Environmental Technology

Prof. Claudio Cameselle

Escola de Enxeñería Industrial

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1.1. Impact of human activities in the environment

Former economic model: (primary sector)

Low living standard

Long lifespan of products

Damaged products were fixed and reused

LOW WASTE GENERATION

Present economic model: (Industry and Services)

Industrial development. High living standards.

Throwaway culture

HIGH WASTE GENERATION

Environmental Regulations:
Waste management, avoiding their environmental impact

Reduce
Reuse
Recycling

Development of the Environmental Technology

1. New technologies for waste valorization and recycling.
2. Moving to new clean technologies (less consumption of raw materials, water and energy, less waste generation).

1.1. Impact of human activities in the environment

Challenges for the XXI century: Agenda 21.
United Nations Conference on Environment and Development, Rio Summit, 1992.

1. Natural resources depletion
2. Deforestation and change of land uses
   a. Soil erosion
   b. Less biodiversity
   c. Soil and groundwater pollution
3. Air pollution
   a. Urban activities
   b. Industrial activities
4. Water pollution
   a. Agriculture
   b. Industry
   c. Urban sources of pollution
   d. Eutrophication
   e. Sea water pollution
5. Global warming
6. Ozone depletion
7. Ecotoxicological impact in wildlife and toxicological effects on humans
8. Noise pollution
9. Radioactive contamination

1.1. Impact of human activities in the environment

In 2015, all member states of the United Nations (UN) approved the 2030 Agenda for Sustainable Development, an action plan for people and the planet which includes the 17 sustainable development goals (SDG) with 169 integrated and indivisible goals that cover the economic, social and environmental spheres.

1.1. Impact of human activities in the environment

1. Love Canal

Niagara Falls, New York

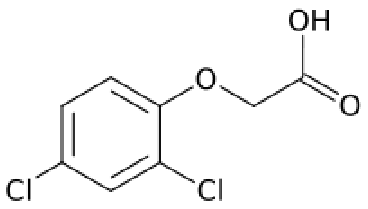
Hooker Chemical dumped in this area about 21000 t of toxic waste until 1953. The site was sold. The construction in the site affected the containment structures in a number of ways allowing the chemicals to seep out. Rainstorms favored the spread of the chemical waste leading to a public health emergency.

2. Minamata disease

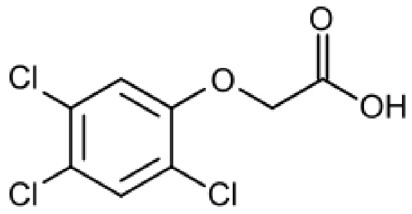
Chisso chemical company discharged Hg contaminated wastewater to the Minamata Bay (Japan) from 1932 to 1968, when the production process changed. It was estimated that 81 t of Hg were discharged in the bay for 36 years. Hg underwent some chemical transformations due to the environmental conditions in the Minamata bay forming methyl-Hg. This compound is much more toxic than Hg itself.
Hg contaminated fish and shellfish. The consumption of contaminated seafood affected human health as an acute neurological syndrome due to Hg poisoning.

3. Agent Orange

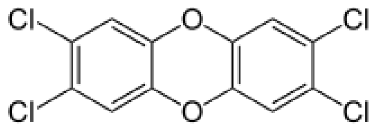
It was a mixture of two herbicides, that was used in the Vietnam war (1961-1971) for forest defoliation. The exposition to the herbicides is harmful, but the main problem in the significant amount of dioxin formed in the synthesis of 2,4.5-T herbicide. Dioxin is one of the most toxic compounds ever synthetized.



2,4-D



2,4,5-T



2,3,7,8-TCDD

Application of Agent Orange

Defoliated forest

4. Seveso disaster

Séveso (Italy), July 10, 1976. Hoffmann-La Roche synthetized the 2,4,5-T herbicide in an old factory. A reactor for the production of dichlorofenate came out of control , temperature and pressure increased. The reactor relief valve eventually opened, causing the aerial release of 6 tons of chemicals, which settled over 18 km^2. Among the substances released was 1 kg of dioxin (TCDD).

This disaster favored the issue of a new regulation in the UE on the control of major-accident hazards involving dangerous substances, also known as “SEVESO I”.

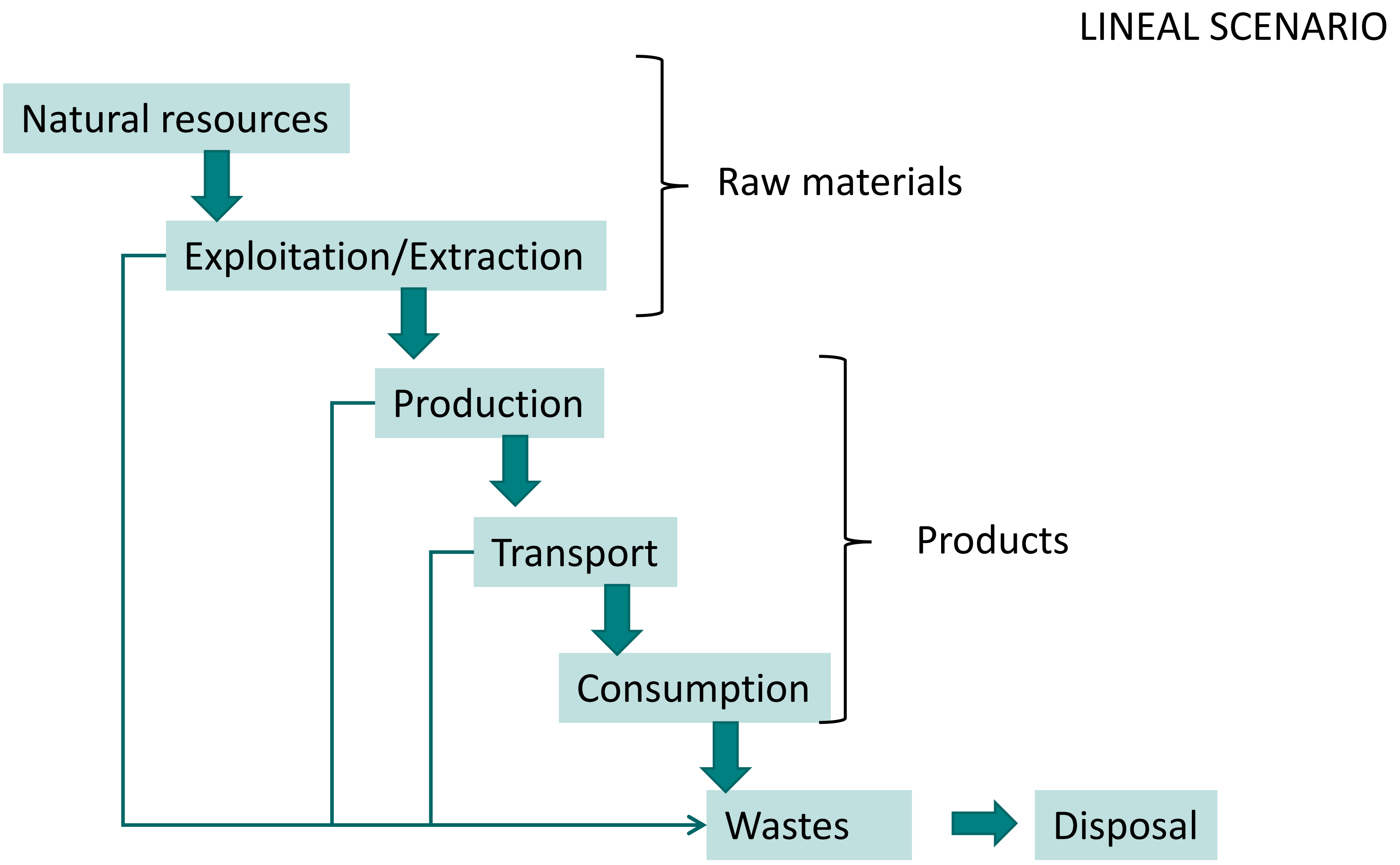
The more recent revision of this regulation in the SEVESO III: Directive 2012/18/EU.

1.2. Definition of Environmental Technology

Environmental Technology comprises any technique or technology developed to reduce the negative effects of human activities (household, urban, commercial, industrial,… activities) on the environment, using the basic principles of the biology, physics and chemistry.

- **Technologies for the elimination of contaminants from the environment:** decontamination and recovery of soils, industrial areas, mines, lakes and waterbodies….
- **Technologies for management and treatment of waste, wastewater and emissions to the atmosphere:** Collection, treatment and final disposal of waste, treatment of wastewater, control and reduction of emissions to the atmosphere...
- **Technologies for the use and recovery of residual materials:** reuse and recycling of residual materials, valorization of wastes, obtaining products with commercial value from wastes….
- **Development of green technologies:** They are those that allow obtaining products with the same quality but consuming less raw materials, water and energy; and generating less waste, wastewater and emissions to the atmosphere.

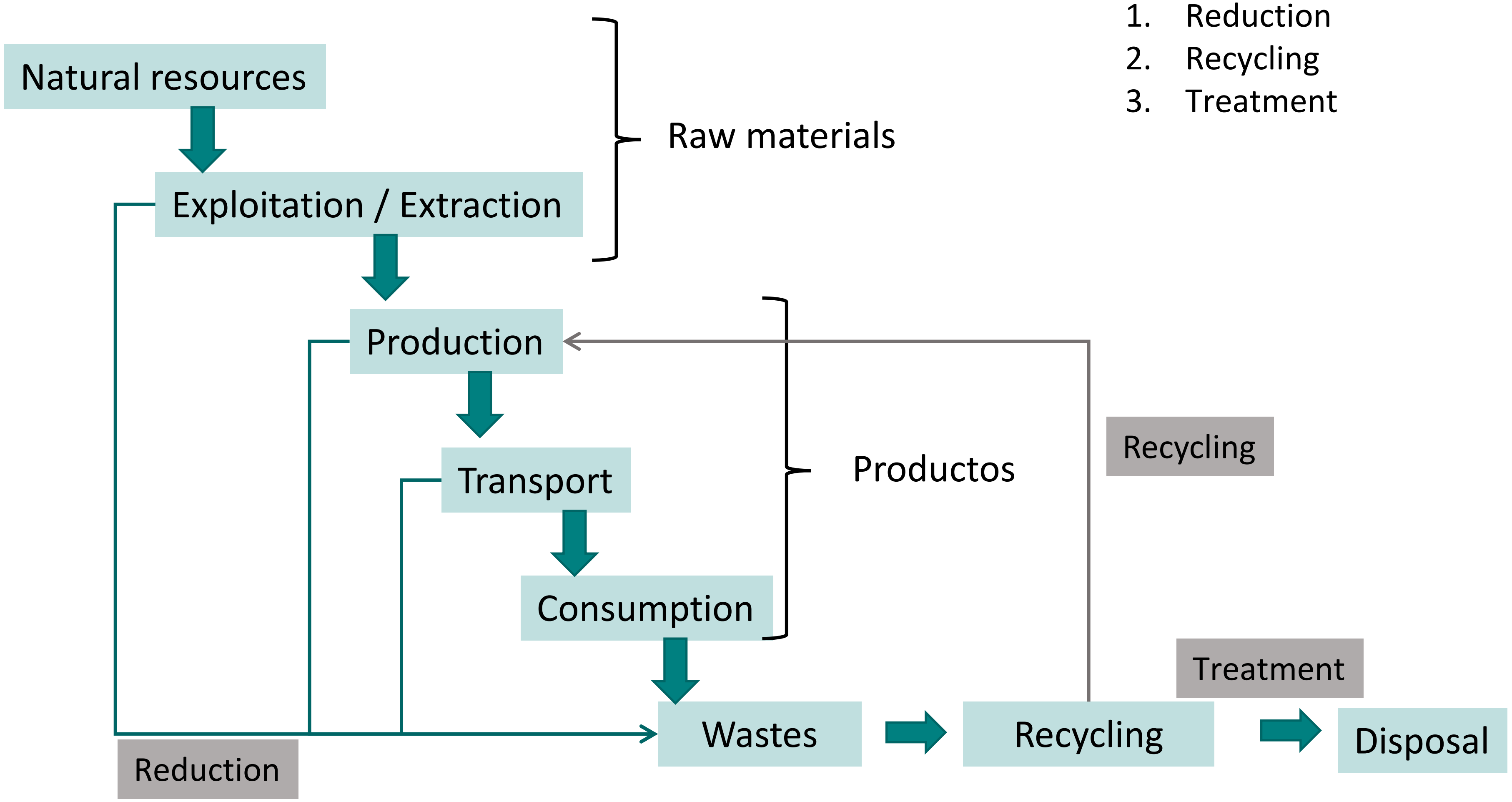
1.3. Material cycle economy



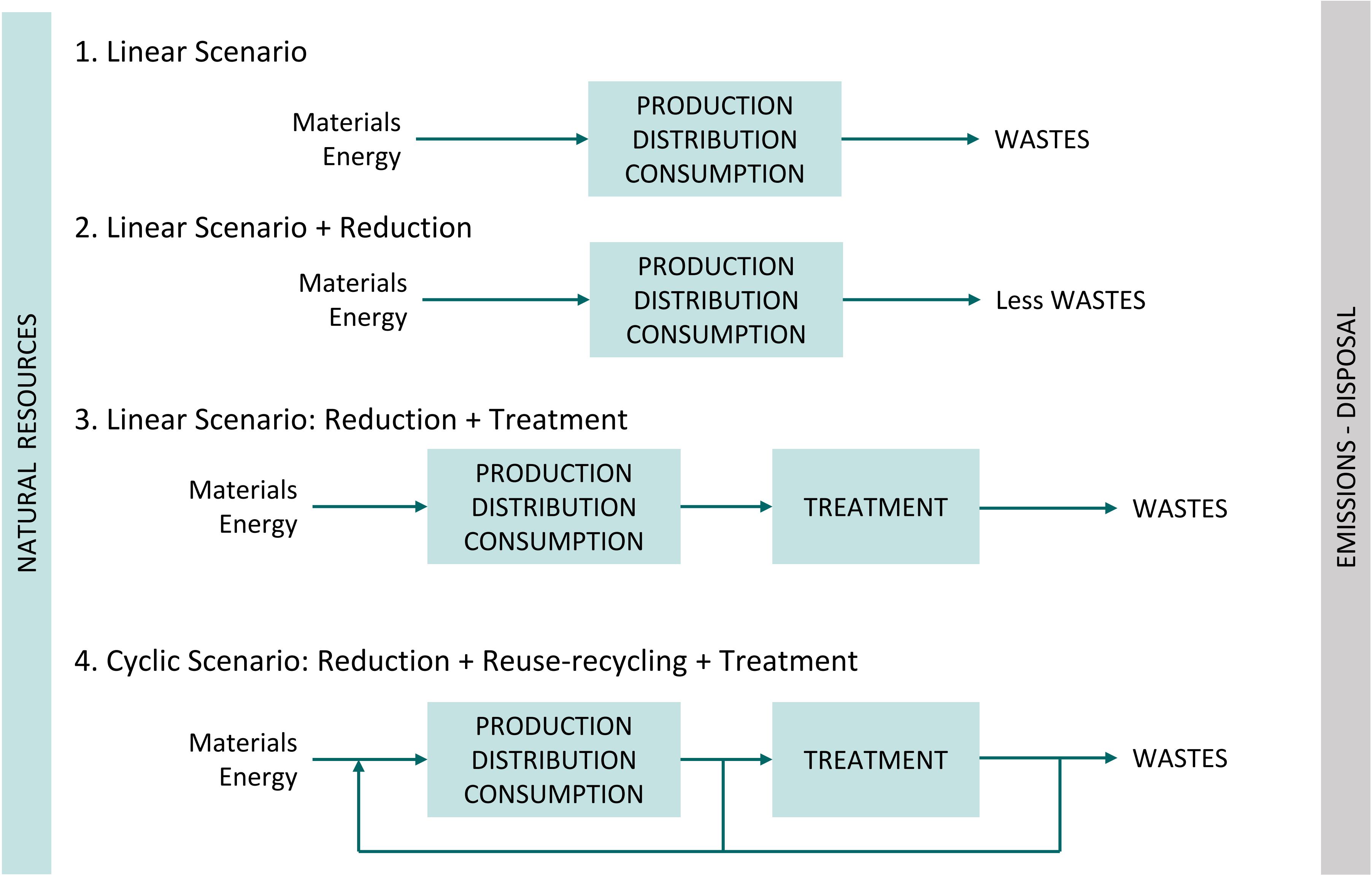
1.3. Material cycle economy

CYCLIC SCENARIO

1. Reduction
2. Recycling
3. Treatment

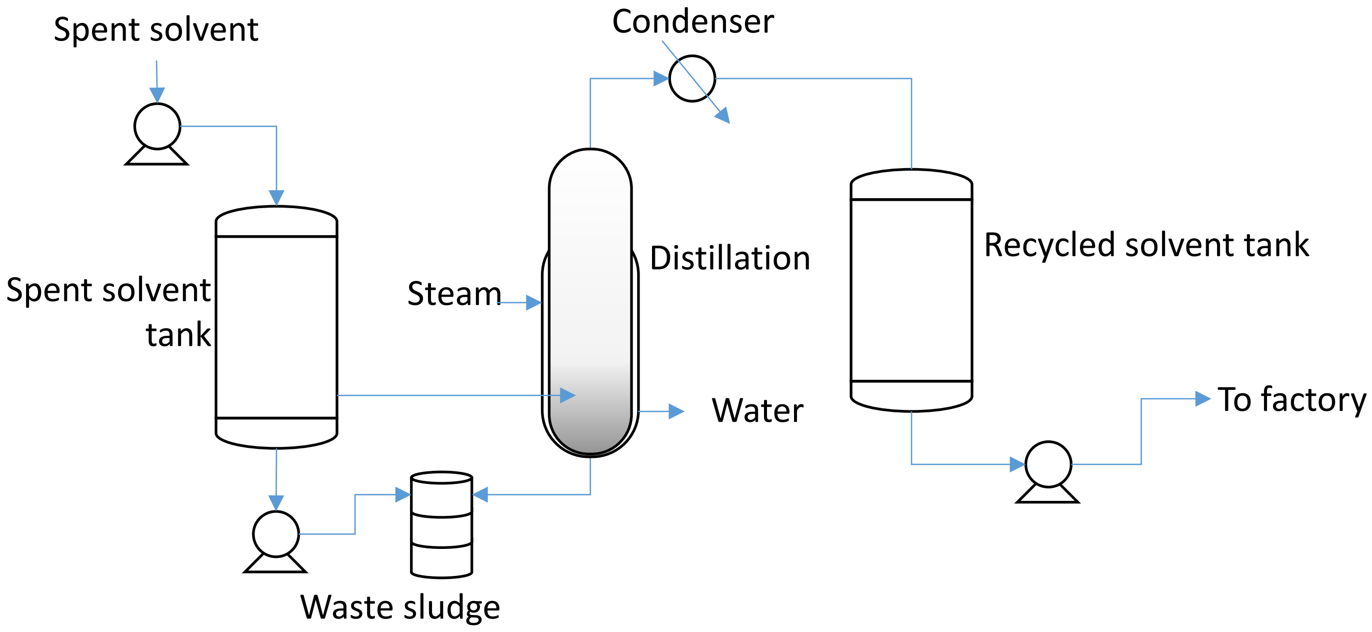


1.3. Material cycle economy



Example: Minimization of wastes and emissions

Organic solvent recovery and recycling



Example: Minimization of wastes and emissions

Organic solvent recovery and recycling

	Former Process	New Process	
Mass balance			
Fresh solvent	69 230	18 740	kg/year
Recycled solvent (external source)	21 280	-	kg/year
Waste sludge	58 590	18 740	kg/year
Recycled solvent *in situ*	-	56 221	kg/year

Economic balance			
Cost of fresh solvent (0.73 €/kg)	50 762.93	13 741.11	€/year
Recycling (external source)	5 115.82		€/year
Waste disposal	19 015.18	5 631.60	€/year
Recycling *in situ*	-	11 713.52	€/year
Total cost	74 893.93	31 086.23	€/year
Savings		43 807.70	€/year
Investment		82 068.20	€
Return on investment		**1.9**	**years**

Industrial simbiosis / Industrial Ecology

Example: Kalundborg industrial park (Denmark)

Exercise

An environmental disaster or ecological disaster is defined as a catastrophic event related to the natural environment due to human activity. Environmental disasters show how the impact of ecosystem disruption by humans has had widespread and/or long-lasting consequences. These disasters have included the death of wildlife, humans, and plants, or severe alteration of people's health and way of life, possibly leading to migration.

Exercise: Describe an environmental disaster and its consequences, identify the causes of the disaster, and how it should have been acted upon to prevent it.

Step 1: Write an essay (max. 400 words).

Step 2: Repeat the same exercise using the artificial intelligence (max. 400 words).

Step 3: Compare your work with that produced by artificial intelligence, commenting on the positive and negative aspects of both essays.

Submit your report in a PDF file.

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1.4. Introduction to the mass balances

a) Input – Output

Mass balance equation

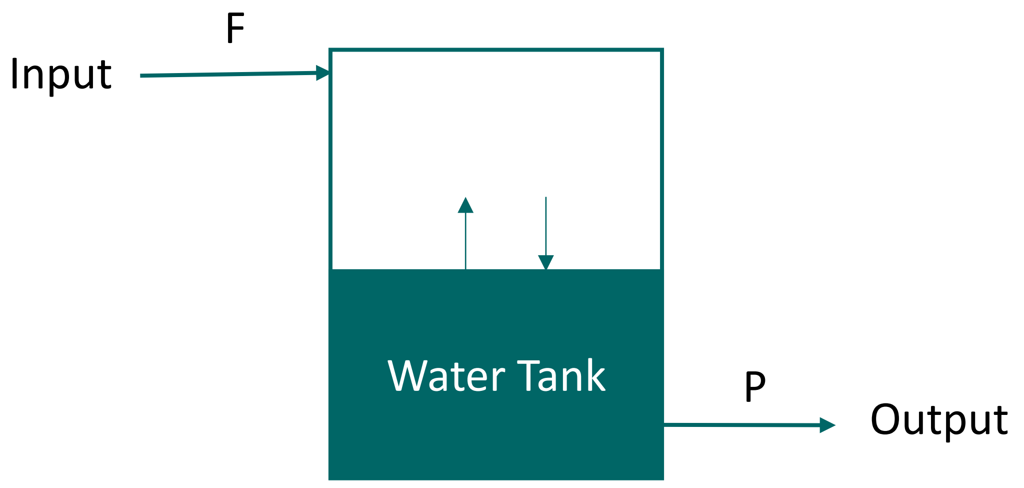
Input = Output

a) Generation

$N_2 + 3\ H_2 \longrightarrow 2\ NH_3$

Input + Generation = Output

a) Accumulation

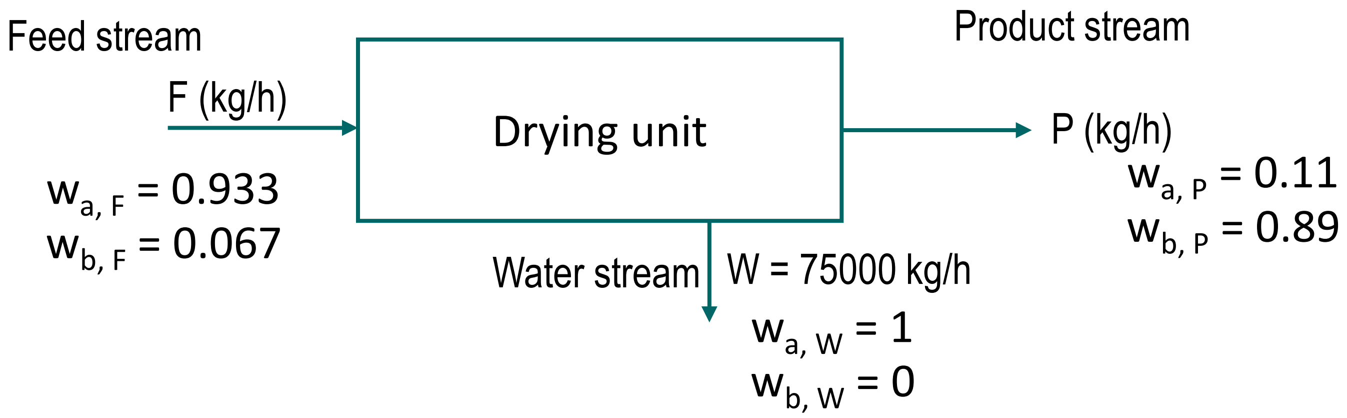


Mass balance equation:

$$\text{Input} + \text{Generation} = \text{Output} + \text{Accumulation}$$

1. A stream of pulp paper, 6.7 wt. % is fed to a drying unit. The pulp paper leaves the drying unit at 11 % water content. The dryer removes 75000 kg/h of water. What is the daily production of pulp paper (11 wt. % water)?

Answer: 146.54 t/day.



Components

Water: a

Fibers: b

Composition
- Water: a
- Fibers: b

Mass fraction

Flow: kg/s

- $w_{a,F} = 0.933$
- $w_{b,F} = 0.067$
- $w_{a,F} + w_{b,F} = 1$

Molar fraction

Flow: mol/s

- $x_{a,F} = 0.$---
- $x_{b,F} = 0.$---
- $x_{a,F} + x_{b,F} = 1$

Volumetric concentrations

Volumetric Flow: m^3/s

- $C_{a,F}$ = --- kg/m^3
- $C_{b,F}$ = --- mol/m^3

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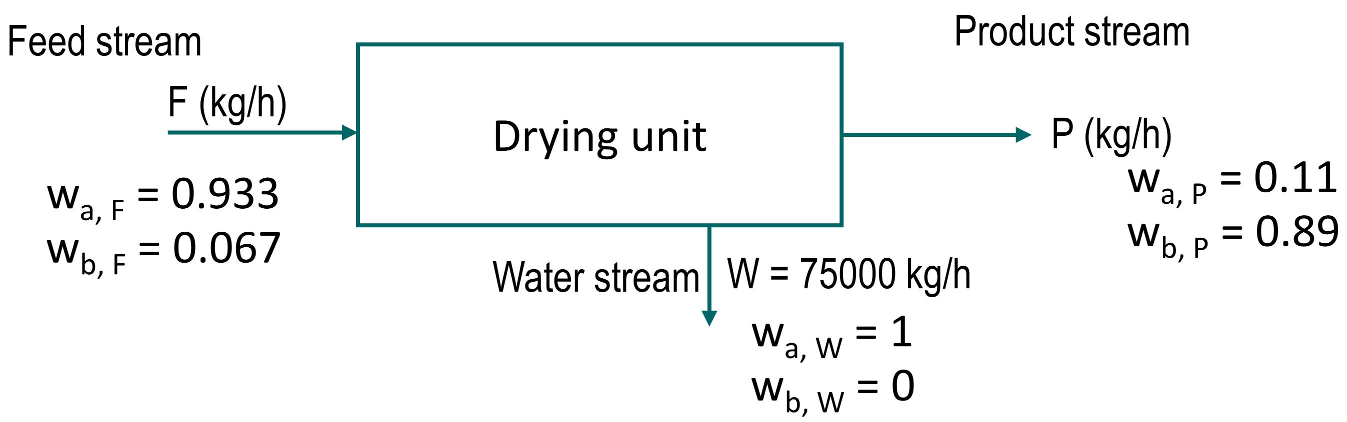

Components

Water: a

Fibers: b

Global mass balance: $F = P + W$

Mass balance to componente a: $F \cdot w_{a,F} = P \cdot w_{a,P} + W \cdot w_{a,W} \Rightarrow 0.933\ F = 0.11\ P + 75000\ kg/h$

Mass balance to componente b: $F \cdot w_{a,F} = P \cdot w_{a,P} + W \cdot w_{a,W} \Rightarrow 0.067\ F = 0.89\ P$

n components

n+1 mass balances

Use only "n mass balances"

1. A stream of pulp paper, 6.7 wt. % is fed to a drying unit. The pulp paper leaves the drying unit at 11 % water content. The dryer removes 75000 kg/h of water. What is the daily production of pulp paper (11 wt. % water)?

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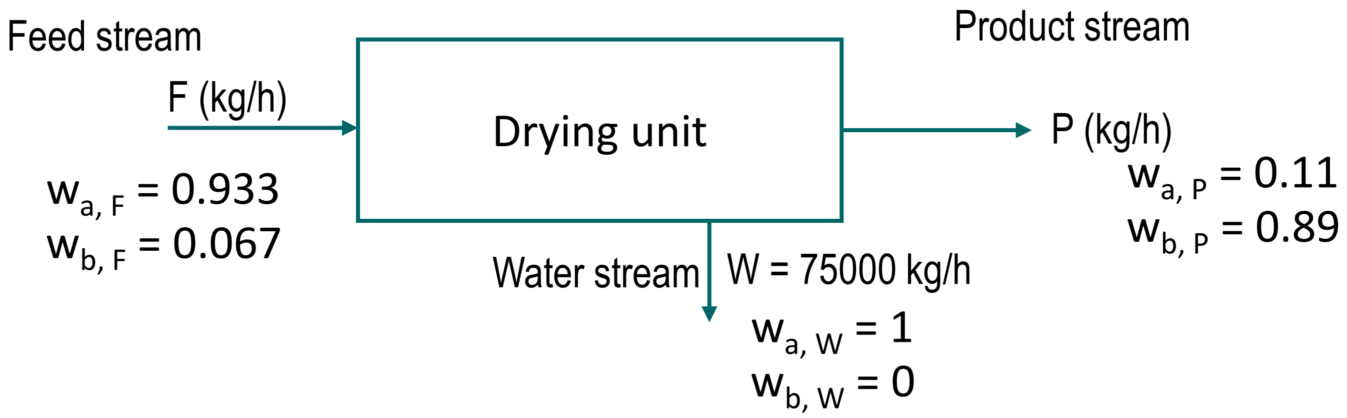

Components

Water: a

Fibers: b

Global mass balance: $F = P + W$

Mass balance to fibers, b: $0.067\,F = 0.89\,P$

$$\left.\begin{array}{l} F = P + W \\ 0.067\,F = 0.89\,P \end{array}\right\} \Rightarrow \left\{\begin{array}{l} F = 81105.71 \text{ kg/h} \\ P = 6105.71 \text{ kg/h} \end{array}\right.$$

$$\Rightarrow \mathrm{P = 6105.71\ kg/h\ \frac{24\ h}{day}\ \frac{1\ t}{10^3 kg} = 146.54\ t/day}$$

1. A stream of pulp paper, 6.7 wt. % is fed to a drying unit. The pulp paper leaves the drying unit at 11 % water content. The dryer removes 75000 kg/h of water. What is the daily production of pulp paper (11 wt. % water)?

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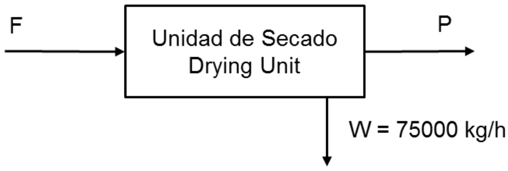
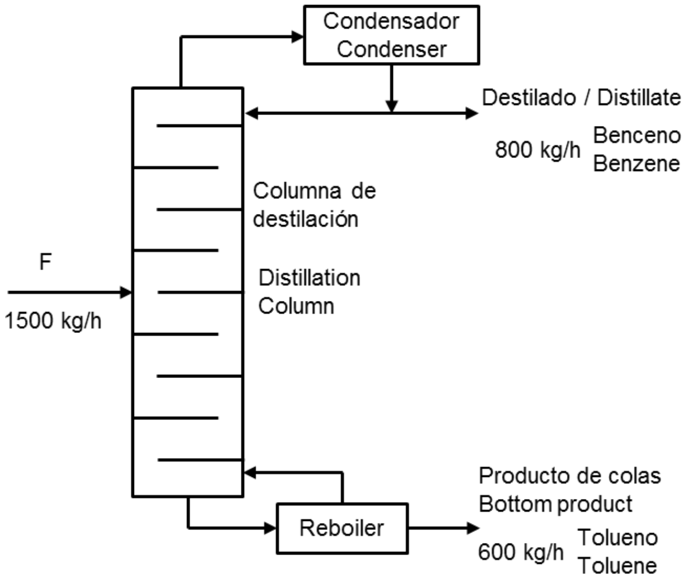


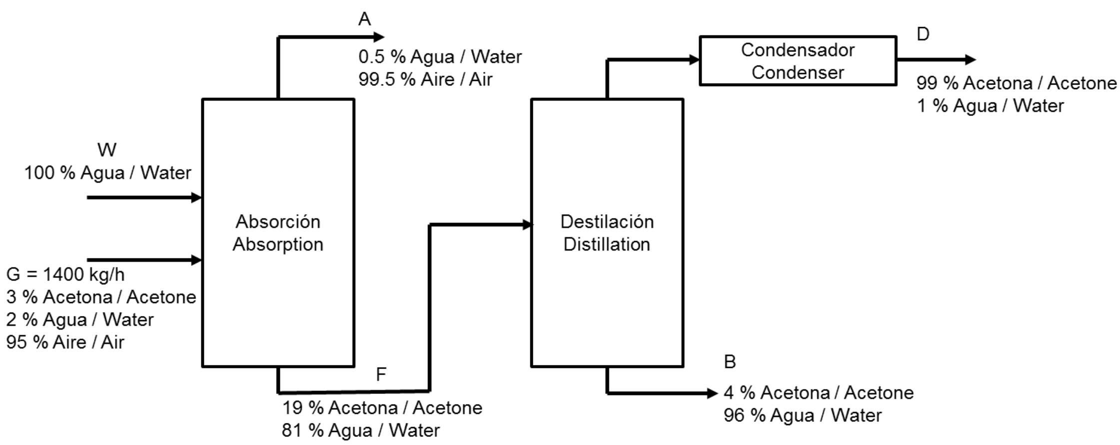
2. 1500 kg/h of a mixture of benzene and toluene contains 55% wt. benzene. The mixture is separated by distillation in two streams. 800 kg/h benzene are recovered in the distillate stream, and 600 kg/h toluene are recovered in the bottom stream. Determine the flux of benzene and toluene and the composition in all the system streams.

Answer: Distillate: 875 kg/h; 91.43 % benzene; 8.57 % toluene. Bottom product: 625 kg/h, 4.00 % benzene; 96.00 % toluene.



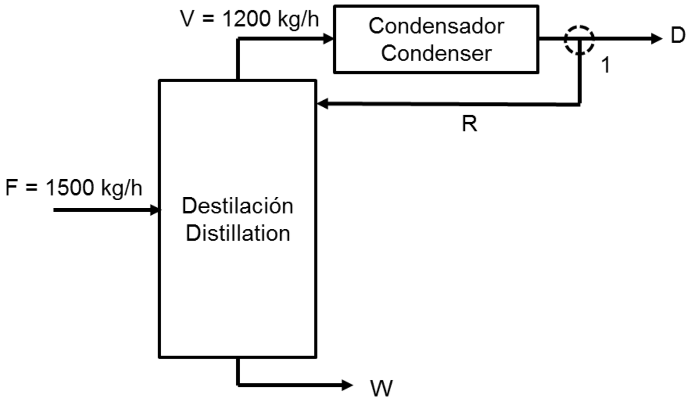
3. The design of a new system for acetone recovery is shown in the figure. The design department forgot to include in the figure the flow of the streams. Determine the flow of the streams: A, F, W, B, and D in kg/h.

Answer: F: 221.05 kg/; A: 1336.68 kg/h; W: 157.74 kg/h; D: 34.90 kg/h; B: 186.15 kg/h.



4. 1500 kg/h of a mixture of benzene (55 wt. %) and toluene is separated by distillation. The condensate contains 91 % benzene and the bottom stream 96 % toluene. The vapor stream to the condenser is 1200 kg/h. Knowing that the composition of the vapor in the head of the column, the condensate and the reflux are the same, determine the ratio reflux/condensate.

Answer: D: 879.31 kg/h; R/D: 0.365.

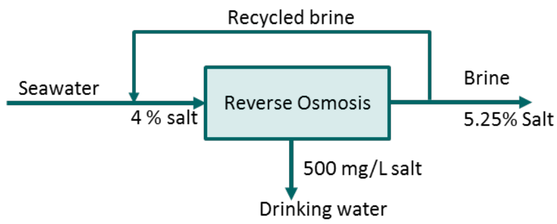


5. A desalination process of seawater (salt content: 3.1 %) produces drinking water with 500 ppm of salt as it is shown in the figure. Determine:

a) The daily production of drinking water for a feed flow of 1000 kg/h of seawater.

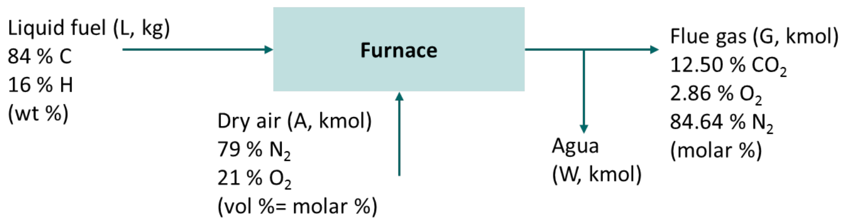
b) The fraction of brine recycled to the osmosis cell

Answer: 9923 L/day; 55.10 %.



6. The main advantage of the catalytic incineration is its lower cost because the operating temperature is in the range 500 – 900 ºC whereas the flame incineration requires about 1100 – 1500 ºC. A liquid fuel was burnt with dry air. The fuel composition was (wt. %) 84 % of C and 16 % of H. The composition of the flue gas was (vol. %, without water): 12.50 % of CO_2, 2.86 % of O_2 and 84.64 % of N_2. Determine the amount of kmol in the flue gas produced per 100 kg of liquid fuel. ¿What is the excess of air?

Answer: 56 kmol flue gas, 14.55% excess of air.



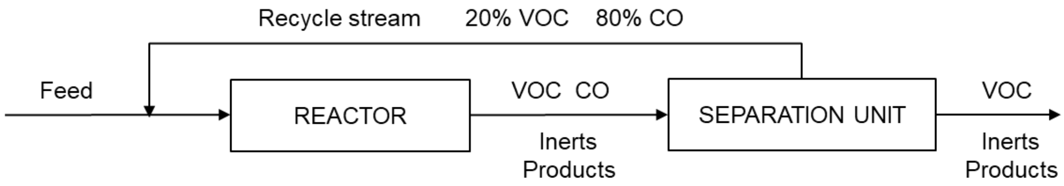
7. Many industrial processes generate emissions of volatile compounds that must be eliminated. One possible method to remove volatile compounds is based in their reduction with carbon monoxide (CO). Consider the scheme of the process in the figure. The feed stream contains 10 % of CO, 40 % of volatile compounds and 50 % of inerts. The fractional conversion is 73 % and the global conversion is 90 %. Determine:

a) The molar flow rate for each stream.

b) The molar ratio between the recirculation and product streams.

DATA: The stoichiometry of the reaction is 2 mol of volatile compound:2.5 mol of products

Answer: a) 100 mol, 146.58 mol, 145.58 mol, 99 mol, 46.58 mol. b) 0.47.



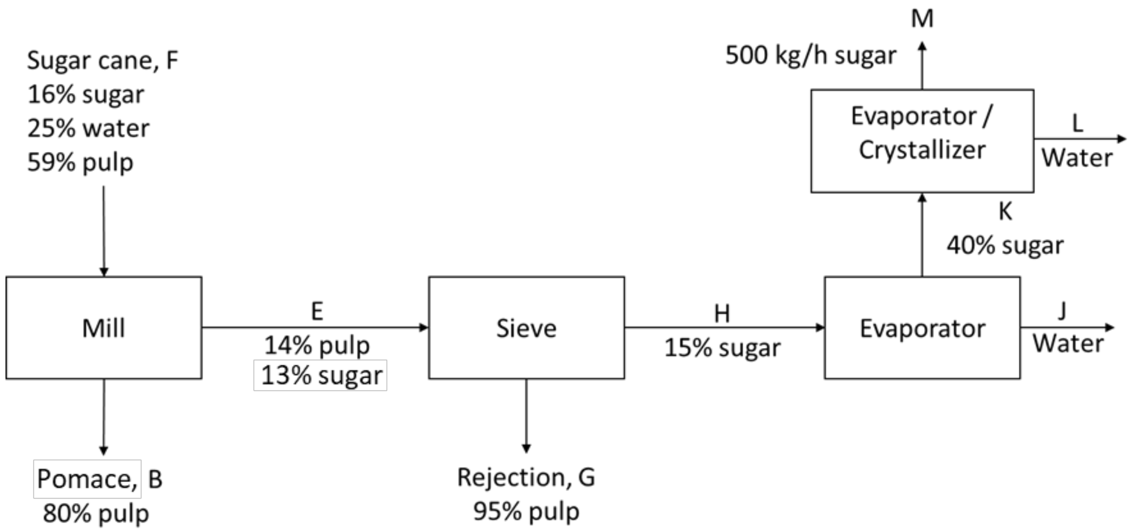
8. A simplified flow chart for the manufacture of sugar is shown in the figure below. The sugar cane (F) is fed to a mill where the syrup is separated from the pomace (B) that contains 80% wt. of pulp. The syrup (E) passes through a sieve to remove all the pulp and obtain a clear syrup (H), with 15% wt. of sugar and 85% wt. of water. The evaporator concentrates the syrup and the crystallizer allows for a production of 500 kg/h of crystallized sugar.

a) Determine the water removed in the evaporator, in t/day

b) Determine the composition (as mass fraction) of the rejection stream, G

c) Determine the flow of the feed stream, F.

d) What is the percentage of sugar lost in the pomace, B?



9. A paint producing company generates a highly polluted wastewater with a high content of dyes. The wastewaters are treated with ethyl acetate, an organic solvent that extract the colored substances from the water. After extraction, the mixture "ethyl acetate + colored substances" undergoes a vacuum distillation to recover the ethyl acetate, which is condensed and recycled to the extraction process to minimize the costs and the generation of wastes.

The outlet stream from the extraction process is fed to the distillation column at a flow rate of 1500 kg/h. The composition of the feed stream (F) is 55% wt. ethyl acetate and 45% wt. colored substance. Ethyl acetate is collected in the head of the distillation column (stream V) and then, condensed forming the stream P with 91% wt. of ethyl acetate. The bottom stream of the distillation column (W) contain 96% wt. of the colored substance. The flow stream to the condenser (V) is 1200 kg/h. After the condenser, a fraction of the stream is returned back to the distillation column as reflux stream (R) and that the rest is obtained as a product (P) to be reused by the paint company.

a) Draw a sketch of the distillation-condensation process with all the streams and data available

b) Determine the flowrate (kg/h) of ethyl acetate obtained as a product (P)

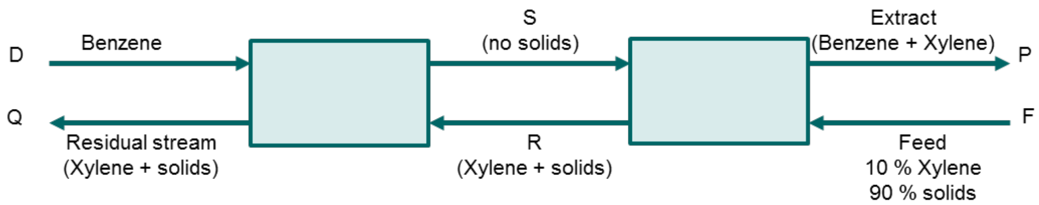
c) Calculate the flowrate (kg/h) of reflux stream (R).

ADDITIONAL EXERCISES (LESSON 1)

1. In the late 80s the Chemical Manufacturers Association (CMA) US started a comprehensive and ambitious environmental project: "Responsible Care". This program includes six policies, one of them deal with pollution prevention forcing companies to reduce the generation of hazardous waste. The application of this policy implies the use of different raw materials, significant changes in the production process or even the entire redesign of the manufacturing process. For instance, the preferred method for purifying xylene from a process stream involves the removal of xylene using benzene as solvent in countercurrent. The flow rates of the feed and solvent streams are 2000 kg/h and 1000 kg/h, respectively. 80 % of xylene in the feed is extracted. The percentage of xylene in S and R streams are the same. Determine:

a) The flow rates and concentrations of xylene and benzene in all of the streams

b) The percentage of xylene extracted in each unit



Answer:

	Flow (kg/h)	Xylene	Solids	Benzene
F	2000	10 %	90 %	-
D	1000	-	-	100 %
P	1160	13.79 %		86.21 %
Q	1840	2.17 %	97.83 %	-
S	1050	4.76 %	-	95.24 %
R	1890	4.76 %	95.24 %	-

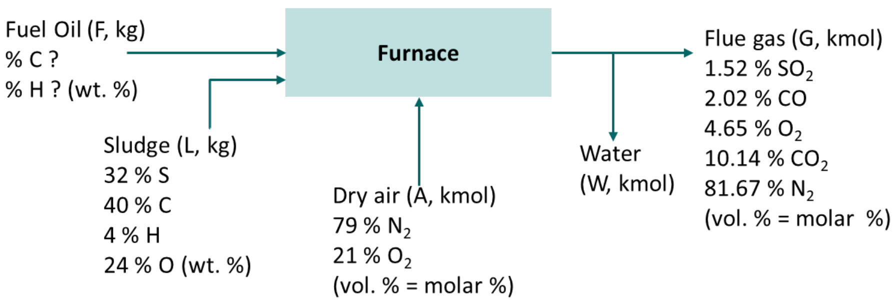
Xylene extracted in unit 1: 55.5 %, and unit 2: 55%.

Global xylene extraction: 80%

2. The wastewater treatment plants (WWTP) generate a large amount of sewage sludge. The sludge is dehydrated and then it can be used as soil amendment or fertilizer, or it can be incinerated. The sludge from a WWTP is incinerated with fuel oil (it only contains C and H) in a furnace with air. The table shows the composition of the sludge and the flue gas (without water). a) Determine the composition of the fuel oil (wt. %). b) the amount of fuel oil for the incineration of 2 kg/day of sludge.

Answer: Fuel oil F = 1.331 kg/day, Composition: w_C = 0.841, w_H = 0.159

Sludge (wt.%)		Flue gas (vol. %)	
S	32	SO_2	1.52
C	40	CO	2.02
H	4	O_2	4.65
O	24	CO_2	10.14
		N_2	81.67



3. A cellulose waste ($C_6H_{10}O_5$) is burned in a fluidized bed incinerator, with the addition of calcium hydroxide to neutralize and remove acid substances from the combustion gases. The cellulose waste and the calcium hydroxide are fed together to the incinerator, at a global rate of 370 kg/h (20 kg/h corresponds to $Ca(OH)_2$). Considering complete incineration of the cellulose, all the calcium hydroxide is transformed into lime (CaO) and the combustion gases contain 9% CO_2 (wet basis), determine:

a) The amount of calcium oxide obtained per day in the incineration process.

b) The composition of the combustion gases (wet basis).

c) The percentage of excess of air in the incineration.