BEE 4750/5750 Homework 1

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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.

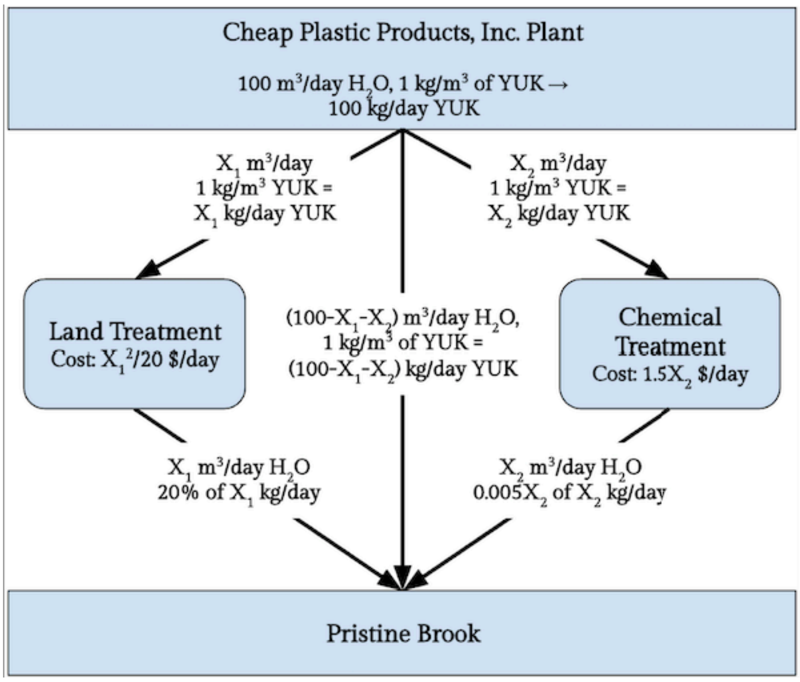


Figure 1: System Diagram

```
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

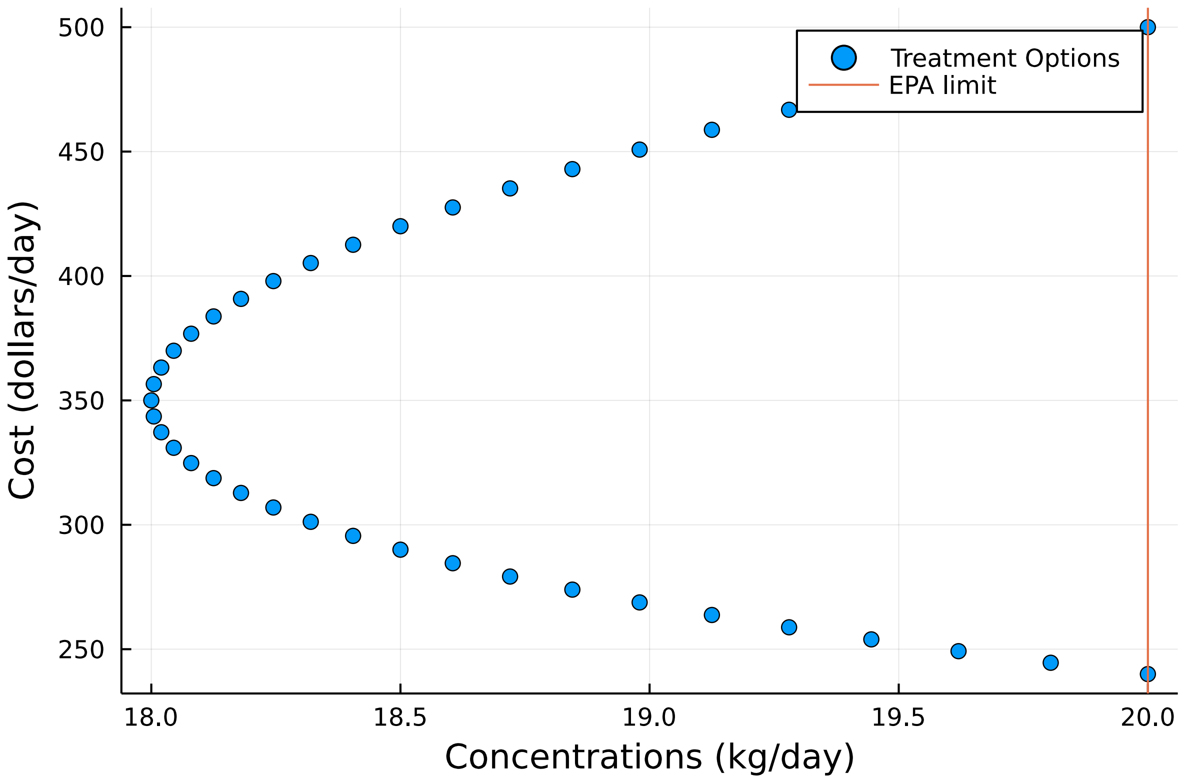
After inputting some test values, it becomes clear that most valid treatment options will have the water completely split between land and chemical treatments (i.e. none will go directly to the brook).

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/*day*. If we wanted to reach as low costs as possible, we could meet the 20 kg/day limit for approximately 240/*day*.

Problem 1.5

Based on the plot from Problem 1.5, how would you select a treatment plan? How might this plan reflect the perspectives of various interested parties (factory owners, the public, regulatory agencies, etc)? Did how you set up your numerical experiment in Problem 1.5 influence your conclusions? Might they have changed with a different experimental design?

Problem 1.6

What do you think should be investigated further to improve your model? What assumptions did the problem or you make that should be kept in mind when interpreting your results?

References