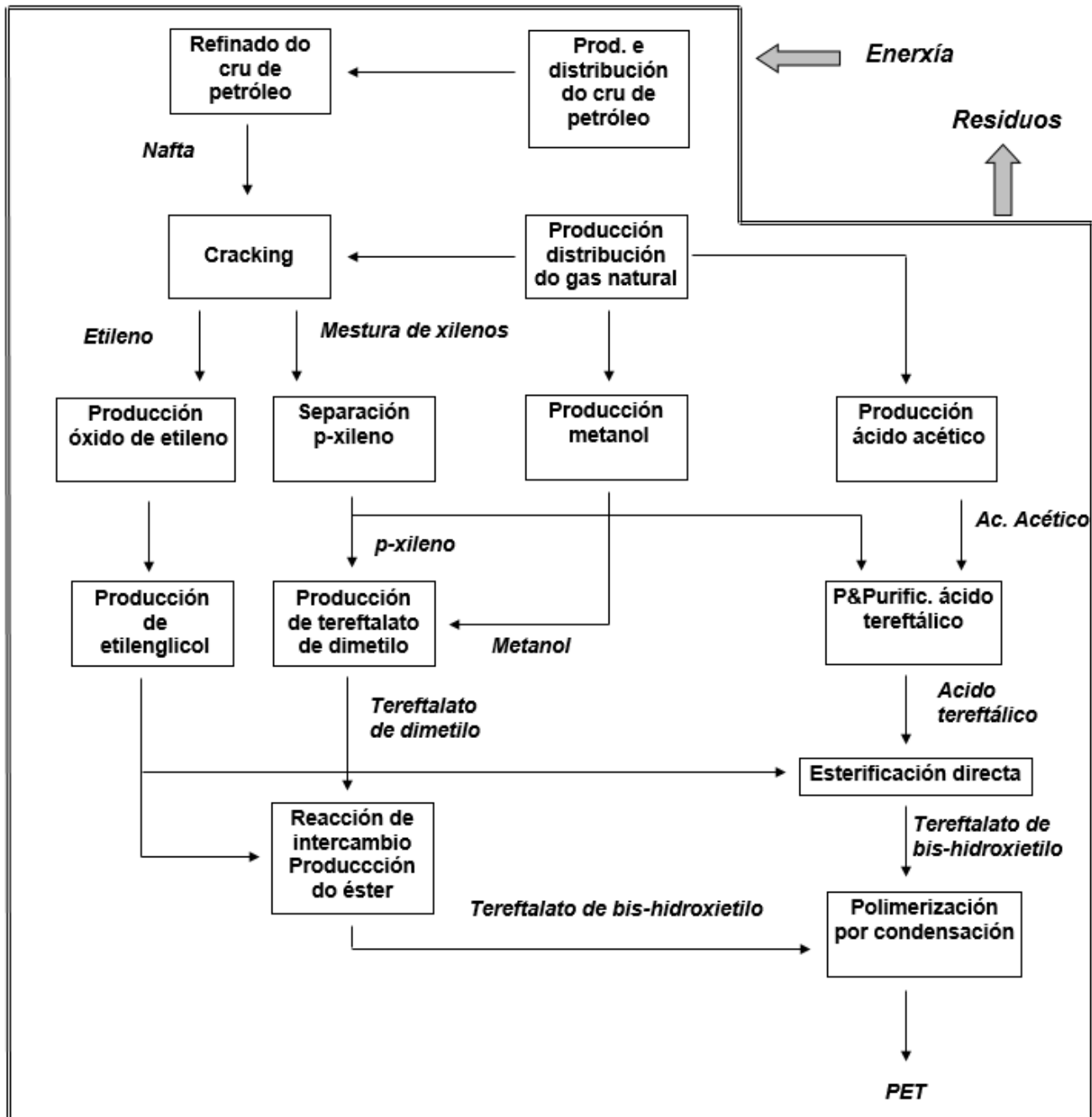
Inventory analysis

Raw materials, water and energy consumption

Waste generation

- Solid
- Liquid
- Gas

PET Production



System boundaries

(raw material - manufacturing)

Inventory analysis

Raw materials, water and energy consumption

Waste generation

- Solid
- Liquid
- Gas

Inventory analysis

Tabla A1. Inventario global de las entradas y salidas del PVC (base de cálculo 32 g).			
ENTRADAS	CANTIDAD	SALIDAS	CANTIDAD
Materias Primas		Emisiones al aire	
Mena de hierro	0,0118 g	CO ₂	57,60 g
Piedra calcaria	0,480 g	CH ₄	0,1820 g
Roca de sal	21,6 g	N ₂ O	0,0002 g
Arena	0,032 g	NO _x	0,3110 g
Agua de proceso y refrigeración	640 g	SO _x	0,2950 g
Bauxita	0,0071g	HCl	0,0075 g
		HF	0,0003 g
		HALON 1301	0,00118 mg
		Pb	0,00384 mg
		Cd	0,0045 mg
Energía		Mn	0,0016 mg
Carbón	0,197 MJ	Hg	0,00109 mg
Aceite crudo (alimentación)	0,516 MJ	Metales	0,041 mg
Aceite crudo	0,167 MJ	Benceno	1,58 mg
Gas natural (alimentación)	0,461 MJ	PAH*	0,0015 mg
Gas natural (vol.)	0,339 MJ	C _x H _y aromáticos	0,387 mg
Uranio procedente de mena	0,250 MJ	Emisiones al agua	
Potencial energético del agua	0,026 MJ	C _x H _y cloro	0,0003 g
Energía sin especificar	0,022 MJ		

Tabla A2. Inventario global de las entradas y salidas del PET (producción de 25 g)							
ENTRADAS		CANTIDAD		SALIDAS		CANTIDAD	
Materias primas				Emisiones al aire			
Mena de hierro		13,75 g		CO ₂		53,0 g	
Piedra calcaria		6,75 g		CH ₄		0,0925 g	
Roca de sal		112,5 g		N ₂ O		0,00013 g	
Arena y arcilla o lodo		0,50 g		NO _x		0,278 g	
Agua de proceso y refrigeración		437,5 g		SO _x		0,320 g	
Bauxita		7,75 g		HCl		0,0025 g	
				HF		0,00013 g	
Energía				HALON 1301		0,00175 mg	
Lignito*		0,0033 kg	0,124 MJ	Pb		0,00203 mg	
Aceite crudp (alimentación)		0,0088 kg	0,370 MJ	Cd		0,0038 mg	
Aceite crudo		0,0081 kg	0,340 MJ	Mn		0,00068 mg	
Gas natural (alimentación)		0,008 m³	0,293 MJ	Hg		0,0007 mg	
Gas natural (vol.)		0,011 m³	0,403 MJ	Metales		0,008 mg	
Carbón		0,0035 kg	0,103 MJ	Benceno		0,085 mg	
Uranio procedente de la mena		0,180 MJ	0,180 MJ	PAH**		0,00092 mg	
Potencial energético del agua		0,055 MJ	0,055 MJ	C _x H _y aromático		0,3 mg	
Total energía			1,868 MJ	Emisiones al agua			
				AOX**		0,00142 mg	

Impact Categories



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Impact category list (SETAC)

Categorías de impacto	Alcance espacial	Unidad de equivalencia
A. Relacionadas con entradas		
1. Recursos abióticos	Global	Según subcategoría
2. Recursos bióticos	Global	
3. Suelo	Global	
B. Relacionadas con salidas		
4. Calentamiento global	Global	kg CO ₂ ←
5. Agotamiento del ozono estratosférico	Global	kg CFC-11 ←
6. Impactos toxicológicos en humanos	Global/continental/ regional/global	no consensuado
7. Impactos toxicológicos	Global/continental/ regional/local	no consensuado
8. Formación de fotooxidantes	Continental/regional/local	kg eteno
9. Acidificación	Continental/regional/local	kg SO ₂ ←
10. Eutrofización	Continental/regional/local	kg PO ₄ ³⁻ ←
11. Olor	Local	no consensuado
12. Ruido	Local	no consensuado
13. Radiación	Regional/local	no consensuado
14. Accidentes	Regional/local	no consensuado
<i>Pro memoria</i> (flujos económicos)		
- Relacionados con entradas (energía, materiales, etc.)		Según subcategoría
- Relacionados con salidas (residuos sólidos, etc.)		

Characterization and normalization factors

Category 4. Global warming

PVC		Caracterización PVC		
Componente	Cantidad (g)	Factor	(kg CO2-eq)	(%)
CO ₂	57.6	1	5.760E-02	93.12
CH ₄	0.182	23	4.186E-03	6.77
N ₂ O	0.0002	296	5.920E-05	0.10
HALON 1301	0.00000118	6900	8.142E-06	0.01
			6.185E-02	100.00

Characterization
Factors

Category 5. Stratospheric ozone depletion

PVC		Caracterización		
Componente	Cant. (mg)	Factor	(kg CFC-eq)	(%)
HALON 1301	0.00118	12	1.416E-08	100.00
			1.416E-08	100.00

Characterization
Factors

Comparison of categories

- 4. Global warming potential
- 5. Ozone depletion potential
- 9. Acidification potential
- 10. Eutrophication potential

FACTORES DE NORMALIZACION		
	Europa, 1995	
PCG	4.81E+12	
PDO	8.33E+07	
PA	2.73E+10	
PE	1.25E+10	
	El Mundo, 1995	
PCG	4.15E+13	
PDO	5.15E+08	
PA	3.22E+11	
PE	1.32E+11	

Exercises

Exercise 1. Life cycle assessment of a product

Compare the environmental impacts of 2 products

1 PVC bottle, 32 g

1 PET bottle, 25 g

Use only the following 4 categories (SETAC):

- Global warming potential (GWP)
- Ozone depletion potential (ODP)
- Acidification potential (AP)
- Eutrophication potential (EP)

Exercise 2. Life cycle assessment of a product

Compare the environmental impacts of 2 products

1 PVC bottle, 25 g

1 PET bottle, 25 g

Use only the following 4 categories (SETAC):

- Global warming potential (GWP)
- Ozone depletion potential (ODP)
- Acidification potential (AP)
- Eutrophication potential (EP)

	A	B	C	D	E	F	G
1	CML 2 Baseline 2000 V2.03						
2	CLASIFICACIÓN PVC-PET						
3							
4							
5	Calentamiento global	$(kg\ CO_2)_{eq} = (kg\ CO_2) \cdot F_{CO_2} + (kg\ CH_4) \cdot F_{CH_4} + (kg\ N_2O) \cdot F_{N_2O} + (kg\ HALON) \cdot F_{HALON}$					
6							
7	PVC	Caracterización PVC					
8	Componente	Cantidad (g)	Factor	(kg CO2-eq)	(%)		
9	CO ₂	57.6	1	5.760E-02	93.12		
10	CH ₄	0.182	23	4.186E-03	6.77		
11	N ₂ O	0.0002	296	5.920E-05	0.10		
12	HALON 1301	0.00000118	6900	8.142E-06	0.01		
13				6.185E-02	100.00		
14							
15							
16							
17	PET	Caracterización PET					
18	Componente	Cantidad (g)	Factor	(kg CO2-eq)	(%)		
19	CO ₂	53	1	5.300E-02	96.05		
20	CH ₄	0.0925	23	2.128E-03	3.86		