BEE 4750/5750 Homework 1

Akanksha Srivastava (as2752)

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Problem 1

Problem 1.1

Figure 1 (next page) shows a diagram of the system.

The two key parameters in this diagram are X_1 (the amount of water treated by land in m^3/day) and X_2 (the amount of water treated chemically in m^3/day).

Problem 1.2

In order to determine the YUK concentration of the total $100m^3/day$ after treatment, we must determine the individual amount of YUK that is actually making it to Pristine Brook. Here, M_l is the mass of YUK from land treatment, M_c is the mass of YUK from chemical treatment, M_u is the mass of YUK going directly to the brook, and M_t is the total mass of YUK reaching the brook.

$$M_l = 0.2kg/m^3 * X_1 m^3/day = 0.2X_1 kg/day$$
$$M_c = 0.05X_2 kg/m^3 * X_2 m^3/day = 0.005X_2^2 kg/day$$
$$M_u = 1kg/m^3 * (100 - X_1 - X_2)m^3/day = 100 - X_1 - X_2 kg/day$$
$$M_t = M_l + M_c + M_u = 100 - 0.8X_1 - X_2 + 0.005X_2^2 kg/day$$

We then divide the total mass by the volume of water that is being delivered to the brook to find C_Y, the YUK concentration in kg/m^3:

$$C_Y = M_t/100m^3/day = 1 - 0.008X_1 - 0.01X_2 + 0.00005X_2^2 kg/m^3$$

Problem 1.3

The following function takes X_1 and X_2 as parameters and returns the concentration of YUK and cost of treatment in tuple form. Note that the concentration calculated in the function is in units of kg/day. This is to make comparisons between the calculated mass of YUK and the EPA limit easier.

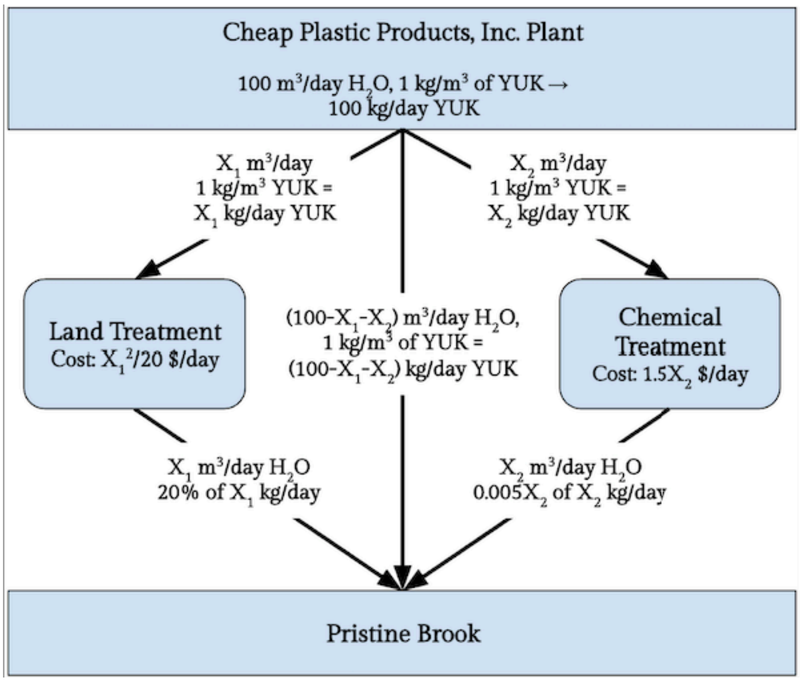


Figure 1: System Diagram

```
julia> function YUK(X1, X2)
           Ml = 0.2*X1
           Mc = 0.005*X2*X2
           Mu = 100-X1-X2
           conc = Ml + Mc + Mu #kg/day
           cost = X1^2/20 + 1.5*X2 #dollars per day
           return conc, cost
       end
YUK (generic function with 1 method)
```

Problem 1.4

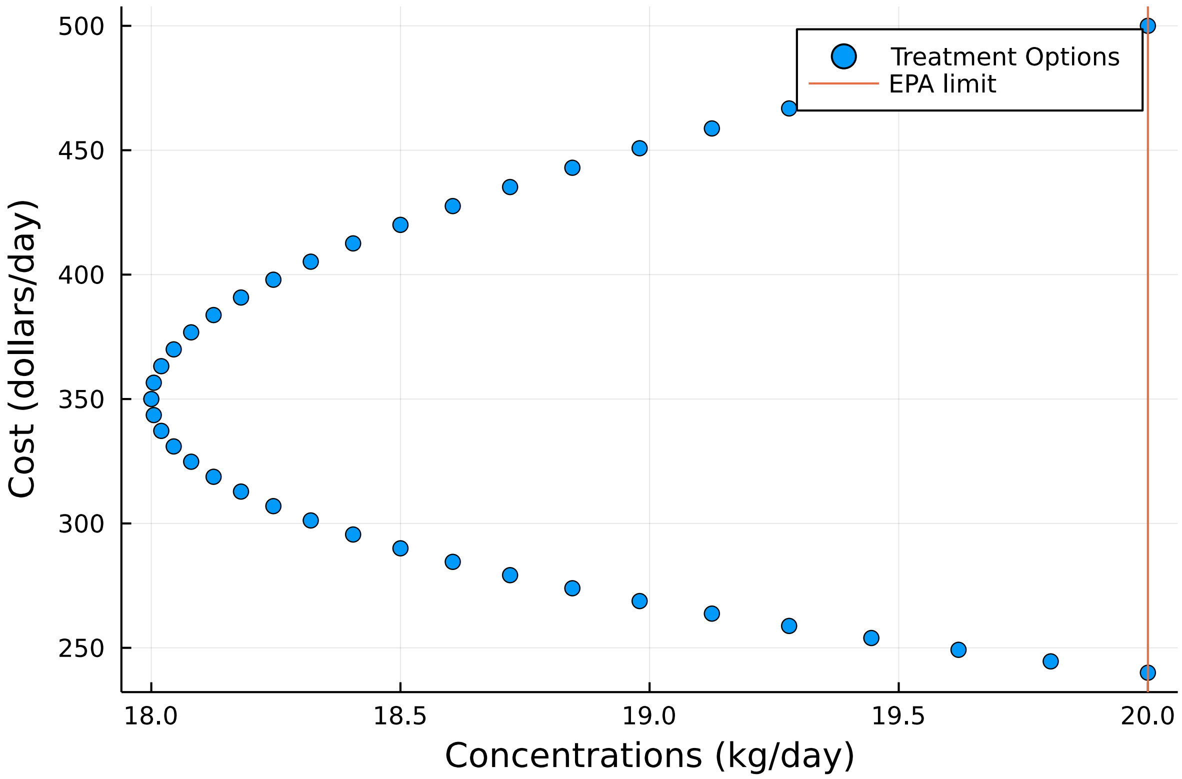
After inputting some test values, it becomes clear that most valid treatment options will have the water completely split between land and chemical treatments (i.e. none will go directly to the brook).

It is noted that the land treatment option has an efficiency of exactly 80%, and the chemical treatment option has an efficiency ranging from 50% (if $X_2 = 100m^3/day$) to 99.99% (if X_2 is as small as possible without being zero). Given that the 100 kg/day must be reduced by 80% to reach the 20 kg/day limit, the chemical treatment option will have to have at least an 80% efficiency as well, which means that $X_2 < 40m^3/day$.

Therefore, the above model is evaluated for X_1 values ranging from $60m^3/day$ to $100m^3/day$ and X_2 values ranging from $40m^3/day$ to $100m^3/day$. This should ensure that all treatment options follow the effluent standard (in a red line).

```
julia> X1 = 60:1:100;

julia> X2 = 40:-1:0;
```

```
julia> conc = zeros(length(X1));

julia> cost = zeros(length(X1));

julia> for i in 1:length(X1)
           conc[i], cost[i] = YUK(X1[i], X2[i]);
       end

julia> using Plots

julia> scatter(conc,cost,label="Treatment Options", xlabel="Concentrations
(kg/day)", ylabel="Cost (dollars/day)");

julia> vline!([20], label="EPA limit")
```



Based on the resulting scatter plot, it seems as though the array of treatments is somewhat parabolic. If we wanted to reach as low YUK concentrations as possible, we could reach 18 kg/day for 350$dollars/day$. If we wanted to reach as low costs as possible, we could meet the 20 kg/day limit for approximately 240$dollars/day$.

Problem 1.5

I would select a treatment plan depending on my priorities; if I care primarily about cost, I would choose the treatment plan that costs the least while still meeting EPA regulations, i.e. the 240 dollars/day plan. This would reflect the perspectives of factory owners and other financial stakeholders (investors, workers, etc.).

If I was the "public", or someone living in the area that made direct contact with Pristine Brook (through recreation, drinking water, fishing, etc.), then I might push for a more expensive but more effective treatment plan, such as the 350 dollars/day plan that reduces YUK concentrations to 18 kg/day.

Interestingly, I think that regulatory agencies might be indifferent to the cost vs concentration debate as long as their limits are reached. In setting this limit, there must be some certainty that concentrations of 20 kg/day are not a significant danger to public health.

The way that my numerical experiment in Problem 1.4 was set up ensured that the treatment options tested would all meet regulations; the experiment was purely a comparison of cost vs *how far* below the limit a treatment plan went. This is why I do not think a regulatory agency (the EPA in this case) would have a strong preference for any of the tested treatment plans; all of them meet requirements and are therefore outside the concern of the EPA.

My conclusions might have changed if I had allowed some of the water to be sent directly to Pristine Brook; it is possible that there would have been even more cost reductions possible had I tested out these scenarios.

Problem 1.6

As I stated in Problem 1.5, the key assumption I made was that all of the water had to be treated (i.e. none of it could be sent directly to Pristine Brook). Given the fact that we were able to meet EPA standards with a wide variety of combinations indicates that this assumption was not necessarily true.

Therefore, one could improve my model by adding in (X_1, X_2) pairs that do not follow the $X_1 + X_2 = 100$ constraint. Instead, these pairs would follow a $X_1 + X_2 < 100$ constraint. I believe that this could reduce the minimum cost for meeting regulations and lead to slightly different conclusions about the most cost-effective treatment options.

References