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Application of mathematical model using advanced programming languages to estimate lake pollution

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***Abstract*---**The goal of this article is to develop an online simulation of lake pollution. The mathematical model for detecting the load of various pollutants in a lake was developed earlier. Through this model, different pollutants are disseminated throughout the lake and their discharge is calculated. Manual arithmetic calculations were possible, but they had many limitations due to the logarithmic equations as well as the length of time it took. In order to accomplish this, C++ and Java were used to create the Lake Pollution Model. A manual scientific calculation has been used to calibrate this model, which has an error of 0.114 to 0.25 mg/L. Based on the results, it can generate lake pollution output in a very short amount of time without involving scientific calculations.

***Keywords*---**lake water, pollution model, calibration, software, water pollutants.

Introduction

Over two thirds of Earth's surface is covered by water, less than a third is taken up by land. As Earth's population continues to grow, people are putting ever-increasing pressure on the planet's water resources. In a sense, our oceans, rivers and other inland waters are being "squeezed" by human activities - not so they take up less room, but so their quality is reduced. Poorer water quality means

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water pollution. It is known that pollution is a human problem because it is a relatively recent development in the planet's history: before the 19th century Industrial Revolution, people lived more in harmony with their immediate environment. As industrialization has spread around the globe, so the problem of pollution has spread with it. When Earth's population was much smaller, no one believed pollution would ever present a serious problem. It was once popularly believed that the oceans were far too big to pollute. Today, with over 8 billion people on the planet, it has become apparent that there are limits. Pollution is one of the signs that humans have exceeded those limits.

Water pollution

Water pollution can be defined in many ways. Usually, it means one or more substances have built up in water to such an extent that they cause problems for animals or people. Oceans, lakes, rivers, and other inland waters can naturally clean up a certain amount of pollution by dispersing it harmlessly. If you poured a cup of black ink into a river, the ink would quickly disappear into the river's much larger volume of clean water. The ink would still be there in the river, but in such a low concentration that you would not be able to see it. At such low levels, the chemicals in the ink probably would not present any real problem. However, if you poured gallons of ink into a river every few seconds through a pipe, the river would quickly turn black. The chemicals in the ink could very quickly have an effect on the quality of the water. This, in turn, could affect the health of all the plants, animals, and humans whose lives depend on the river.

Thus, water pollution is all about quantities: how much of a polluting substance is released and how big a volume of water it is released into. A small quantity of a toxic chemical may have little impact if it is spilled into the ocean from a ship. But the same amount of the same chemical can have a much bigger impact pumped into a lake or river, where there is less clean water to disperse it. Water pollution almost always means that some damage has been done to an ocean, river, lake, or other water source. A 1971 United Nations report defined ocean pollution as:

"*The introduction by man, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resources, hazards to human health, hinderance to marine activities, including fishing, impairment of quality for use of sea water and reduction of amenities.*"

Lake pollution

- Waste water:- Factories are point sources of water pollution, but quite a lot of water is polluted by ordinary people from non-point sources; this is how ordinary water becomes waste water in the first place. Virtually everyone pours chemicals of one sort or another down their drains or toilets. Even detergents used in washing machines and dishwashers eventually end up in our rivers and oceans. So do the pesticides we use on our gardens. A lot of toxic pollution also enters waste water from highway runoff. Highways are typically covered with a cocktail of toxic chemicals—everything from spilled fuel and brake fluids to bits of worn tyres (themselves made from chemical additives) and exhaust emissions. When it rains, these chemicals wash into drains, lakes and rivers. It is not unusual for heavy summer rainstorms to wash toxic chemicals into lakes and rivers in such concentrations that they kill large numbers of fish overnight. It has been estimated that, in one year, the highway runoff from a single large city leaks as much oil into our water environment as a typical tanker spill. Some highway runoff runs away into drains; others can pollute groundwater or accumulate in the land next to a road, making it increasingly toxic as the years go by.

- Chemical Waste: - Another kind of toxic pollution comes from heavy metals, such as lead, cadmium, and mercury. Lead was once commonly used in gasoline (petrol), though its use is now restricted in some countries. Mercury and cadmium are still used in batteries (though some brands now use other metals instead). Until recently, a highly toxic chemical called tributyltin (TBT) was used in paints to protect boats from the ravaging effects of the oceans. Ironically, however, TBT was gradually recognized as a pollutant: boats painted with it were doing as much damage to the oceans as the oceans were doing to the boats.

The best known example of heavy metal pollution in the oceans took place in 1938 when a Japanese factory discharged a significant amount of mercury metal into Minamata Bay, contaminating the fish stocks there. It took a decade for the problem to come to light. By that time, many local people had eaten the fish and around 2000 were poisoned. Hundreds of people were left dead or disabled.

Modeling/computation

Lake Water pollution can be measured by different ways viz. sampling, physical testing, chemical testing, etc. But we can also measure the lake water pollution by computational modeling (i.e. by designing models using different mathematical tools). For computational modeling, measurement of input parameters is necessary, which is done by either of the testing methodologies. In lake water modeling, we design a model using C++ and Visual Basic languages to calculate the concentration of the contaminants.

Lake pollution modeling

According to “Differential Equations", by Blanchard, Devaney, and Hall, mixture problems refer to a large collection of different problems where two or more substances are mixed together at various rates. Mixture problems range from mixing chemicals in a vat to the diffusion of cigarette smoke in the air of a room. We did our model on the mixing of pollutants in a lake.

Objectives

- To find lake pollution problem
- To analyse the significance of Lake Pollution Model for predictions.
- To design the Lake Pollution Model using C++ and VB languages.
- To validate the computational developed with suitable standards.

Materials and Methods

Lake pollution model

We start by using the basic mixture model,

$$Mass/Time = rate\ in - rate\ out,$$

and a list of variables:
C = concentration of the contaminant;
Q = the volumetric flow rate through the lake;
V = the volume of the lake;
M = the mass of the contaminant;
Where mass is defined as,

$$M = C * V$$

The rates are defined as,

$$\frac{dM}{dt} = C * Q,$$

where,

$$C = \frac{mass}{Volume},$$
$$Q = \frac{Volume}{Time},$$

Leaving

$$\frac{dM}{dt} = \frac{Mass}{Time}$$

Then the mixture equation becomes;

$$\frac{dM}{dt} = Cin\ (t) * Qin\ (t) - Cout\ (t) * Qout\ (t)$$

The *k* variable

Pollutants come in various chemical properties. Some pollutants are non-polar and do not react with water. This leaves the pollutant only one way to leave, through the outflow. Some pollutants are polar and react with water, causing either more pollutant, or less pollutant. *k* can be defined as:

$k = 0$; where there is no reaction

We will not consider the case where pollutant is created, so k will always be non-negative.

$k > 0$; where contaminant is not generated

The Lake Pollution Model k is also used in the chemistry world and determines the order of the reaction (in this case 0th and 1st order reactions). Thus another term is added to our differential model, and it becomes:

$$\frac{dM}{dt} = Cin\,(t)\ \mathbf{X}\ Qin(t) - Cout\,(t)\ \mathbf{X}\ Qout\,(t) - k\,(t)\ \mathbf{X}\ C(t)\ \mathbf{X}\ V\,(t)$$

Assumptions

Assumptions are made for the model, to make it easier to apply. Without assuming too much and drastically affecting the accuracy of the model these assumptions were made:

- The volume of the lake remains constant
- The flow rate remains constant
- The reaction rate remains constant
- The lake is well mixed

Lakes do not usually fluctuate in volume over a short period of time, so ssumption #1 seems plausible. In assuming that the volume is constant, the flow rate must also remain constant; therefore, assumption #2 is plausible. Assumption #3 is made to make the model easier to use but limited to only zero'th and first order reactions. Assuming the lake is well mixed means that the concentration of the pollutant inside the lake is the same as the concentration of the outflow. This assumption is also to make the model easier to manage and is also limited to its use.

Revamped model

The lake pollution model is modified with these assumptions to become:

$$\frac{dM}{dt} = Q * Cin\ (t) - Q * C\ (t) - k * C\ (t) * V;$$

or,

$$V * \frac{dC(t)}{dt} = Q * Cin\ (t) - Q * C\ (t) - k * C\ (t) * V;$$

Since mass is equal to volume times concentration. Now dividing the equation by the volume will give a nice Robust Equation.

$$\frac{dC(t)}{dt} = \frac{Q}{V} * Cin(t) - \frac{Q}{V} * C(t) - k * C(t)$$

Dividing the volume by the flow rate gives units of time. This also gives how long it would take to fill the lake, if there was no outflow, and how long to drain the lake if there was only outflow. The *V/ Q* term stands for *residence time*, and the symbol θ_h is used. The equation becomes:

$$\frac{dC(t)}{dt} = \frac{1}{\theta_h} * Cin(t) - \frac{1}{\theta_h} * C(t) - k * C(t)$$

C++ Script CODE

```
/* LAKE POLLUTION MODEL */

#include<iostream.h>
#include<conio.h>
#include<math.h>


class Lake
 {

  public :
             double k;                //pollutant factor k > 0
             long double V;          //volume of the lake
             long double Q;          //volumetric flow rate of the lake
             long double C;          //concentration of the contaminants
             long double Cin;        //concentration of the pollutants inside lake
             long double theta;      //residence time
             long double result;     //result of lake pollution

             Lake()
             {
                  // default constructor
             }
             void Accept();
             double Calculate();
             void Display();
             ~Lake();

  }; //end of class declaration Lake

 void  Lake :: Accept()
  {
    cout << endl;
    cout << "Please enter the parameters to calculate \n"
```

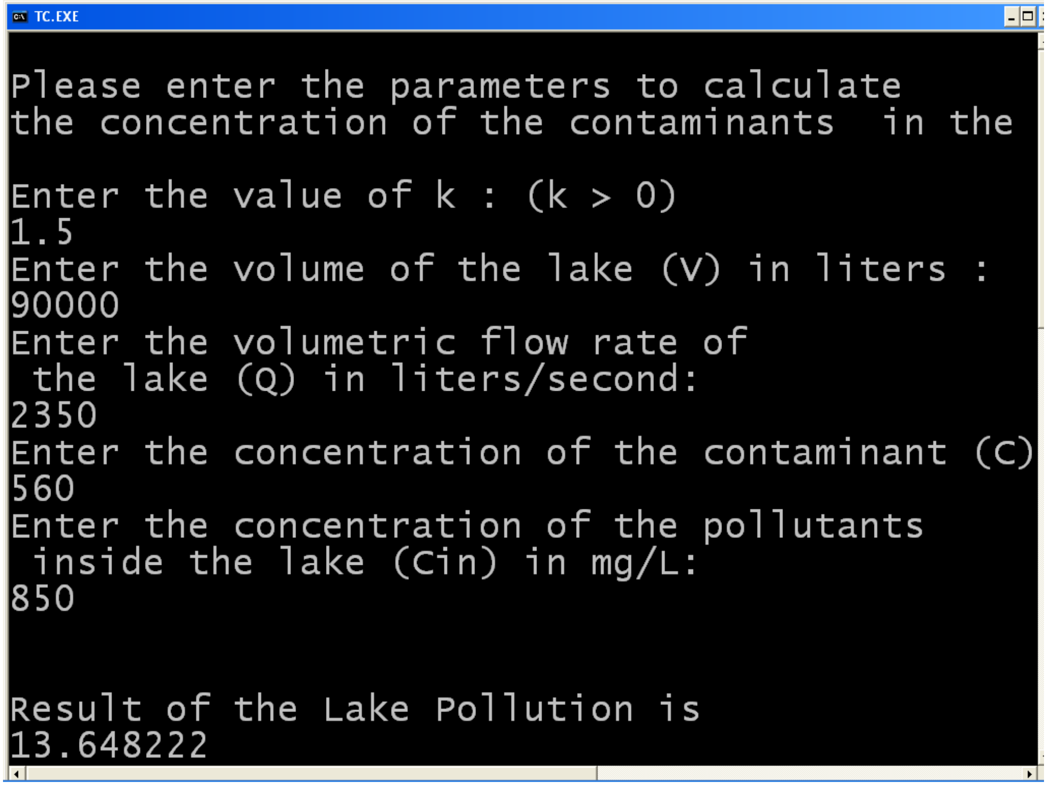
```
          << "the concentration of the contaminants "
          << " in the lake."
          << endl << endl;

   cout << "Enter the value of k : (k > 0) "
          << endl;
   cin  >> k;

   cout << "Enter the volume of the lake (V) in liters : "
          << endl;
   cin  >> V;

   cout << "Enter the volumetric flow rate of \n "
          << "the lake (Q) in liters/second: "
          << endl;
   cin  >> Q;

   cout << "Enter the concentration of the "
          << "contaminant (C) : "
          << endl;
   cin  >> C;

   cout << "Enter the concentration of the pollutants \n"
          << " inside the lake (Cin) in mg/L: "
          << endl;
   cin  >> Cin;

 }

 Lake :: ~Lake()
   {
        k   = 0.0000;
        V   = 0.0000;
        Q   = 0.0000;
        C   = 0.0000;
        Cin = 0.0000;
    }

double Lake :: Calculate()
  {
   theta = V/Q;

   result = (((1/theta)*Cin) - ((1/theta)*C*0.01) - (k*C*0.01));

   return result;

   }

void Lake :: Display()
  {
```

```
    cout << endl << endl;
    cout << "Result of the Lake Pollution is "
           << endl << result;

   }

 void main()
   {
    clrscr();

    Lake obj;
    obj.Accept();
    obj.Calculate();
    obj.Display();

    getch();
   }
```

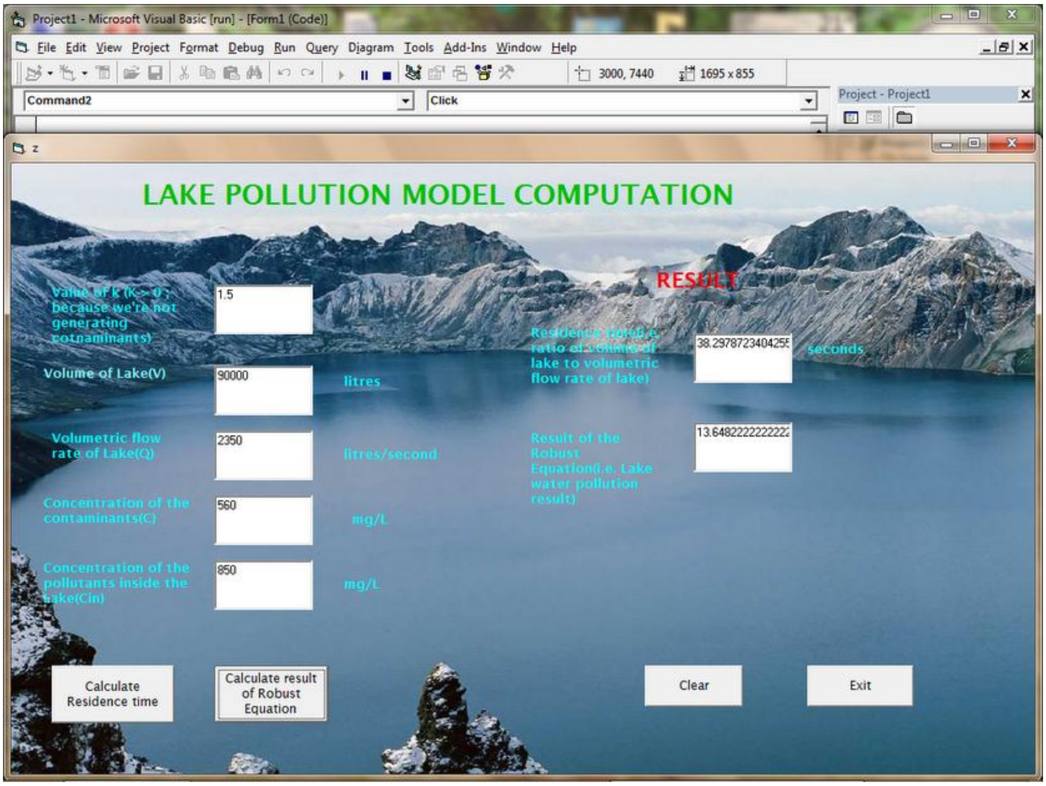
Visual basic script CODE

```
Private Sub Command1_Click()
Text6.Text = Text2.Text / Text3.Text

End Sub

Private Sub Command2_Click()
Text7.Text = (((1 / Text6.Text) * (Text5.Text)) - ((1 / Text6.Text) * (Text4.Text) * 0.01) -
(Text1.Text * Text4.Text * 0.01))

End Sub

Private Sub Command3_Click()
Text1.Text = ""
Text2.Text = ""
Text3.Text = ""
Text4.Text = ""
Text5.Text = ""
Text6.Text = ""
Text7.Text = ""

End Sub

Private Sub Command4_Click()
End
End Sub
```

Results and Discussion



The above screen is the output obtained by the computational modeling using C++ language. The inputs to the model are as: Volume of the lake in liters, Volumetric flow rate of the water in liters/sec, concentration of the contaminants in mg/L, Concentration of the pollutants inside the lake in mg/L. The resultant output is the result of the Robust Equation which gives the contamination concentration of the water for a specific time period.



The above form is the output obtained by the computational modeling using Visual Basic language. The inputs to the model are as : Volume of the lake in liters, Volumetric flow rate of the water in liters/sec, concentration of the contaminants in mg/L, Concentration of the pollutants inside the lake in mg/L. Resultant outputs are : the Residence Time in seconds, and the result of the Robust Equation which gives the contamination concentration of the water for a specific time period.

Conclusion

Pollution has been increasing its dimensions from local to global. Measurement and prediction of these pollutions are available now-a-days. Present study is attempted to find the concentration and predict pollution concentration in water body. Here we are using Lake Pollution Model derived by Joel Aguirre and Darren Tully and we have converted this into computational environment. C++ and Visual Basic scripts are used to develop Lake Pollution computational model. This model is validated by one previous study results and has got 98% of accuracy. This model will save the calculation time and useful for wide applications and prediction of pollution in lake.

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