PROSIMPLUS APPLICATION EXAMPLE

FROZEN POTATOES PROCESSING

EXAMPLE PURPOSE
This example presents the simulation of a frozen potatoes processing plant. A Water Pinch Analysis (WPA) is performed and the different new water networks are simulated to evaluate the reduction of water consumption and waste water of the process.

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CORRESPONDING PROSIMPLUS FILES	*PSPS_EX_EN–V1- Process-Without-Reuse.pmp3* *PSPS_EX_EN–V2-Current-Process.pmp3* *PSPS_EX_EN–V3-Integrated-Process.pmp3* *PSPS_EX_EN–V4-Integrated- Process-With-Regeneration-Unit.pmp3*

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1 PROCESS MODELING

1.1 Process description

This example presents the simulation of a frozen potatoes production site ([GAR20] and [GAR21b]). The transformation process is carried out in several steps, detailed below.

The frozen potatoes production process consumes water. During the different steps, water is mainly used for cleaning and rinsing the product. The rejected water is loaded with contaminants, which makes water recycling complex. Indeed, for quality reasons, "clean water" (water distribution network) is generally used to limit the risks of product contamination.

Considering the increasing pressure on water resources, the food industry is facing challenges about its supply.

Apart from the water used as an ingredient, a large part of the water used by the food industry is effluents, which can also include water contained in the agricultural raw material. The treatment and management of these effluents represent in some cases a heavy burden for the industry, as well as a significant loss of raw material.

Faced with these challenges, the minimization of water consumption is necessary. The optimization and redesign of the water network including the possibility of recycling lightly loaded water or aqueous flows after an adequate purification treatment (regeneration) can be interesting solutions.

One of the methods for process water integration is the Water Pinch Analysis (WPA). This method allows to reduce the water consumption of the processes via the pinch method. More details about this method are provided in the appendix (cf. 4 Appendix). In the same way, it is possible to consult the "Water pinch analysis" help of the module in ProSimPlus to obtain more information on its use in this steady state processes simulation software.

The main goal of this example is to present the simulation of the agri-food process of a frozen potatoes production in order to apply the water pinch analysis. The following steps are studied:

- In order to check the performance of the existing reuses, a first analysis of the process (version V1) is performed without these existing reuses, by using the "Water Pinch Analysis" module. The goal of this analysis is to propose new water reuses with a water diagnostic of the actual network. The new reuses thus found can be compared to those already present on the production site. In addition, this initial analysis will determine the maximum amount of reusable water, which will then be used as a benchmark in quantifying the performance of the water network.
- In a second step (version V2), a water pinch analysis is done with the current process (taking into account these existing reuses). The reuses found during this 2nd step will be added to the existing ones. At the end of this step, there is no more direct reuse possible (version V3) in theory. The only way to further reduce water consumption is to use regeneration units to purify one or more water rejects (wastewater) in order to reuse it within the process [GAR21a].

- During this last step for the water consumption reduction, a regeneration unit by membrane filtration is added to the process to treat one of the effluents. A final water pinch analysis is performed on this process with regeneration (version V4).

Consequently, 4 versions of the process are presented (associated with 4 different simulation files « .pmp3 »):

- Process without reuse (V1);
- Current process (V2);
- Integrated process (V3);
- Integrated process with a regeneration unit (V4).

1.2 Process flowsheet

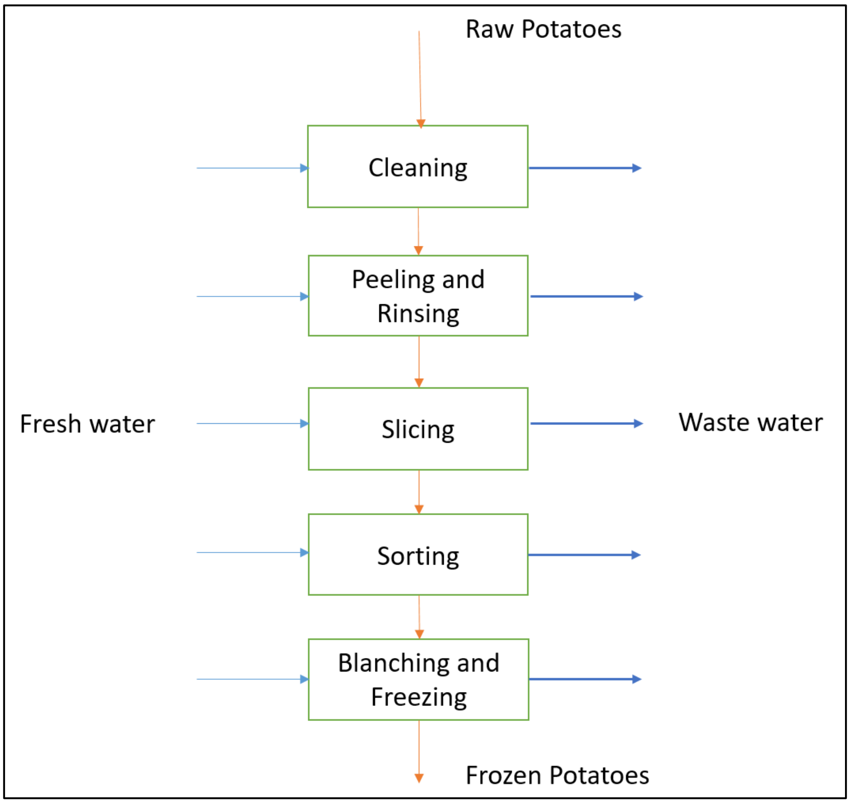
This agri-food process transforms a raw vegetable into a frozen product in 5 main steps:

- Cleaning;
- Peeling and Rinsing;
- Slicing;
- Optical sorting;
- Blanching and Freezing.

During the cleaning step, the remaining impurities, such as sludge or sediments, are removed from the vegetable. Then the vegetables are peeled and rinsed to remove the skin and the remaining sludge from the potatoes. After the peeling and rinsing step, the potatoes are cut such as French fries or potato chips. Poorly cut vegetables or pieces that do not meet the specifications are sorted. At the end of the sorting step, the French fries are blanched with steam, to improve the visual aspect and the conservation of the product. Finally, they are frozen.

At the beginning, the impurities are in the potatoes stream. But, during every operation, the concentration of impurities in the vegetable streams will decrease, while the water ones will increase ([GAR20] and [GAR21b]).

It is important to note the significant use of water in all these steps and therefore the interest to carry out an analysis of the water consumption.



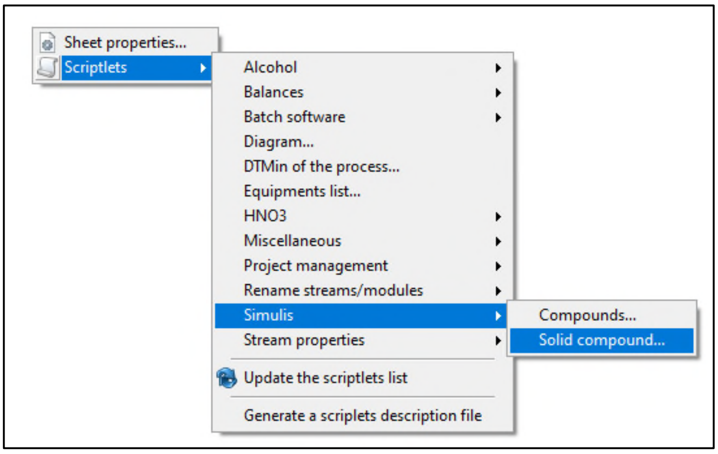
1.3 Compounds

1.3.1 « Potato »

Potatoes are composed of 75% starch and 25% dry matter. More precisely the composition of the starch is described below:

Element	Mass fraction (%)
Carbon (C)	44.4
Hydrogen (H)	6.2
Oxygen (O)	49.4
Total	100

Potato is off course not present in the standard pure components database of ProSimPlus [WIL21]. Therefore, this compound has to be created as a new compound in order to run the simulation via ProSimPlus. For this purpose, the scriptlet "Solid compound..." can be used. An example of use has been provided in the example “PSPS_EX_EN-IGCC-Plant”.

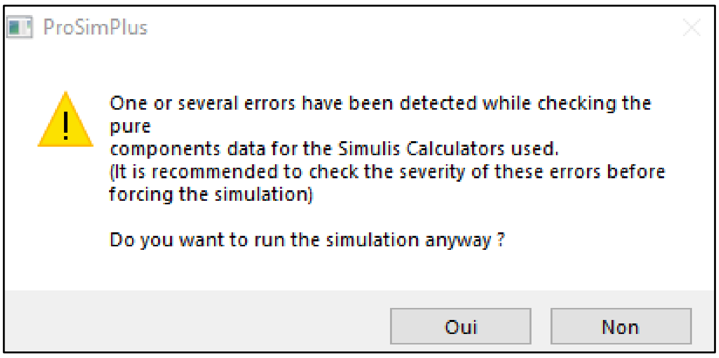


The dry matter is modeled by silica (Si) and the overall composition used to create the “Potato” compound is the following:

Element	Mass fraction (%)
Carbon (C)	33.30
Hydrogen (H)	4.65
Oxygen (O)	37.05
Silica (Si)	25.00
Total	100

This composition is provided to the "Solid compound… " scriptlet, to automatically create this new compound.

During the creation of the "Potato" compound, some properties are not calculated, and the user has to fill them to avoid the following warning.



The following potato properties are missing:

- Liquid viscosity;
- Vapor viscosity;
- Liquid thermal conductivity;
- Vapor thermal conductivity;
- Surface tension;
- Critical temperature.

In this study case, the above properties are filled by using the properties of the Glucose compound from the standard pure components database [WIL21]. These properties are not used for the analysis of this example.

Comment: It is also possible not to fill the above properties and to use the "standard" or "medium" mode for printing formats in the setting of the simulation report.

1.3.2 « COD » (Chemical Oxygen Demand)

In the case of potatoes processing, there are many contaminants, such as glucose, fructose and various organic materials. In order to simplify the example and to illustrate the water pinch analysis, all contaminants are aggregated via a pseudo-compound named “COD”. This pseudo-compound is used to represent the Chemical Oxygen Demand (COD). The COD represents everything that is likely to consume oxygen. This COD is the contamination level which limits the reuse of water within the process.

For this study, the COD is mostly due to the significant presence of glucose. Therefore the "Glucose" compound is used to model all the sugars present and the COD in general.

1.3.3 Final compounds list

In summary, the compounds considered in the simulation are listed in the table below, as well as their origin and their CAS numbers[1]. The properties of pure substances are taken from the standard ProSim database [WIL21]

Compound	Origin	CAS Number[1]
Potato	Created component	55000-00-5
COD	Standard database (Glucose renamed)	50-99-7
WATER	Standard Database	7732-18-5

[1]CAS Registry numbers® are the intellectual property of the American Chemical Society and are used by ProSim SA with the express permission of ACS. CAS Registry Numbers® have not been verified by ACS and may be inaccurate

1.4 Thermodynamic model

The “Bio applications with solids” model is selected. This model is specifically used to simulate bio processes for which few information is available about solid compounds.

Moreover, the main objective is to perform a water mass balance of the process. Thermodynamic equilibrium and thermal aspects are not taken into account. Indeed, all calculations are done at 25°C and 1 atm (except for the filter step of the spiral wound membrane filter, which is done under pressure, see 1.8 Integrated process).

So, the choice of the thermodynamic model is not the critical point for the analysis of this study case.

1.5 Operating conditions

In all versions, the potatoes feed and the component splitters are configured with the same settings

✓ Potatoes feed

		Inlet Potatoes
Mass fraction	Potato	95.5
	COD	4.5
Total mass flowrate (t/h)		4.0
Temperature (°C)		25
Pressure (atm)		1

✓ Component splitters

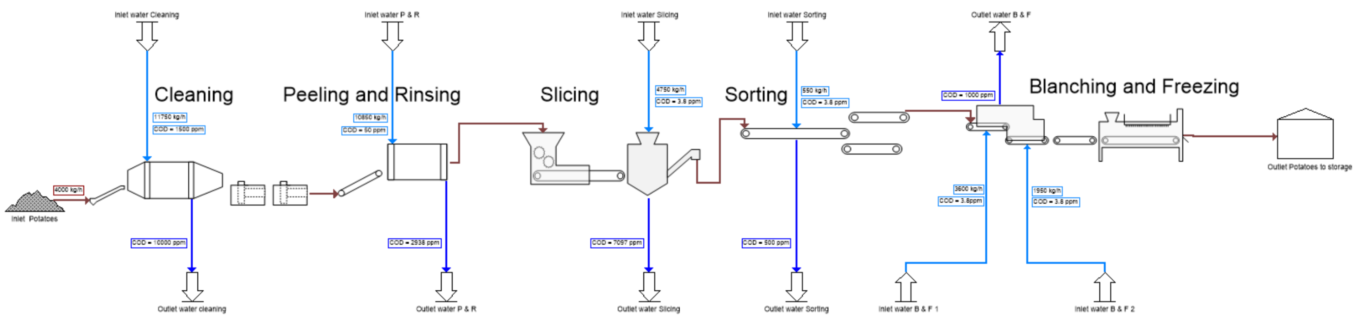
		Cleaning	Peeling and Rinsing	Slicing	Sorting	Blanching and Freezing
Overhead recovery ratios	Potato	1	1	1	1	1
	COD	0.400335	0.5986	0.288256	0.979994	0.58843
	Water	0	0	0	0	0

For each splitter, the overhead product is the potatoes stream whereas the bottom product is discharged water.

1.6 Process without reuse

The aim of this part is to carry out a water balance and a water pinch analysis by considering a process without any existing reuse. This case will be used as the reference case to quantify the water network improvement for the subsequent versions.

1.6.1 Simulation flowsheet



Simulation of a frozen potatoes processing without water reuse

1.6.2 Operating conditions

Most of the time, water distribution network ("clean water") is used as input to the food processing stages. This water is characterized by an absence of contamination (no impurities for the process). With these operating conditions, it is impossible to perform a water pinch analysis. More precisely, there is no overlap between the composite curves of the sinks and the sources and therefore no improvement is possible (cf. 4 Appendix).

The challenge is to determine the unit operations that can work with a higher level of contamination to propose water reuses within the process.

For this process, the cleaning and peeling/rinsing steps were identified as operations that can operate with contaminant loaded water without impacting the performance of the devices. This is the reason why the COD mass percentage of the cleaning and peeling/rinsing feeds is greater than the other ones.

✓ Water feeds

		Inlet water					
		Cleaning	**P & R**	**Slicing**	**Sorting**	**B & F 1**	**B & F 2**
Mass flowrate (kg/h)		11 750	10850	4750	550	3600	1950
Temperature (°C)		25	25	25	25	25	25
Pressure (atm)		1	1	1	1	1	1
Weight percent	**Water**	99.85	99.995	99.99962	99.99962	99.99962	99.99962
	COD	0.15	0.005	0.00038	0.00038	0.00038	0.00038

1.6.3 Results

✓ Water balance

Water balance (water consumption)	m^3/h	33.5
	kg/h	33 432

The amount of water consumed for the process without considering the existing water reuses is 33.5 m^3/h (it will be the reference point for the comparisons between the different cases).

✓ Water Pinch Analysis

All sinks and sources with their flowrates and mass fraction of contaminants are listed in the report:

STREAM NAME	STREAM TYPE	MASS FLOWRATE (F) (kg/h)	CONTAMINANT MEASUREMENT (C) (-)
Out Cleaning	Source	11850.9	9.999996E-03
Out P & R	Source	10881.4	2.938492E-03
Out Slicing	Source	4783.93	7.096971E-03
Out Sorting	Source	550.273	4.999893E-04
Out B & F	Source	5555.53	9.999978E-04
In Cleaning	Sink	11750.0	1.500000E-03
In P & R	Sink	10850.0	5.000000E-05
In Slicing	Sink	4750.00	3.800001E-06
In Sorting	Sink	550.000	3.800001E-06
In B & F 1	Sink	3600.00	3.800001E-06
In B & F 2	Sink	1950.00	3.800001E-06

Water Pinch Analysis	
MWR: Maximum Water Reuse (kg/h)	10 317
FW: Minimum Fresh Water (kg/h)	23 133
WW: Minimum Wastewater (kg/h)	23 305

Actual fresh water consumption and discharges can be calculated as follows:

$$Curent\ water\ consumption = MWR + FW$$

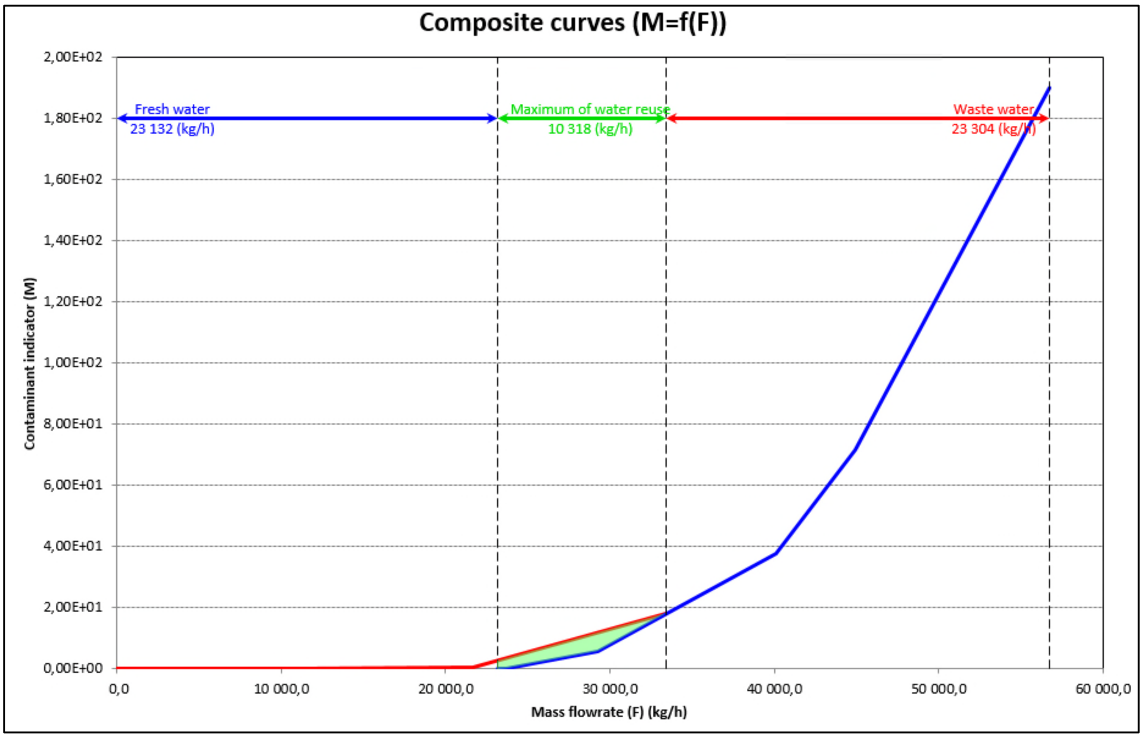
$$Curent\ water\ discharge\ = MWR + WW$$

Water consumption (kg/h)	33 450
Water discharge (kg/h)	33 622

Comment: The "Water balance" module computes the water consumption and discharge of the process without considering the other components. The module "Water Pinch Analysis" provides the total flowrate of water streams taking into account the impurities (COD contamination in the present case). This is the reason why the results are not exactly the same between the "Water balance" module and the "Water Pinch Analysis" module. In any case, the water consumption of the "Water balance" module is used as a reference.

✓ Composite curves

The composite curves are automatically drawn in the « Profiles » tab of the “Water Pinch Analysis” module:



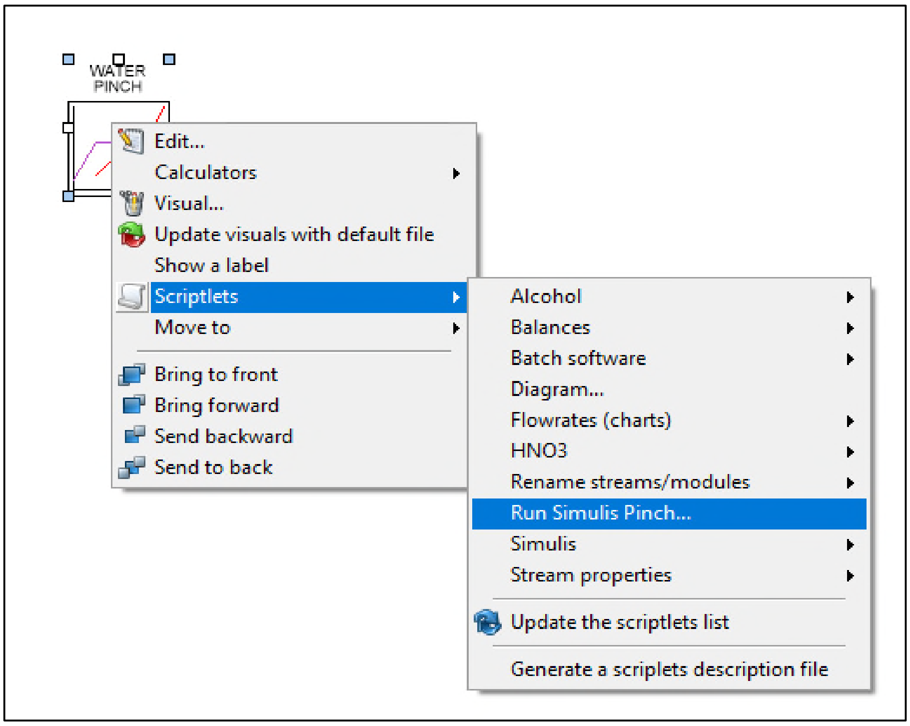
The composite curves plot is one of the main results of the water pinch analysis. For this example, it is possible to notice a reuse potential (MWR) of ≈ 10.3 t/h.

Comment: the graph above is extracted from the Simulis Pinch Water results.

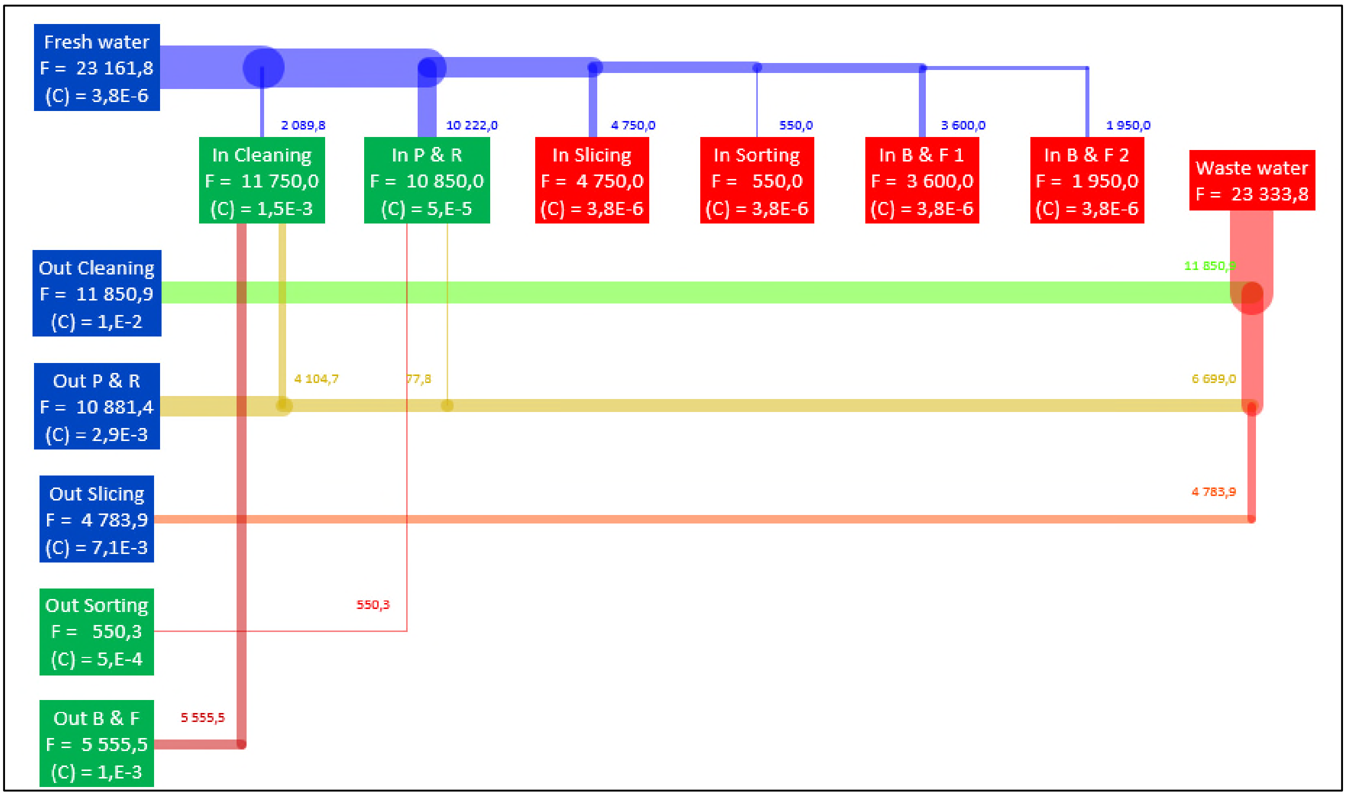
✓ Water network

The water pinch analysis is a water diagnosis of the process. This method does not directly propose a new water network to reduce water consumption and discharges. ProSim has developed a tool to solve this problem: Simulis Pinch. This software works in the Microsoft Excel® environment. There are 2 modules: "Simulis Pinch Energy" for the proposal of a heat exchanger network based on the thermal pinch method and "Simulis Pinch Water" for the proposal of a water network based on the water pinch method.

It is possible to use Simulis Pinch by using a scriptlet in the ProSimPlus environment:



By using Simulis Pinch Water, a new water network can be proposed (a license for this software is required):



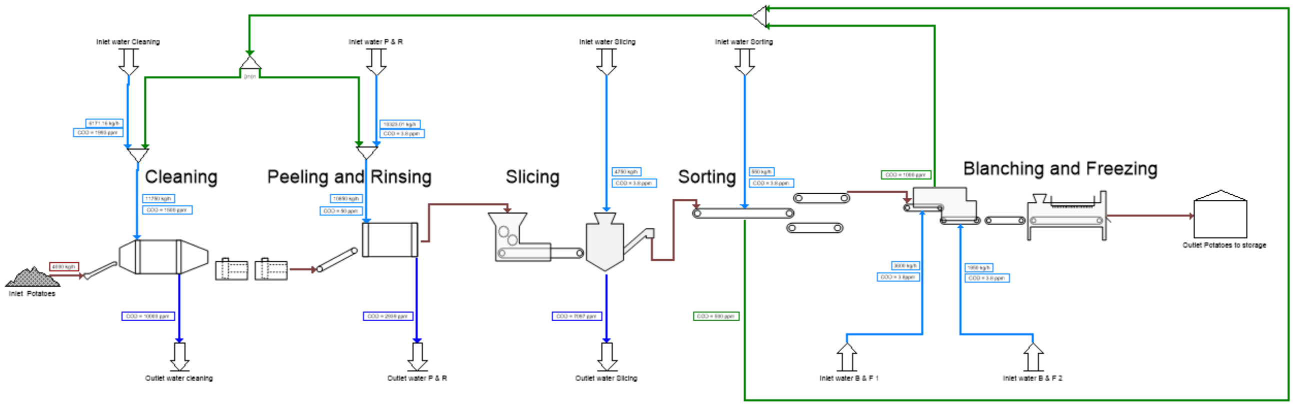
The network proposes to reuse the blanching and optical sorting output streams to partially replace the cleaning and peeling operations inputs. In addition, the discharge water from the peeling could be partially reused to also feed the cleaning and peeling operations. In this case, 99.71% of the water is reused, or ≈ 10.3 t/h.

The current process has already reused between the discharges from the blanching and optical sorting stages and the water supplies for the cleaning and peeling/rinsing stages. The existing reuses are consistent with the network proposed by Simulis Pinch Water: therefore, these reuses are efficient and relevant.

1.7 Current process

This second version (V2) presents the process in its current configuration. A water pinch analysis and the data from the previous version (V1) will allow to quantify the performances of the current process.

1.7.1 Simulation flowsheet



Simulation of the current frozen potatoes processing

1.7.2 Operating conditions

✓ Water feeds

		Inlet water					
		Cleaning	**P & R**	**Slicing**	**Sorting**	**B & F 1**	**B & F 2**
Mass flowrate (kg/h)		6 171	10 323	4 750	550	3 600	1 950
Temperature (°C)		25	25	25	25	25	25
Pressure (atm)		1	1	1	1	1	1
Mass fraction	**Water**	99.8007	99.99962	99.99962	99.99962	99.99962	99.99962
	COD	0.1993	0.00038	0.00038	0.00038	0.00038	0.00038

✓ Recycling stream splitter

Parameters	D101
Supplied specification	Mass flowrates
Stream from splitter to rinsing feed (kg/h)	527

1.7.3 Results

✓ Water balance

Water balance (water consumption)	m^3/h	27.4
	kg/h	27 332

✓ Water Pinch Analysis

STREAM NAME	STREAM TYPE	MASS FLOWRATE (F) (kg/h)	CONTAMINANT MEASUREMENT (C) (-)
Out Slicing	Source	4783.93	7.097024E-03
Out Cleaning	Source	11850.9	1.000009E-02
Out P & R	Source	10881.4	2.938514E-03
In Cleaning	Sink	6171.16	1.993000E-03
In P & R	Sink	10323.0	3.800000E-06
In Slicing	Sink	4750.00	3.800001E-06
In Sorting	Sink	550.000	3.800001E-06
In B & F 1	Sink	3600.00	3.800001E-06
In B & F 2	Sink	1950.00	3.800001E-06

The reuses already present on the site have the effect of reducing the number of sources, from 5 to 3. In addition, the flowrates and concentrations of some sinks have been reduced by considering the existing reuses.

Water Pinch Analysis	
MWR: Maximum water reuse (kg/h)	4 212
FW: Minimum Fresh Water (kg/h)	23 132
WW: Minimum Wastewater (kg/h)	23 304
Water consumption (kg/h)	27 344
Water discharge (kg/h)	27 516

The water pinch analysis still highlights an integration potential (MWR) for the current process. Thus, the actual water network on the site is not the optimal one. It remains 40% of the MWR calculated at the first step (simulation V1). The Simulis Pinch Water tool indicates an additional reuse between the waste water of the peeling/rinsing step and the cleaning water inlet. This reuse is implemented in the version V3.

1.8 Integrated process

For this version, the current process with the additional reuse between the peeling/rinsing and cleaning is implemented. With this reuse, 99.3% of the water is reused within the process through direct reuse (without regeneration unit). With this current status, it is impossible to significantly reduce water consumption by adding new reuses (MWR ≈ 0 kg/h).

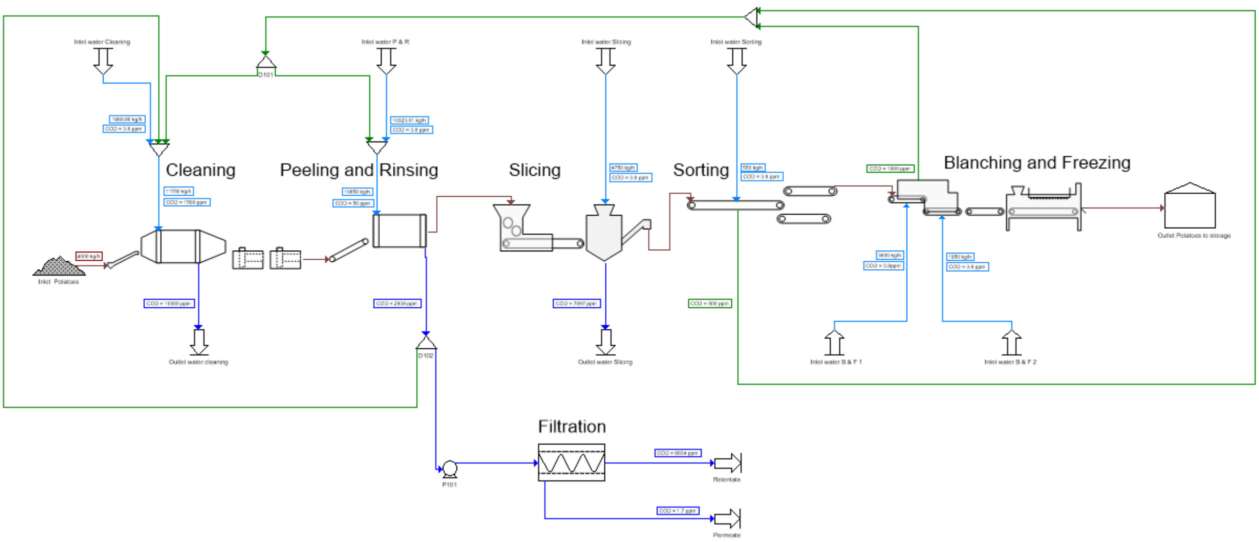
Nevertheless, to further reduce water consumption, it is possible to use one or more regeneration unit(s). The purpose of the regeneration units is to purify one or more water discharges (by removing contaminants) to be able to reuse it within the process.

The V3 version is the simulation of the integrated water network presented in the results of the V2 version, with a regeneration unit.

By analyzing discharge concentrations and flowrates, the wastewater from the peeling/rinsing step is the most relevant for testing the implementation of a regeneration unit. A membrane filter (regeneration unit) is added to treat the wastewater from the peeling/rinsing stage.

The interest of this membrane filter is to reduce the contaminant load to reuse the treated flow within the process.

1.8.1 Simulation flowsheet



Simulation of an integrated frozen potatoes process

1.8.2 Operating conditions

✓ Water feeds

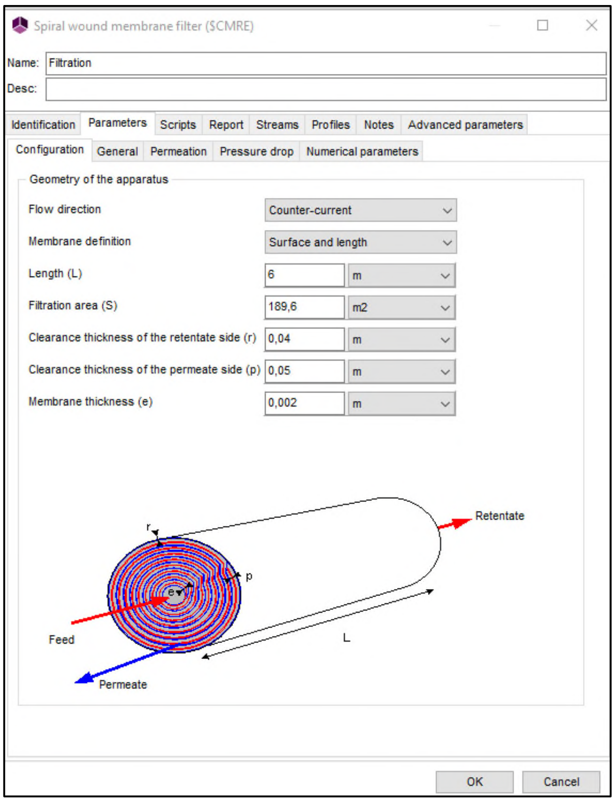
		Inlet water					
		Cleaning	**P & R**	**Slicing**	**Sorting**	**B & F 1**	**B & F 2**
Mass flowrate (kg/h)		1 989	10 323	4 750	550	3 600	1 950
Temperature (°C)		25	25	25	25	25	25
Pressure (atm)		1	1	1	1	1	1
Mass fraction	**Water**	99.99962	99.99962	99.99962	99.99962	99.99962	99.99962
	COD	0.00038	0.00038	0.00038	0.00038	0.00038	0.00038

✓ Centrifugal pump

Exhaust pressure (bar)	6.5585
Volumetric efficiency	0.65
Mechanical efficiency	0.95
Electrical efficiency	0.99

✓ Spiral wound membrane filter

Setting up the desing and operating parameters of this filter is made through the 5 tabs presented below:



1. Configuration

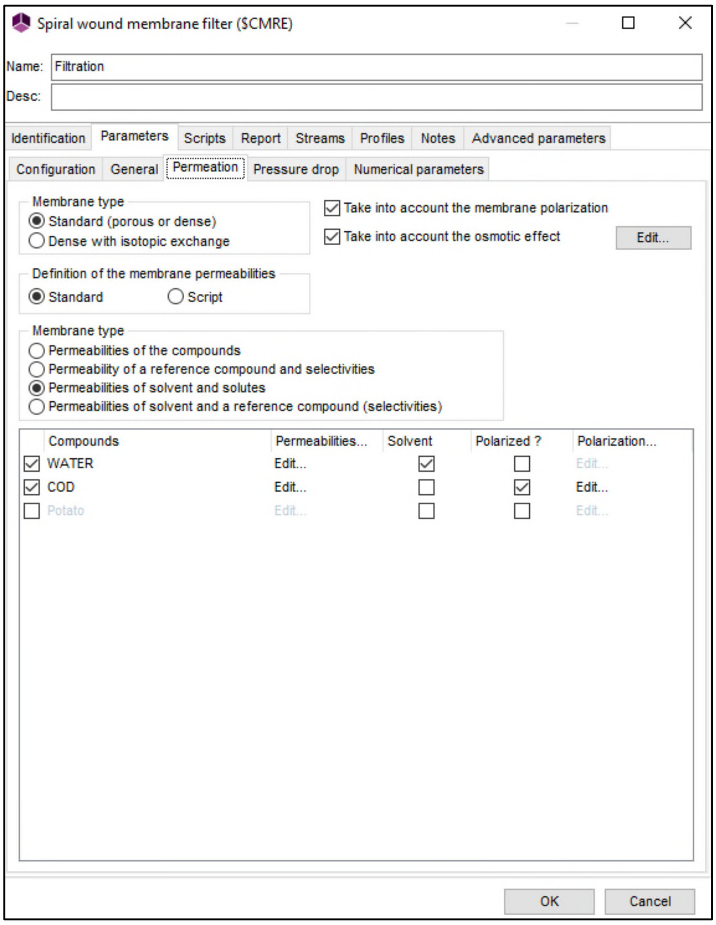
Flow direction	Counter-current
Membrane definition	Surface and length
Length (m)	6
Filtration area (m²)	189.6
Thickness of the retentate side (m)	0.04
Thickness of the permeate side (m)	0.05
Membrane thickness (m)	0.002

2. General

Temperature (°C)	25
Physical state	Liquid
Permeate side pressure (bar)	1

3. Permeation

All the following ckeckboxes have be ticked:



Default osmotic values are used. The permeabilities and polarization values of water and COD are the following:

Water permeability	
Permeation model	Partial pressure
Definition type	Constant
Type	Volume
Molar permeability (m²/h/atm)	1.058×10^{-5}

COD Permeability	
Permeation model	Concentration
Permeability (m/s)	1.65×10^{-9}
COD Polarization	
Model for the mass transfer coefficient (ki)	Constant
ki (m/s)	2.02×10^{-5}

4. Pressure drop

Default values are used.

5. Numerical parameters

Only the number of cells is changed to 200.

✓ Recycling stream splitter

Parameters	D101
Supplied specification	Mass flowrates
Stream from splitter to rinsing feed (kg/h)	527

Parameters	D102
Supplied specification	Mass flowrates
Stream from splitter to cleaning feed (kg/h)	4182.3

1.8.3 Results

✓ Water balance

Water balance (water consumption)	m^3/h	23.2
	kg/h	23 162

✓ Water Pinch Analysis

STREAM NAME	STREAM TYPE	MASS FLOWRATE (F) (kg/h)	CONTAMINANT MEASUREMENT (C) (-)
Out Cleaning	Source	11850.9	9.999992E-03
Out Slicing	Source	4783.93	7.096953E-03
Retentate	Source	2196.90	8.834321E-03
Permeate	Source	4501.99	1.744950E-06
In Cleaning	Sink	1988.86	3.800000E-06
In P & R	Sink	10323.0	3.800000E-06
In Slicing	Sink	4750.00	3.800001E-06
In Sorting	Sink	550.000	3.800001E-06
In B & F 1	Sink	3600.00	3.800001E-06
In B & F 2	Sink	1950.00	3.800001E-06

The concentration of all sinks is of 3.8 ppm. Only a source with a concentration below this value could be used to create additional reuse. The permeate concentration is of 1.7 ppm so, a reuse is possible.

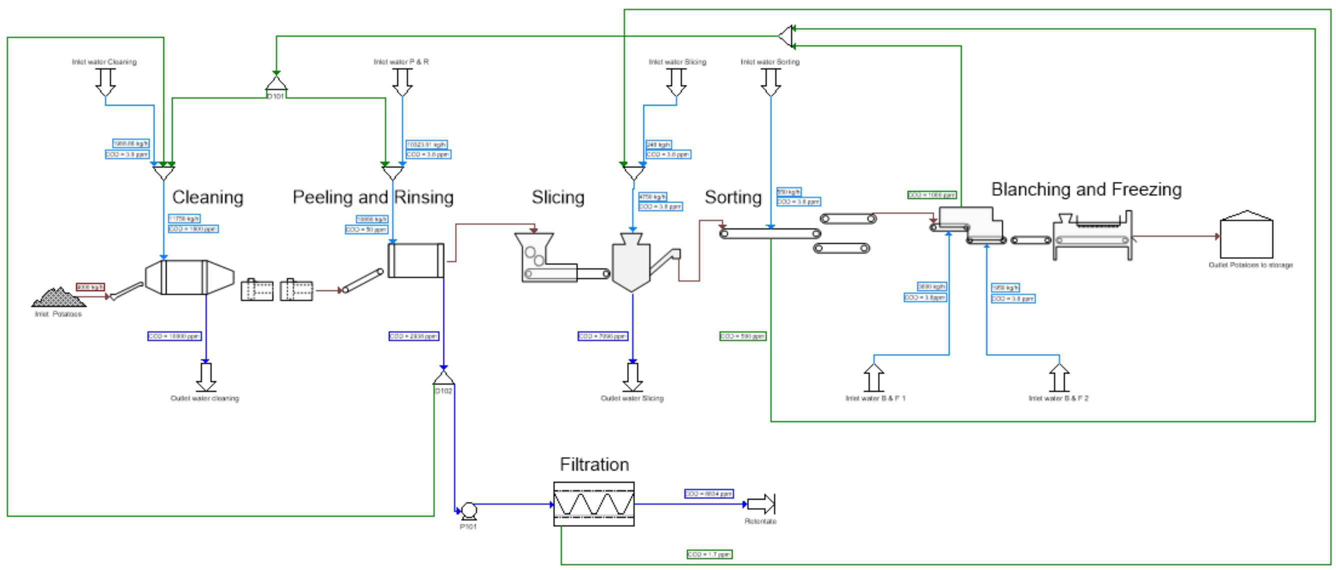
Water Pinch Analysis	
MWR: Maximum water reuse (kg/h)	4513
FW: Minimum Fresh Water (kg/h)	18 649
WW: Minimum Waste Water (kg/h)	18 820
Water consumption (kg/h)	23 162
Water discharge (kg/h)	23 333

The regeneration unit reduces the concentration of peeling/rinsing reject from 2938 ppm to 1.7 ppm. Under these conditions, the “Water Pinch Analysis” module indicates a potential reuse of 4.5 t/h.

1.9 Integrated process with regeneration unit

In this latest version, the fully integrated process with the different reuses and the regeneration unit is simulated. The “Water balance” module is used as in the previous versions to determine the water consumption and thus quantify the improvement of the water network.

1.9.1 Simulation flowsheet



Simulation of an integrated frozen potatoes process with a regeneration unit

1.9.2 Operating conditions

✓ Water feed

		Inlet water					
		Cleaning	**P & R**	**Slicing**	**Sorting**	**B & F 1**	**B & F 2**
Mass flowrate (kg/h)		1 989	10 323	248	550	3 600	1 950
Temperature (°C)		25	25	25	25	25	25
Pressure (atm)		1	1	1	1	1	1
Mass fraction	**Water**	99.99962	99.99962	99.99962	99.99962	99.99962	99.99962
	COD	0.00038	0.00038	0.00038	0.00038	0.00038	0.00038

The parameters of the stream splitters, the compound splitters and the filter are identical to the previous version (V3).

1.9.3 Results

✓ Water balance

Water balance (water consumption)	m^3/h	18.7
	kg/h	18 660

✓ Water Pinch Analysis

STREAM NAME	STREAM TYPE	MASS FLOWRATE (F) (kg/h)	CONTAMINANT MEASUREMENT (C) (-)
Out Cleaning	Source	11850.9	9.999934E-03
Retentate	Source	2196.89	8.834283E-03
Out Slicing	Source	4783.93	7.095524E-03
In Cleaning	Sink	1988.86	3.800000E-06
In P & R	Sink	10323.0	3.800000E-06
In Slicing	Sink	248.000	3.800001E-06
In Sorting	Sink	550.000	3.800001E-06
In B & F 1	Sink	3600.00	3.800001E-06
In B & F 2	Sink	1950.00	3.800001E-06

All sink concentrations are lower than source concentrations. There is no more reuse possible. The flowrates of the different streams (water supplies and discharges) have decreased during the different versions, hence the interest of this method.

Water Pinch Analysis	
MWR: Maximum water reuse (kg/h)	10
FW: Minimum Fresh Water (kg/h)	18 650
WW: Minimum Wastewater (kg/h)	18 822
Water consumption (kg/h)	18 660
Water discharge (kg/h)	18 832

The water consumption and discharge flowrates are lower than those of the version without membrane filter. Water consumption is reduced from 23.2 m^3/h to 18.7 m^3/h. The membrane filter is used to regenerate a water flow with a low concentration (the permeate) in order to reuse it within the process.

2 CONCLUSION

The table below shows the comparison of the different versions of the frozen potatoes production process.

Name	Process without reuse	Current process	Integrated process	Integrated process with a regeneration unit
Version	V1	V2	V3	V4
Pump power consumption (kW)	0	0	0	1.7
Water consumption (m^3/h)	33.5	27.5	23.3	18.6
Water discharge (m^3/h)	33.7	27.6	23.4	18.9
Specific consumption (m^3/t)	8.4	6.9	5.8	4.7
Reduction of water consumption (%)	0	18.1	30.7	44.5

The water consumption of the reference process (without reuse) is ≈33.5 m^3/h.

The implementation of reuses and of a regeneration unit reduced the process water consumption by ≈44%. Compared to the consumption of the current process (V2), the reduction is 27.5 - 18.6 = 8.9 m3/h or ≈26%.

The use of regeneration units (such as membrane filtration) reduces water consumption by increasing the potential for reuse. Nevertheless, these equipment are often more expensive (maintenance costs, replacement costs, electrical consumption...) compared to the implementation of direct reuse at low cost (mainly costs for piping and pumps). A technical-economic analysis is necessary to evaluate the proposed solutions.

The various improvements proposed have reduced the specific water consumption of the process from 8.4 m^3 to 4.7 m^3 per ton of frozen potatoes.

3 REFERENCES

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4 APPENDIX

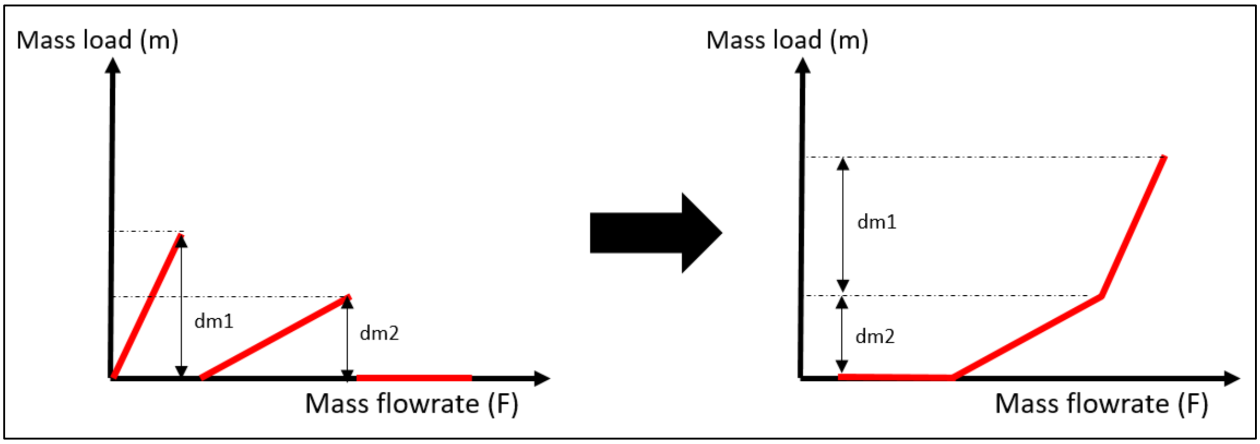
Pinch analysis or Pinch technology is a rigorous and structured method for optimizing the consumption and discharge of a process. This pinch analysis (or method) was initially developed and applied to the energy domain.

The main characteristic of Pinch analysis is to determine, for a particular process or for the whole plant, the minimum consumption of energy, water or even hydrogen necessary for its operation. It is therefore possible to assess the maximum potential for improvement, even before starting detailed design work. The method can be applied systematically for each process of the plant or globally for the entire site.

Typical savings identified with a Pinch analysis in industrial sectors such as petroleum refining, chemicals, steel, pulp and paper, petrochemicals, and agribusiness are in the range of 10-35% (for the energy pinch applications) [CAN03].

The first step of the pinch method is to construct the composite curves. To draw these curves, it is necessary to know the values of the flowrates *F* (in t/h for example) and the concentration of contaminant *C* (in ppm for example) for each inlet and outlet stream of the process. The composite curves represent the profile of the available water sources ("source composite curve") and the profile of water needs ("sink composite curve"). Depending on their shape and location, these curves provide information on the possibilities for water recovery within the process.

The following figure shows the construction of the sink composite curve on a Mass load-Mass flowrate diagram. The sink composite curve is constructed simply by accumulating the load and flow of currents taken by increasing load value.



The construction is based on the following equation:

$$m = \frac{F \times C}{1000}$$

With:

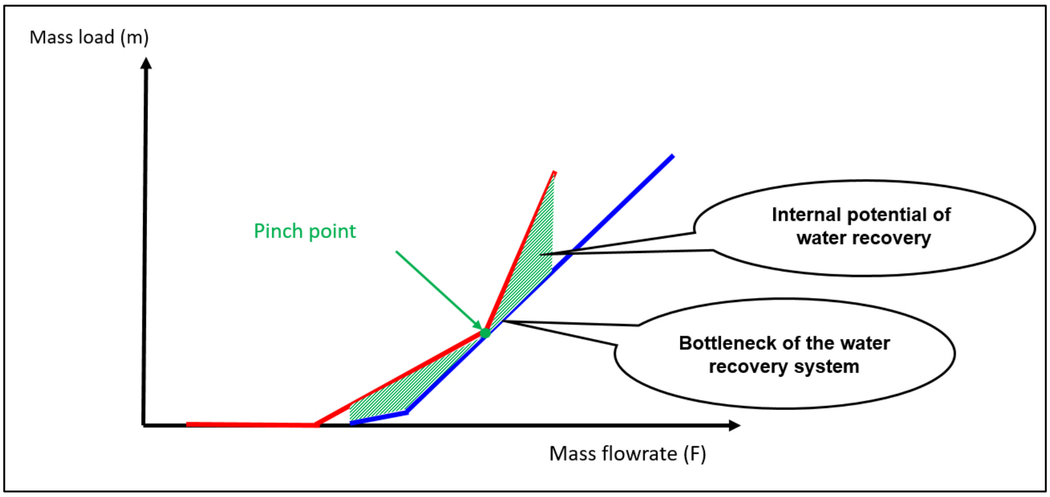
m : Mass load of contaminant (kg/h)

F : Mass flowrate (t/h)

C : Contaminant concentration (ppm)

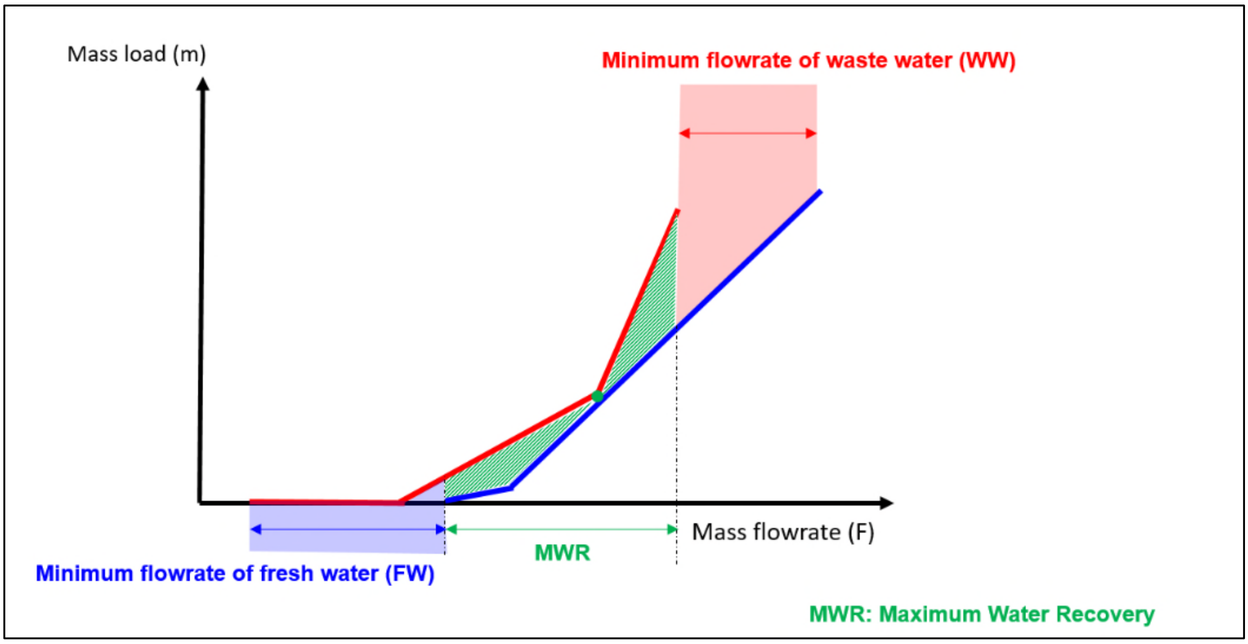
The source composite curve is calculated with the same method.

To establish the minimum water consumption and discharge targets for the process, the sink composite curve (the red one) is positioned on the same diagram as that of the source composite curve (the blue one).



The 2 curves are translated horizontally until they touch each other. The sink composite curve must be above the source composite curve. The contact curve between the two curves is called the “Pinch point”.

The overlap area between the two curves represents the Maximum Water Reuse (MWR). The side areas (on the right and left of the overlap area) represent respectively the minimum flowrates of Fresh Water (FW: Fresh Water) and Waste Water (WW: Waste Water).



Pinch analysis is used to establish targets for the minimum water consumption and discharge flowrates necessary to meet the needs of a process, even before starting the design of the water network. This allows to quickly identify the extent of water savings that can be considered at an early stage of the analysis. This advantage is probably the most interesting that Pinch analysis offers.

