Separation techniques at ARA Rhein

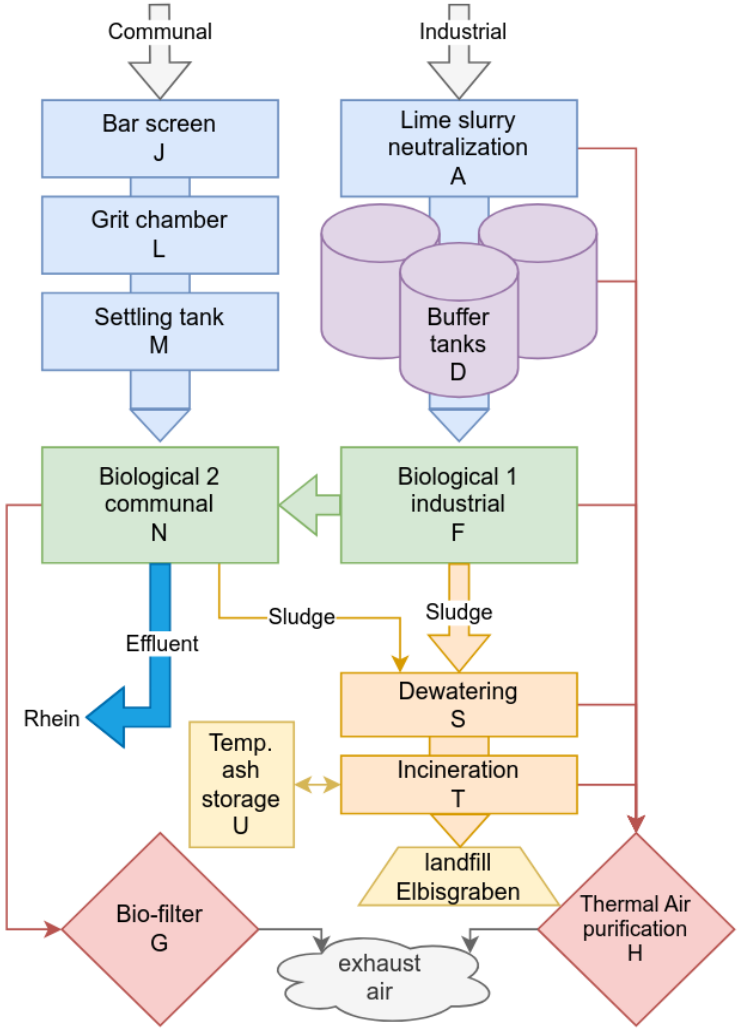
Precipitation, Flocculation, and EC

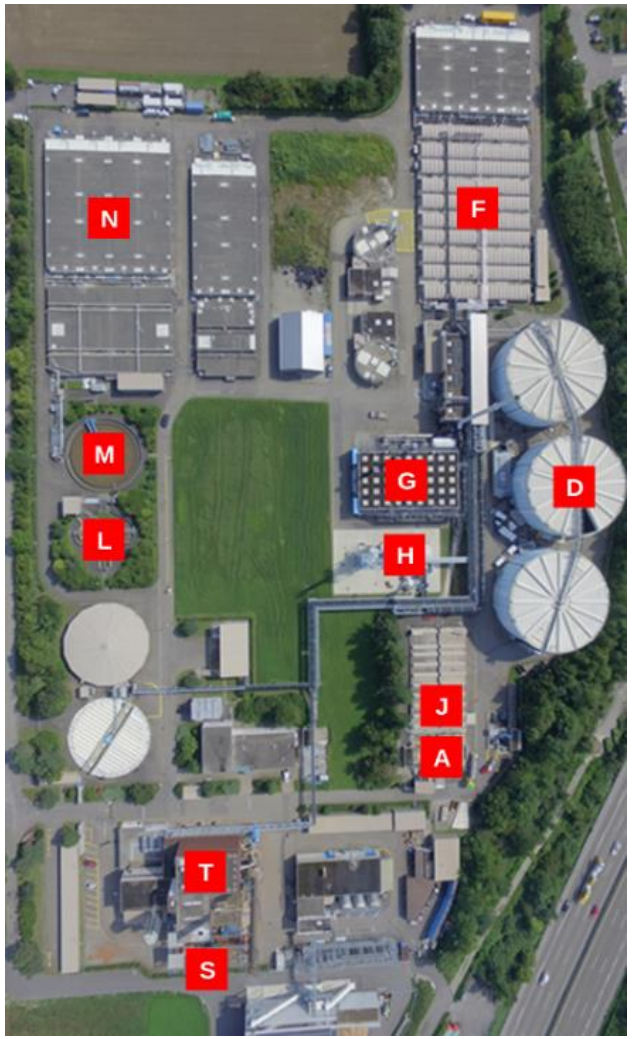
Team 1
Bürli Norman
Frongillo Matteo
Murali Arjun
Neukom Yannik
Rossi Anthony

ara rhein

ARA Rhein

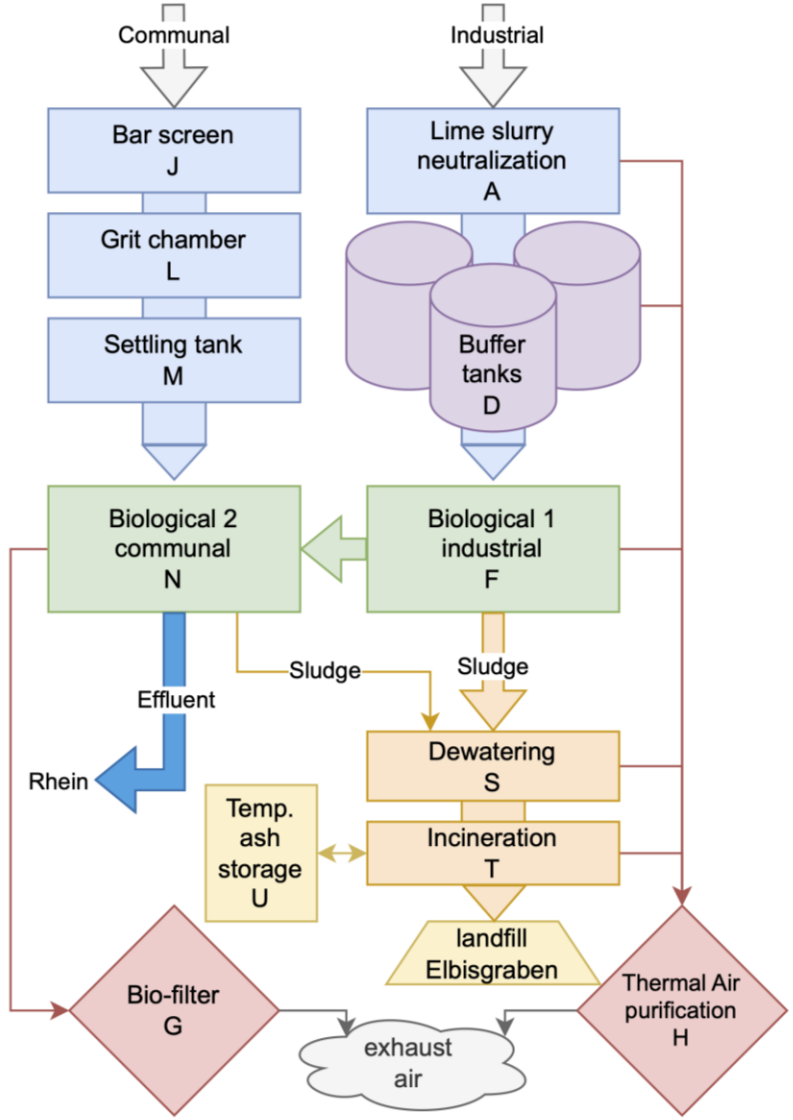
- 1975
- DAF (2019)
- Investments (6 – 10 million CHF / year)
- Industrial (450'000PE)
- Communal (50'000)
- 6.4 GWh heating grid
- Future Phosphorus recycling
- Odor purification





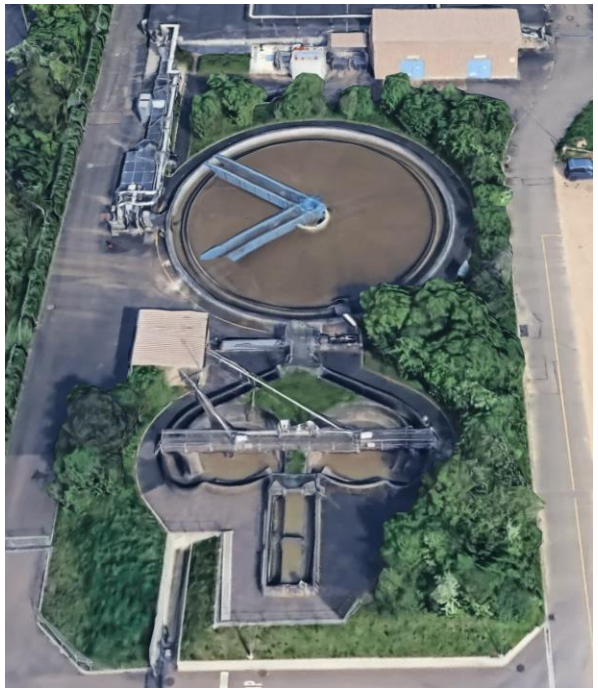
Seperation Techniques at Ara Rhein

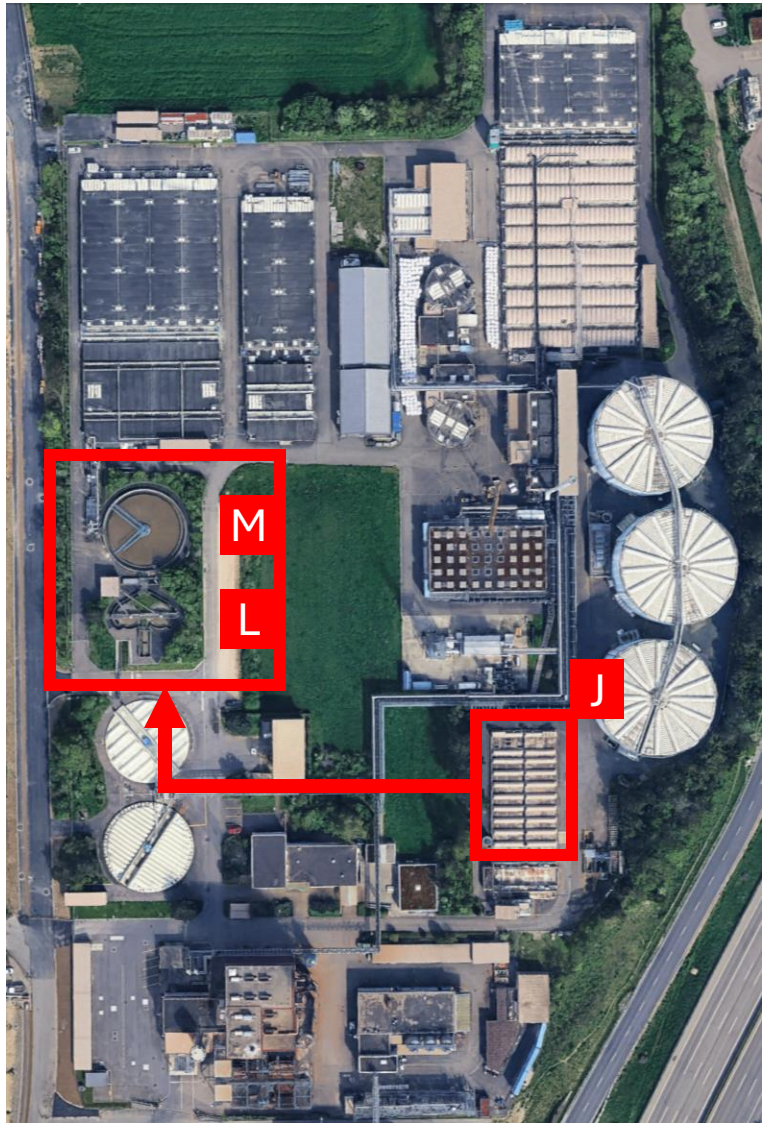
- Essential for removing contaminants
- Techniques target specific pollutants
- Applying them in the correct order and combination is vital

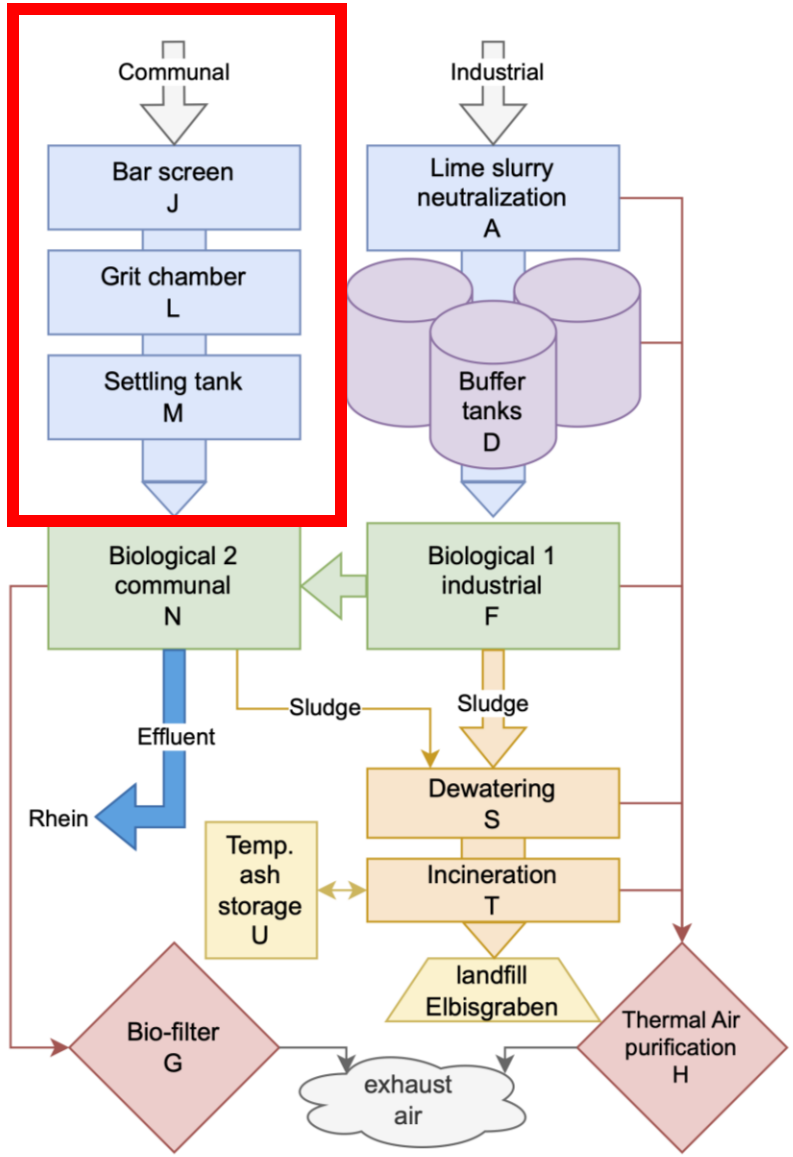


Communal: Mechanical

- Removes solids
- Large, dense and suspended

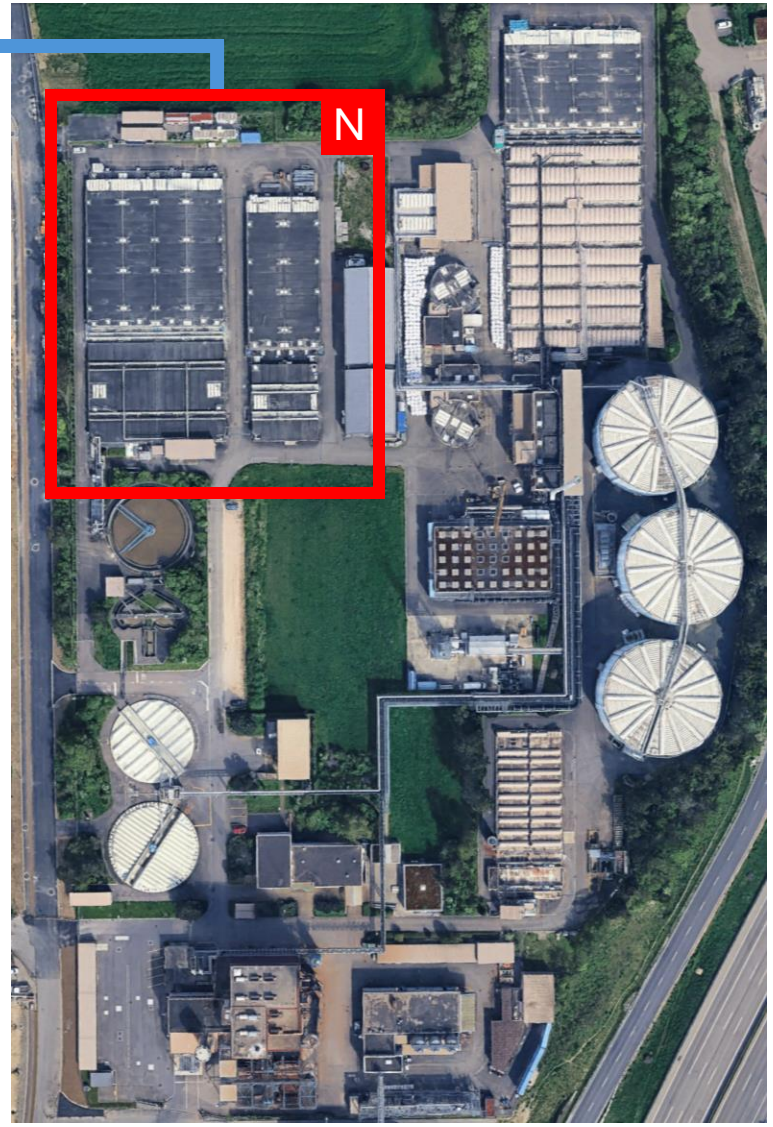


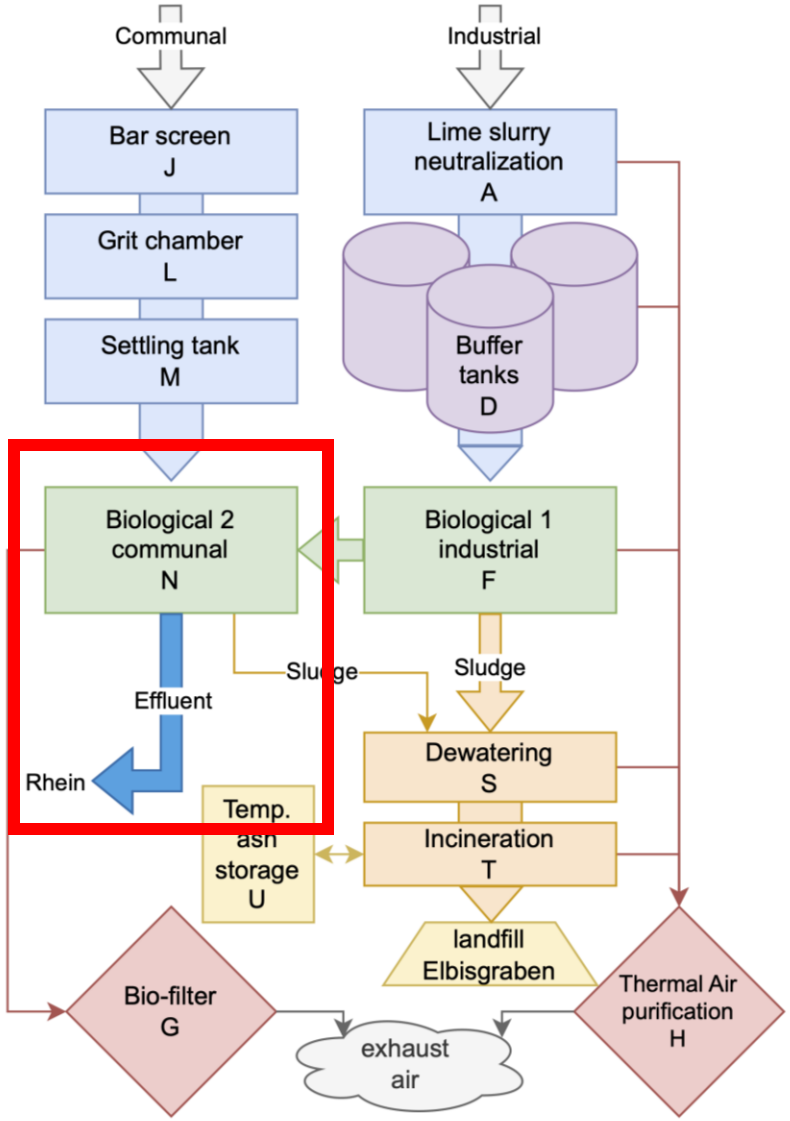




Communal: Biological

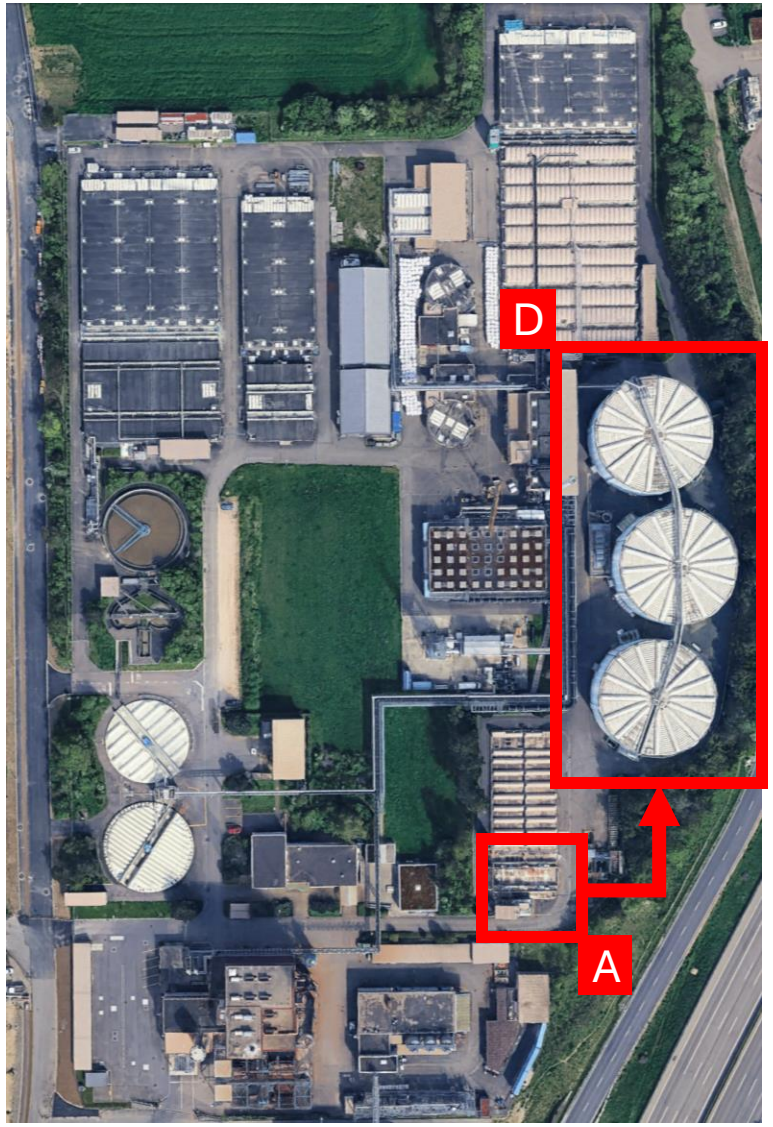
- Microorganisms remove organic matter
- Effluent enters Rhein

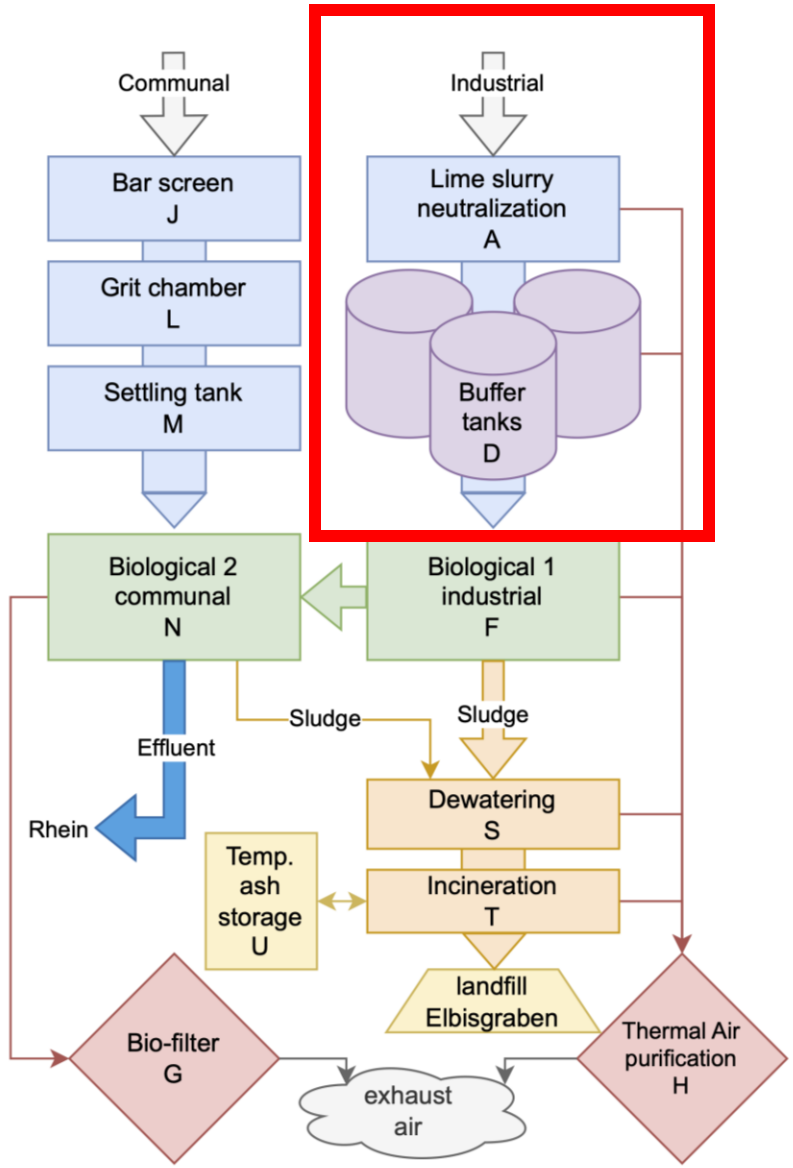




Industrial: Chemical

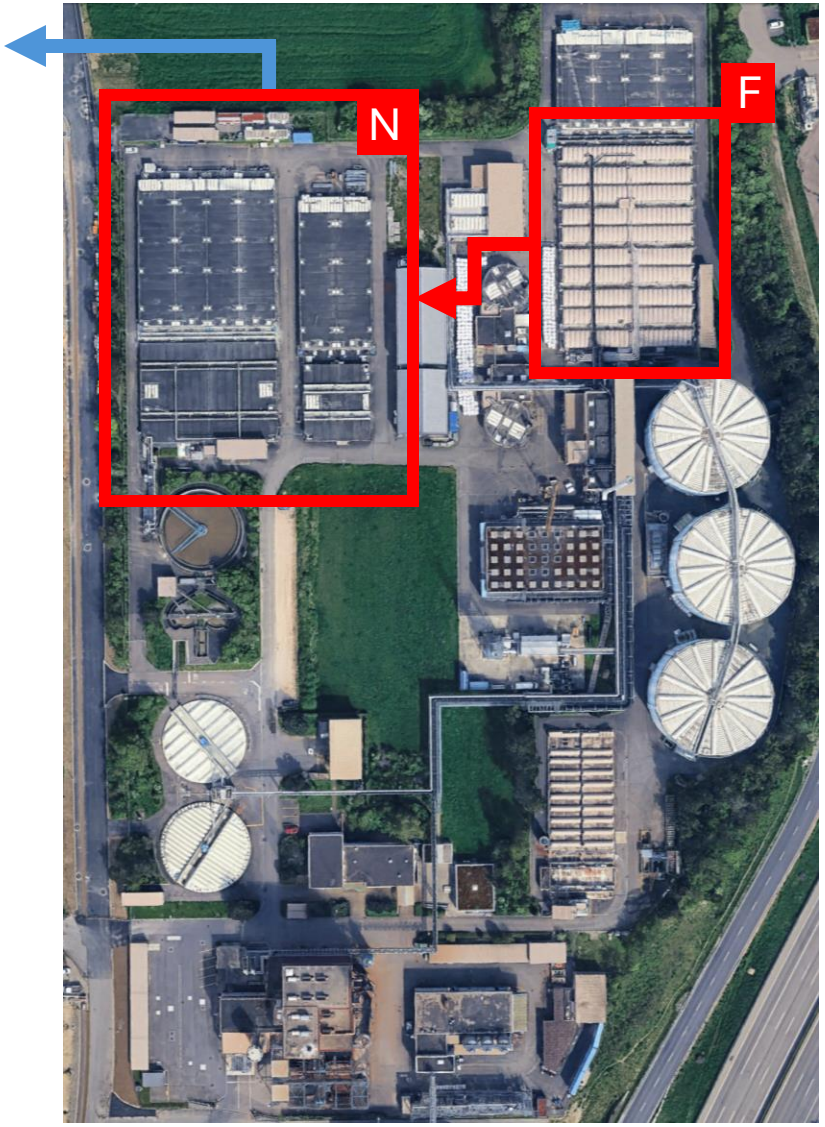
- Less mechanical seperation
- Neutralises the pH

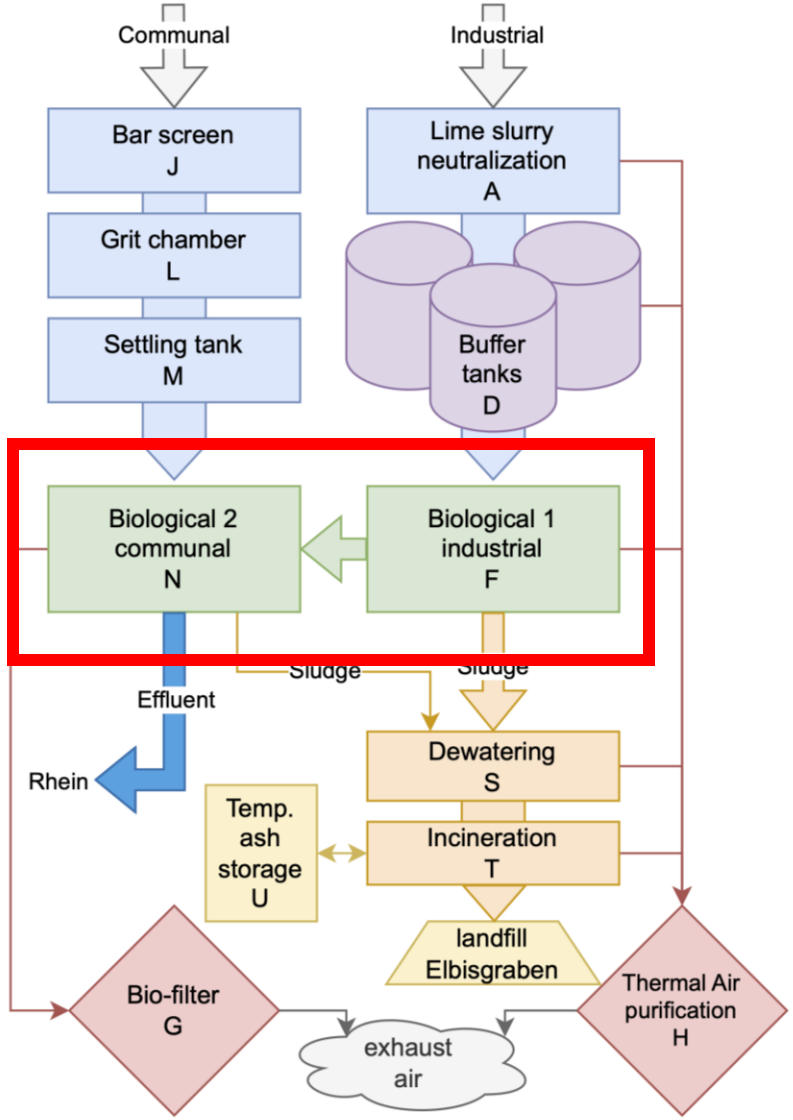




Industrial: Biological

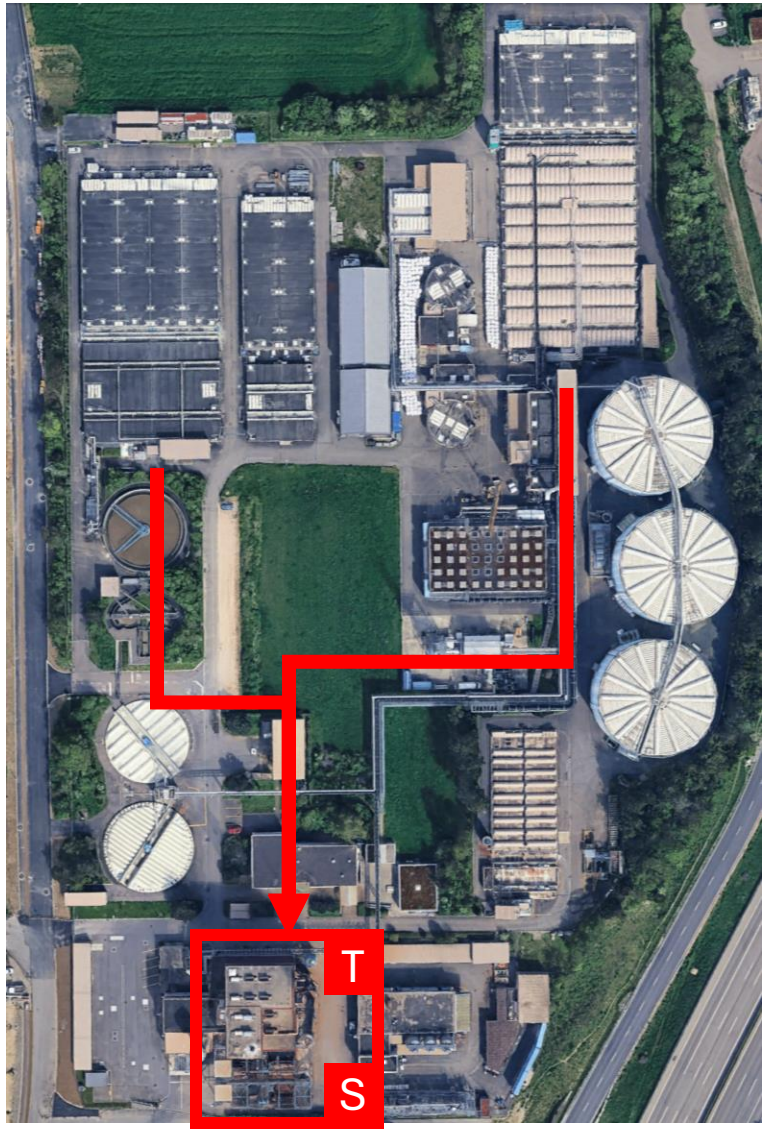
- Microorganisms break down industrial organic pollutants
- F protects N

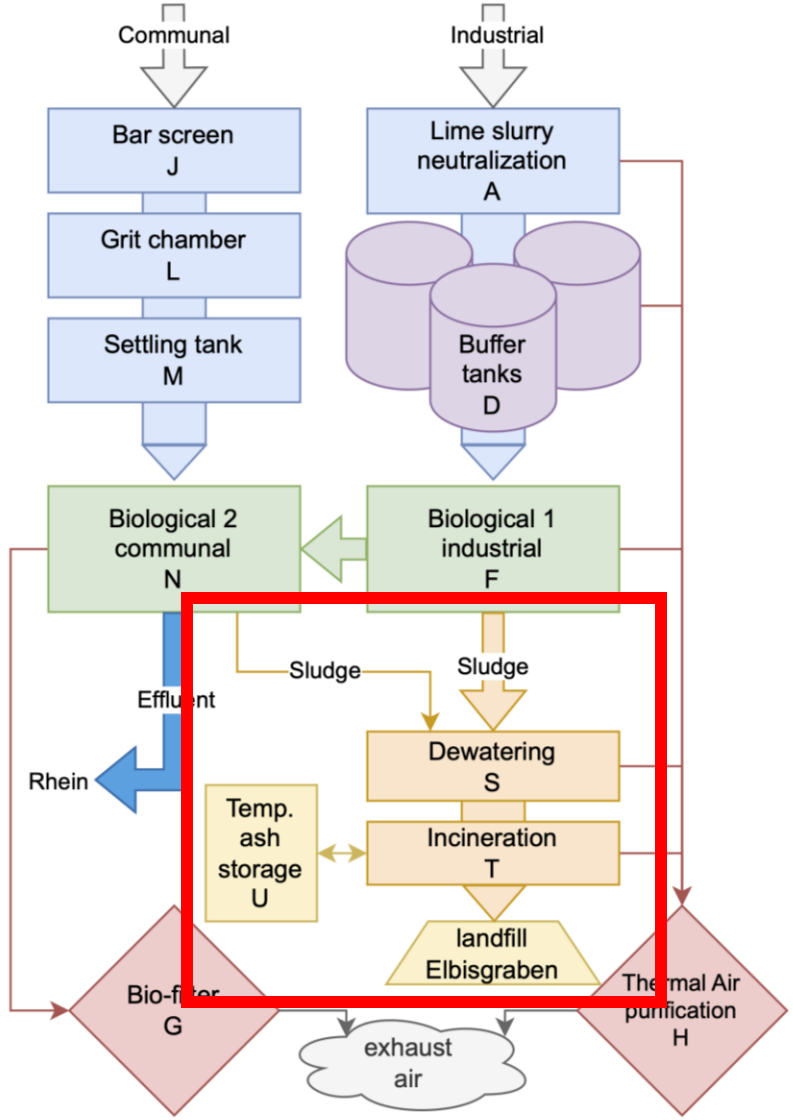




Sludge Treatment

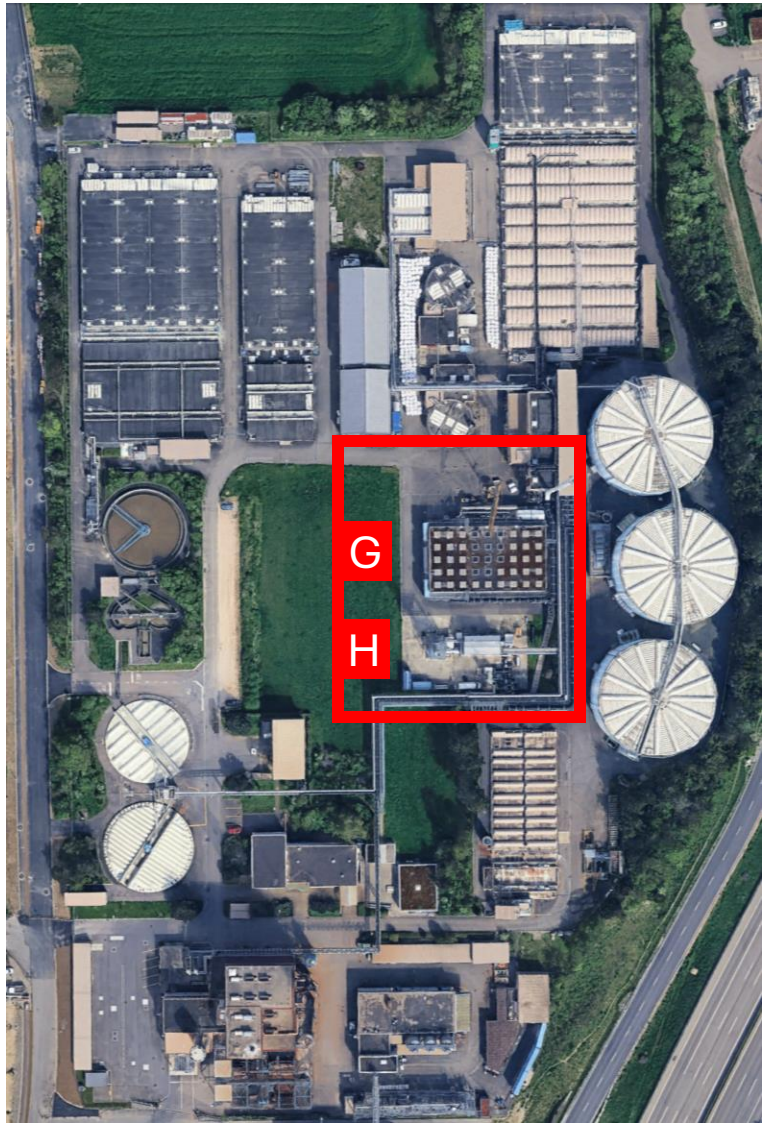
- Reduces sludge volume
- Sanitises sludge

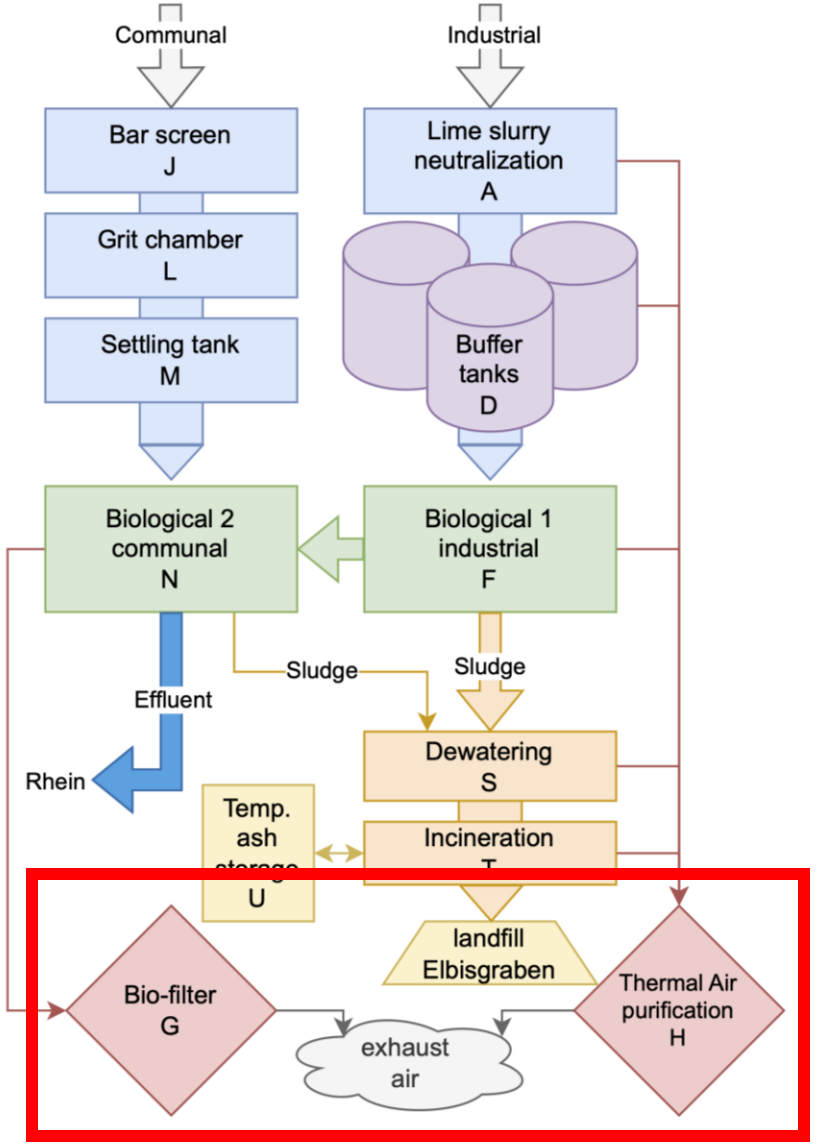




Off-gas Treatment

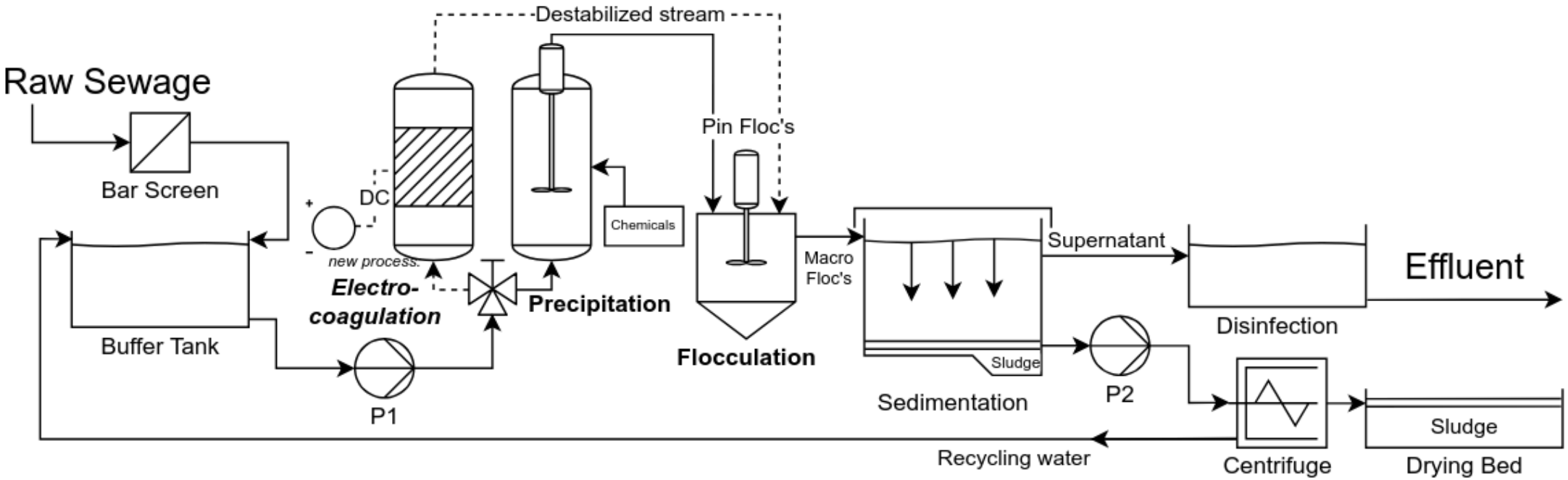
- Cleans off-gases
- Prevents strong odours and volatile pollutants





Precipitation, Flocculation, and Electrocoagulation

- Potential flow diagram

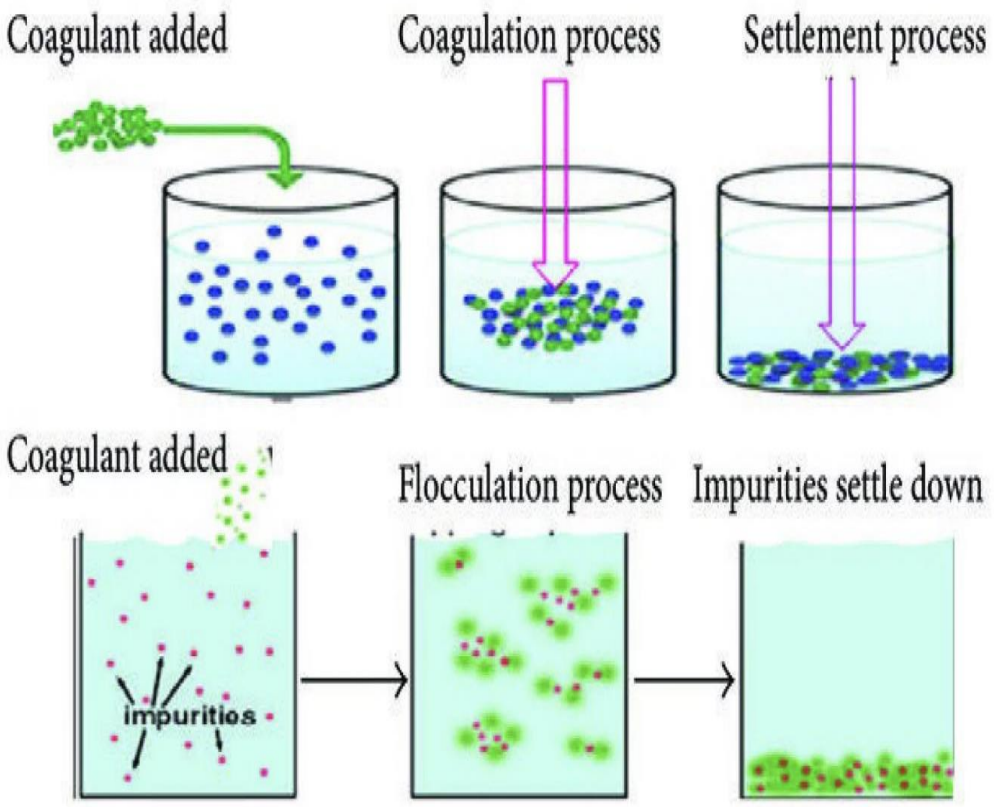


Flocculation

IUPAC definition: **a process of contact and adhesion whereby the particles of a dispersion form larger-size clusters**

General Process

- **Destabilization:** Coagulant is added to reduce particle surface charge..
- **Initial contact:** Small destabilized particles begin to collide during gentle mixing.
- **Bridging/aggregation:** Flocculant (e.g. PAM) links particles together into larger clusters.
- **Floc growth & settling:** Large, strong flocs form and can settle or be removed easily.



Sources: Ion Exchange (N.D) Understanding Flocculation: Key Processes and Benefits. https://bd.ionexchangeglobal.com/understanding-flocculation-key-processes/

Flocculation (polyacrylamide)

Most widely used Flocculant in water treatment.

Works by trapping particles in their long chains.

Pros

- Reduces sludge volume.
- Less toxic and more biodegradable.

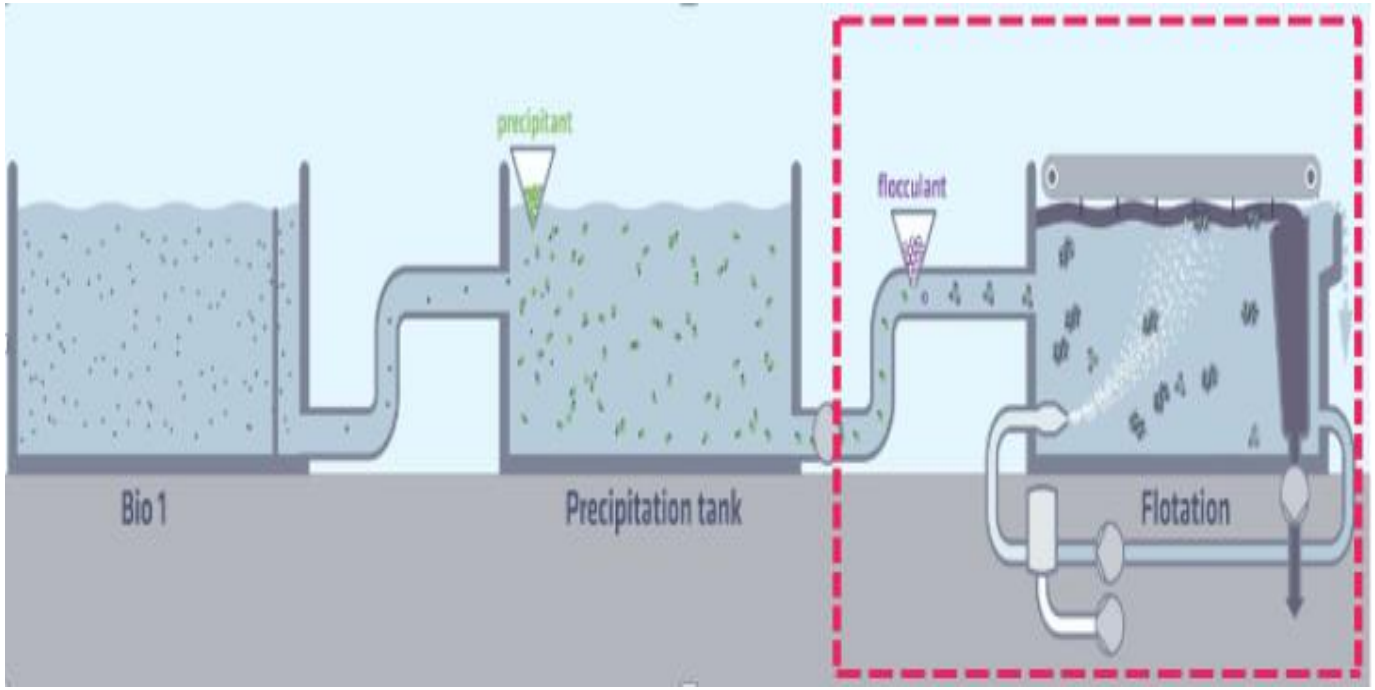
Cons

- Formation of hydrogen sulfide which causes corrosion in piping systems
- Performance sensitivity(Temp, pH…)

Sources: Kingsley Ogemdi Iwuozor (2019) Prospects and Challenges of Using Coagulation-Flocculation Method in the Treatment of Effluents.
Zoomri (2023) Cationic polyacrylamide (CPAM) used at wastewater treatment plants as flocculant. https://www.youtube.com/shorts/YO6ROyrbhC0

Flocculation at ARA Rhein

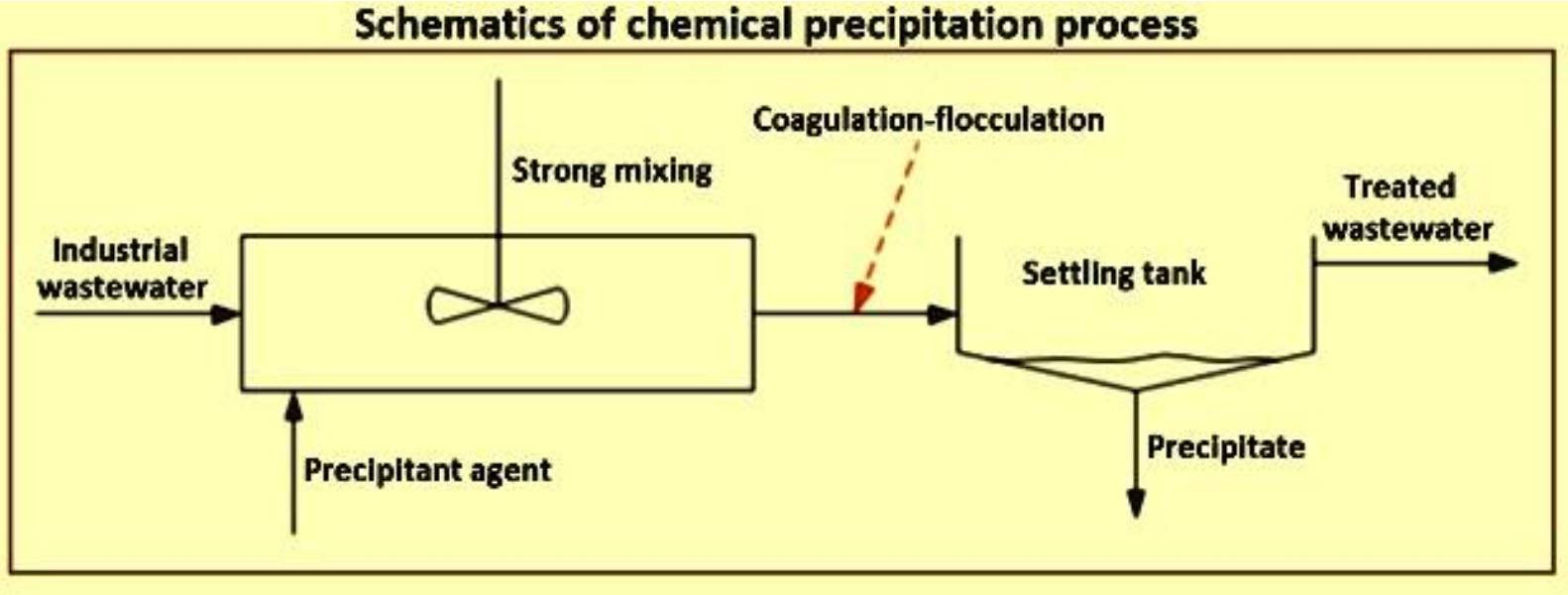
- Removal of phosphorous and nitrogen compounds is necessary to prevent eutrophication.
- Thermal heat from wastewater is used to heat processing water.
- Cationic polymer is used as flocculant.
- Injection of bubbles make the flocs float to the surface.
- Separation of >90% of total suspended solids.



Sources: ARA Rhein (N.D) Flotationsanlage der ARA Rhein für noch besser gereinigte Abwässer, https://www.ararhein.ch/info-center/medienmitteilungen/flotationsanlage/

Precipitation

Chemical Process

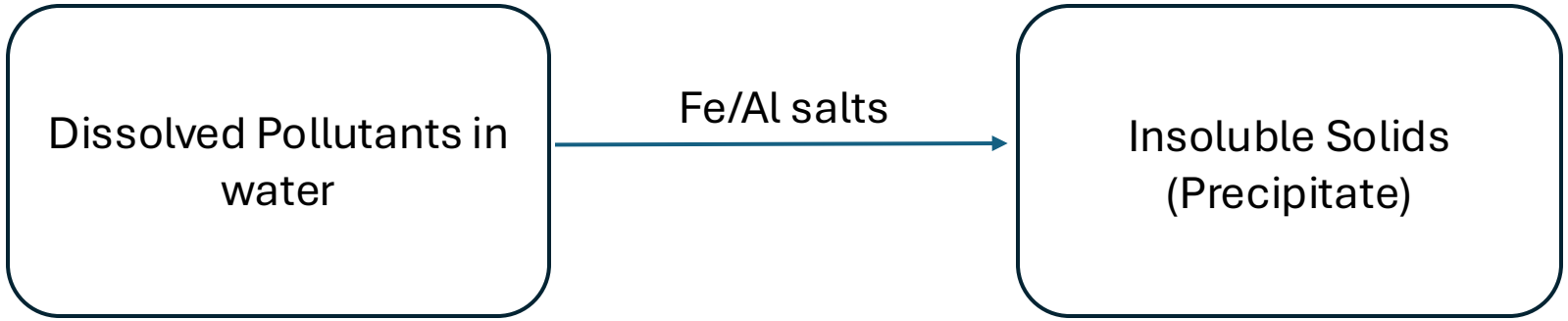


The precipitates must be removed by a physical separation technique

Source:
Kato, S., & Kansha, Y. (2024). Comprehensive review of industrial wastewater treatment techniques. Environ Sci Pollut Res, 31, 51064–51097. https://doi.org/10.1007/s11356-024-34584-0

Precipitation

Chemical Process



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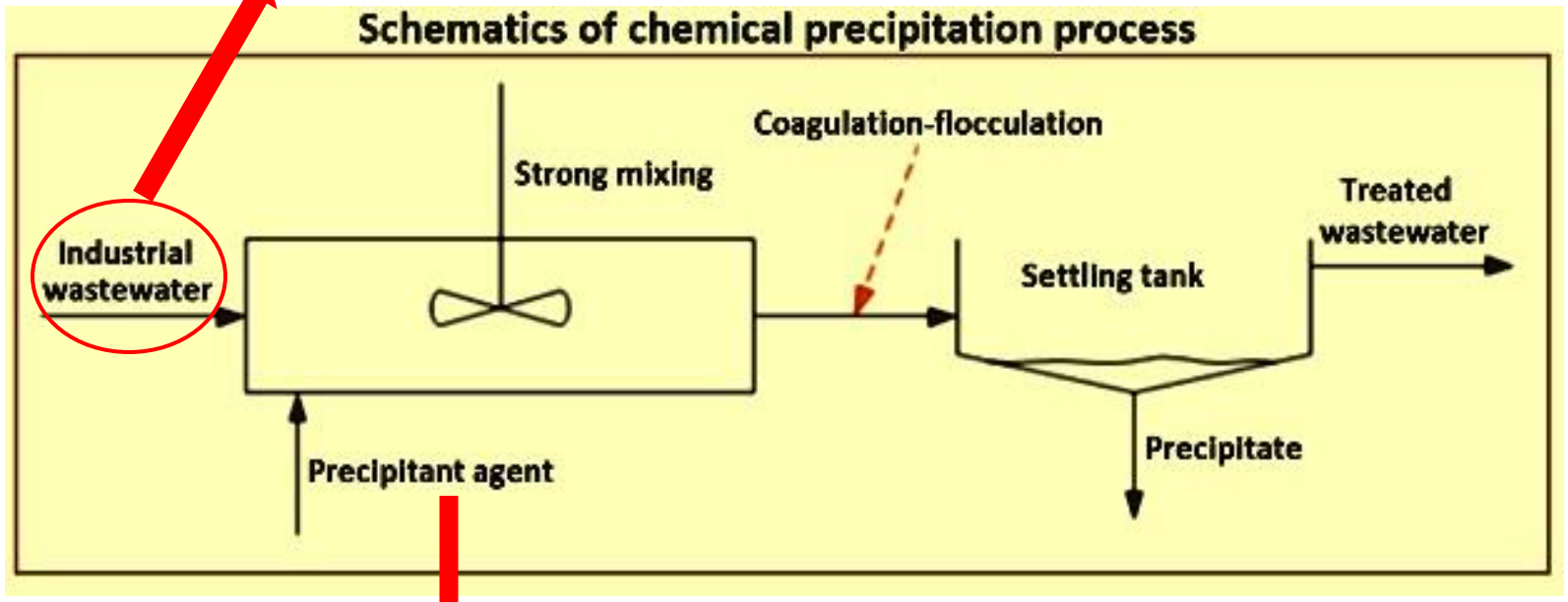
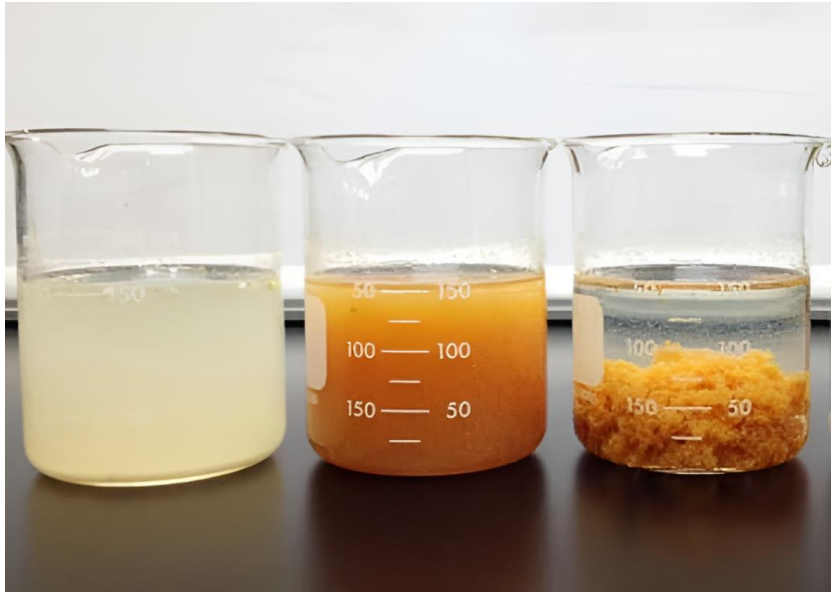
Precipitation

Acidic/Basic



Polyaluminium Chloride



Source:
DAS Environmental Experts GmbH. (2023). Case study ara rhein: Das. https://www.das-ee.com/en/case-study-ara-rhein/.

Precipitation

Advantages

- Removal of dissolved pollutants
- => Improves effluent quality
- => Meet discharge standards
- Combined with flocculation greatly increases efficiency

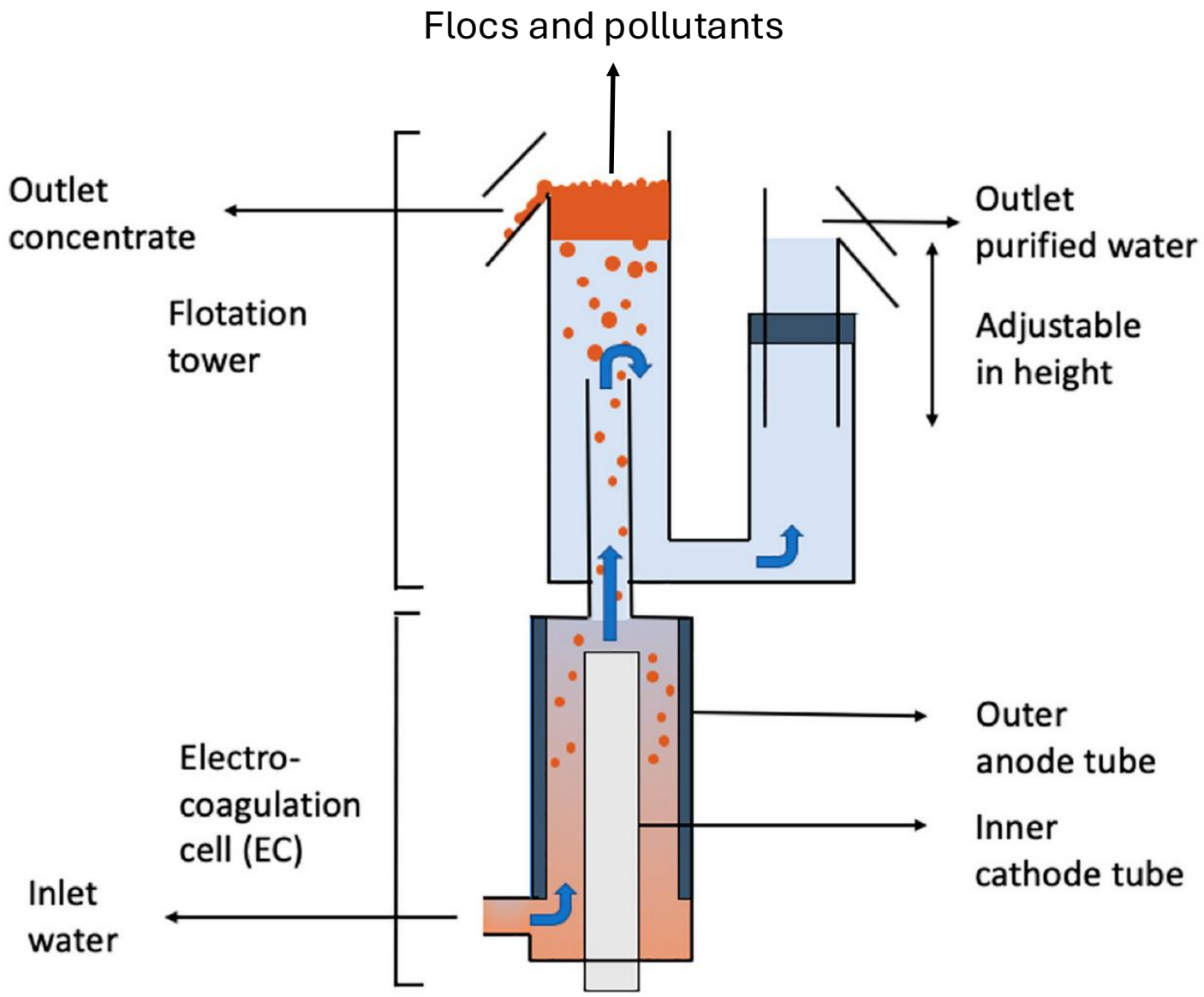
Disadvantages

- Precipitates captured (Sludge) need treatment. Added costs.
- Efficiency heavily depends on control of pH and reaction conditions.

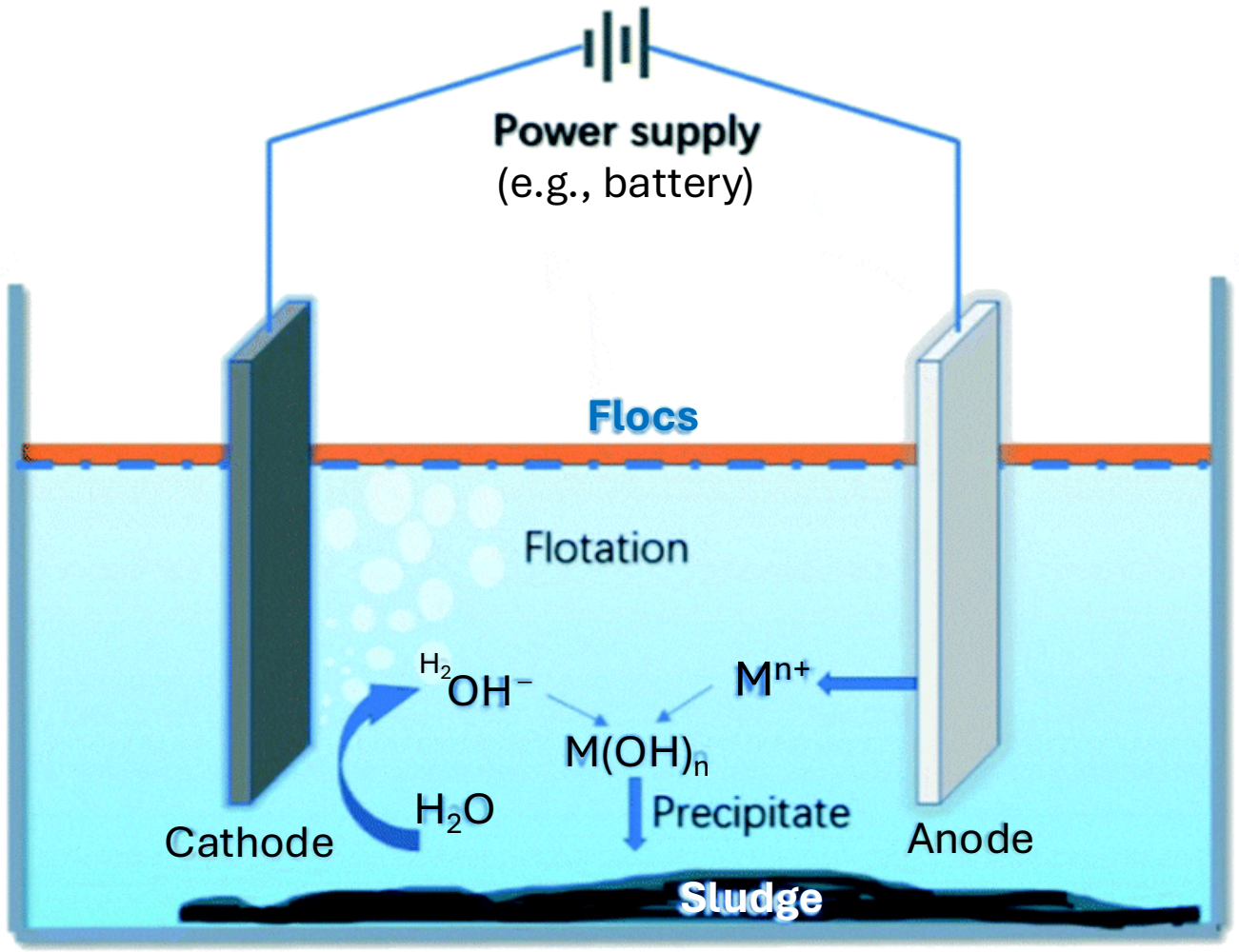
Source:
Koul, B., Yadav, D., Singh, S., Kumar, M., & Song, M. (2022). Insights into the domestic wastewater treatment (dwwt) regimes: A review. Water, 14(21), 3542. https://doi.org/10.3390/w14213542

Electrocoagulation

- (Electro)chemical separation technique
- Sacrificial metal
- Electrolysis / Hydrolysis
- Coagulant generation
- Electro flotation
- → Sludge



Source:
Al-Qodah Z et al. Performance of Continuous Electrocoagulation Processes (CEPs) as an Efficient Approach for the Treatment of Industrial Organic Pollutants: A Comprehensive Review. *Water*. 2025; 17(15):2351. https://doi.org/10.3390/w17152351



Anode and Cathode

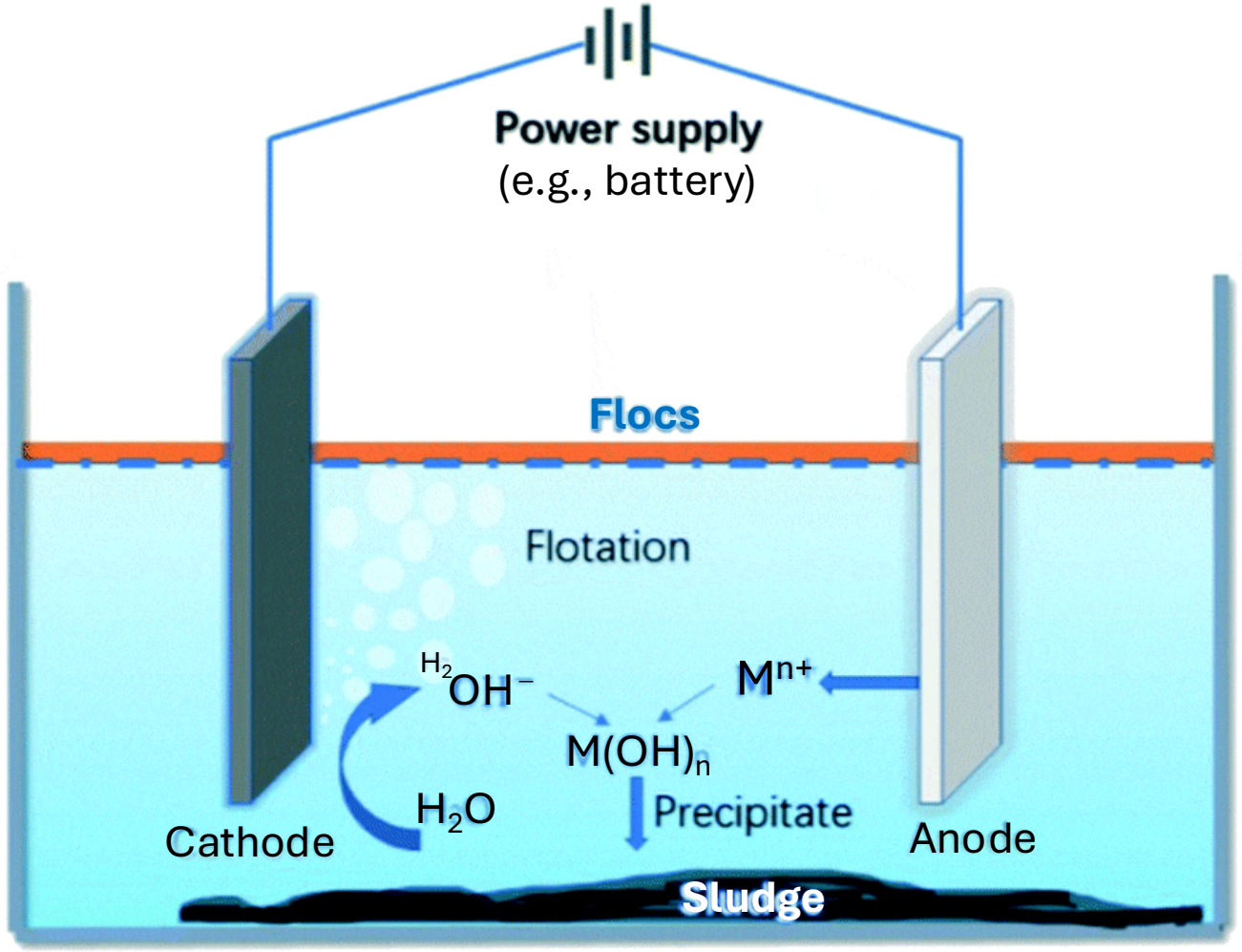
- Anode:
  Iron (Fe) or Aluminum (Al)

$$Fe \rightarrow Fe^{2+} + 2e^-$$

- Cathode:
  Stainless steel (high conductivity) or Fe or Al

$$2H_2O + 2e^- \rightarrow H_2\uparrow + 2OH^-$$

Source:
Jing, G., Ren, S., Pooley, S., Sun, W., Kowalczuk, P., & Gao, Z. (2021). Electrocoagulation for industrial wastewater treatment: an updated review. Environ. Sci.: Water Res. Technol., 7, 1177-1196. http://dx.doi.org/10.1039/D1EW00158B



Ferrous and ferric hydroxide

- Ferrous hydroxide:
  Intermediate step

$$Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2$$

- Ferrite hydroxide:
  Coagulant and flocculant

$$4Fe^{2+} + 10H_2O + O_2 \rightarrow 4Fe(OH)_3\downarrow + 8H^+$$

Source:
Jing, G., Ren, S., Pooley, S., Sun, W., Kowalczuk, P., & Gao, Z. (2021). Electrocoagulation for industrial wastewater treatment: an updated review. Environ. Sci.: Water Res. Technol., 7, 1177-1196. http://dx.doi.org/10.1039/D1EW00158B

Example of EC treatment of Oil and Gas Wastewater

Source: https://youtu.be/x0m8QCgbsoM?si=Cq-PuolalkKO67X8

Possible implementation of EC in ara rhein

Advantages

- EC and Flocculation combined:
  higher efficiency,
  increased capacity
- Less sludge volume, lower costs
- Natural coagulant:
  No chemicals to add
- (Green hydrogen production:
  H_2 can be stored and used)

Disadvantages

- Correct selection of EC plates:
  inappropriate metals can reduce the treatment efficiency

Conclusion

- Wastewater treatment is necessary for minimizing contamination and eutrophication.
- Process of wastewater treatment can vary depending on nature of pollutants available.
- Introduction of Electrocoagulation at ARA Rhein can aid in the removal of complex contaminants like heavy metals and pharmaceutical residues