IPRO 346 BP Whiting Refinery Expansion

Developing Wastewater Cleanup Option

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1. The Objective

Explore ways in which BP can expand the capacity of their Whiting, IN refinery without increasing the amount of waste released into the environment.

2. The Controversy

BP files for and receives a permit to increase its total suspended solids (TSS) and ammonia (NH3-N) waste that it dumps into Lake Michigan. Public outcry ensues.

3. The Compromise

In response to the public outcry spurred by the city of Chicago's Mayor Daley and the Chicago Sun-Times, BP executives decide that they will scrap the project unless they can keep the emissions at their current levels before the expansion.

4. The Problem

Whiting's wastewater treatment facility, dubbed "The Lakefront", must be expanded significantly in order for this to succeed.

5. The Potential Ideal Solution

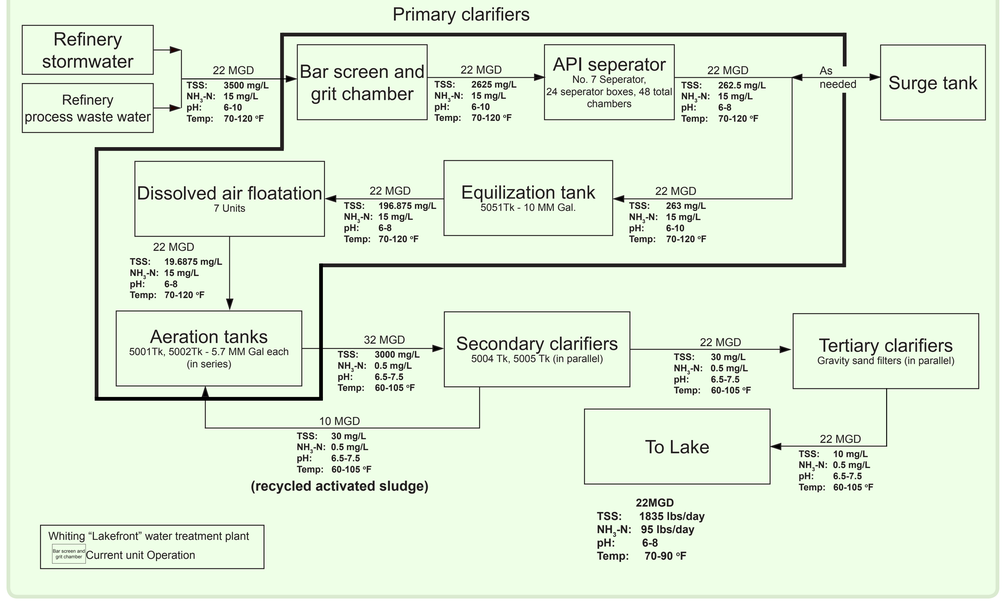
While being interviewed, Mr. Moye was asked what technology, if given an unlimited budget, would be the technology that he would like to see in place. His answer was that he wanted to see if membranes could be developed for this type of application.

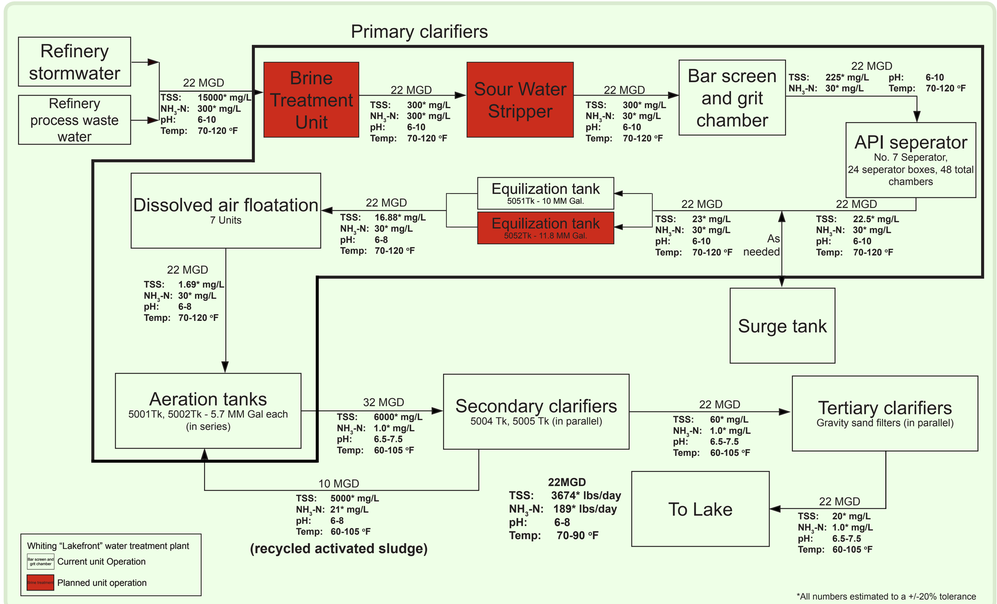
6a. The Current Configuration (right)

This process diagram shows how the water flows through the treatment plant and what the levels of the pollutants are as they go through the different units.

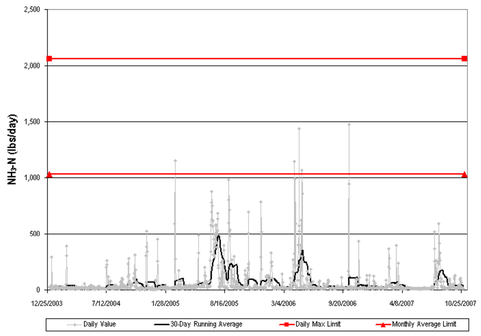
6b. The David Moye (BP) solution (down)

The engineer at BP in charge of the Lakefront, David Moye, has proposed the following plant retrofit and expansion as a solution to eliminate the increased TSS and ammonia levels from the Canadian crude modernization.





8a. The Ammonia History



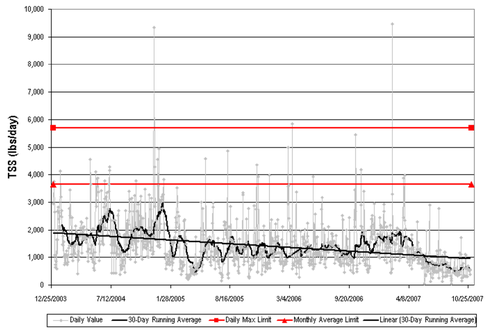
The ammonia output of the Whiting plant for the past four years is shown here. The red lines are the limits, both daily and monthly maximums.

As can be seen here, the lakefront does a good job of removing the ammonia necessary in order to comply with their dumping permits.

7. The Site

This arial photo shows the lakefront as it is today. That giant empty space, though tempting, is unusable due to the way that it is filled.

8b. The TSS History



The TSS output of Whiting's Lakefront facility for the past four years is shown here. The red lines are the limits - daily and monthly maximums.

The gray points are the daily outputs of TSS into the lake, while the thick black line is the running monthly average.

As is visible in these plots, the plant is outputting under their limits.

9. The New Unit Operations

The largest part of the retrofit/ expansion to the Lakefront is the addition of two new unit operations, the brine treatment unit and the sour water stripper. Both units pre-treat the water before it enters the main water treatment plant. This lightens the extra burden on the plant due to the increased ammonia and TSS throughput.

10. The Tetra Tech Report

In response to the claims by BP's officials that the reduction of ammonia and TSS were initially unfeasible, Mayor Richard Daley of Chicago commissioned a report of viable technical options from Tetra Tech Inc., a large multinational engineering firm. The firm specializes in resource management and environmental consulting.

11. The Membrane

Though accurate membrane models are not yet available for this type of application, membrane modeling software was obtained and the system was modeled to evaluate the potential performance of membranes in this situation. Membrane lifetimes are still not known for this application, though they are expected to be short and have a high overhead cost.

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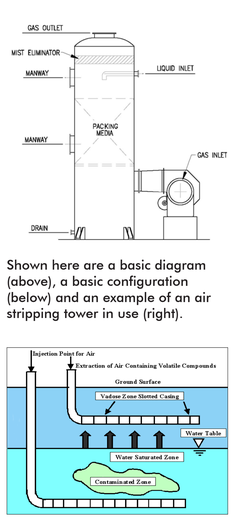
12. The Tetra Tech report suggestions

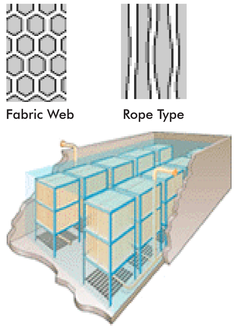
The Tetra Tech report studied the BP Whiting facility as a black box system and suggested several options for reducing the ammonia and TSS emmissions. Tetra Tech estimated that the necessary retrofits would cost BP at most $40 mil. These suggestions were the starting point for the research for this IPRO.

13a. The Ammonia Air Stripping units

These units take the waste stream and essentially do a controlled evaporation of the ammonia and other volatile organic compounds. The stream is sprayed over a packing membrane with air blown in the other direction, removing all of the more volatile compounds while water drips down and out as the exit stream. This option was eliminated because the other outlet stream was ammonia gas, which is costly to convert and remove.

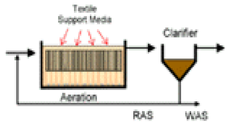


Shown here are a basic diagram (above), a basic configuration (below) and an example of an air stripping tower in use (right).



Fabric Web | Rope Type | Plastic Cylinders | Sponge

The four main types of IFAS substrates (above) for the bacteria to grow on are the fabric web, the rope type, plastic cylinders or a sponge material. The chosen medium is suspended in the tanks with aeration pipes below the fixtures (left and bottom).

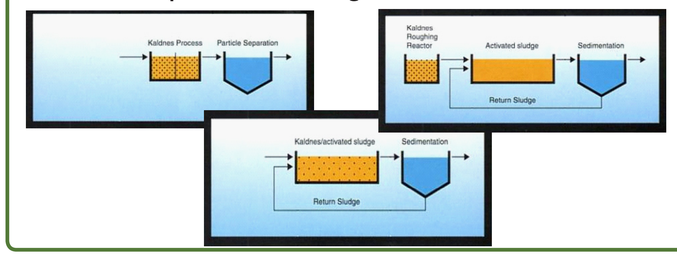


13c. The Integrated Fixed Film Activated Sludge Tanks

The IFAS process is very similar to the BAF process, except instead of floating suspended materials for the biological agents to grow on, the agents are fixed to screens. These screens are aerated as well, and like the BAF option, it is relatively cheap and very efficient.

13d. The Moving Bed Biofilm Reactors

A Moving Bed Biofilm Reactor (MBBR) is made up of several floating plastic media, known as biocarriers, which drift around in a tank. Attached to these biocarriers are microorganisms that remove the ammonia. The biocarrier is optimized for both the largest surface area possible for the microbes to grow on, and to let it be moved around by the aeration bubbles. This system is also used in combination with other treatment options including a sedimentation tank and activated sludge.



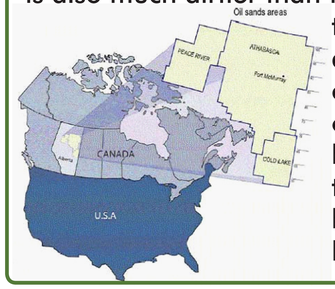
The basic process diagrams for differing MBBR configurations are shown here. A system with only an MBBR tank (far left) is the simplest MBBR configuration. Another configuration is combining a hybrid system of MBBR and activated sludge, with a return stream (left). The last common configuration of MBBR is called the Kaldnes roughing reactor (near left), which contains an MBBR system that also includes activated sludge after the MBBR system.

14. The public reacts

Some considered the Whiting expansion to be an infringement on their rights while others viewed it as a way to help ease our dependence on unstable regions. Several activist groups reacted in outrage towards BP, the Indiana Department of Environmental Management and the EPA, primarily through legislative bodies. Another form of expressing their outrage was via YouTube, where any opinion can be displayed.

15. The tar sands of Alberta

The main source of the Canadian crude that Whiting's expansion will use is from three regions in Alberta, Canada. These "tar sands" are sands that have been saturated with a thick viscous oily substance called bitumen. Bitumen is a much lower grade oil than the oil typically found in the Middle East or other parts of the world, and therefore needs much more refining than those crudes. Bitumen is also much dirtier than these oils, so the nitrogen and sulfur content in these oils is much higher, thus the increased burden on the lakefront.

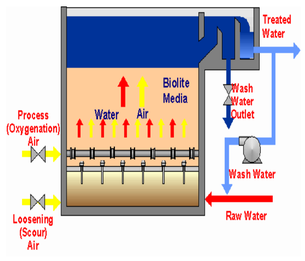


16. The regulations

Under current regulations required by the federal and Indiana governments, the amount of TSS and ammonia that Whiting's new permit would have allowed them to release to the lake is less than the maximum amounts that are deemed as harmful by the law, as is their current, lower levels.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

IDEM



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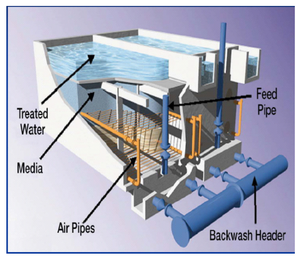

13b. The Biological Aerated Filter option

This process takes the wastewater stream and uses aerated biological agents to remove the ammonia. The biological agents create an activated sludge in the tank. The agents are grown on materials that are suspended in the tank with high surface area to volume ratios, thus giving the agents lots of space to grow in a relatively small volume. The process is very effective and relatively cheap.

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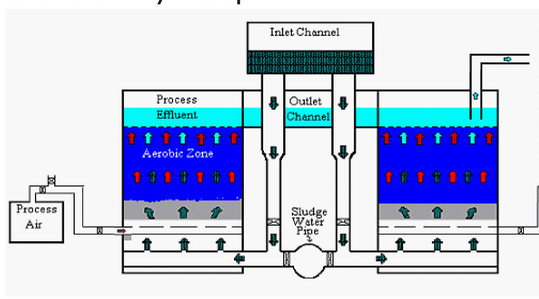
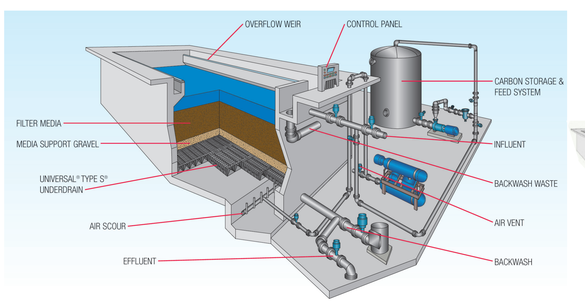


A basic process diagram of a BAF system (left) shows the waste stream going into the unit through the bottom. As the waste water rises through the filter, it is treated with biological agents that treates the ammonia. The TSS are trapped in the filter as well.

13f. The Elimi-NITE Denitrification System

The Elimi-NITE denitrification system is a combination of a porous membrane filter and a biological filter. The system allows the growth of biological agents that feed off of the ammonia and convert it to nitrogen gas, which is trapped in the porous media until the backwash cycle is completed. Since the membrane is porous, the system also traps the TSS, which reduces the amount of TSS in the outlet stream. This was removed as a viable technical option due to the fact that there is a very similar system already in place at the lakefront.



A cutaway of the Elimi-NITE system (left) shows how the system works and where its main components are. As can be seen, the flows the water that needs to be treated through the gravel first (middle left), then the nitrogen release cycle blows the trapped nitrogen gas into the air (middle) then the final full backwash cycle (middle right) to clean out the trapped solids and the microbes.