Team 1: Zhengyuan Huang, Jingyu Li, Mia Palmer, and Hannah Reed

Design of an Ammonia and Iron Removal Water Treatment System

A proposal for a treatment train which will be able to handle and treat leachate from the Tillamook Closed Landfill in Tillamook County.

Problem Statement

The Tillamook County Public Works Department (TCSW) is requesting a long-term, sustainable solution to treat 10-15 million gallons per year of dilute leachate from the Tillamook Closed Landfill (TCL). The solution should be able to treat excess ammonia and iron from the leachate to acceptable limits so that it may safely be discharged to a vegetated swale where it will eventually reach the Tillamook River. TCSW requests that the treatment process be low-maintenance, require little energy or chemical inputs, and need infrequent monitoring.

Project Significance

The leachate produced by the Tillamook Closed Landfill drains into Beaver Creek and is ultimately discharged into the Tillamook River. High concentrations of nitrogen within rivers will cause eutrophication, promote harmful algal bloom growth, and threaten aquatic life. Water from rivers containing high levels of iron will have an unpalatable rusty taste, odor, and color, and potentially clog pipes over time. To provide a safe and healthy environment for the local ecosystem, treating leachate before being discharged is necessary. This is an issue that many industries, including agricultural and municipal, have struggled with for decades, making the design of low-maintenance, low-cost solutions which minimize land requirements crucial.

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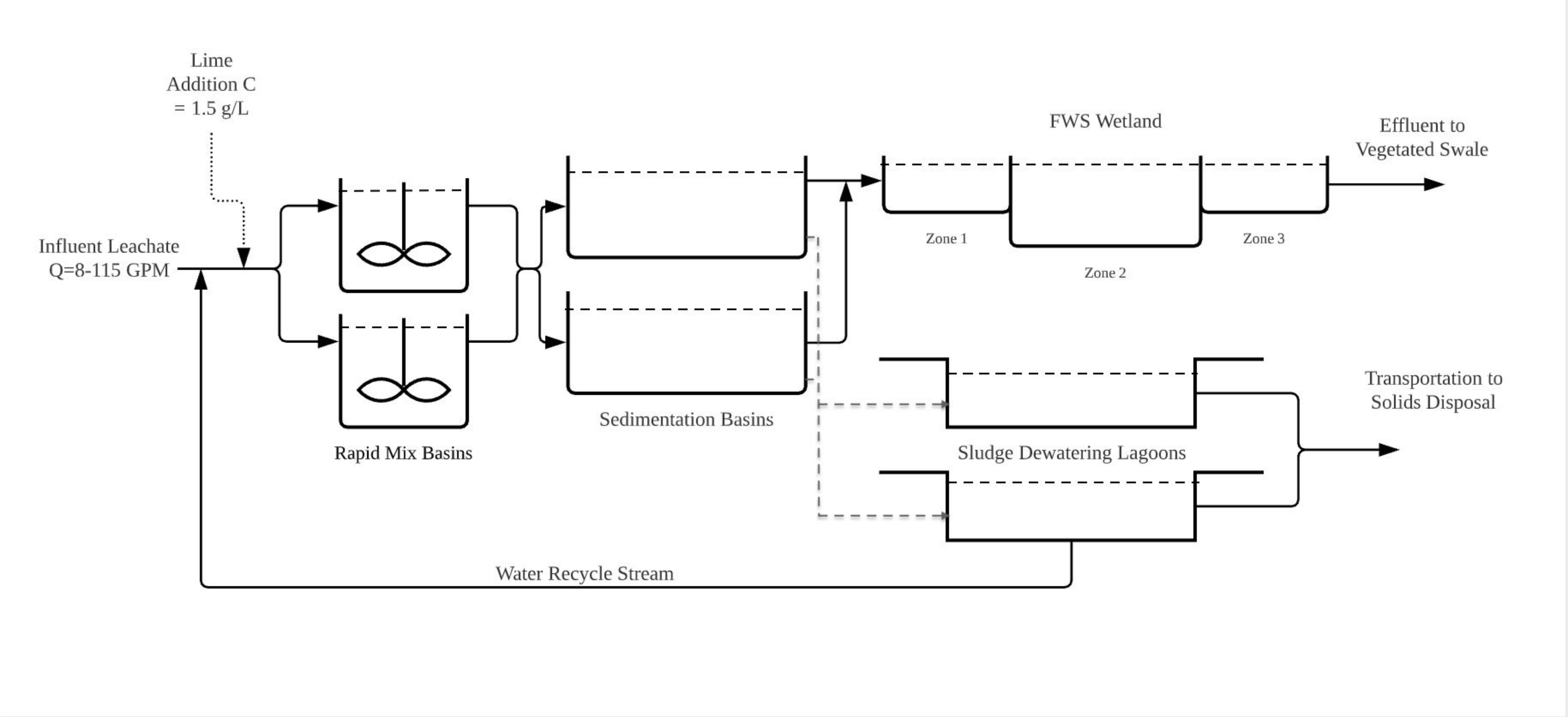

Figure: *Process flow diagram showing arrangement of the unit operations in the proposed design: rapid mix basins, sedimentation basins, a FWS wetland, and sludge dewatering lagoons. Leachate and solids levels in each unit are shown as dashed lines, chemical additives as dotted arrows, and leachate pipelines as solid arrows. Grey dashed arrows leading to the dewatering lagoons represent sediment sludge flow.*

Methodology

The full-scale flow was chosen as 113-115 GPM to reflect the maximum flow that the system would receive at the TCL (the pilot-scale was reduced to 8 GPM). The lime addition pond was designed as a continuous stirred-tank reactor (CSTR) at steady-state. The concentration of lime added to the mixer was determined by its solubility limit of 1.5g/L. The effect of hydrogen ions produced by ferrous oxidation (Eqn.1), leachate alkalinity, and pH changes from the lime addition were considered in the flow rate calculation for lime addition.

$4Fe^{2+} + O_2 + 10H_2O \rightleftharpoons 4Fe(OH)_3\ (s) + 8H^+$ (Eqn.1)

A material balance of ferrous iron determined the volume of the pond. Design criteria for vertical turbine flocculators, and power and pumping numbers for common impellers determined pond dimensions and impeller design.The sedimentation basin was designed for type II settling. Flow through the basin was determined to be laminar because of its low Reynolds number. Basin dimensions were determined by calculating the critical settling velocity of particles. A free water-surface (FWS) wetland was chosen to treat ammonia levels via nitritation and subsequent nitrification. Temperature-dependent areal rate constants were calculated using site monitoring data data, then used to determine the wetland area which would be required to reach an effluent quality of 2.5mg ammonia per liter via the k-C* model presented by Kadlec and Knight (1996). The sludge dewatering lagoons, used in a batch cycle manner, were designed to have fill, settle, and decant stages. One lagoon would be filled for six months and left to dewater the sludge via gravity settling for another six months as the 2nd lagoon enters the fill stage. The supernatant layer would be decanted post-settling and directed back to the beginning of the treatment system, as dewatered solids would be disposed of off-site.

Design Description

- **Lime addition pond:** Two 3m x 3m x 3m basins were included for maintenance redundancy. The basins would receive an aqueous solution of 3.0 grams of lime per liter at 1.3 GPM. One pitched-blade turbine was included in each, with a diameter of 1m and speed of 20 rpm.
- **Sedimentation basin:** Following the rapid mix basin, two 10.1m x 2.0m x 5.0m sedimentation basins were included.
- **FWS Wetland:** A wetland with three zones and a total surface area of 6.8 acres would accept effluent from the sedimentation basins. Zones 1 and 3 would be fully vegetated with *Scirpus californicus* and *Typha latifolia*, and have dimensions of 185.0m x 37.0m x 0.75m. Zone 2 would have an open-water surface and dimensions of 262.0m x 52.0m x 3.0m.
- **Sludge Dewatering Lagoons:** Two lagoons, each with an area of $7m^2$ and depth of 1.5 meters, would accept solids from the sedimentation basin for dewatering. The 6-month filling periods would be January-June for Lagoon 1, and July-December for Lagoon 2.

Conclusions

- A low-cost, low-maintenance treatment system capable of treating the TCL leachate to acceptable iron and ammonia levels was completed.
- Areal site restrictions (0.8 and 0.1 acres for the full-scale and pilot-scale, respectively) were exceeded in the final full-scale and pilot-scale designs. The unit operation which contributed to this the most by far was the FWS wetland, suggesting that the use of another method to reduce ammonia should be explored in the future.
- It is suggested that methods to handle the excess flow during winter months be implemented, i.e. via flow equalization, as this would lower the areal requirements significantly.
- A more conclusive design evaluation would be able to be given after pilot-scale testing, which would determine whether the models used for the design were accurate.