University Learning in Schools

Chemistry

The Engineer's Guide to Cleaning up an Oil Company's Mess: Process Economics

Lesson 5

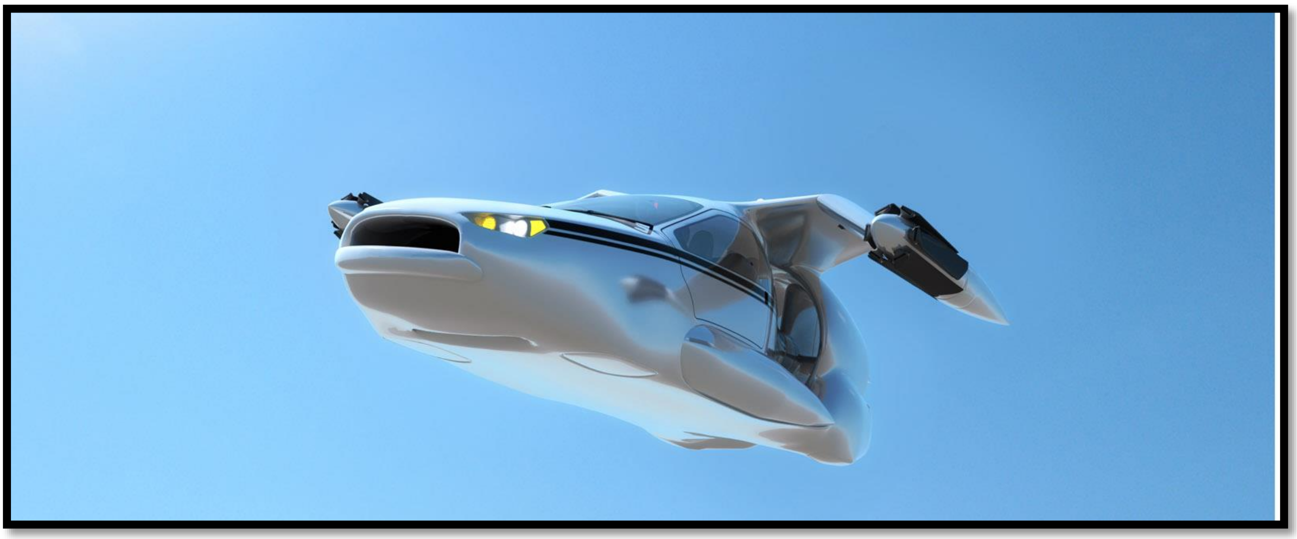
The Brilliant Club
Department for Education
SUPPORTED BY MAYOR OF LONDON

A Contemporary Challenge in Chemical Engineering

You may have noticed from your homework tasks in Lesson 3, that there are some treatment techniques that are far more effective than others. For example, the **advanced oxidation process** has the ability to remove 99% of the COD from a wastewater stream, whereas the physical process can only remove 60% of the COD. So why do people still use the physical process over the advanced oxidation process? The answer is that the costs associated with the advanced oxidation process may be too much for the local wastewater company to pay.

This means that even though we have the technology that is required to treat the streams to the full extent, we cannot implement it on a commercial scale. It is very much like the flying car concept. We actually have all of the technology to build one, but it cannot be implemented on a commercial scale, so it remains unsustainable.

It is our job as engineers to not only offer a solution that meets our treatment specification, but one that will also be financially viable.



Flying cars- An unsustainable reality

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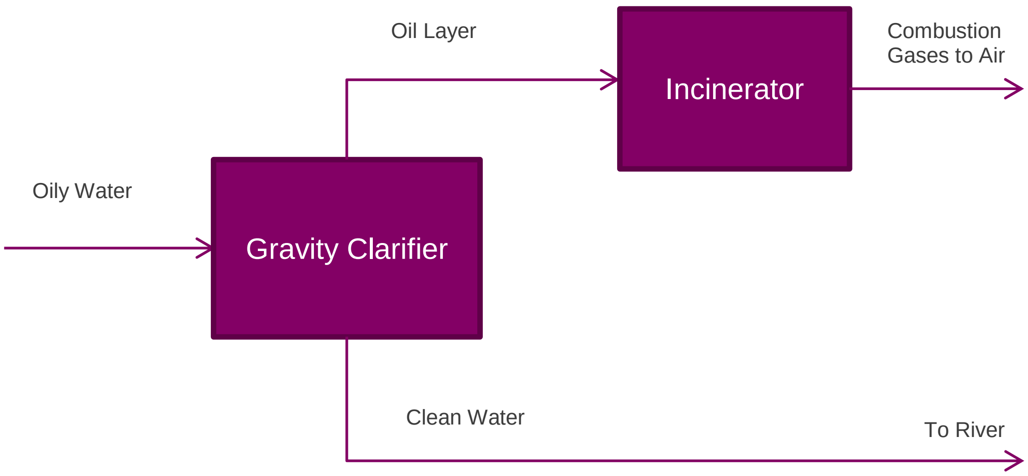
Process Economics -- Using the Physical Process as an Example

Let's return to our example of treating our petroleum waste water using the physical process:

- Suppose we are given a specification of treating 10 000 litres of waste over a year within a 100L gravity clarifier vessel.
- We wish to use a physical process which is known to remove 65% of the incoming COD.
- Our investors are willing to accept a cost of £10 000 in the first year for the treatment facility to be built.
- Discharge limits require the streams leaving the process to have a COD of no more than 3.5 g/L.

The block flow diagram of the process is given below:



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Fixed Costs

Fixed costs are the costs associated with the equipment that is needed for the process. Below is a list of equipment pieces that we can buy, as well as the cost associated with each piece of equipment:

Piece of Equipment	Capital Cost
AOP Reactor	£10 per litre
Bioreactor	£10 per litre
Gravity clarifier	£30 per litre
UV Disinfection vessel	£1000
Incinerator	£1500

We need a gravity clarifier and an incinerator for the above process. We can see that the incinerator costs £1500 and the cost of the gravity clarifier costs £30 per litre. The gravity clarifier cost is thus dependent on the size of the equipment required.

Since we are planning to purchase a gravity clarifier that is 100L in size, the cost of the gravity clarifier would thus be:

$$Cost\ of\ gravity\ clarifier = 100\ L * \frac{£30}{1\ L} = £3000$$
$$Cost\ of\ incinerator = £1500$$
$$Total\ capital\ cost = £3000 + £1500 = £4500$$

Operation Costs in the First Year

We now need to calculate the cost of operating our plant for the first year of operation. Generally, we will be given information regarding how much our units will cost in terms of the amount of COD that they are capable of removing. We will also be provided with cost sheets for the units that don't remove COD. An example of an information sheet is provided below:

Operational Cost Name	Cost
Advanced oxidation (using hydrogen peroxide)	£ 0.1 per g of COD removed
UV Light for disinfection of microbes	£ 0.02 per g of COD removed
Physical process (fuel for the incinerator)	£ 0.04 per g of COD removed

We can see from the above table that the cost of running the physical process would be £0.04 per mg of COD removed. This means we need to calculate the total amount of COD.

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$$Removal\ Efficiency = \frac{COD_{removed}}{COD_{in}} * 100$$ ** Using the formula we learnt

$$65 = \frac{COD_{removed}}{10\ g/L} * 100$$ ** Adding in the numbers

$$\frac{65 * 10\frac{g}{L}}{100} = COD_{removed}$$

$$COD_{removed} = 6.5\ g/L$$

Since we are treating 10 000 litres of waste, the amount of COD removed in total would be:

$$Total\ COD\ removed\ in\ a\ year = 6.5\frac{g}{L} * 10\ 000\ L$$

$$Total\ COD\ removed\ in\ a\ year = 65\ 000\ g$$

According to the table above, the cost of operating the physical process is given as £0.04 per mg of COD removed, thus the operating costs for the first year are given as:

$$Operation\ costs\ in\ first\ year = 65\ 000\ g * \frac{£0.04}{g} = £2\ 600$$

$$Total\ cost\ of\ operation = £4500 + £\ 2600 = £\ 7\ 100$$

A summary of the process is given as follows:

	Required	**Achieved**
COD, out	< 3 g/L	3.5 g/L
Total Cost	< £10 000	£7 100

We see that although the cost of the process is well within our budget of £ 10 000, the requirement for the outlet COD of the process is not met.

We would thus tell our investors that the physical process is economically feasible, but not suitable for treating the stream completely.

Recommendations could be exploring other treatment processes, or combining this process with either the physical or the biological process.

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