Calculating the Impact of Greenhouse Gas Emissions from Heavy Metal Industrial Wastewater Treatments

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Introduction

- Municipal wastewater treatment of potable water generates 0.46 kg CO_2/m^3, or 2.1% of all carbon emissions generated annually.[1]
    - However, industrial wastewater can be more hazardous and require more energy to treat, resulting in increased greenhouse gas (GHG) emissions
- **Our mission with the GHG calculator program is to accurately estimate the GHG emissions of the 3 prevalent industrial wastewater treatment methods, specifically heavy-metal containing wastewater.**
- Information surrounding industrial wastewater streams and treatment methods, particularly in semiconductor and heavy metal industries, often lacks transparency.
- It is vitally important to understand the waste stream compositions and treatment methods of these industries, as treatment methods can have significantly different results for metal-containing wastewater as compared to municipal wastewater.
- The calculator not only helps record a processes' implementation (or lack) of sustainable practices, but it can also be used to compare different treatment processes between companies and industries.
- **We leveraged Microsoft Excel to help build and implement our calculation program, allowing for easy and accessible use for our stakeholders.**

Methods

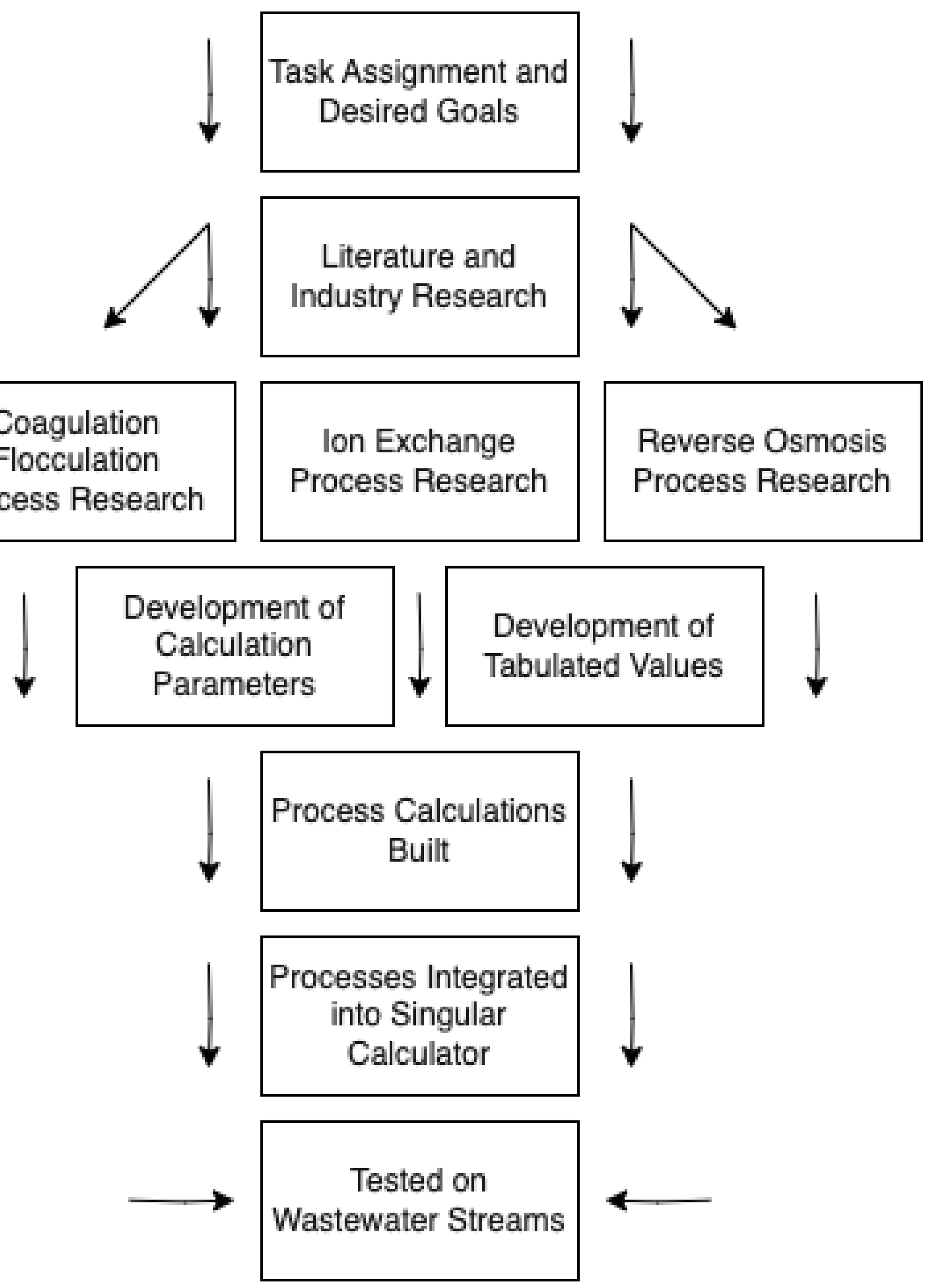

Figure 1. *Timeline of the development of the GHG calculator.*

Coagulation/Flocculation

Coagulation/Flocculation (C/F) is one of the most common forms for wastewater treatment. In C/F, coagulant is added to pH-treated wastewater with alkaline properties, trapping and aggregating precipitated metal particles into clumps, or "flocs", that can be easily separated from the wastewater.

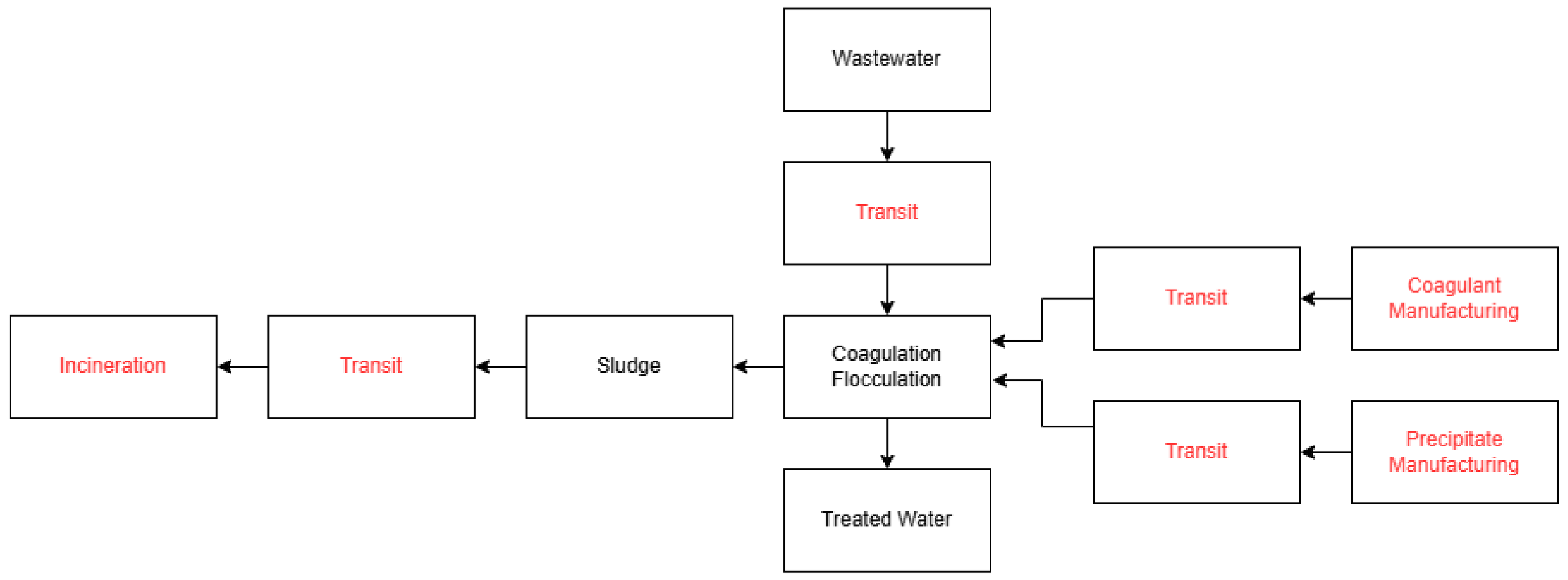

Figure 2. *Block flow diagram detailing the surrounding variables of the Coagulation/Flocculation process. Red labels indicate that the variable contributes to GHG emissions.*

Key Assumptions

- Sludge is 80% water by mass
- Total Suspended Solids (TSS) is to be completely removed by C/F
- Sludge that is generated is 20% of mass of treated wastewater
- Sludge incineration emissions that are generated is based on municipal wastewater values from industrial and literature research

Reverse Osmosis

Reverse Osmosis (RO) is a popular water treatment for its ability to filter out dissolved salts, ions from a wastewater stream. RO functions by forcing wastewater through a semipermeable membrane using high pressures. As the water passes through, the ions and salts are trapped on the membrane side, and leave through a concentrated stream known as retentate, with the purified water stream leaving as a permeate.

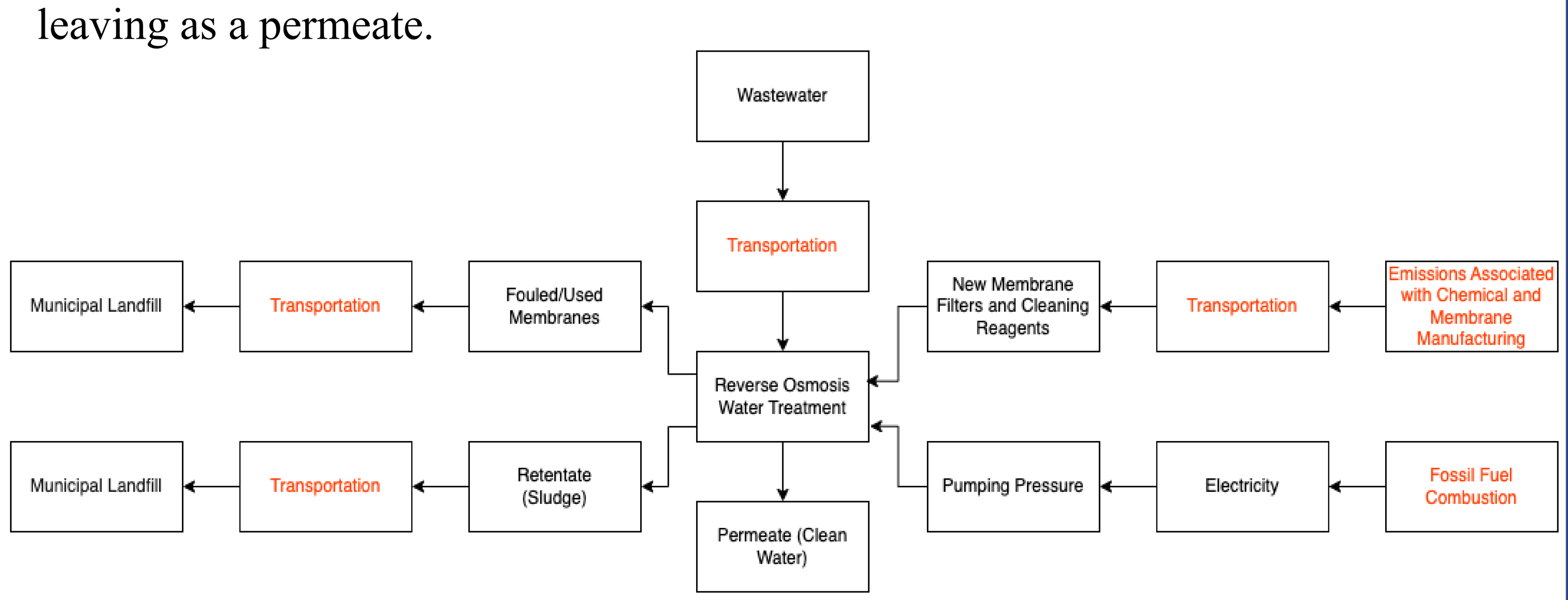

Figure 3. *Block flow diagram detailing the surrounding variables of the Reverse Osmosis process. Red labels indicate that the variable contributes to GHG emissions.*

Key Assumptions

- Electricity is the main source of emissions for an RO process
- Based on an average of estimations, the amount of total dissolved solids (TDS) removed by the RO membranes is about 98%, leaving 2% in the retentate
- Reverse Osmosis membranes are assumed to be a spiral wound design and made of polymer (thin film polyamide composite or cellulose acetate) instead of ceramic

Ion Exchange

Ion Exchange (IX) is a method in which charged solutes interact with a resin, exchanging ions and preventing uncharged components from passing. There are cation and anion exchange resins exchanging with positively and negatively charged ions, respectively. It is viewed as a cost-effective method as little energy is required, and it can produce high purity treated water.

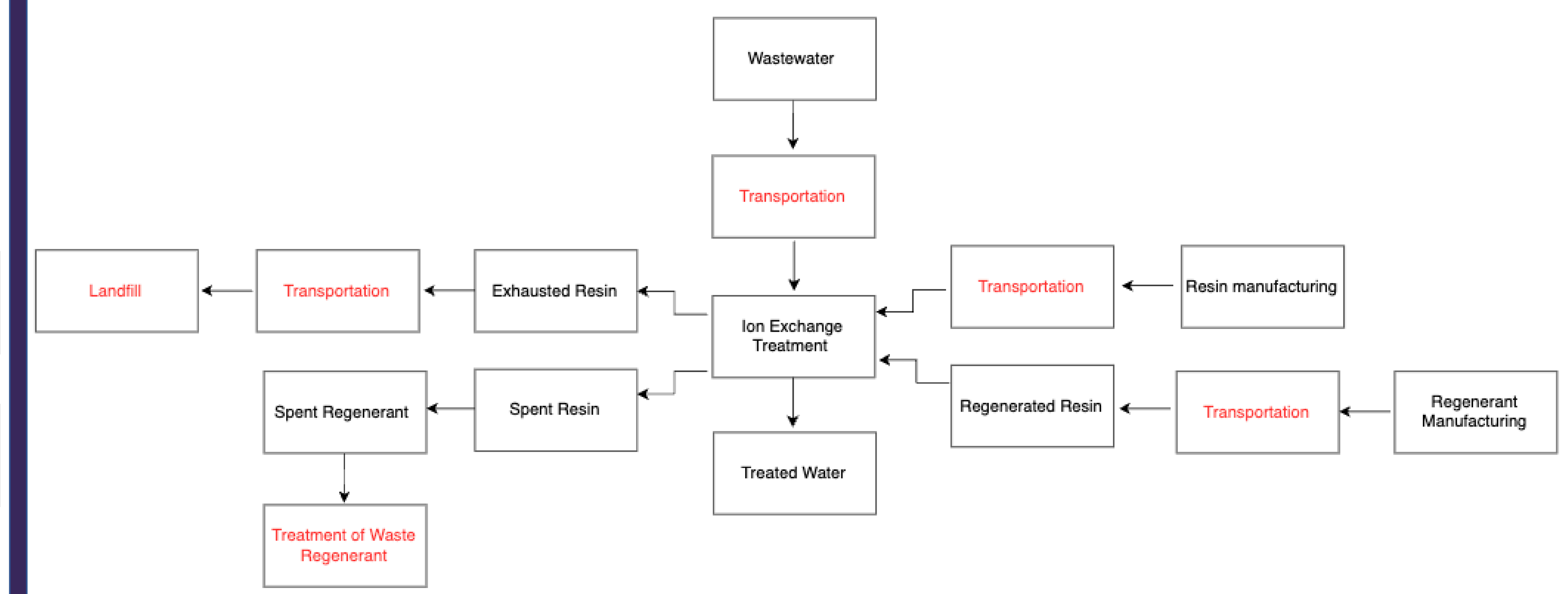

Figure 4. *Block flow diagram detailing the surrounding variables of the Ion Exchange process. Red Labels indicate that the variable contributes to GHG emissions.*

Key Assumptions

- Regenerant wastewater treatment accounts for an additional 10% of total GHG emissions
- Regeneration takes place once a day for industrial IX which ranges from every 12 to 24 hours
- TSS to be completely removed by IX treatment

Results and Conclusions

To test the calculator, a mock waste stream was run through, testing a variety of hypothetical conditions using several different cases:

- Case 1: Testing how transit contributes to greenhouse gas emissions by having separate coagulation and reverse osmosis facilities being used for treatment.
- Case 2: Like Case 1, however pH pretreatment was done by ion exchange compared to coagulation be used in Case 1.
- Case 3: Occam's Razor approach using only coagulation to treat the waste stream.
- Case 4: Like Case 1, but now all treatment steps are contained to the same facility.

Case 1 Result: 9,600 tonne of CO_2 per year

Case 2 Result: 13,000 tonne of CO_2 per year

Case 3 Result: 43,000 tonne of CO_2 per year

Case 4 Result: 9,300 tonne of CO_2 per year

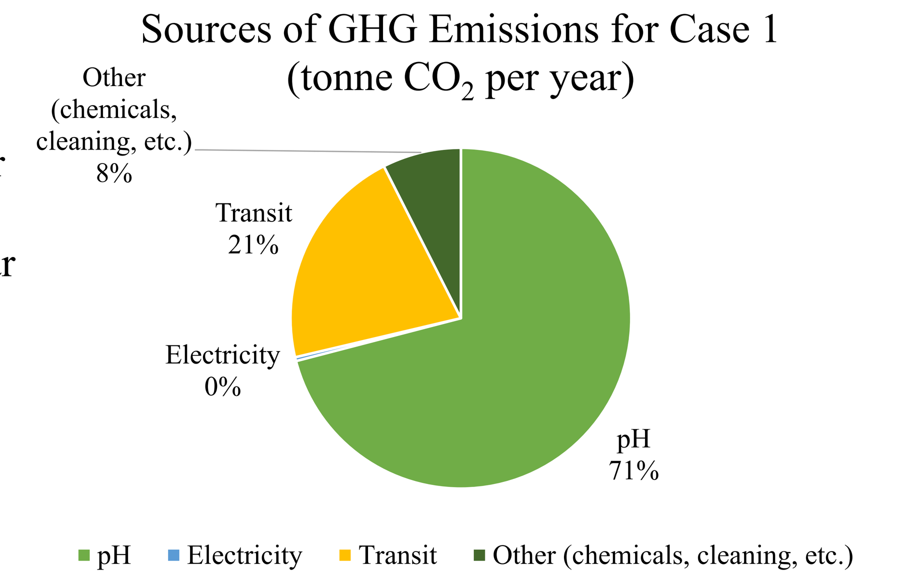

Figure 5. *Comparison of CO_2 emission sources for Case 1 using GHG Calculator.*

Based on cases above, transit, as shown in by emission differences in Cases 1 and 4, contributed negligibly to greenhouse gas emission. The largest contributor by far is pH pretreatment and the removal of suspended solids before and after reverse osmosis.

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