Process Optimization
For Wastewater Minimization

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OUTLINE

1. Background
2. Waste water Minimization 종류 및 방법
3. Water Regeneration
   - Single Contaminants
   - Multiple Contaminants
4. Water Regeneration re – use
   - Single Contaminants
   - Multiple Contaminants
5. Water Regeneration recycling
   - Single Contaminants
6. Concluding Remarks

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6. Concluding Remarks

1. Back ground

- 환경오염규제강화 (수질오염)
- 물 사용량 최소화
- Total Re-cycle System 구현을 위한
  Minimum Water System

- 물 사용 억제

  ⬇

  물의 중수도화 (재사용)

  ⬇

  물의 재생 (오염물 제거)

  ⬇

  Water Total Re-cycle System 의 최적 설계 구현

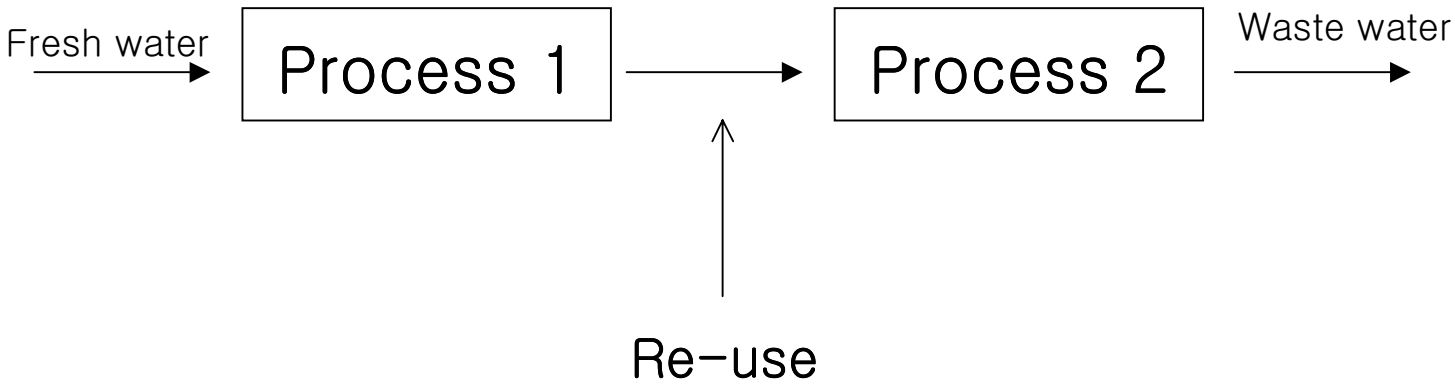
- 적용 사례 - 두산 파카 크리스탈

2. Waste Water Minimization

2-1. 종 류

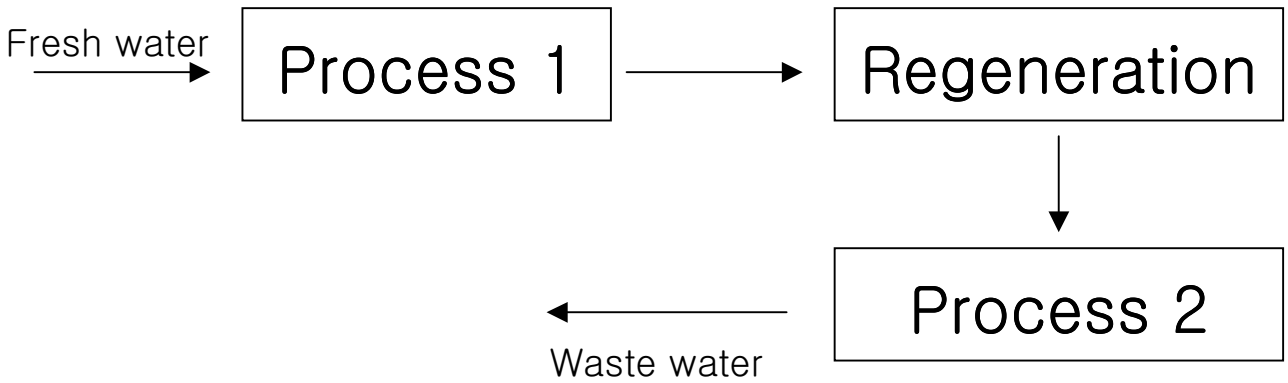
- Re - use
- Regeneration Re-use
  - Chemical Oxidation
  - Filteration
  - Carbon absorption
  - Steam Stripping
- Regeneration recycling

- Re – use



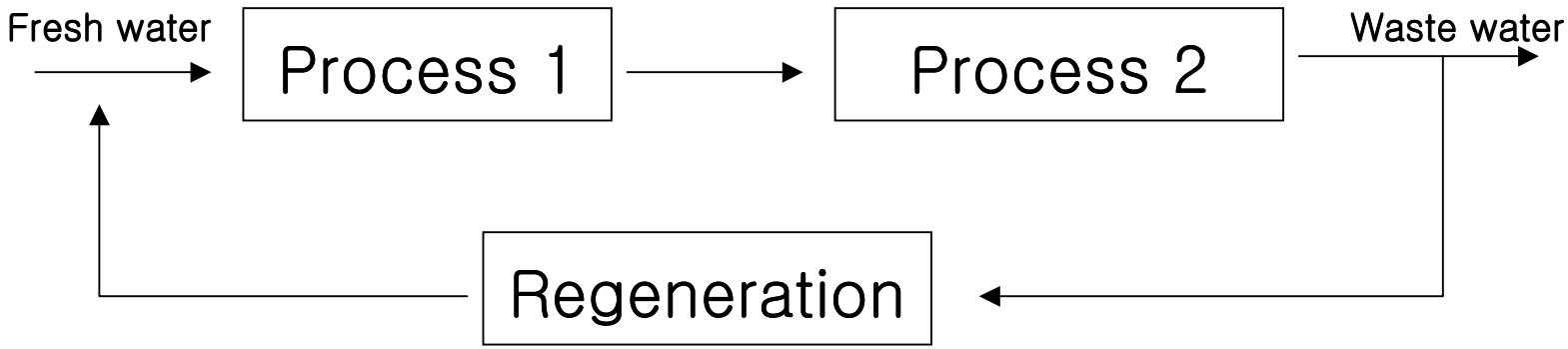
– 사용된 water 가 다른 공정에서 재사용되어진다.

- Regeneration re-use



- Water 의 유속이 모두 같다.

- Regeneration recycling



– Water 의 유속이 다르고, 부반응이 개입될 수 있다.

• 3 가지 방법의 공통점

(1) Fresh water 의 Volume 감소

(2) Waste water 의 Volume 감소

– 각 방법의 Volume 감소 정도는 차이를 보인다.

※ Volume = [m^3 / hr]

• 3 가지 방법의 특징

▶ Re-use : Waste water load 오염물질량이 대부분 불변이다.

▶ Regeneration re-use : Waste water load 가 줄어든다.

▶ Regeneration recycling :

Waste water load 가 Regeneration re-use 보다 더 줄어든다.

Regeneration 비용이 많이 들어간다.

부가적인 오염물질 생성 (e.g. byproducts of corrosion)

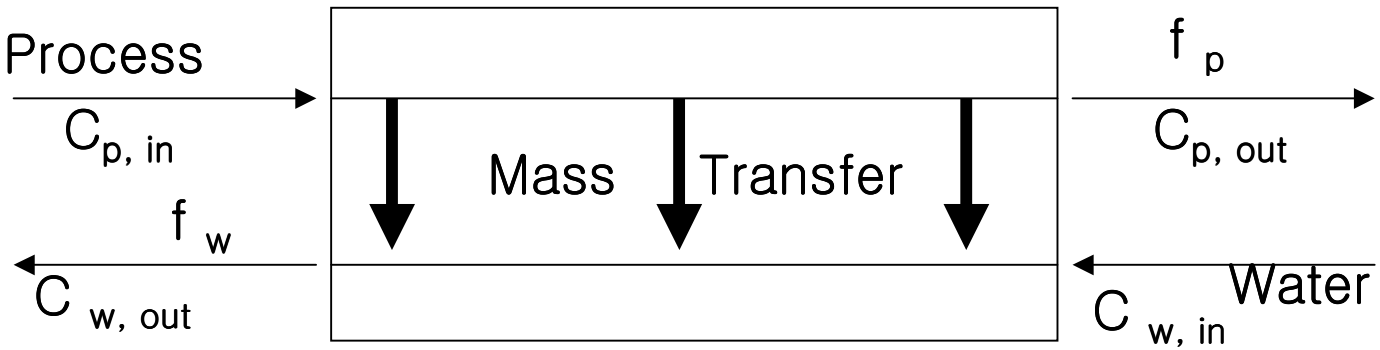
※ regeneration takes up part of the effluent load

- 3가지 Waste water Minimization 의 오염물의 수에 따른 접근법

1) Single contaminants 의 경우 Waste water 의 최소화

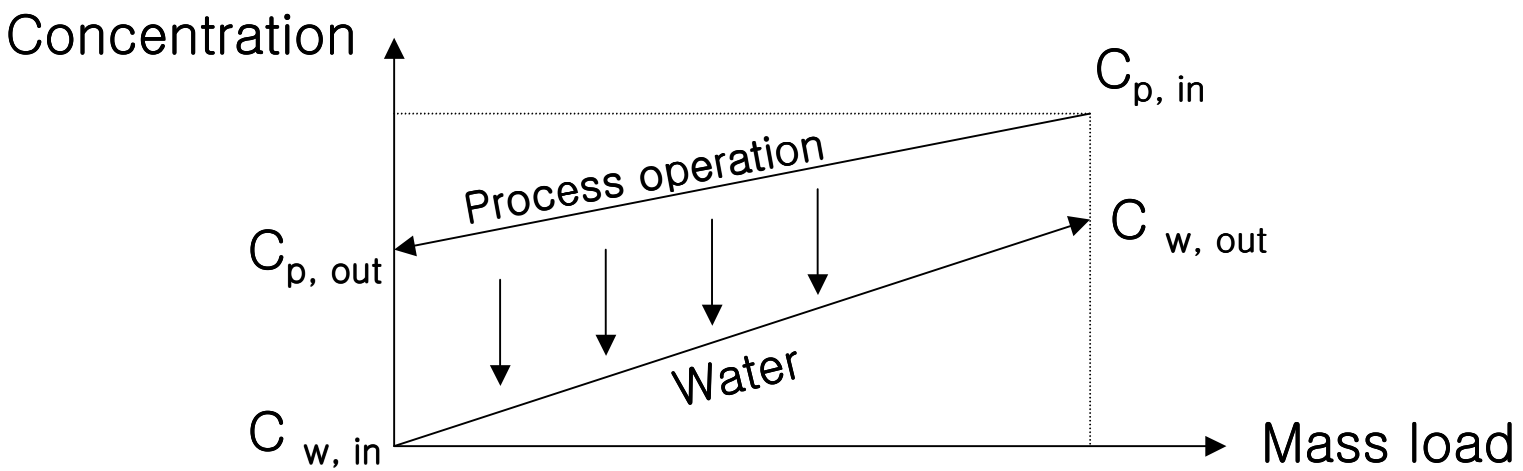
2) Multiple contaminants 의 경우 Waste water 의 최소화

- Water 사용의 원리



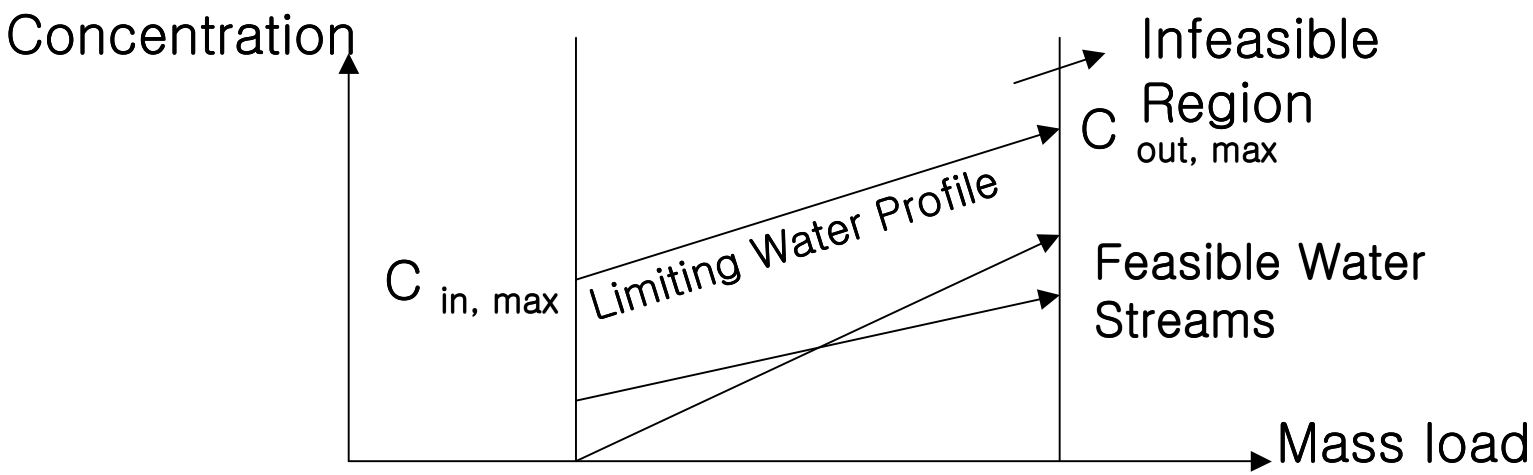
- Process 는 오염 정도가 점점 낮아지게 된다.
- Water 는 오염 정도가 점점 높아지게 된다.

- Water 의 사용 분석



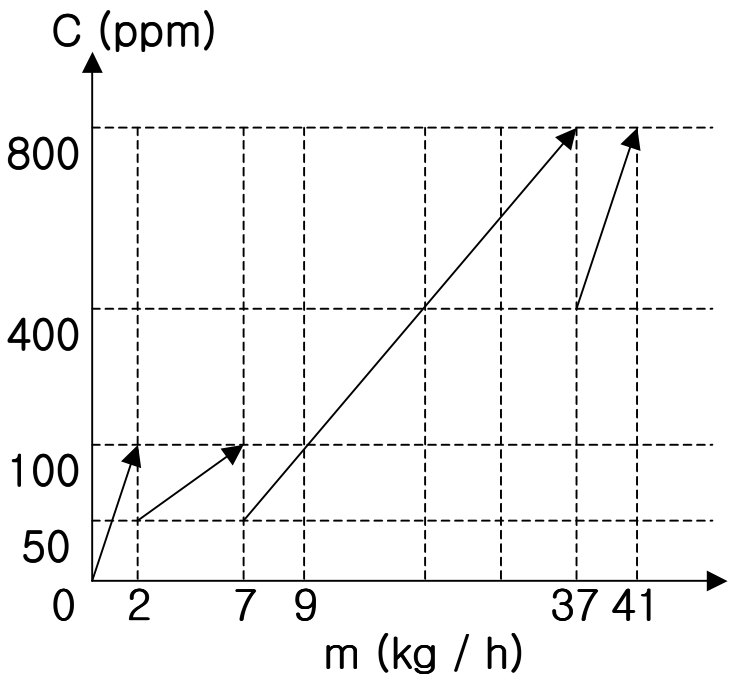
※공정에 사용되는 Water 의 inlet 과 outlet 의 농도와 전달되는 오염물의 양을 비교하여 Water의 flow rate 를 나타내고 있다.

- Limiting Water Profile

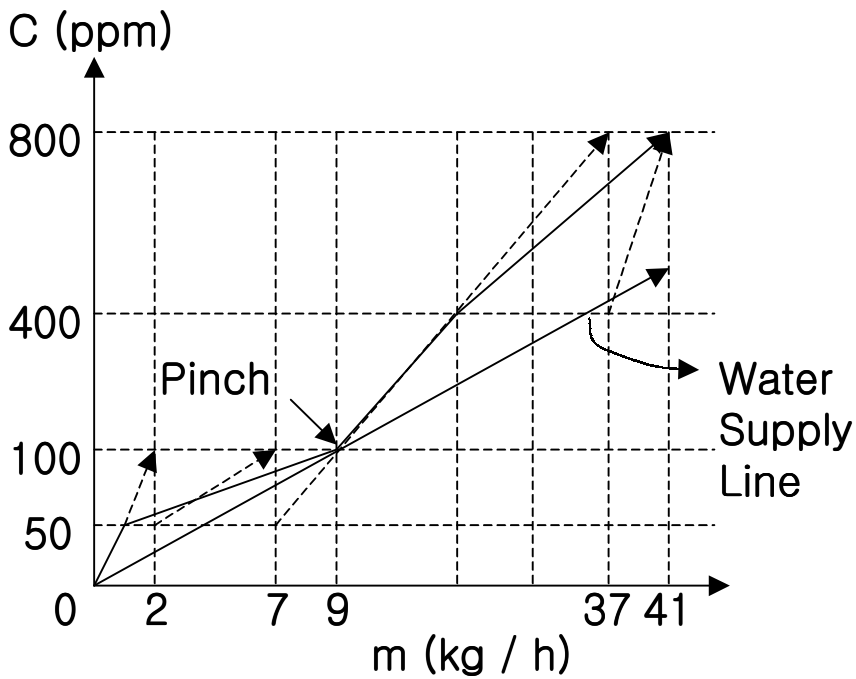


※ Limiting Water Profile 은 오염물질 처리에 있어서 Water 의 Inlet 과 Outlet 의 가장 높은 농도일 때를 나타내고 있다.

- Water 사용의 Limiting Composite Curve



Limiting Water Profile



Limiting Composite curve

3. Water Re - use

3-1. Water System Design for Single contaminants

방 법 1: maxing driving forces

⇒ Limiting composite curve 와 Water Supply line 의 농도 차를 이용하여 농도 driving force 를 최대화하는 설계법 이다.

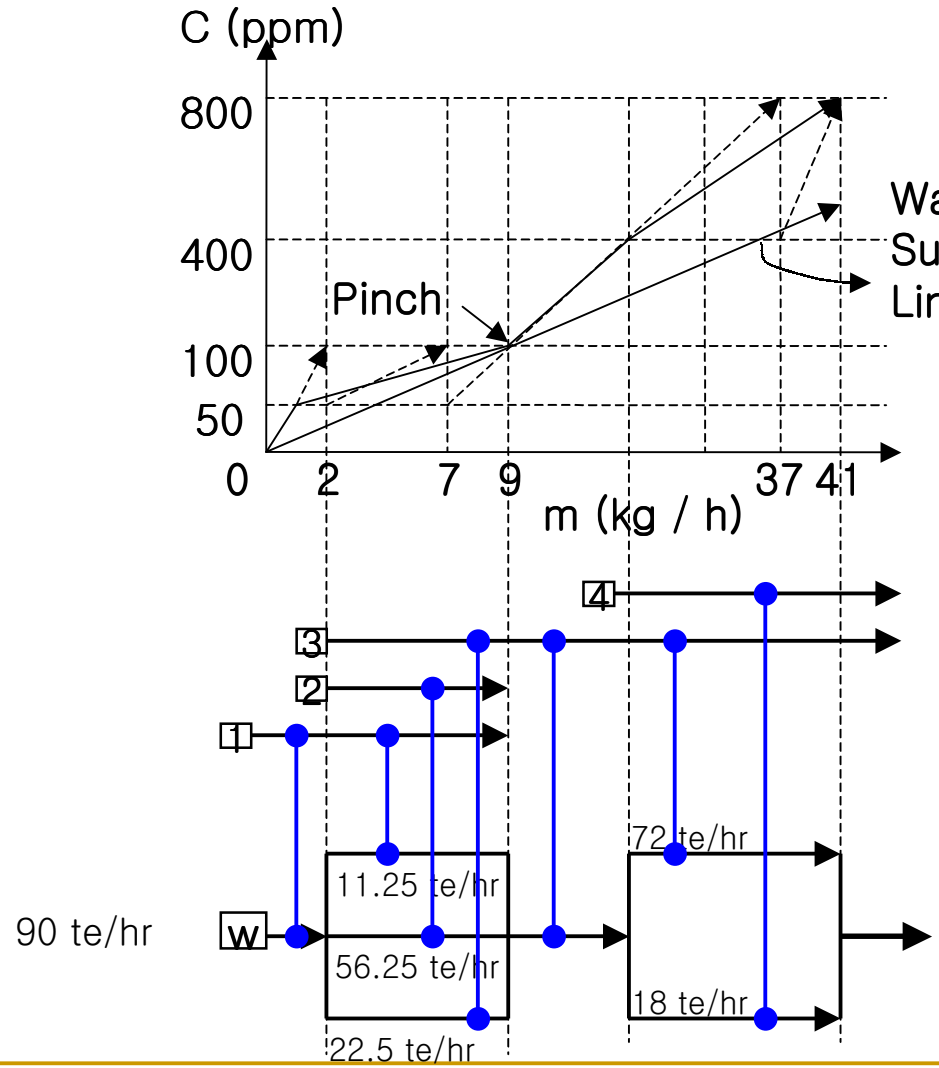
방 법 2: minimum number of water sources

⇒ Bypassing 와 Mixing 을 이용하여 최소의 flow rate를 구하여 이용한 설계법 이다.

Table 1 Wastewater System 의 예 1.

Process number	Mass load of Contaminant (kg/h)	C_{in} (ppm)	C_{out} (ppm)	Water Flowrate (te/h)
1	2	0	100	20
2	5	50	100	100
3	30	50	800	40
4	4	400	800	10

Water re-use (Maximum diving forces) 방법 1.



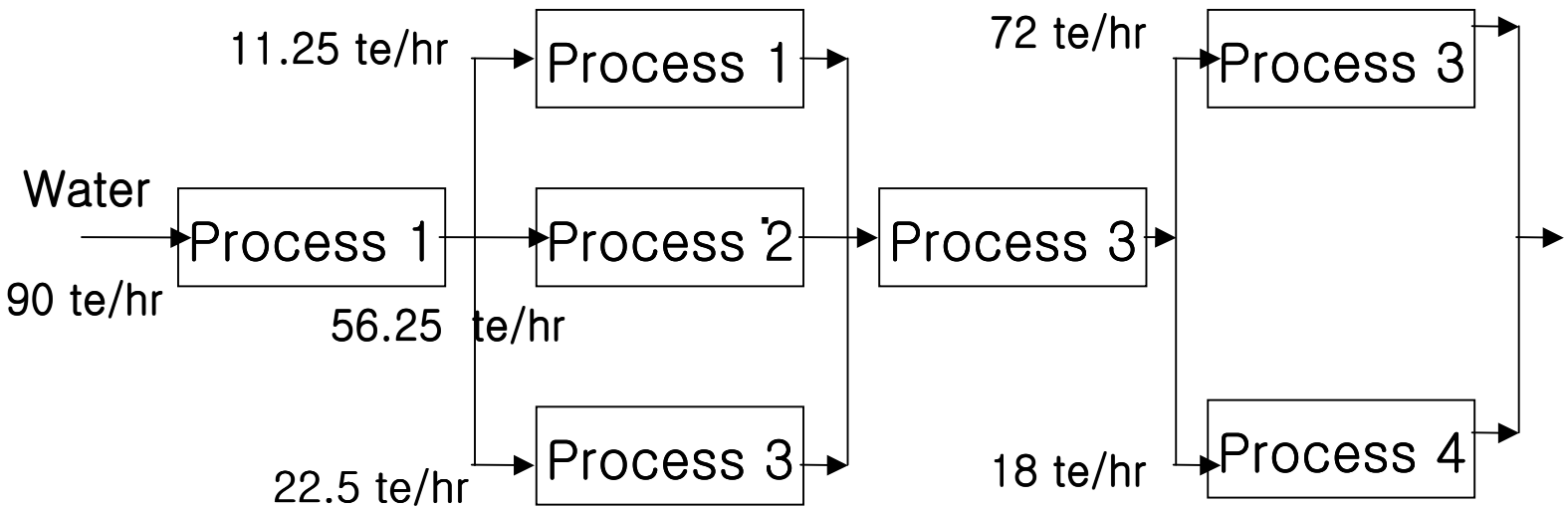
- Max. driving forces
  수직물질전달
- $\frac{1}{\text{기울기}} = \frac{\Delta m(kg/h)}{\Delta C(ppm)}$
- Water flowrate

$$= \frac{\Delta m(kg/h)}{\Delta C * (10^{-6})}$$

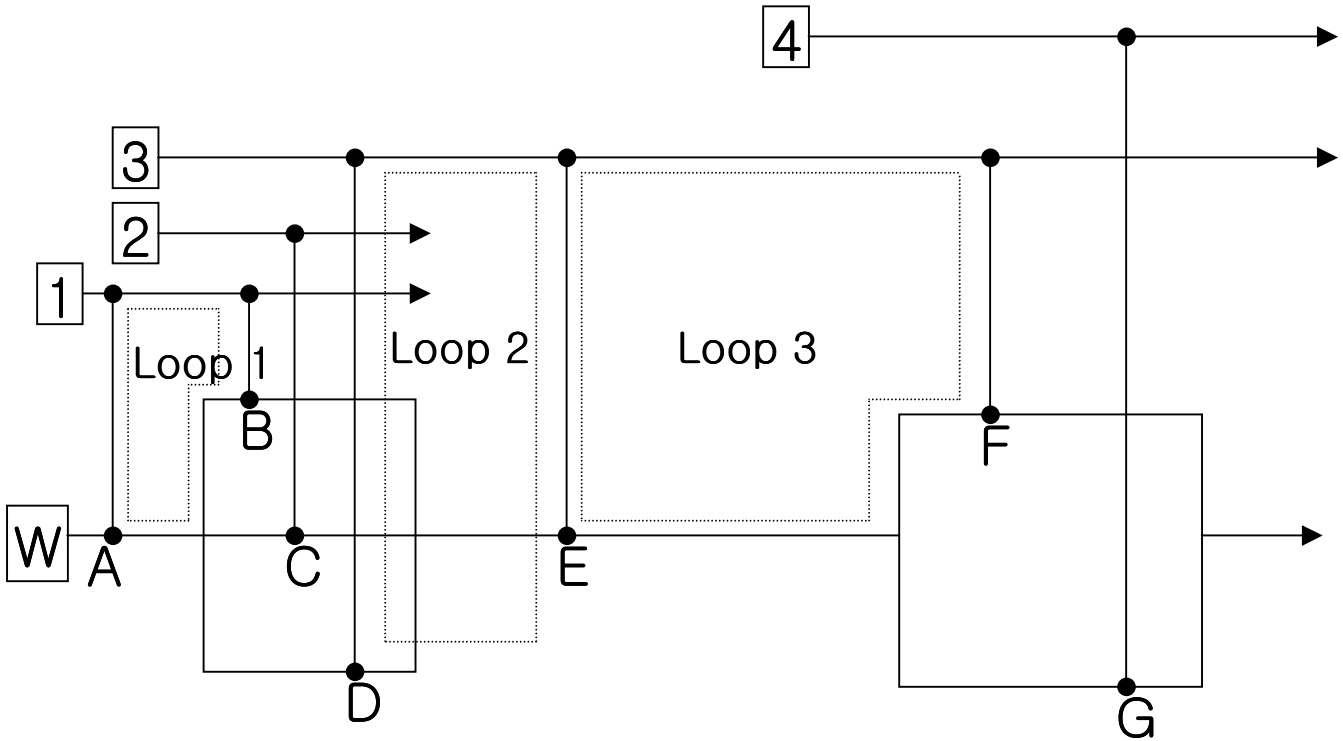
$$= \frac{\Delta m * (10^{6})}{\Delta C}(kg/h)$$

$$= \frac{\Delta m * (10^{3})}{\Delta C}(tone/h)$$

Water re-use 방법 1.

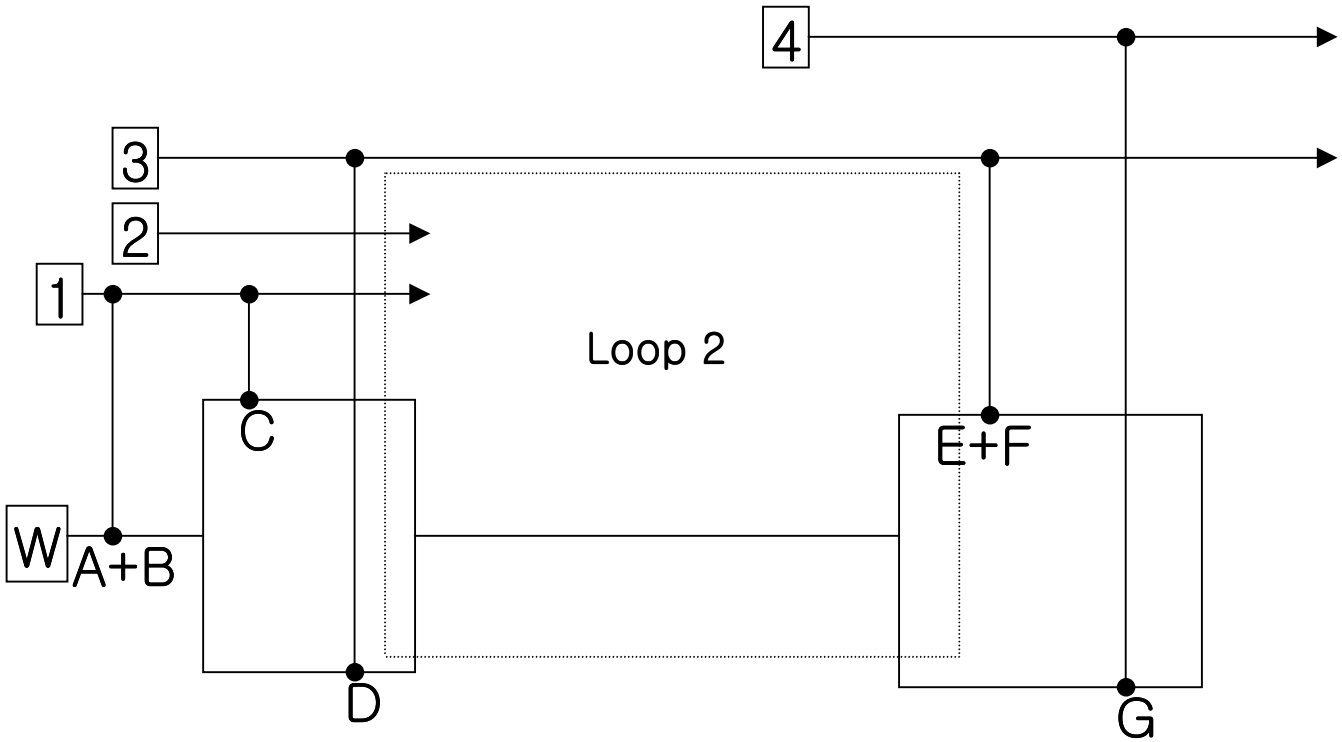


Water re-use 방법 1.



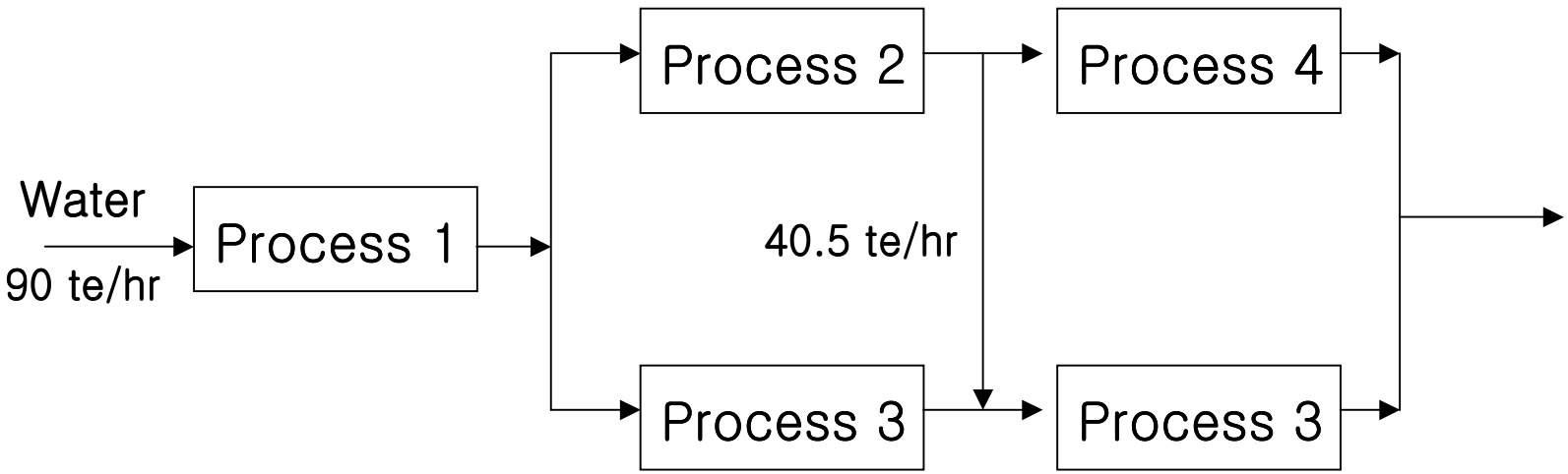
Initial design

Water re-use 방법 1.



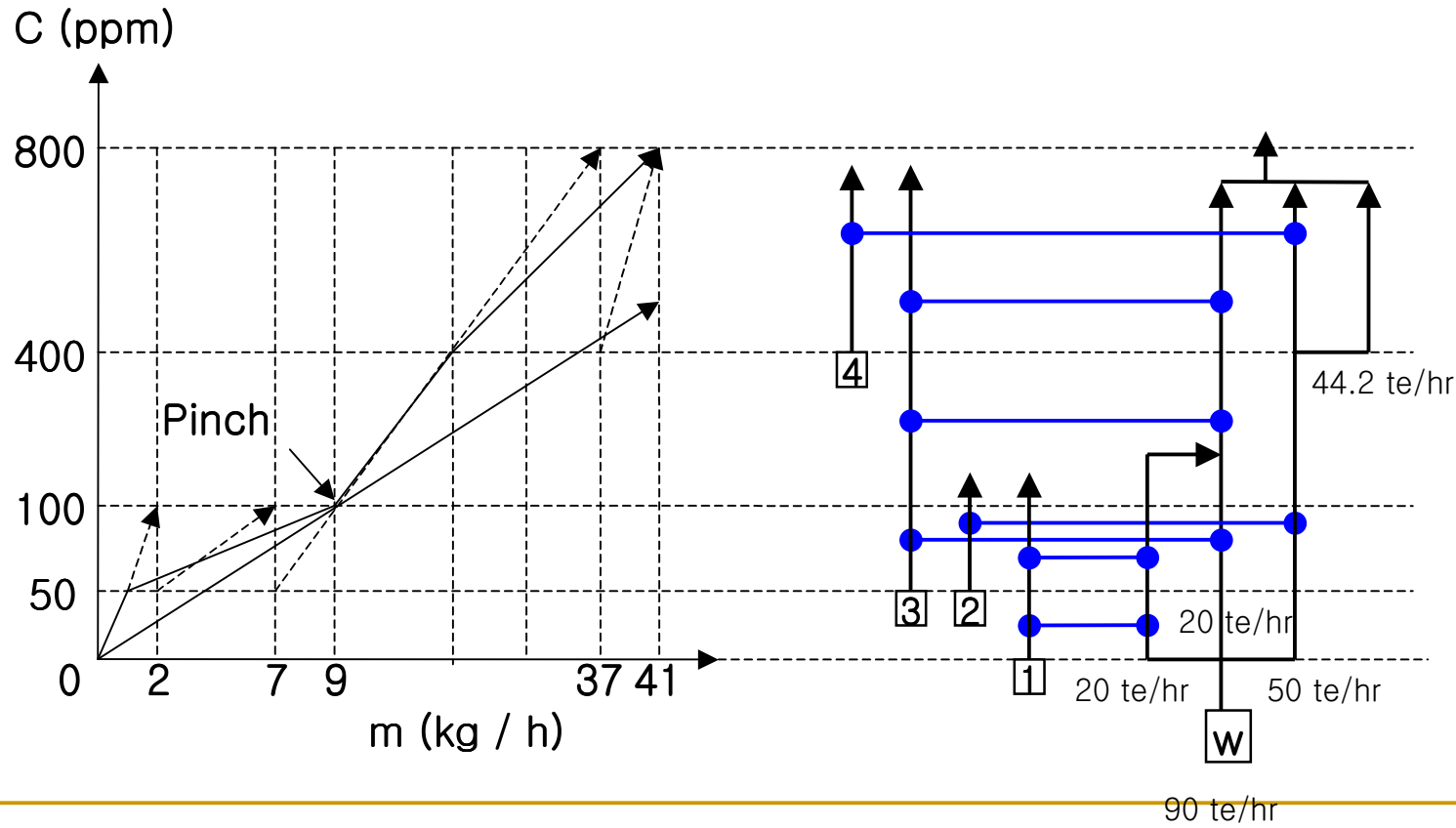
Simplified design with two loops broken

Water re-use 방법 1.

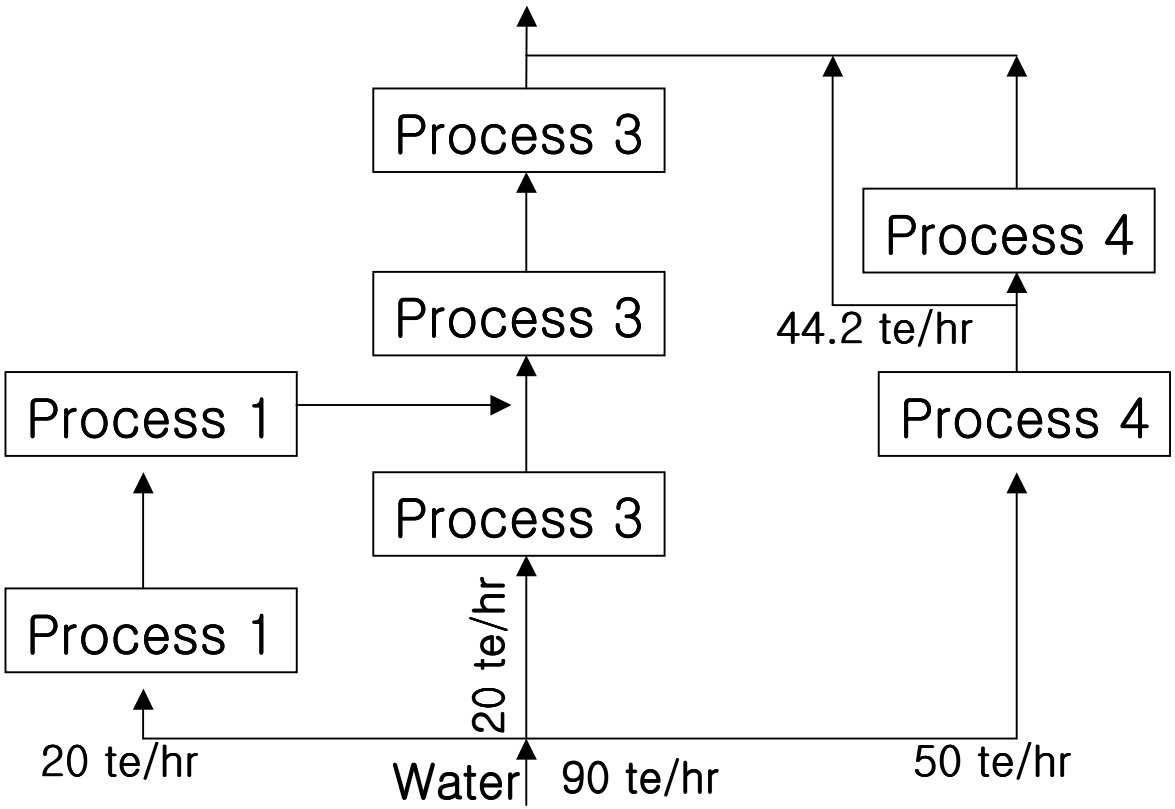


Conventional flowsheet for simplified design

Water re-use 방법 2.



Water re-use 방법 2.



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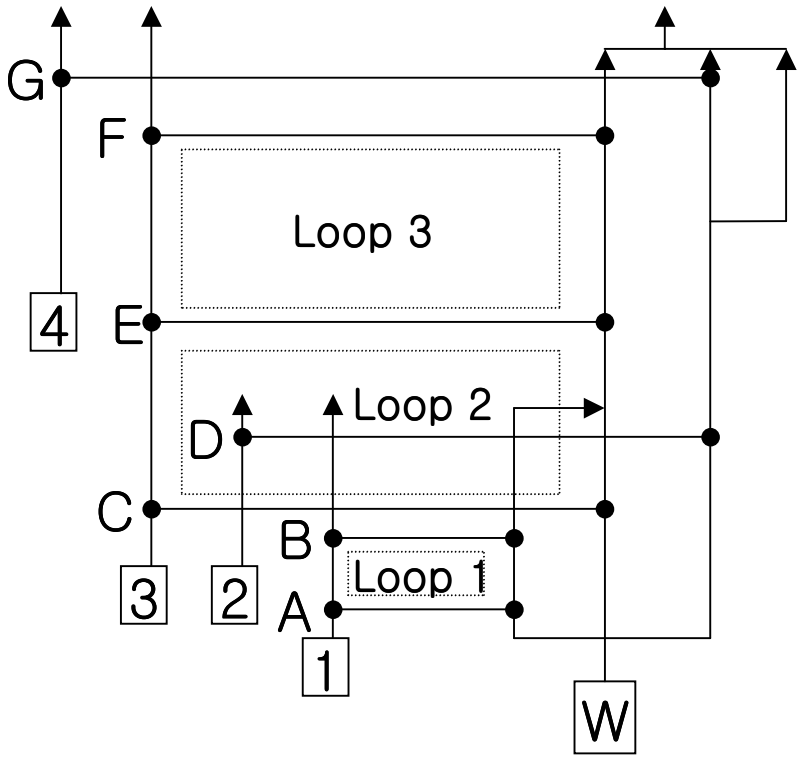

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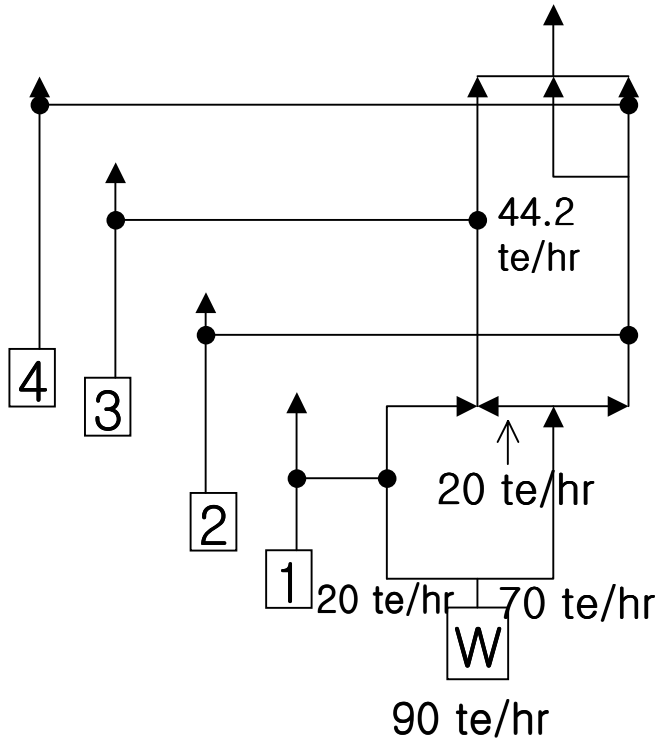
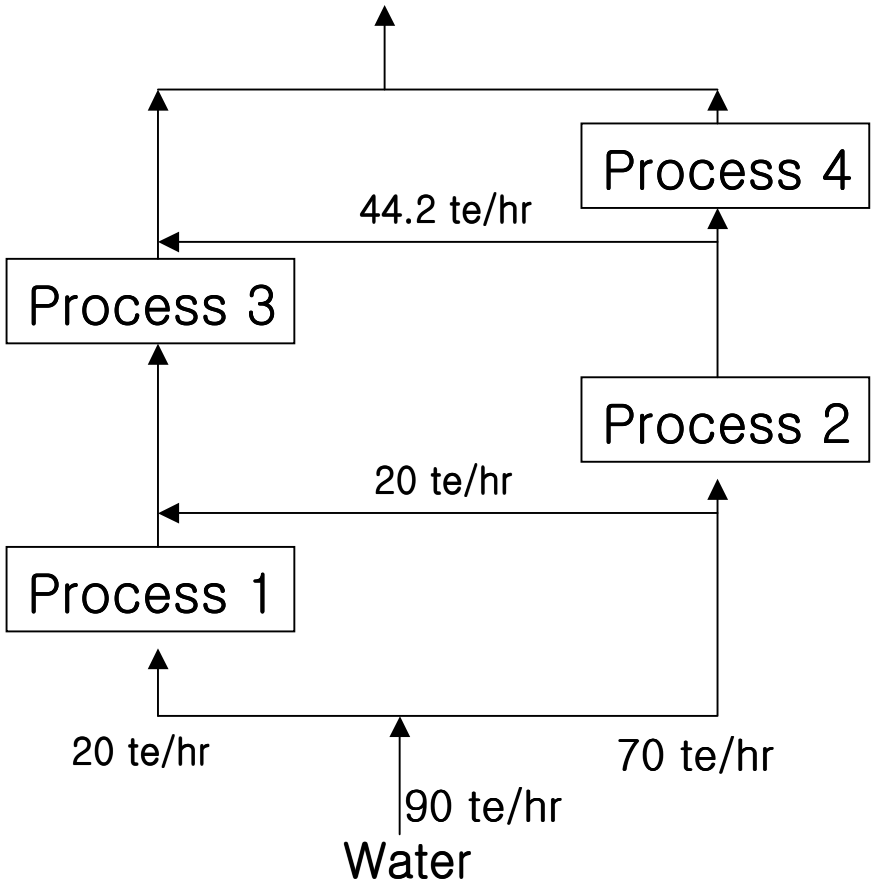


Simplified design with two loops broken

Water re-use 방법 2.



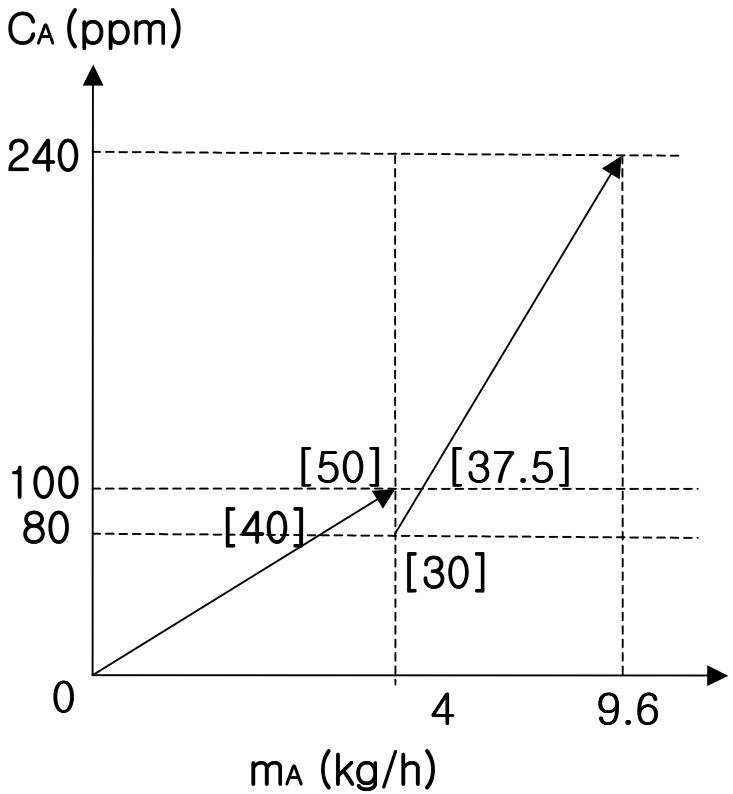
Conventional flowsheet for simplified design

Wastewater System의 예 2.

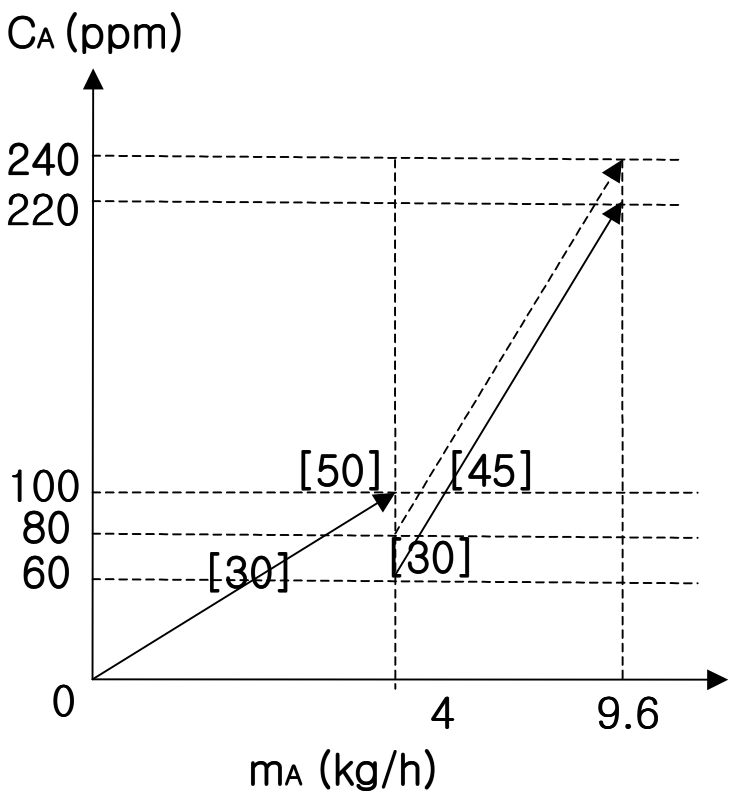
Table 2

Process number	Contaminant	Mass load of Contaminant (kg/h)	C_{in} (ppm)	C_{out} (ppm)	Water Flowrate (te/h)
1	A	4	0	100	40
	B	2	25	75	
2	A	5.6	80	240	35
	B	2.1	30	90	

Wastewater System의 예 2.

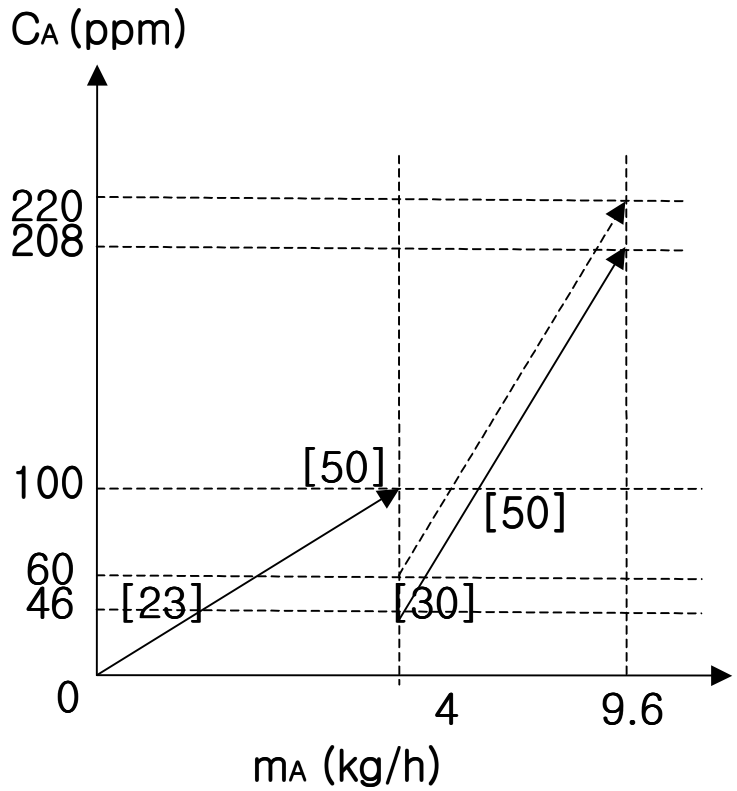


Limiting water profiles

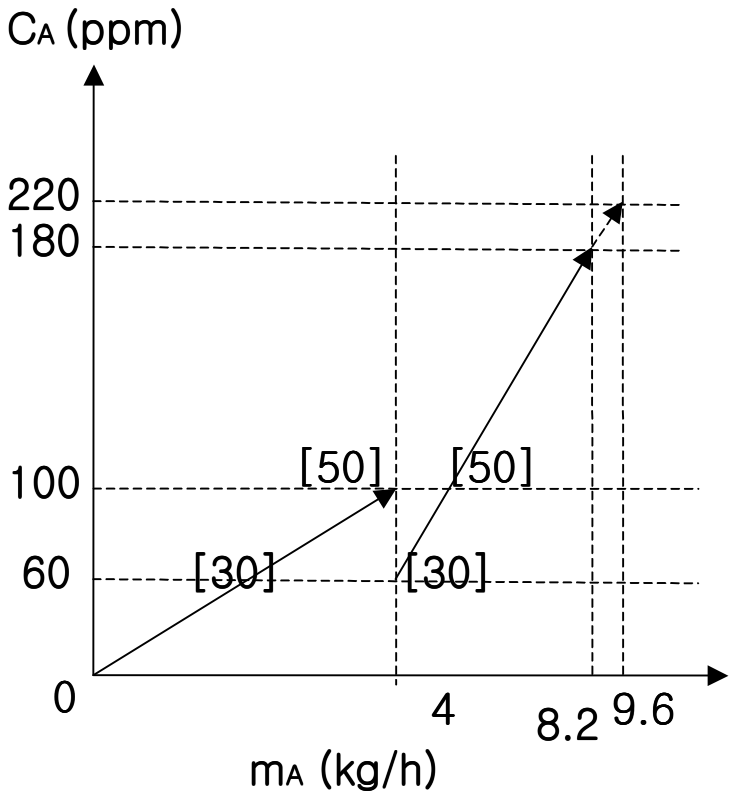


Limiting water profiles after inlet concentration shift

Wastewater System의 예 2.

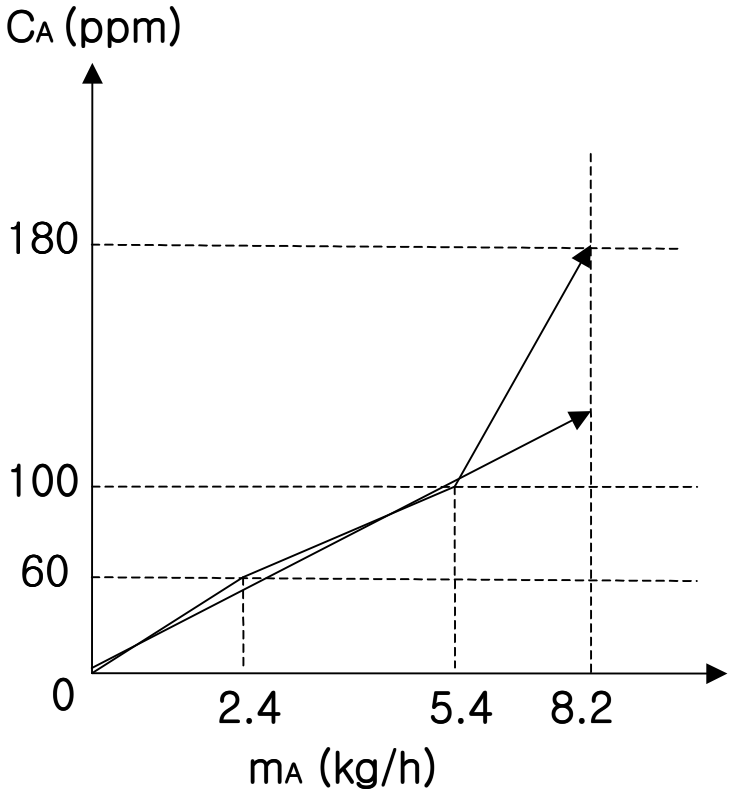


Limiting water profiles after another inlet concentration shift

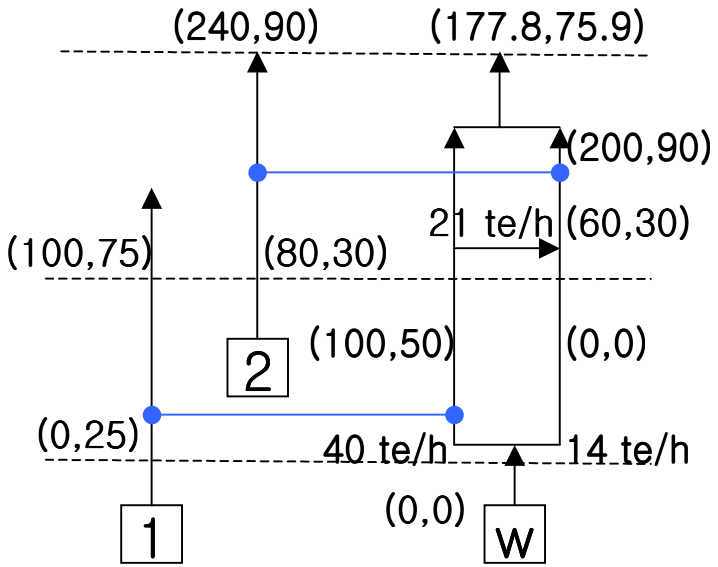


Limiting water profiles after inlet and outlet concentration shift

Wastewater System의 예 2.

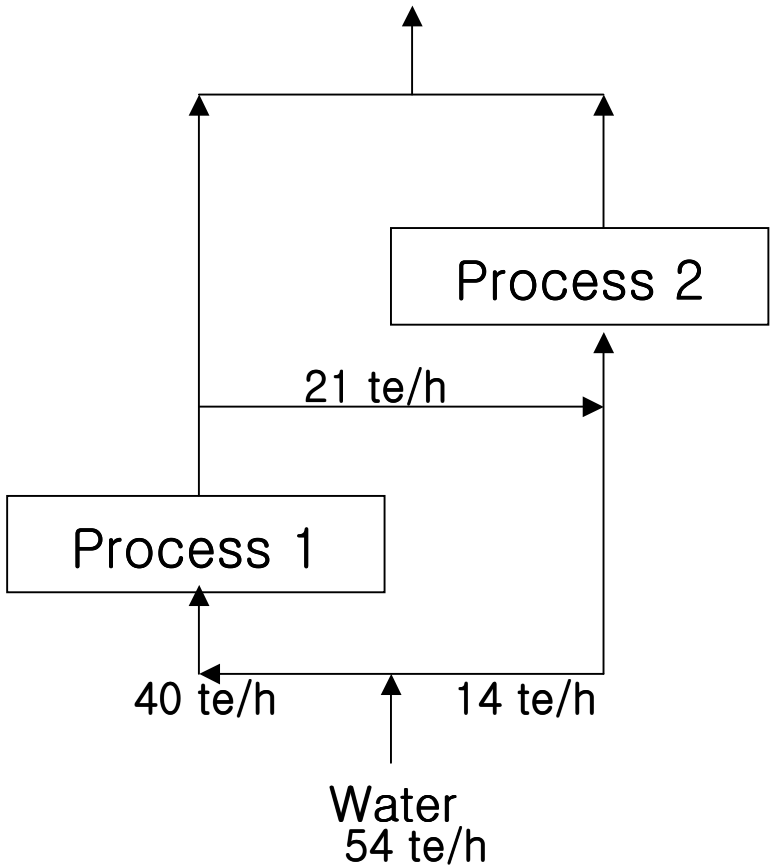


Limiting composite curve



Grid design to achieve target

Wastewater System의 예 2.



Conventional flowsheet to achieve target

4. Water Regeneration re-use

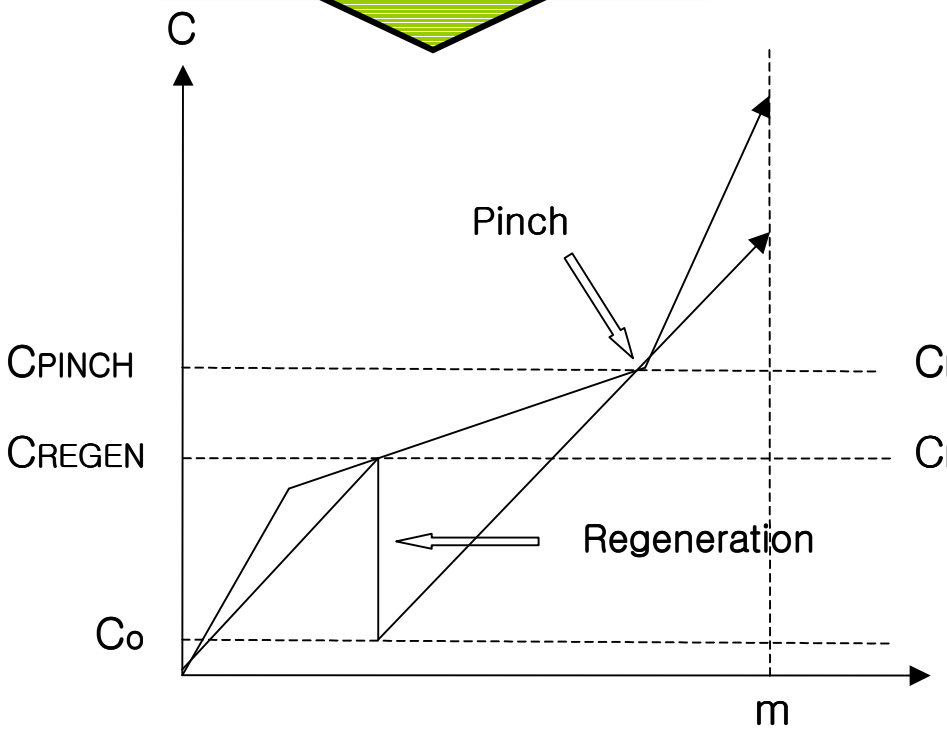
(i) A minimum outlet concentration of Co, i.e.

$$C_{out} <= C_o$$

(ii) A removal ratio R, i.e.

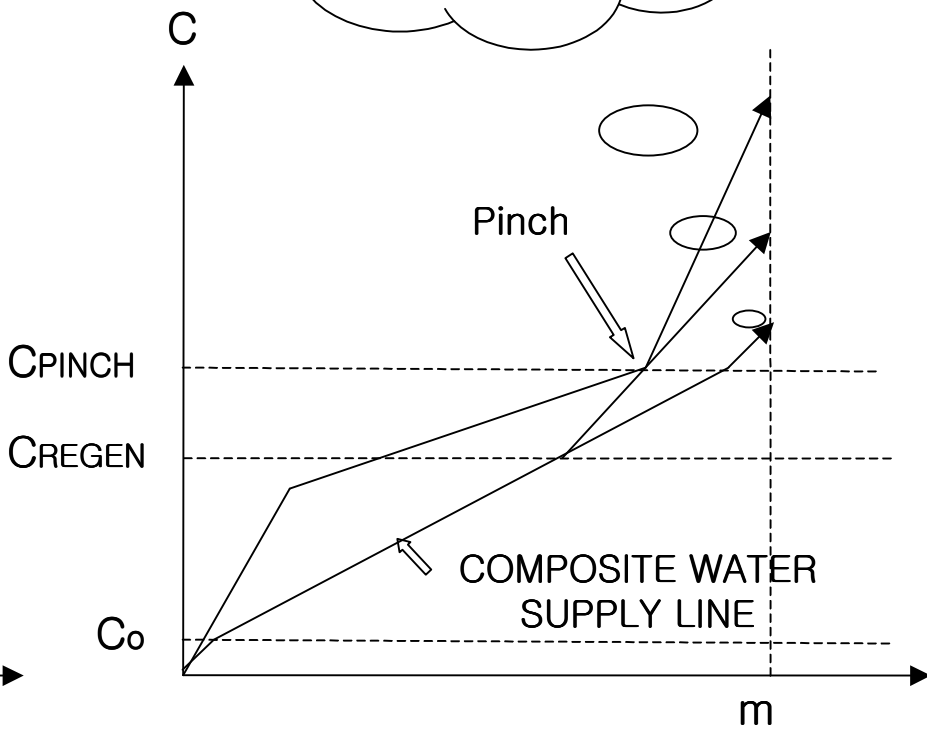
$$R = \frac{f_{IN}C_{IN} - f_{OUT}C_{OUT}}{f_{IN}C_{IN}}$$

Regeneration Re-use
-below pinch



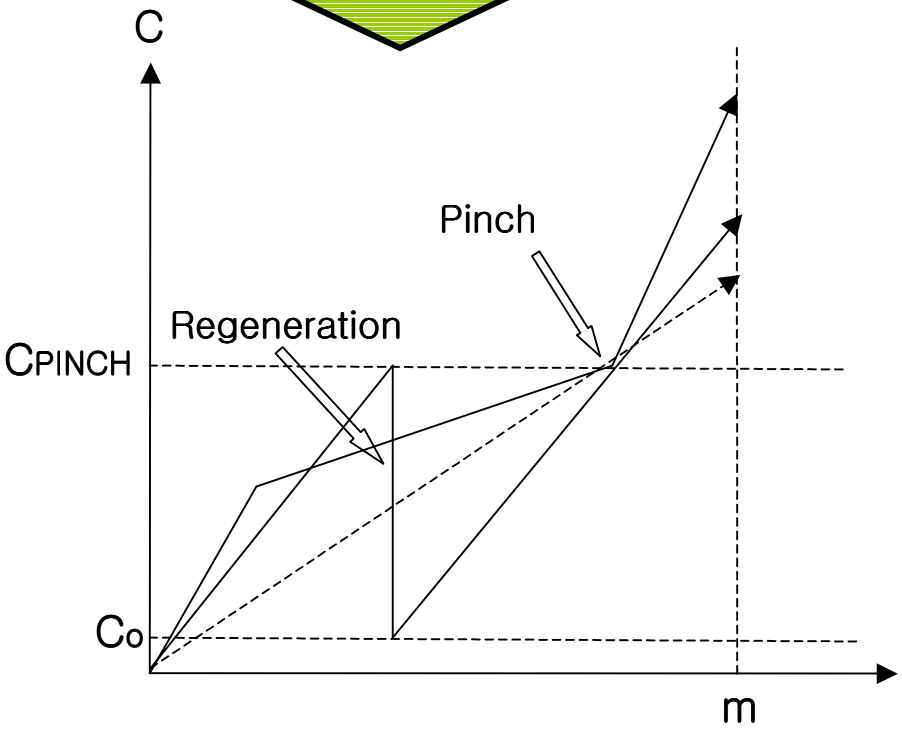
Regeneration of water reduces the flowrate of freshwater and wastewater

POSSIBLE HIGHER CONCENTRATION FOR REGENERATION

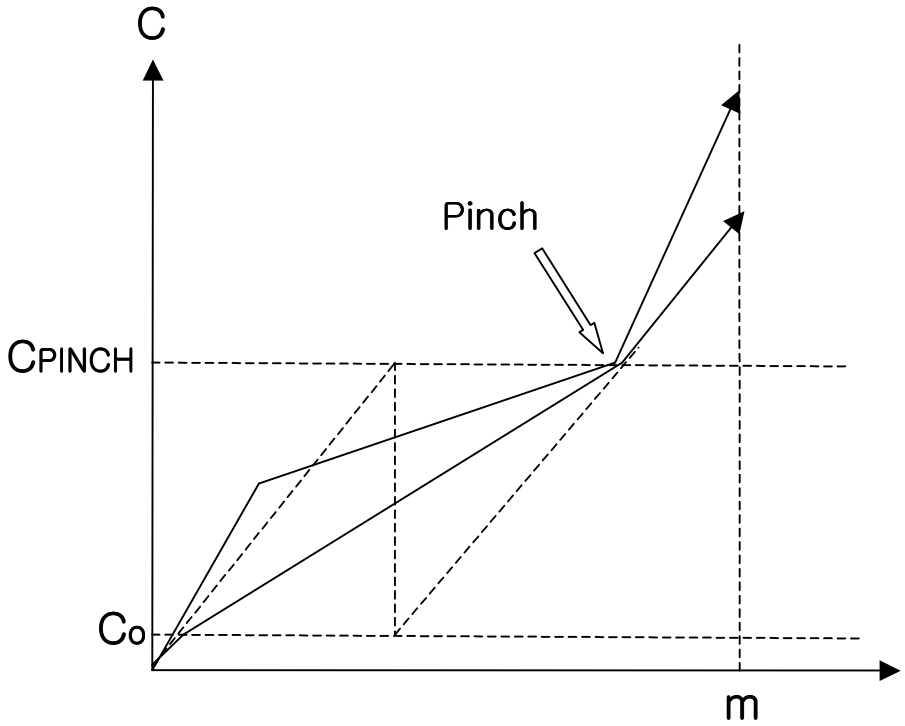


Composite water supply line indicates that the water flowrate is not minimised

Regeneration Re-use -at the pinch

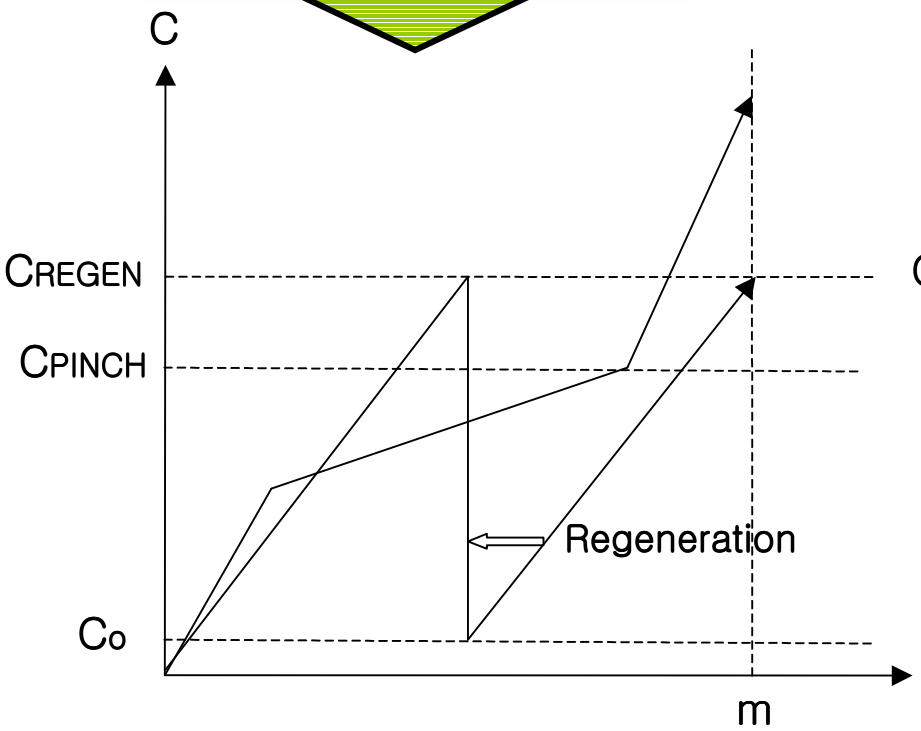


Regeneration of water at pinch concentration

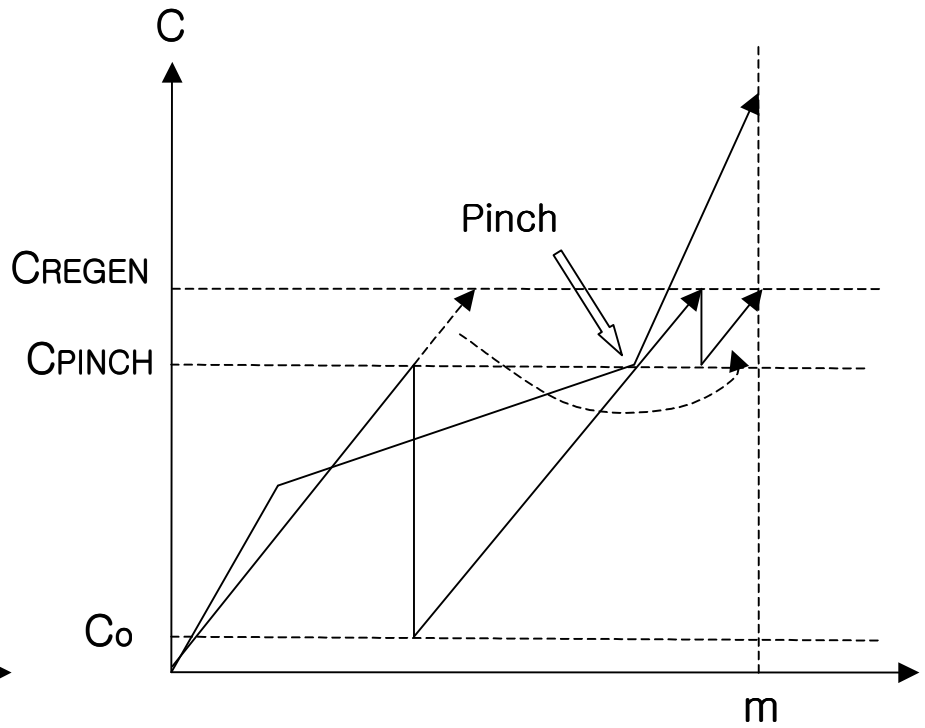


A composite of the water supply line before and after regeneration indicates the water flowrate minimised

Regeneration Re-use -above pinch



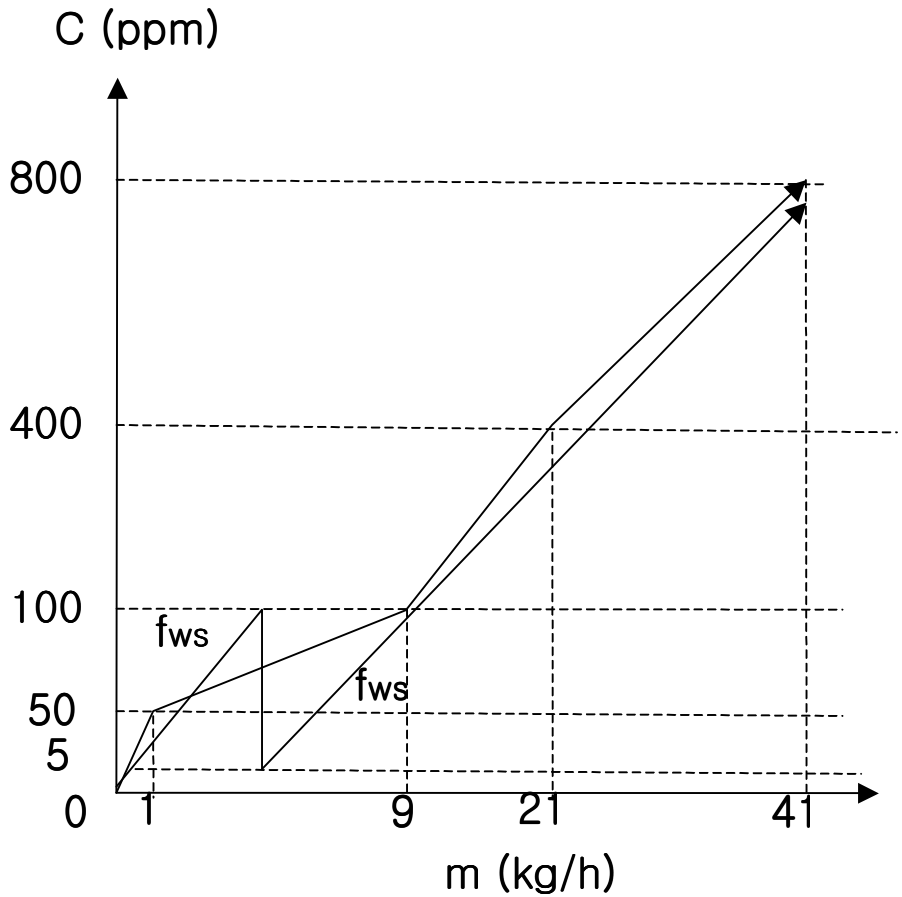
Regeneration of water above pinch concentration



Construction of a composite of water supply line

Wastewater System의 예 1.

(Table 1) --- Max. driving forces

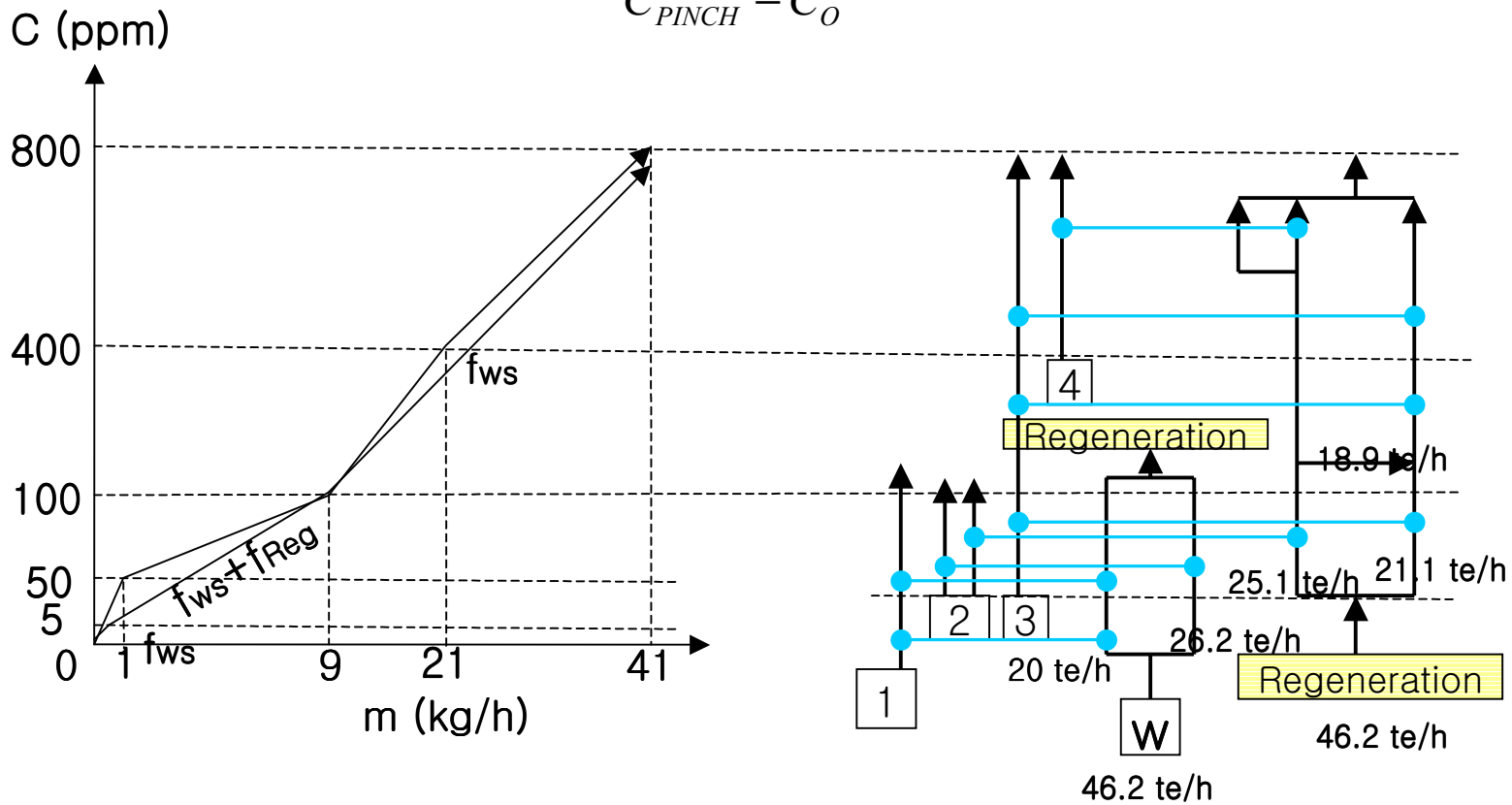


Regeneration up to pinch concentration

Wastewater System의 예 1.

(Table 1) --- Max. driving forces

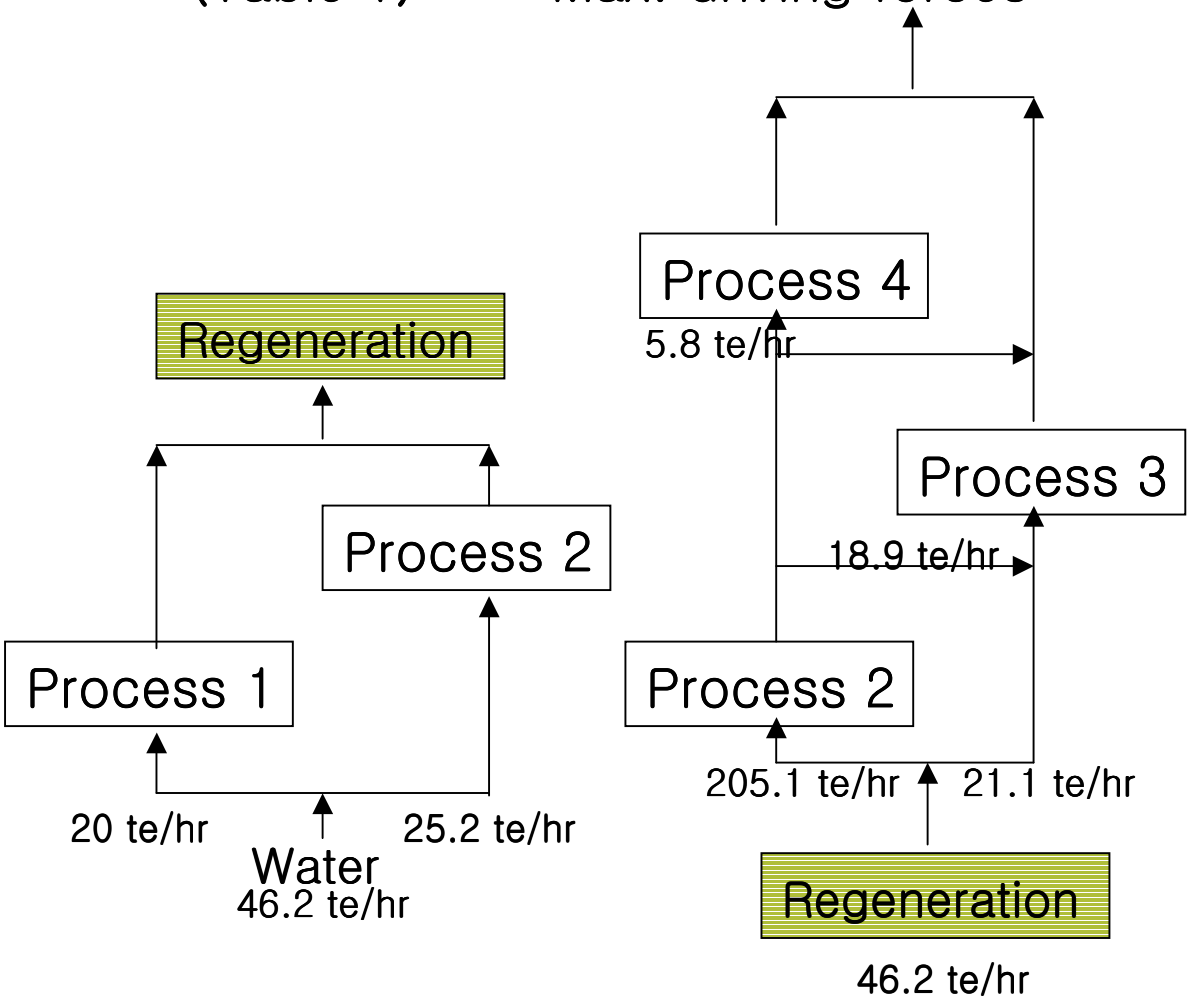
$$f_{WS} = \frac{m_{PINCH} - f_{ws} C_{PINCH}}{C_{PINCH} - C_O}$$



Water supply composite shows minimum flowrate Design to achieve target

Wastewater System의 예 1.

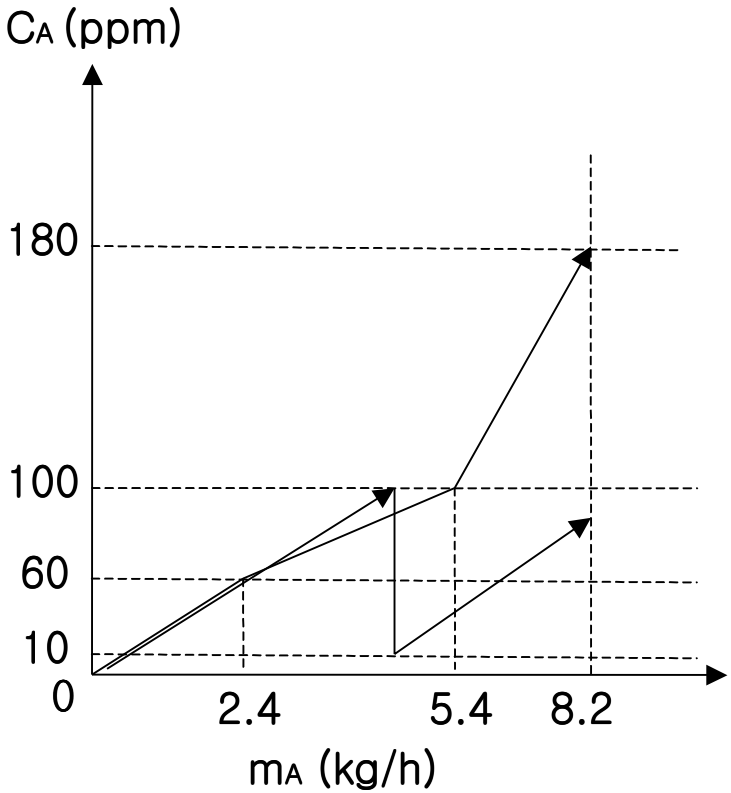
(Table 1) --- Max. driving forces



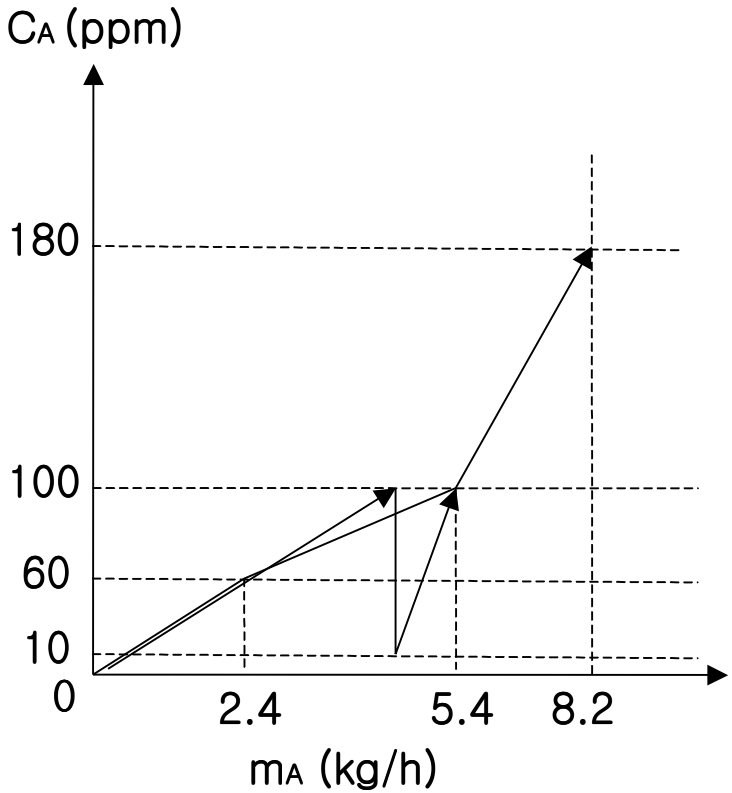
Conventional flowsheet after evolution

Wastewater System의 예 2.

(Table 2 예제) --- Min. # of water sources



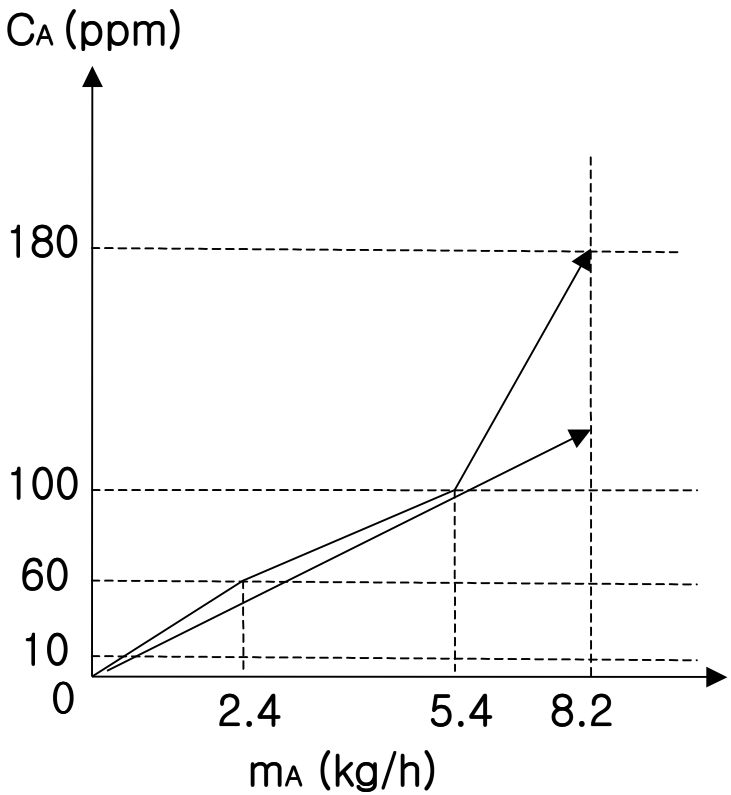
Total regeneration is restricted



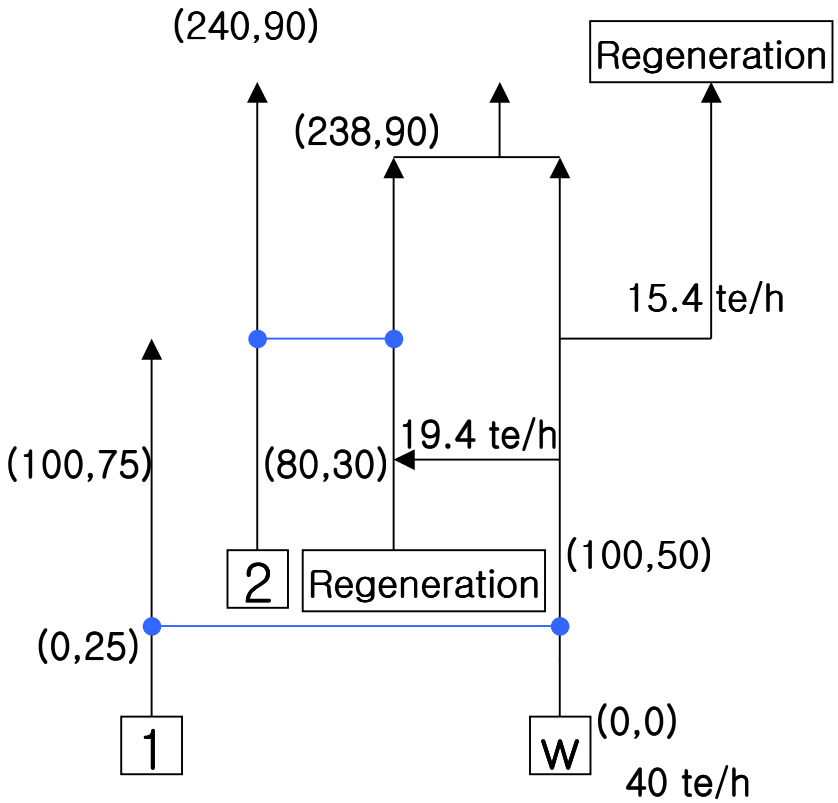
Patrial regeneration

Wastewater System의 예 2.

(Table 2 예제) --- Min. # of water sources



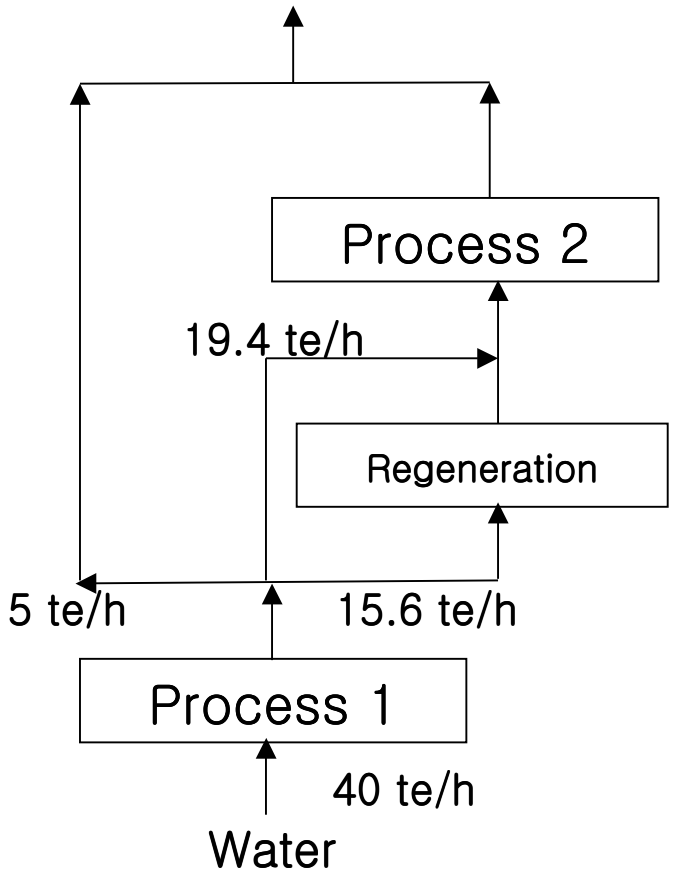
Composite of water supply with Partial regeneration



Grid design

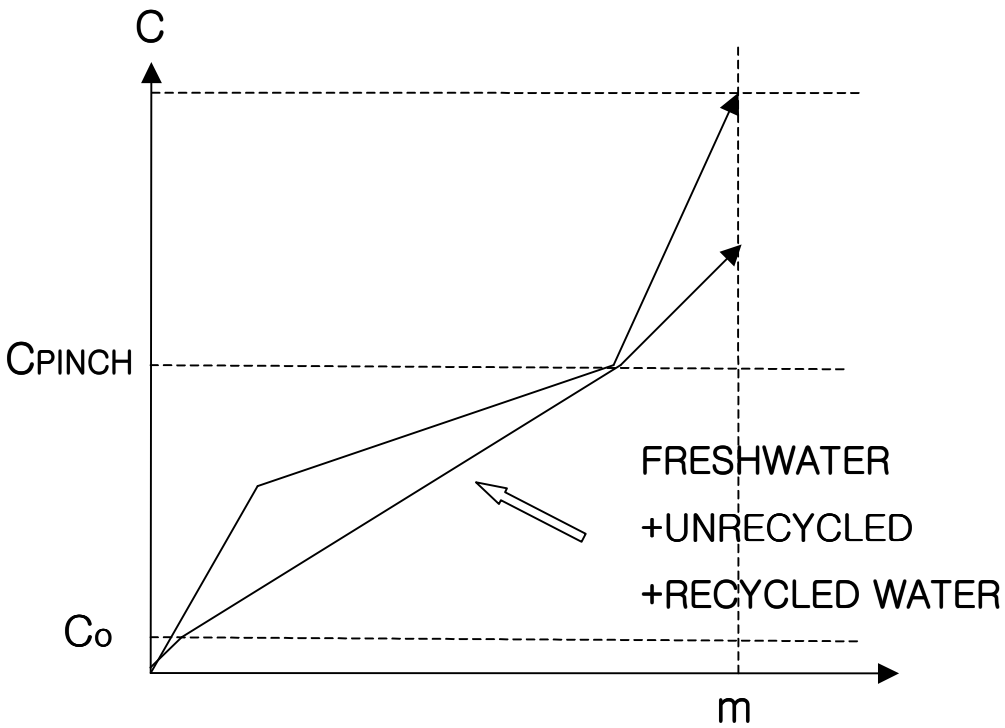
Wastewater System의 예 2.

(Table 2 예제) --- Min. # of water sources



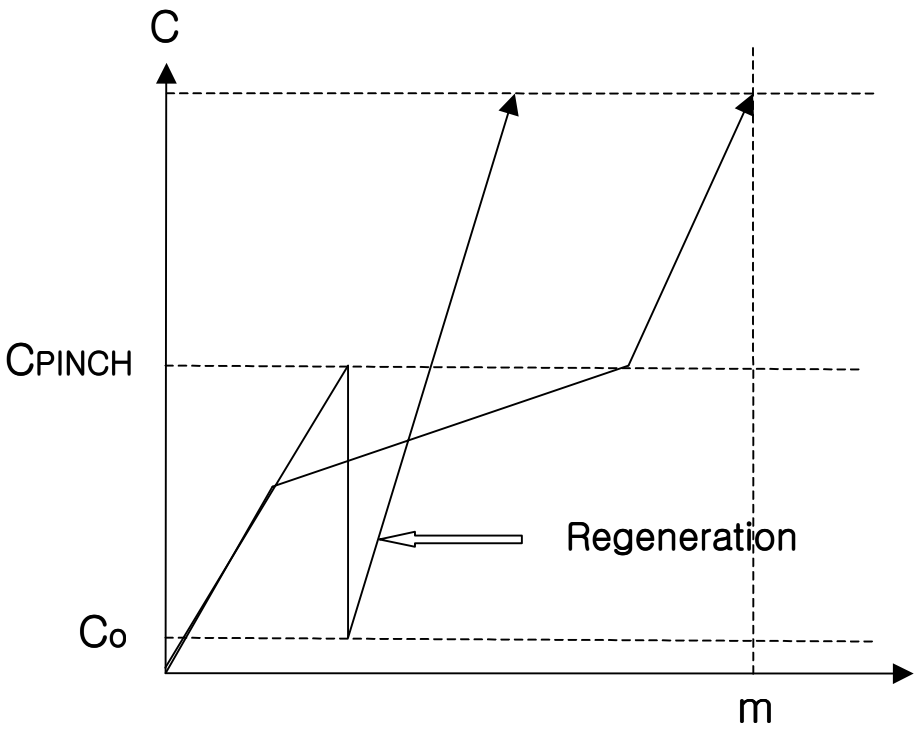
Conventional flowsheet

5. Water Regeneration Recycling

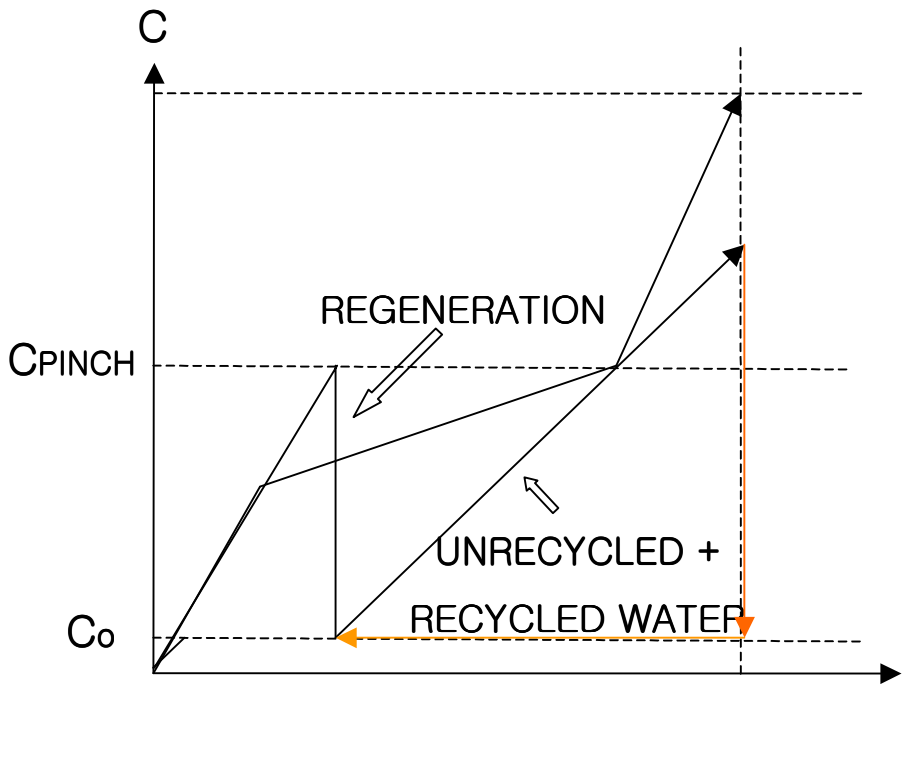


A Composite of the water supply before and after regeneration

Regeneration Recycling



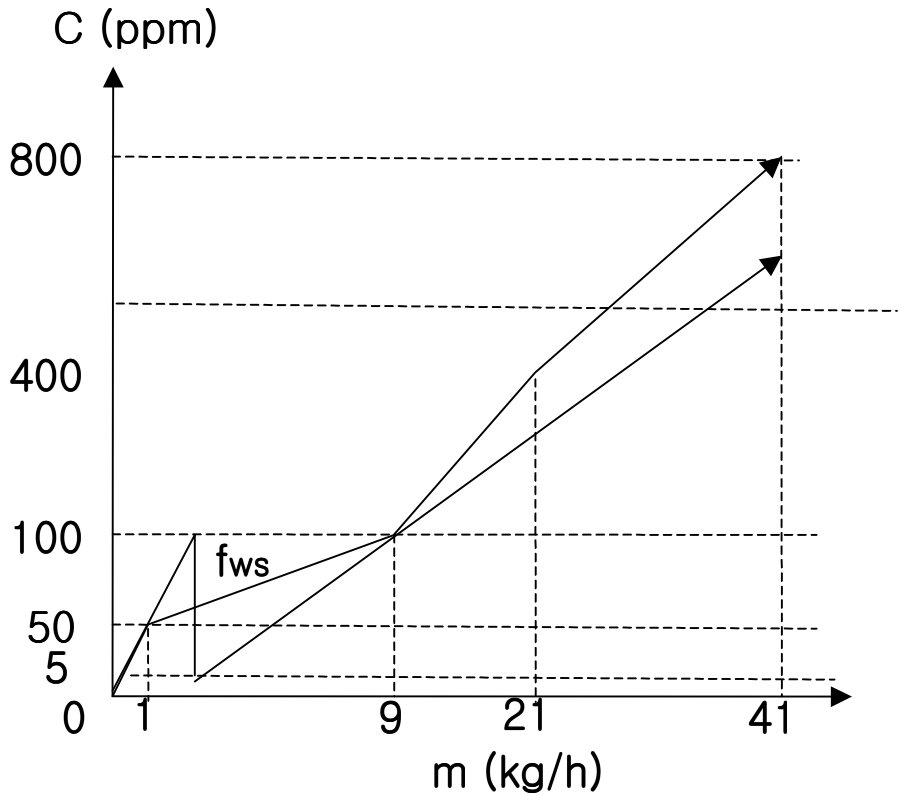
Minimum flowrate set by slope of limiting composite curve below C_o



An Increase in flowrate after regeneration require recycling

Wastewater System 의 예제 1.

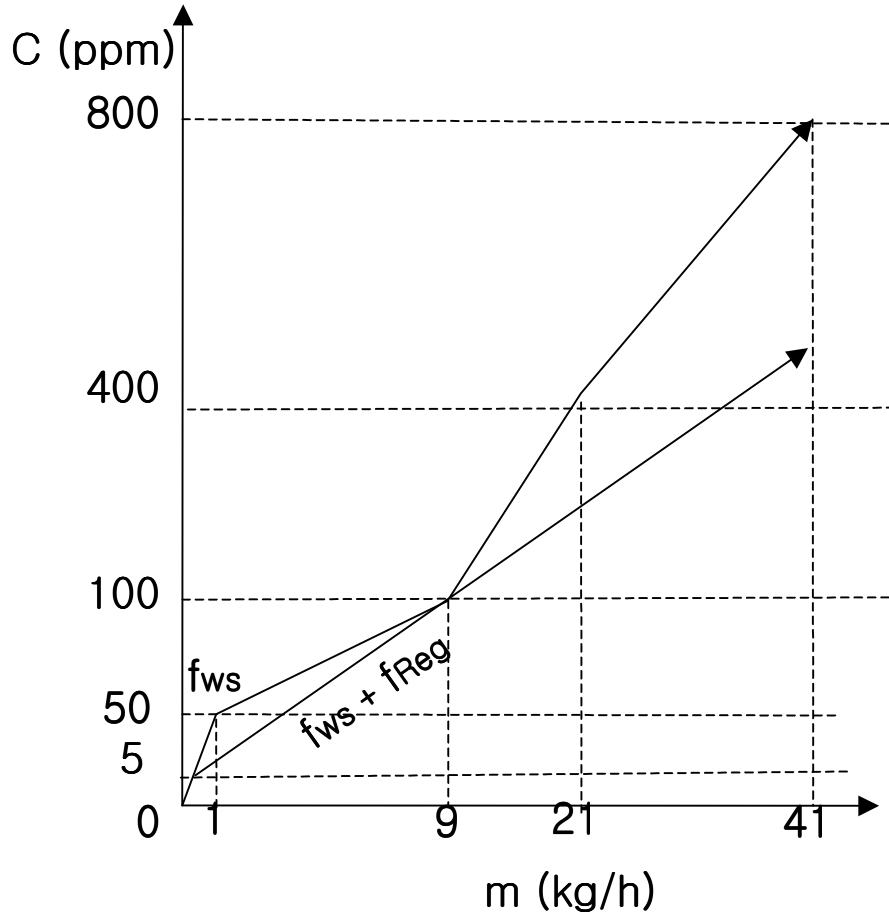
(Table 1) --- Min. # of water sources

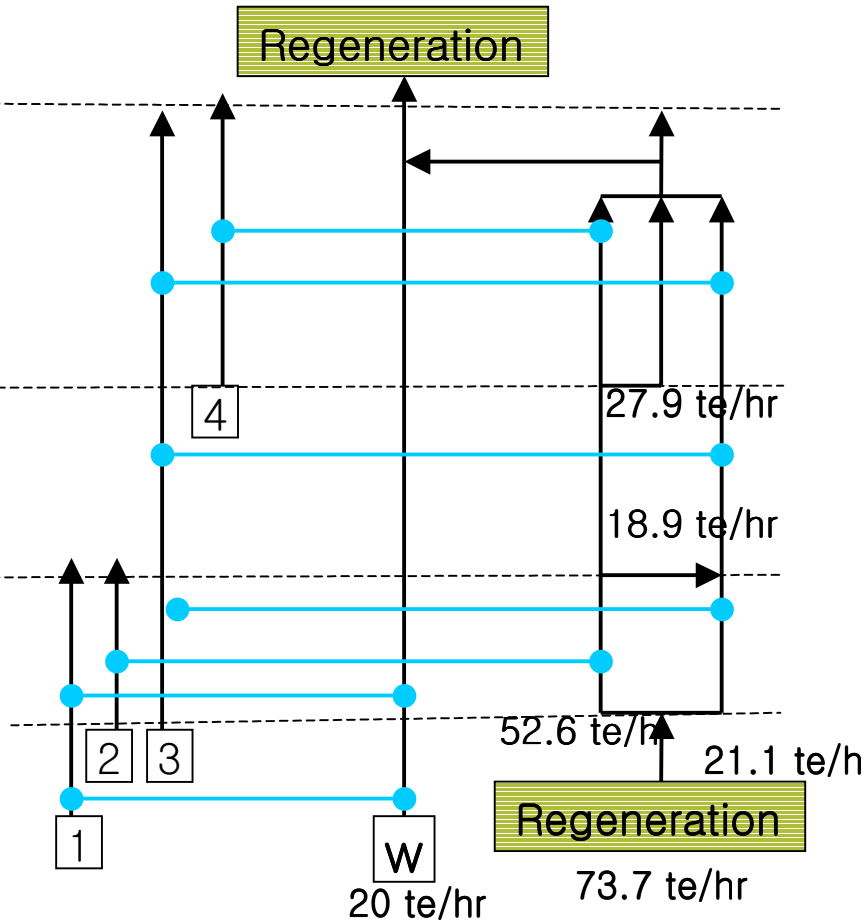


Regeneration Recyclying

Wastewater System 의 예제 1.

(Table 1) --- Min. # of water sources





Water Supply composite

Design to achieve target using Design

6. Concluding Remarks

- Water Minimization System 을 석유화학, 특수화학, 그리고 염색, 식음료업 등의 넓은 부분에 적용을 하면 보통 30 – 50 % 정도의 물을 아낄 수가 있다.
- 공정 통합 기술은 기존의 기술보다 더 낮은 비용으로 환경적인 측면에서 효율을 증대 시킬 수 있다.