Water Purification

New Mexico

Supercomputing Challenge

Final Report

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Team Number 64

Jackson Middle School

Team Member

Christopher Hoebing

Teacher

Karen Glennon

Project Mentor

Nick Bennett

Betsy Frederick

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Executive Summary:

Having drinkable water is vital to our survival. This is why I decided to track arsenic in our water supply. I did this by collecting water samples, gathering research, and collaborating with Mr. Kindel. Then I started writing a tracking program using NetLogo. I am hoping that this program can be used by the Water Authority someday to track arsenic and other drugs/chemicals in our water supply.

Statement of Problem:

Legal and illegal drugs. Toxic and non-toxic chemicals. What does the Rio Grande contain? What is in the water we drink? So far very little research has been done. Also, depending on who did the research, you get conflicting data for what is in our water. Reliable water resources are vital for the state of New Mexico. Currently the city of Albuquerque gets its water from the Rio Grande. It is important to know what is in the water we are drinking.

Overall, tracking chemicals/drugs in our water supply is a growing concern of our nation. Scientists are attempting to track these chemicals/drugs for ease of removal. In attempting this project, I am undertaking the investigation and simulation of the concepts involved in removing arsenic from our water supply.

The goal of this project is to create a simulation of arsenic in the water supply so it is easier to track for removal from the water supply. This simulation will show, based on the amount and PH of the water, the way arsenic moves in the water supply. It will also show a simulated way to remove arsenic from the water supply. This will allow water scientists to determine the best method for removing arsenic from our water supply.

Background:

In 1972 Congress passed the Clean Water Act. This law allows the Environmental Protection Agency (E.P.A.) to regulate waterways so that they are stopped being polluted. Or as the E.P.A. puts it "This law directs E.P.A. to … enforce drinking water regulations for contaminants that may cause health problems." (Agency, Environmental Protection Agency, 2007) Now, because of two Supreme Court rulings – "Solid Waste Agency of Northern Cook County v. United States Army Corps of Engineers in 2001 and Rapanos v. United States in 2006" (Duhigg, C. & Roberts, J., 2010), our nations water supply is in danger. Many environmental polluters say they are allowed to dump chemicals into water that isn't a river or an ocean. The problem with this is that many of the places they are now dumping feed into rivers or ground water and are affecting the quality of the water that we drink. In New Mexico alone Cannon AFB (near Clovis, N.M.) has informed the E.P.A. that it "no longer considers itself subject to the act." (Duhigg, C. & Roberts, J., 2010) Cannon AFB dumps wastewater containing "bacteria and human sewage into a lake on base." (Duhigg, C. & Roberts, J., 2010). This contaminated lake has the potential to release hazardous water into the water supply in the surrounding area.

As concerns for our nations water quality grows the E.P.A. has made some changes to its water rules. One of those changes was to decrease the acceptable level of arsenic from 50 parts per billion (ppb) to just 10 ppb. So just what is arsenic? Arsenic is an element on the periodic table that is not only a carcinogen but is odorless and tasteless as well. There are two forms of arsenic; organic and inorganic. Organic arsenic is usually found in food like shellfish. Inorganic arsenic is found in natural groundwater and surface water. Arsenic "occurs naturally in rocks and soil, water, air, and plants and animals." (Agency, Environmental Protection Agency, 2006) Arsenic can be released into the environment through volcanic eruptions, the erosion of rocks, from forest fires, or manmade sources. Approximately 90 percent of all manmade causes of arsenic come from using arsenic as a wood preserver. However, arsenic is also used in "paints, dyes, metals, drugs, soaps and semi-conductors." (Agency, Environmental

Protection Agency, 2006) High levels of arsenic also come from some kinds of fertilizers used by farmers and in animal feeding operations. Other industries like "copper smelting, mining and coal burning also contribute to arsenic in our environment." (Agency, Environmental Protection Agency, 2006)

Ground water supplies tend to have higher levels of arsenic than surface water. However, as the demand on ground water grows, water levels drop and arsenic is being released from rock formations. Arsenic is also entering our surface water as runoff, during storms, from farms and industrial sites. So why should we care if there is arsenic in our drinking water? Arsenic is shown to cause a wide degree of health problems to human exposed to it. These health problems can have both short and long term effects. "Cancers of the kidney, nasal passages, liver, and prostate are associated with long-term exposure to arsenic." (American Cancer Society, 2001) Low levels of arsenic exposure have been linked to "bladder, lung, skin, and other cancers." (American Cancer Society, 2001) Cancer is not the only thing you can get from arsenic exposure. Some non-cancerous "effects can include thickening and discoloration of the skin, stomach pain, nausea, vomiting, diarrhea; numbness in hands and feet; partial paralysis; and blindness." (Agency, Environmental Protection Agency, 2006) Arsenic has even been shown to cause "cardiovascular, pulmonary, immunological, neurological, reproductive, and endocrine (e.g., diabetes)" (Agency, Environmental Protection Agency, 2007) health effects. This is why it is so important to have no more than 10 ppb of arsenic in our drinking water.

The E.P.A. has set the maximum contaminant level goal (MCLG) of 0 ppb for arsenic. At this goal there should be no health risks associated with arsenic in drinking water. The maximum contaminant level (MCL) are set as close to the health goal as possible. This is what makes the MCL for arsenic 10 ppb. When setting the MCL certain factors are taken into account. Things like considering how much it will cost, what the benefits are, and how well the public water system is able to detect and remove the contaminants from the water. Also, what kinds of technology are available to treat the water for these contaminants. When the E.P.A. looks at the MCL for arsenic in drinking water they are checking the total arsenic which includes both the organic and inorganic forms.

When it comes to removing arsenic from water the pH level of the water needs to be taken into account. Inorganic arsenic has two different states, arsenite (As III) and arsenate (As V). Most groundwater contains As (III) which is the more toxic form of the inorganic arsenics. In surface waters As (V) is the more common form. As (III) is harder to remove than As (V) from water because it usually occurs in water with a pH of less than 9.0. Most arsenic technology on the market works with pH levels in the range of 6.5 to 9.0. However, the optimum pH for arsenic removal is shown to be between 5.5 and 6.0. This is why water systems with As (III) in them have used an arsenic removal method that changes, through oxidation, As (III) to As (V). Technology available now can effectively remove As (V) from water supplies.

The Albuquerque Bernalillo County Water Utility Authority uses a chemical and mechanical process to remove containments from water pulled from the Rio Grande. This technology cleans up to “92 million gallons per day”. (Authority, 2008 Water Quality Report, 2008) Right now about 70-90 percent of our drinking water comes from the Rio Grande. This reduces the amount of water we are pulling from the aquifer so that it can recover. As we depend less on ground water we should see the arsenic levels in the ground water decrease. At the end of 2007 the amount of arsenic detected ranged from 1 ppb to 15 ppb. The source for the arsenic came primarily from natural volcanic rock erosion. Just recently the city of Bernalillo was issued a violation notice for exceeding the recommended arsenic levels in its water supply. The plant they were using to remove the arsenic from the water supply used a process called electrofloculation. “Electrofloculation uses aluminum anodes to suspend arsenic molecules in the water.” (Rayburn, 2010) Two Bernalillo wells with the arsenic systems installed were given violation notices. One well had a rating of 10.66 ppb and the other well triggered at 37 ppb.

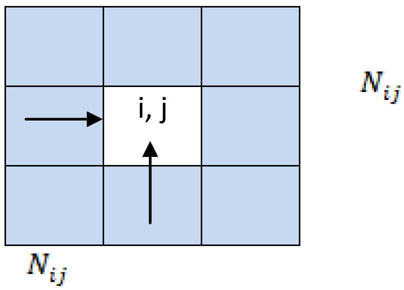
Approach:

Based on my research I decided to use NetLogo to model arsenic in the water supply. The environment of this simulation is the Rio Grande River in New Mexico. In this simulation I will show the water movement, the pH level of the water, the amount of arsenic in the water, the way the arsenic moves, and a simulated way to remove arsenic in the Rio Grande.

I have collected and analyzed water samples from various parts of Albuquerque. With the help of Mr. Kindell, science teacher at Jackson Middle School, I have been gathering data to help in the construction and modification of the computer model of the Rio Grande. I have collected real time data from the United States Geological Survey (USGS) water quality site for the state of New Mexico. I collected data from the EPA for the state of New Mexico as well. I have even collected data from various newspapers and websites to help create variables for the model.

By using a set of predetermined variables the arsenic removal agents will show the effectiveness of tracking and destroying arsenic in the Rio Grande. In the model, the darker the color blue the higher the pH level is. This represents the pH level in the water. The yellow agents in the model are the representation of the arsenic in the water supply. The red agents in the model are the arsenic removal agents in the water supply. Right now I have the water pH levels working. I am still working on finding a substance that will remove arsenic from the water. Eventually this simulated model could be attached to individual water stations to track arsenic for removal on site.

Math/Behavioral Model:



c_{ij} = *contaminant of cell ij*

N_{ij} = *Moore neighborhood of cell ij*

$$\propto\, = diffusion\ of\ contaminant$$

f = *flow rate*

(t) = *time*

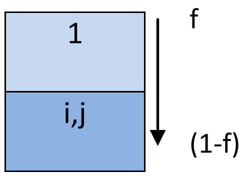
Contaminant before flow rate equation

$$\hat{c}_{ij(t+1)} = (1 - \propto) c_{ij(t+1)} + \frac{\propto}{8} \sum_{N_{ij}} c_{(t)}$$

Contaminant diffusion equation

$$N_{ij} = \{(i',j'): |i'-i| \leq 1, |j'-j| \leq 1, (i',j) \neq (i,j)\}$$

Flow rate



$f \in [0,1]$

Flow equation to shift the cells down

$$c_{ij(t)} = (1-f)\hat{c}_{ij(t)} + f\,\hat{c}_{ij} + 1_{(t)}$$

I would like to extend my extreme thanks here for Mr. Nick Bennett. Without him there would be no math equations because I haven't learned this stuff yet.

Progress to Date:

I started out this project with a very broad topic. I wanted to look at drugs in our water supply. I collected water samples, from various water stations, to analyze. After feedback from the judges I decided to pick just one contaminant to study. This is when I decided to research arsenic.

I gathered data from the USGS water stations in New Mexico. I also gathered data from the E.P.A. and the Albuquerque water quality reports. From here I was able to see that the average pH level for the data I collected is between 8.0 and 8.5. From research I know that the best pH level for arsenic removal is between 5.5 & 6.0.

This is what the code looks like for water pH:

```
to setup-patches
ask patches [
set contaminant-level random-float 15
set pcolor scale-color blue contaminant-level 8.5 8.0
]
end
```

Then I used the data I collected to make the arsenic amounts being found in our water system. I used the range of 1 ppb to 15 ppb and colored it yellow. However, just recently Bernalillo City has had amounts in the levels of 10.66 ppb to 37 ppb.

This is what the code looks like for arsenic in water.

```
to setup
  clear-all
  set active-patches patches with [pycor < max-pycor]
  set top-patches patches with [pycor = max-pycor]
  setup-patches
  setup-turtles
  create-turtles 15 [ set color yellow ]
  create-turtles 30 [ set color red ]
  end
```

Here I just guessed at 30 for the red color. This will be the arsenic removal agent. Eventually the red agents will collide with the yellow agents and make them disappear. Also, I will integrate more yellow agents entering into the Rio Grande as the data allows.

Right now the model shows the water going from dark blue to light blue, based on what cell number it is. The cells change shades based on their pH levels so no two cells are the same color. At around 60 ticks is when the water looks the lightest. This is when the slow side of the slider is at about 1/3 of the way to the left. Furthermore, the red and yellow agents are multiplying in this model. Unfortunately, they are not supposed to do this so it is something I still have to fix.

Results:

At this point I have not been able to achieve the results I was hoping for. I was hoping to show how the arsenic could be tracked and destroyed in our water supply. So far I can only show how the water level changes pH levels and how much arsenic is in the water. In the near future I would like to show how adding a chemical or natural agent will affect both the pH level and arsenic levels in the water supply. I would also like to show how increasing or decreasing the flow and amount of water in the Rio Grande changes the model values of the arsenic.

Conclusion Reached:

At this point I can conclude that this model is “do-able” when the next steps are finished. At this point I can’t draw any conclusions from the current state of my model. I do feel that I will be able to show a correlation between the pH levels and the arsenic amount in the near future. After further programming, testing, and refining of this model, the water authority can use it to track the safety of individual water stations. This will cut down on man-hours needed to test the water. This model will alert the water authority when there are unauthorized amounts of arsenic in the water supply. This will allow the water authority to quickly add agents to remove the arsenic.

Next Steps:

Given more time I would have liked to gather a little more research on what types/amounts of chemicals/natural agents destroy arsenic in water. I would then like to show the relationship between pH levels and higher levels of arsenic. In the future this model could predict when pH levels are right, between 5.5 and 6.0, for the water authority to treat the water supply for arsenic.

I would also add the new data I received today into the model. In the 2009 Water Quality Report it shows “no minimum arsenic levels detected, an average detection of 5 ppb, and a maximum of 8 ppb” (Authority, 2009 Water Quality Report, 2009) recorded at the entry points of the distribution system. This same report also showed “2 ppb minimum arsenic levels detected, an average detection of 4 ppb, and a maximum of 5 ppb” recorded at the New Mexico Utilities, Inc./North West Service Area. This report still contains a low level arsenic warning. Given more time I would run the levels for the area around where I live, go to school, and my favorite restaurant. The arsenic levels in these places range from 3 to 6 ppb but some areas of the city go as high as 8 ppb.

My achievement:

I have been able to study and understand the many facets of ground and surface water. I have also learned about the devastating effects that can be caused by pulling too much water out of our aquifer. I understand the dangers of having even small amounts of arsenic in our water supply. I was able to collect and analyze water samples using the science lab at Jackson Middle School with the help of Mr. Kindel.

Acknowledgements:

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station, U. w. (2010, March 29). *USGS 08317400 Rio Grande below Cochiti Dam, NM.* Retrieved March 29, 2010, from United States Geological survey: www.waterdata.usgs.gov/nm/nwis/uv?cb_all_00010_00060_00095_00065_63680_00300_00400=on&cb_00060=on&cb_00065=on&format=gif_stats&period=7&site_no08317400

Appendix:

Netlogo Code for Water Project

```
patches-own [
  contaminant-level
  new-contaminant-level
]

globals [
  active-patches
  top-patches
]

to setup
  clear-all
  set active-patches patches with [pycor < max-pycor]
  set top-patches patches with [pycor = max-pycor]
  setup-patches
  setup-turtles
  create-turtles 15 [ set color yellow ]
  create-turtles 30 [ set color red ]
  end
```

```
to go
  move-turtles
  update-patches
  tick
end



to move-turtles
  ask turtles [
    right random 360
    forward 1
  ]
end



to setup-patches
  ask patches [
    set contaminant-level random-float 15
    set pcolor scale-color blue contaminant-level 8.5 8.0
  ]
end
```

```
to setup-turtles
  create-turtles 15 [
    setxy random-xcor random-ycor
    setxy random-xcor random-ycor
    set color ifelse-value ((random 2) = 0) [
      red
    ]
    [
      yellow
    ]
  ]
end



to update-patches
let max-contaminant-level 0
  ask patches [
    set new-contaminant-level (1 - k) * contaminant-level + k * mean [contaminant-level] of neighbors
  ]
  ask patches [
    set contaminant-level new-contaminant-level
  ]
  ask active-patches [
    set new-contaminant-level ((1 - flow-rate) * contaminant-level + flow-rate * [contaminant-level] of
patch-at 0 1)
  ]
```

```
  ask top-patches [
    set new-contaminant-level random-float 7
  ]
  set max-contaminant-level max [new-contaminant-level] of patches
  ask patches [
    set contaminant-level new-contaminant-level
    set pcolor scale-color blue contaminant-level 15 0
  ]
end
```