Duel of the Fuel

New Mexico Supercomputing Challenge

Final Report

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Executive Summary

Our project was based on the Kirtland Air Force Base fuel spill and how microbial life forms could assist in the clean-up. Our hope was that microbes would consume the contaminate EDB (ethylene dibromide,) which is an anti-knocking additive that used to be in jet fuel. The EDB leaked into the ground in the 50's and 60's, before it was discovered to be a carcinogen. To test the clean-up we used StarLogo, an agent based program that allowed us to simulate different scenarios, with various circumstances, and produced realistic results. We focused our project only on EDB, at one test well. We did not consider the size of the plume, the flow rate, or any other chemical. Our models represented a charcoal filter and additives such as lactate or oxygen, but we also modeled using no additives at all. We researched lactate and oxygen, making models with these two additives. We also tested if the clean up could be done without any additives, which is called natural attenuation. We hypothesized that with the additive lactate, the EDB would break down the fastest. We thought the EDB would break down the slowest with no additives. For each model we timed how long it took for the EDB agents to disappear. To make our model realistic, we decided that every clock cycle should be considered a day. We used Microsoft Excel to make graphs of our results. We found that our hypothesis was correct and that the lactate was most efficient and natural attenuation was the least effective. To further develop our project after interims, based on the judges' suggestion to combine two of our models, we made a new model, pump and treat, so that we could learn something interesting.

Introduction

The purpose of this project is to see which method would clean up EDB (ethylene dibromide) at the Kirtland Air Force Base jet fuel spill most efficiently. The options we studied were natural attenuation, a charcoal filter, and additives such as lactate and oxygen.

We chose this subject because it is a local problem, which threatens Albuquerque's drinking water supply. We had local resources to help us. We used the KAFB website extensively for maps, data, and information. We were very fortunate to meet Mr. Wayne Bitner, Chief of Environmental Restoration at KAFB, and discuss the spill in person. He helped us to better understand the problems.

The problem's significance to us is that Albuquerque's water comes from the aquifer that could be contaminated by the jet fuel, and most importantly, EDB, a known carcinogen. Now, even though we don't live in Albuquerque, our friends and relatives who live there will be affected.

To prepare ourselves for this project, we researched microbes, aquifers, and fuel spills. Here are the results of this research:

EDB and the Fuel Spill

The research showed that there have been a lot of oil spills all over the world and in many cases contamination got in to the ground water. The one that leaked from Kirtland had EDB (ethylene dibromide), which has not been legal in the USA for a long time. EDB was used in the jet fuel as an anti-knocking substance. The jet fuel that spilt from Kirtland has not reached Albuquerque's ground water supply yet. The Air Force has placed monitoring wells across the city to monitor the spill.

The spill has leaked an estimated 8 million gallons of jet fuel in to the ground. It has been leaking since the late 1950's. Some people dislike what they are doing to try to clean it up. Some people say that the drilling that they do is loud. From websites that I have looked at it says that even a sniff of the EDB can be very harmful to your body. EDB can cause cancer and other side defects that will harm your body. Some of the side defects are breathing difficulties, skin itching and rashes, eye irritation and burning, and coughing and throat irritation.

The fuel has not reached the monitoring wells yet. They estimate that it is 500 feet below ground. Kirtland Air force base says that they are willing to spend whatever it takes to clean it up. From my research it says that the jet fuel is only 1.6 miles away from drinking water wells.

Aquifers

Do you ever wonder where your water comes from? They come from aquifers. We will tell you what an aquifer is!

An aquifer is an area underground where water is. Aquifers can occur at various depths. They can be 5 feet down, or 200 feet down. A lot of the time aquifers can have clean water. But sometimes they do not. There are two different types of aquifers with clean or unclean water.

There are saturated and unsaturated aquifers. Saturated aquifers have clean water usually and their atmospheric pressure is bigger than the water head. The definition of a water table (which is like an aquifer) is that the water head pressure is the same as the atmospheric pressure.

Unsaturated is when above the water table the gauge pressure is negative (absolute pressure can't be negative but gauge pressure can) and the water that doesn't fully go into the pores, goes into a suction (a suction is when water goes into a funnel.)

Many aquifers that are close to the surface get a lot of their water from the rain fall. The ones that are underground mainly get a lot of their water from lakes that go deep downward. Lots of desert areas such as New Mexico can have water resources near silicon and sandstone. The underground water can also be in underground rivers as in underground caves. This has a chance of happening near eroded silicon, which only makes a small percentage of the Earth. Usually this can be like a kitchen sponge; it sucks saturated water into holes, which can be used for water.

We depend on groundwater as much as we depend on air to live. Our fresh-water aquifers (the ones that aren't contaminated) can get water from salt-water. This could turn out to be a serious problem. We cannot drink salt-water so if it (or other contaminates) gets into our water supply, we can cause some serious damage. This can also be a big problem near the ocean, where pumping aquifer water is excessive.

The aquifers that are close to the ground can be used for watering crops. A lot of the aquifers for use of crops are near the surface and are fresh-water aquifers. Also, aquifer depletion is a big concern.

When fresh-water aquifers are near the ocean there is salt-water that leaks into the aquifer. However, salt-water is denser than fresh-water so the salt-water goes downward. So, it makes it easier to get the fresh-water out but you can still have the chance of pumping up salt-water. One of the largest underground aquifers is the Great Artisan Basin. This aquifer provides a lot of water for Queensland and parts of South Africa. This aquifer is 1.7 million KM in area.

Microbes

Have you ever wondered if there are living things inside your body other than cells or dust mites? Well there is. There are microbes too!

Microbes are tiny organisms that can only be seen with a microscope. Some microbes are even *submicroscopic* and can only be seen by special electron microscopes. Microbes have the ability to live in extremely harsh environments of intense heat or extreme cold. Some microbes are referred to as germs or bacteria and can make you sick while others are essential to all life. Surprisingly there are several billion more bacterial cells in the human body than there are human cells. The bacterial form of microbes is vulnerable to Clorox wipes, hot water, air freshener, and to most disinfectants.

Microbes are used for many things. Sometimes they are used at water treatment plants to remove contaminates that cannot be left in water. Another use for microbes is to help clean up fuel spills. The microbes will quite literally eat the fuel. Certain types of microbes can live longer than a human! When microbes die, carnivorous microorganisms will come and eat the dead ones. Other types of carnivorous microbes will eat living microbes.

Microbes can be separated into five different groups; Archae, Bacteria, Fungi, Protista, and Viruses. Archae are bacteria look-alikes that are living fossils and are evidence of the very first living things on earth. Bacteria are often dismissed as germs but some are very helpful. An example of how Bacteria help us is they support the atmosphere or eat types of dangerous garbage. Fungi can be the size of a grain of yeast to a 3 and a half mile wide mushroom and is useful for decomposing waste. Protista is a plant-like algae that produces much of the oxygen that we breathe. Viruses are unable to do much of anything on their own, but they will attack host cells, wreak havoc, and cause diseases. From my research I have discovered that microbes can be both helpful and unhelpful as well as being both essential for life and deadly enough to cause disease or kill.

Description

Our project was chosen because it was a local problem that was threatening Albuquerque's water supply. We wanted to see which additive (lactate or oxygen) would do the best job assisting microbes to clean up the EDB in the Kirtland Air Force Base jet fuel spill. We researched KAFB for information about our project. We researched oil spills, microbes and aquifers. We modeled EDB (Ethylene Dibromide) in the water table and how we could use different ways to decrease the levels of EDB using several types of models like a charcoal filter, and additives such as lactate, oxygen, and natural attenuation. For every model, we used data from KAFB well number 106076. There are 360 µg/L EDB, and 60 µg/L oxygen at the site. We are modeling one liter of water in our models, with the exception of our pumping models. We focused our project only on EDB, at one test well. We did not consider the size of the plume, the flow rate, or any other chemical. The materials we used were the programs StarLogo, Excel, various search engines, poster boards, and Legos.

Natural attenuation means letting nature do the clean up. In this model we used 360 EDB agents, 100 microbe agents, and 60 oxygen agents. When the microbes collided with EDB, the EDB agents disappeared and the microbes gained five energy. When the microbes have over ten energy they hatch, creating more microbes. When the microbes collide with oxygen they gained ten energy. Microbes died when they ran out of energy.

The oxygen model increased the number of oxygen agents from 60 to 180. Like every model, it had 100 microbes. The oxygen assisted the microbes in cleaning up the EDB, because when the oxygen agents collided with the microbe agents, the microbes gained energy and hatched, or reproduced, so that there were more agents to consume the EDB. When the microbes collided with the EDB, the EDB died. When the microbes ran out of energy, they died.

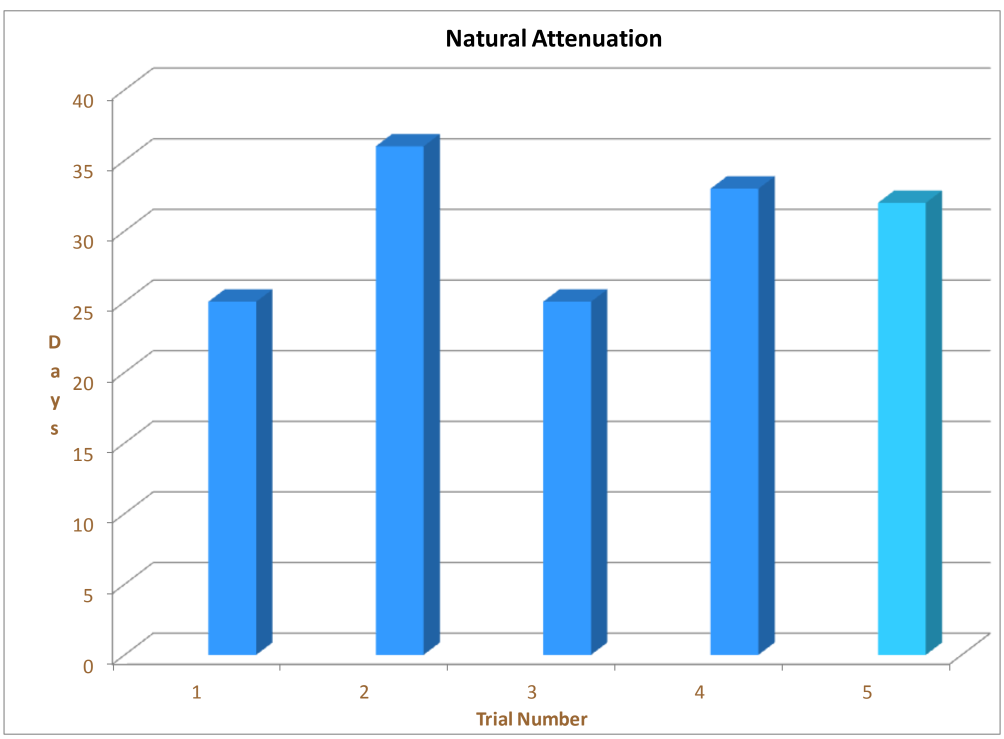
The lactate model had 250 lactate, 100 microbes, and no oxygen agents, because it was an anaerobic model. When the lactate collided with the microbes, the microbes gained energy, reproduced, and died.

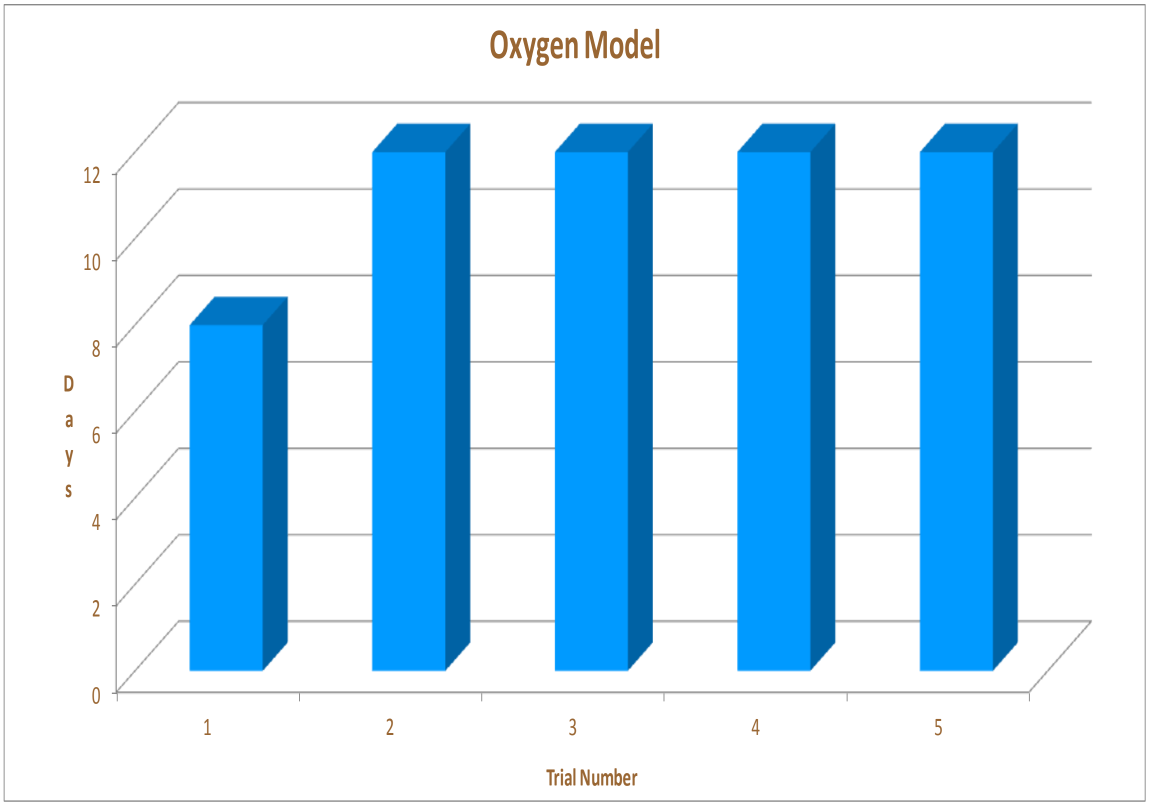
The charcoal filter model is a pump and treat model where EDB-contaminated water is pumped through a charcoal filter, cleaned, and then returned into the ground. In this model, there were 1370 agents total consisting of 1000 water agents, 360 EDB agents, and 10 microbe agents. When the microbes collided with an EDB agent they consumed it but otherwise the EDB moved with the water, by gravity, to the bottom of the pump and were pumped up. After that, the EDB agents disappeared and the water was pumped back into the ground. Then they lost energy. When the microbes collided with EDB, the EDB died.

The pump and treat model has two wells that pump oxygen into the ground on either side of a charcoal filter that pumps the water. The microbes get an oxygen energy boost to help clean up the EDB. The pump and treat model used water, filters, oxygen, and microbes and they all work together to do the job. The pump and treat model has 3 sliders for different variables. The first slider is for how much oxygen we put into each trial, the second slider has microbe aggression, which is how vigorously microbes hunt EDB. Our purpose for this slider is to calibrate the model. The last slider is for how much energy microbes need to reproduce. When the microbes collide with EDB they gain one energy and when they collide with oxygen they gain a random five energy which means they gain anywhere from one to five energy. We manipulated the sliders to see which setting works best. While running this model, we found that EDB agents were getting trapped on one side or the other, so we added another injection well to improve the water flow.

Results

We ran each model 5-10 times. The results for the natural attenuation model were that the EDB was never completely removed from the groundwater; we found out from this model that natural attenuation was the slowest technique for this problem. On average, there were 30 EDB agents left after each trial. This is realistic because you will never remove all of the contaminants from the ground completely. The results for the lactate model were that the EDB disappeared in an average of five days. This sounds like a very short time, but we modeled the amount of EDB in only one liter of water. We learned that lactate is anaerobic, which means that it worked better without oxygen. The results for the oxygen model were that it took an average of 11 days for EDB to be removed from one liter of groundwater. The charcoal filter model took an average of 91 days for all of the EDB to be removed from the groundwater. The results for the pump and treat model were an average of seven days for all the EDB to be removed from the groundwater.

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6
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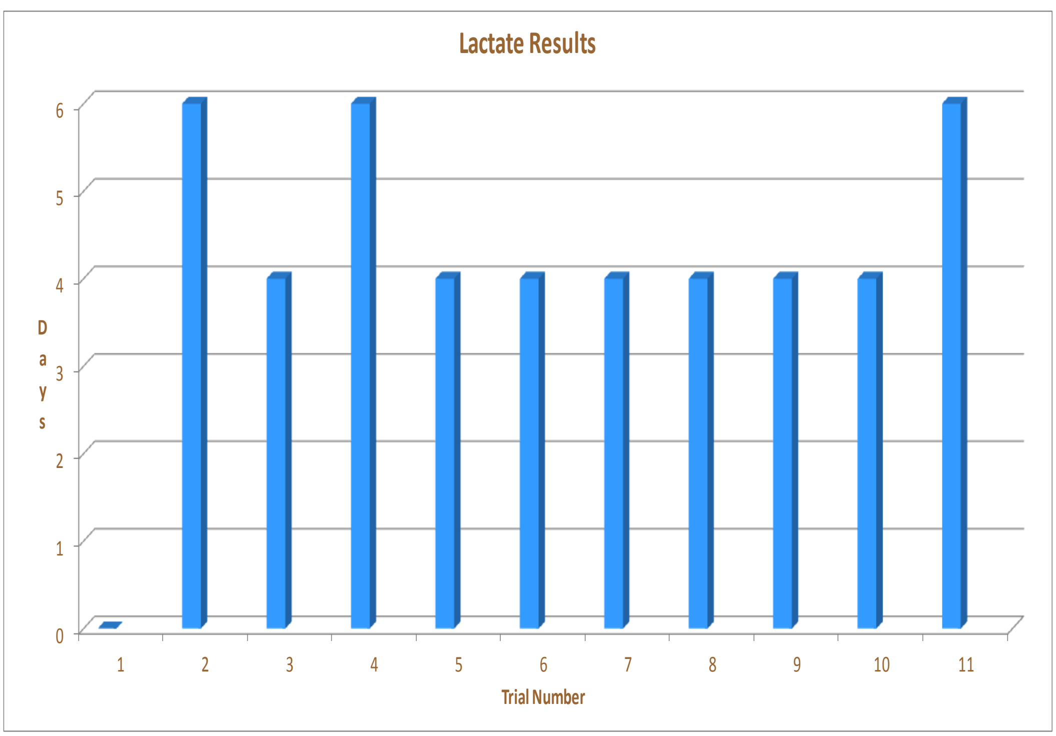
Trial Number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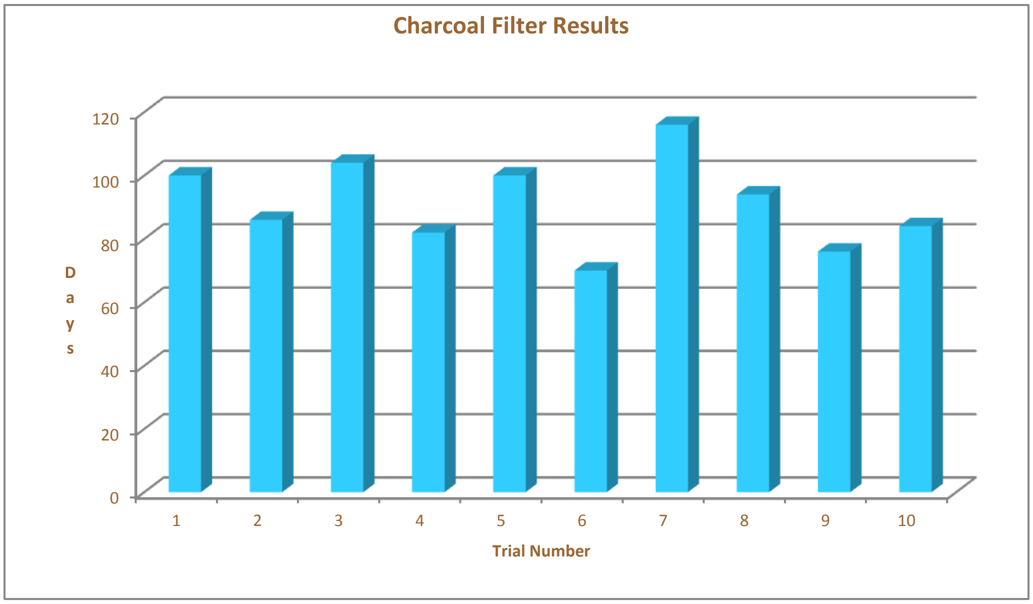
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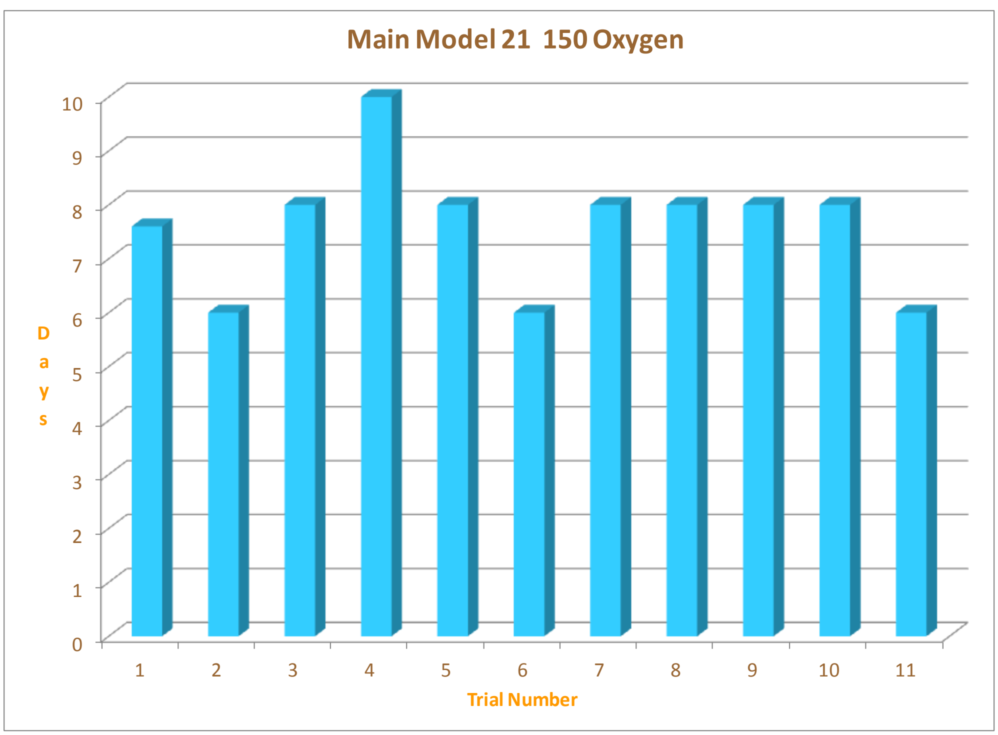
Trial Number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10
9
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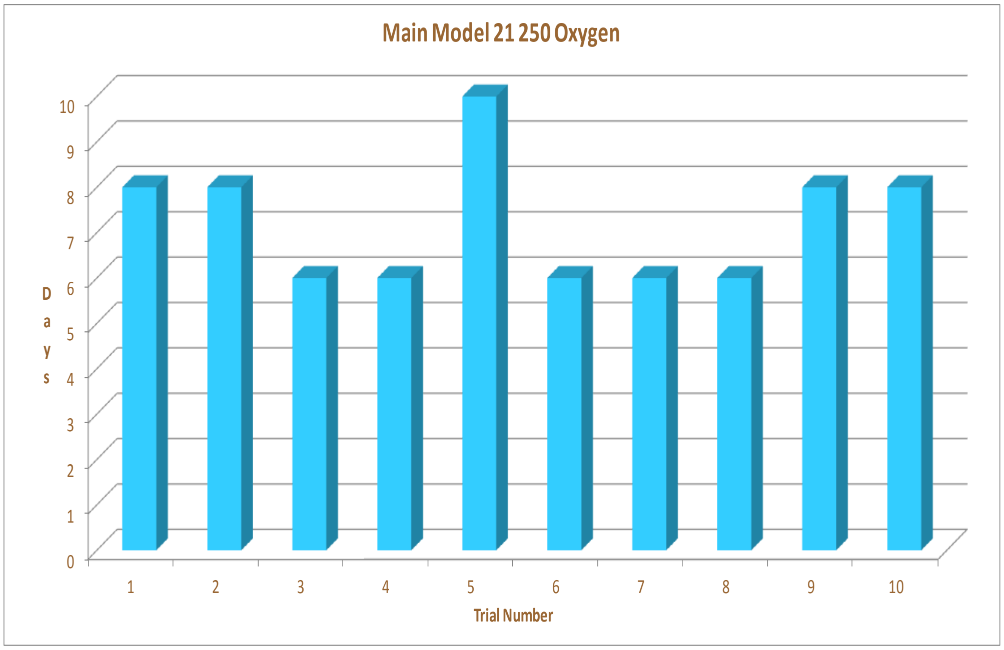
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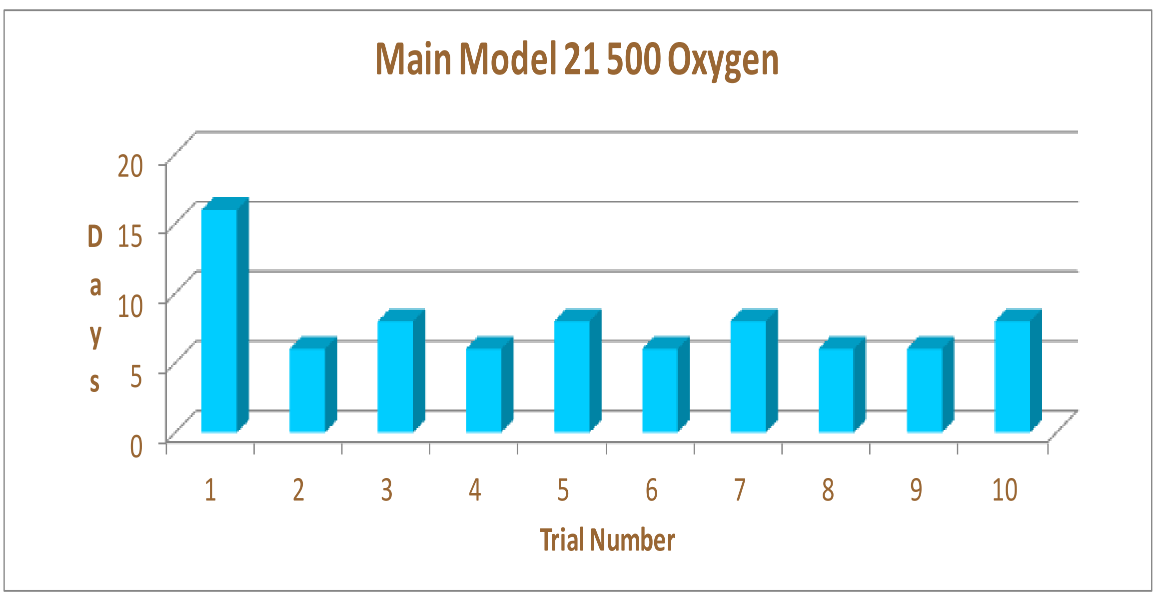
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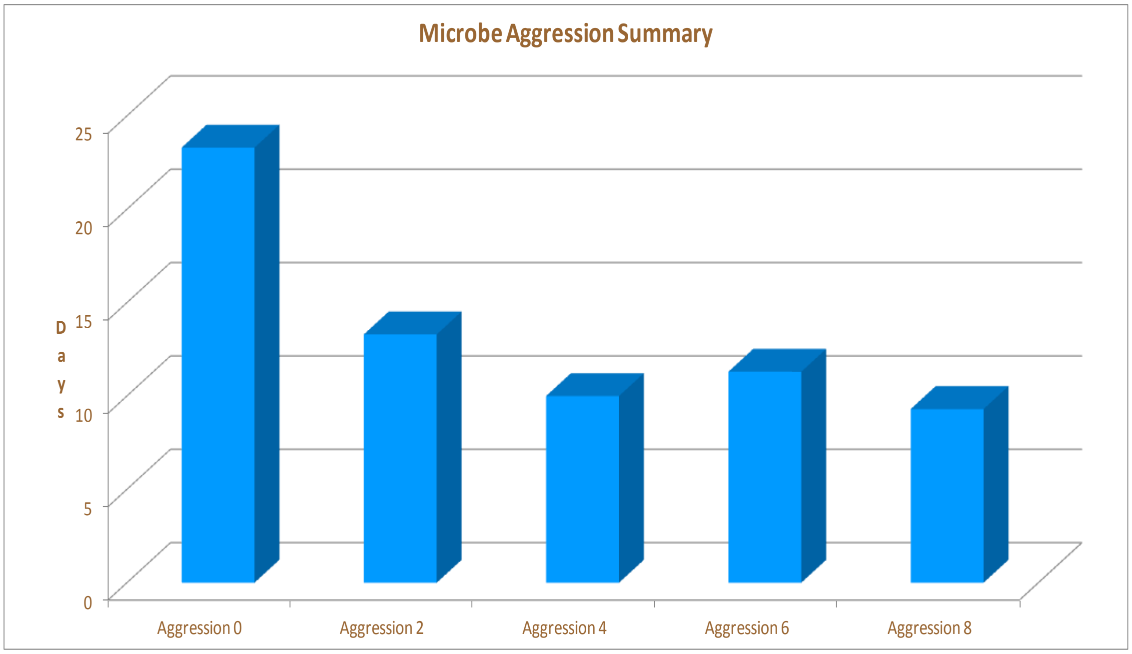
Trial Number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10
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0
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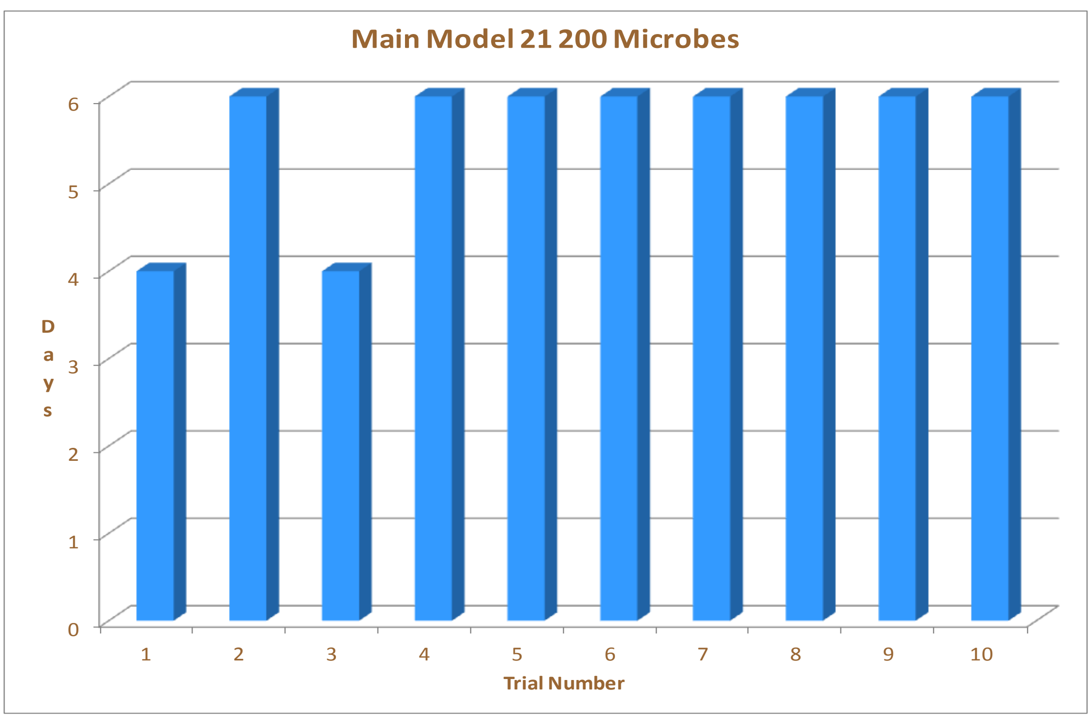
Aggression 2
Aggression 4
Aggression 6
Aggression 8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D a y s
6
5
4
3
2
1
0
1
2
3
4
5
6
7
8
9
10
Trial Number

Conclusion

The conclusion for this project is that the hypothesis was correct because the lactate took, on average, five days to be removed from the groundwater. The lactate idea would work the best in anaerobic conditions. Although the lactate worked the quickest, there was a problem. We learned from our mentor, Mr. Bitner, that lactate will only work in soil and not groundwater, making it ineffective for our purposes. After Interims, based on the judge's suggestions, we created a model that combined the charcoal filter model and the oxygen model to make a pump and treat model. This pump and treat model gave us results almost as good as the lactate model's results. We found that adding more than 250 oxygen agents did not significantly improve our results. These results were unexpected. We found that adding a hunt procedure to the microbes improved results, but increasing microbe aggression did not make a significant difference.

In all our research there is no hard evidence that microbes are able to break down EDB in ground water. We think that pumping and filtering is going to be an important part of the solution. Lactate is very encouraging in its ability to break down EDB in soil. More research needs to be done on how it can be effective in ground water. Our sources at Kirtland Air Force base report that the microbe species Dehalococcoides might degrade EDB over time.

Recommendations

As for recommendations, there are so many ways to go with this project it would be hard to list them all. We only looked at EDB, in one liter of water. We didn't look at any other chemical, any other amount of water, the way the water moved, etc. Our test well was initially the highest concentration of EDB, but during the third quarter, it shifted from 360 µg/L to 180, and a well 1/10 of a mile to the northeast changed to 370 µg/L EDB. If we were to continue working on this project we might want to look at how EDB concentrations change over periods of time. We could also investigate how the geology around the spill affects the fuel.

Unfortunately, after we had already gotten the results from our first models, we found out that lactate wouldn't work in groundwater. Although it wouldn't work where we needed it to, it does work in soil, so if we took the project any further, we could study how to move the EDB into soil, where lactate could break it down. We would want to do this because the fastest way of cleaning up EDB was done with lactate.

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Bibliography

Actionbioscience. "Microbes: What They Do & How Antibiotics Change Them." *Actionbioscience*. Actionbioscience, Jan. 2001. Web. <http://www.actionbioscience.org/evolution/meade_callahan.html>.

Anonymous. "The Mariner Group -- Oil Spill History." *The Mariner Group*. Web. 15 Mar. 2012. <http://www.marinergroup.com/oil-spill-history.htm>.

"Aquifer." *Wikipedia*. Wikimedia Foundation, 03 Nov. 2012. Web. 2011. <http://en.wikipedia.org/wiki/Aquifer>.

ASTDR. "Toxic Substances Portal - Ethylene Dibromide." *Toxic Substances Portal*. ASTDR. Web. <http://www.atsdr.cdc.gov/MMG/MMG.asp?id=1143&tid=251>.

"Aviation Fuel." *Wikipedia*. Wikimedia Foundation. Web. <http://en.wikipedia.org/wiki/Aviation_fuel>.

"Bacteria." *Wikipedia*. Wikimedia Foundation, 03 Nov. 2012. Web. <http://en.wikipedia.org/wiki/Bacteria>.

"Burn Pits - Public Health." *Public Health Home*. Web. <http://www.publichealth.va.gov/exposures/burnpits/index.asp>.

"Decades-old Jet Fuel Spill Sparks Water Contamination Fears in South Bibb County." *- Local & State*. 15 Aug. 2010. Web. <http://www.macon.com/2010/08/15/1229614/south-bibb-residents-fear-contamination.html>.

"Decades-old Jet Fuel Spill Sparks Water Contamination Fears in South Bibb County." *- Local & State*. Web. <http://www.macon.com/2010/08/15/1229614/south-bibb-residents-fear-contamination.html>.

"Decades-old Jet Fuel Spill Sparks Water Contamination Fears in South Bibb County." *- Local & State*. Web. <http://www.macon.com/2010/08/15/1229614/south-bibb-residents-fear-contamination.html>.

"EGeo Services, Inc." *EGeo Services, Inc.* Web. 12 Mar. 2012. <http://www.egeoservices.com/Technology.html>.

Fitzgerald, Matt. "The Lactic Acid Myths." *Competitor.com*. Competitor, 26 Jan. 2010. Web. 7 Dec. 2011. <http://running.competitor.com/2010/01/training/the-lactic-acid-myths_7938>.

Garcia, Eddie. "It Could Take 2 Years to Clean up Jet Fuel Contamination." *Kob.com*. Kob, 19 Oct. 2011. Web. Oct. 2011. <http://www.kob.com/article/stories/s2336566.shtml>.

"Hot Topics:" *Kirtland Jet Fuel Spill Seeps Into Neighborhood*. Web. 2011. <http://www.koat.com/news/27306599/detail.html>.

"Jet Fuel." *Wikipedia*. Wikimedia Foundation. Web. <http://en.wikipedia.org/wiki/Jet_fuel>.

"Killing Us Softly with EDB." *Argyle Bartonville Communities Alliance*. Web. 2011. <http://abcalliance.org/?p=1581>.

Kirtland AFB. "Media Advisory: Kirtland Releases Quarterly Fuel Plume Data Results." *Kirtland AFB*. Kirtland AFB, 10 Mar. 2011. Web. <http://www.kirtland.af.mil/news/story.asp?id=123274506>.

"Kirtland Fuel Spill Ready for Cleanup." *KRQE TV*. Web. 6 Nov. 2010. <http://www.krqe.com/dpp/news/Kirtland-fuel-spill-ready-for-cleanup>.

"The Mariner Group -- Oil Spill History." *The Mariner Group*. Web. <http://www.marinergroup.com/oil-spill-history.htm>.

"Microbes." Web. <http://www.niaid.nih.gov/topics/microbes/pages/default.aspx>.
"The Origin, Evolution and Classification of Microbial Life." *Online Textbook of Bacteriology*. Web. 12 Mar. 2012. <http://textbookofbacteriology.net/themicrobialworld/origins.html>.
"Redirect Notice." *Wikipedia*. Wikipedia. Web. <http://www.google.com/url?q=http%3A%2F%2Fen.wikipedia.org%2Fwiki%2FMicrobial_corrosion>.
"Residents near Kirtland Believe Tap Water Is Contaminated." Web. 2011. <http://www.kob.com/article/stories/S2237756.shtml>.
"Soil & Groundwater Remediation Project." *Hanford Site*. Usa.gov, 8 July 2011. Web. 28 Feb. 2012. <http://www.hanford.gov/page.cfm/SoilGroundwater>.
"Supplemental Content." *National Center for Biotechnology Information*. U.S. National Library of Medicine, Jan. 2003. Web. <http://www.ncbi.nlm.nih.gov/pubmed/12502073>.
United States Environmental Protection Agency. "Ground Water Cleanup at Superfund Site." *EPA*. Environmental Protection Agency, Dec. 1996. Web. Oct. 2011. <http://www.epa.gov/superfund/health/conmedia/gwdocs/brochure.htm>.
USGS. "Groundwater Quality." *Water Science for Schools*. USGS. Web. <http://ga.water.usgs.gov/edu/earthgwquality.html>.
USGS. "Pesticides in Groundwater." *Pesticides in Groundwater*. USGS. Web. <http://ga.water.usgs.gov/edu/pesticidesgw.html>.
"Why Does Lactic Acid Build up in Muscles? And Why Does It Cause Soreness?: Scientific American." *Science News, Articles and Information*. Scientific American, 23 Jan. 2006. Web. 8 Dec. 2011. <http://www.scientificamerican.com/article.cfm?id=why-does-lactic-acid-buil>.

PDF Documents

http://www.kirtland.af.mil/shared/media/document/AFD-100510-060.pdf

http://www.epa.gov/tio/download/citizens/bioremediation.pdf

http://www.epa.gov/tio/download/citizens/mna.pdf

http://www.epa.gov/nrmrl/pubs/600r08107/600r08107.pdf

http://www.ecs.umass.edu/cee/reckhow/courses/697w/papers/Rob1.pdf

http://www.epa.gov/oust/cat/Section_8-Remediation_and_Treatment.pdf

http://www.kirtland.af.mil/shared/media/document/AFD-110930-094.pdf

http://www.epa.gov/ogwdw/pdfs/factsheets/soc/ethylene.pdf http://lakeland.edu/AboutUs/MSDS/PDFs/543/Jet%20Fuel%20No%203%20%28All%20Brands%29.pdf

http://www.kirtland.af.mil/shared/media/document/AFD-080731-037.pdf

http://water.usgs.gov/wrri/00grants/NMaquifers.pdf

http://www.google.com/url?q=http%3A%2F%2Finfo.ngwa.org%2Fgwol%2Fpdf%2F872944335.PDF&sa=D&sntz=1&usg=AFQjCNEgkJqvtyyPEsiHHQhRaF8-SjqLjQ

http://www.kirtland.af.mil/shared/media/document/AFD-100510-060.pdf

http://www.epa.gov/nrmrl/pubs/540s02500/540S02500.pdf

Newspaper Articles

Albuquerque Journal, Tuesday October 4th, 2011. Pages A1 and A2.

Special thanks to abqjournal.com and Kirtland Air Force Base for the map of the oil spill that we used all throughout the project!

Appendix A: Starlogo Code

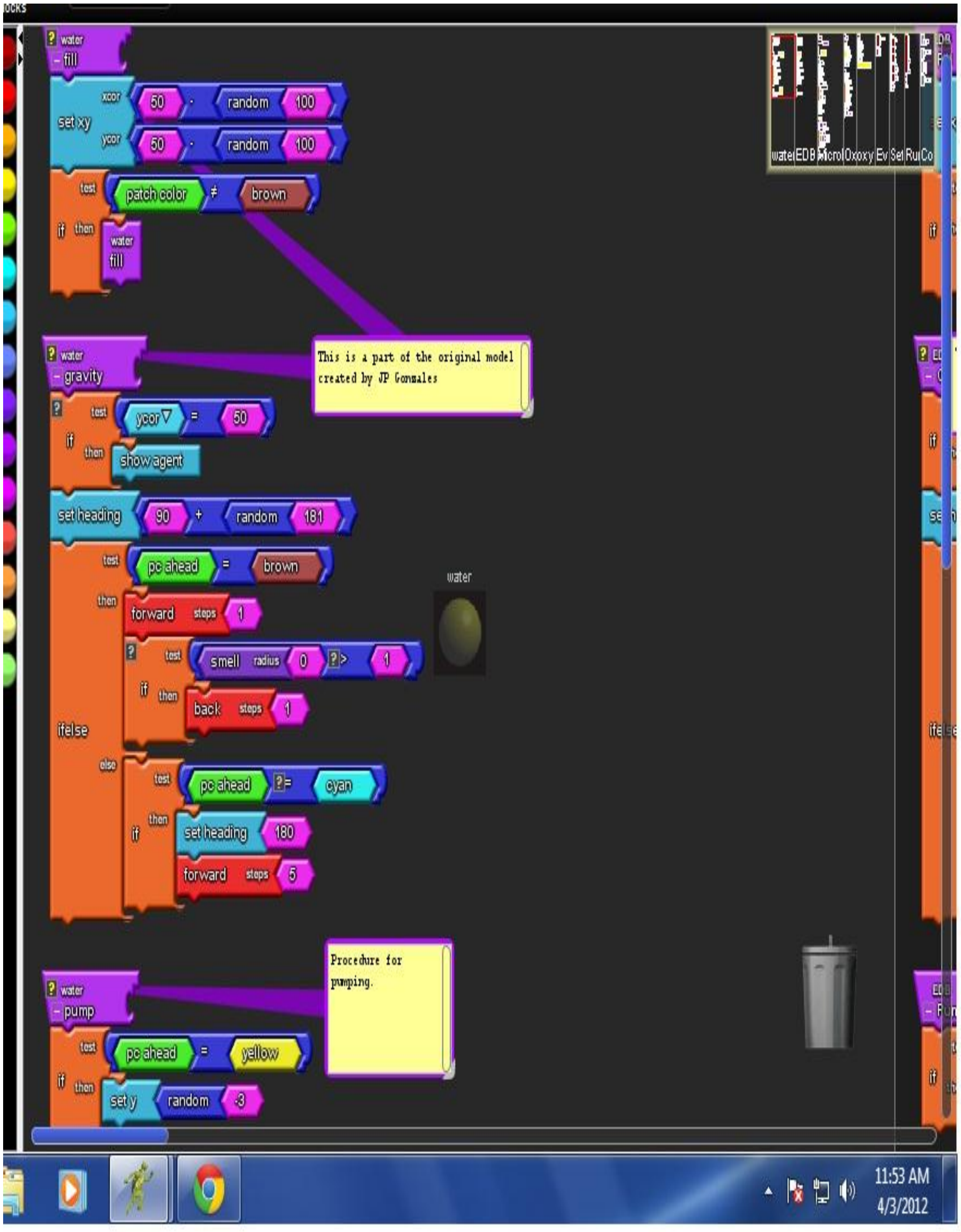

Figure 1 Water Agents

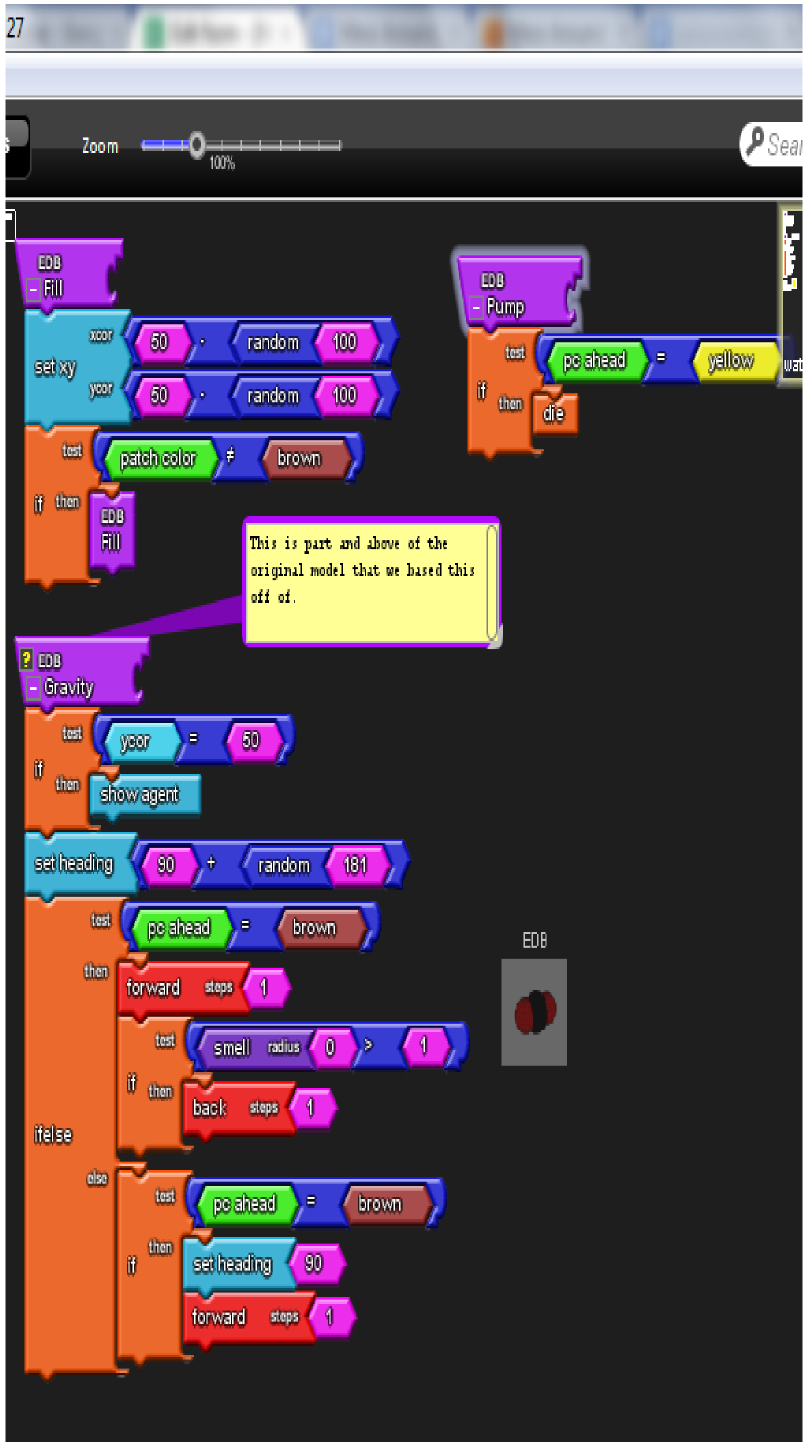

Figure 2 EDB Agents

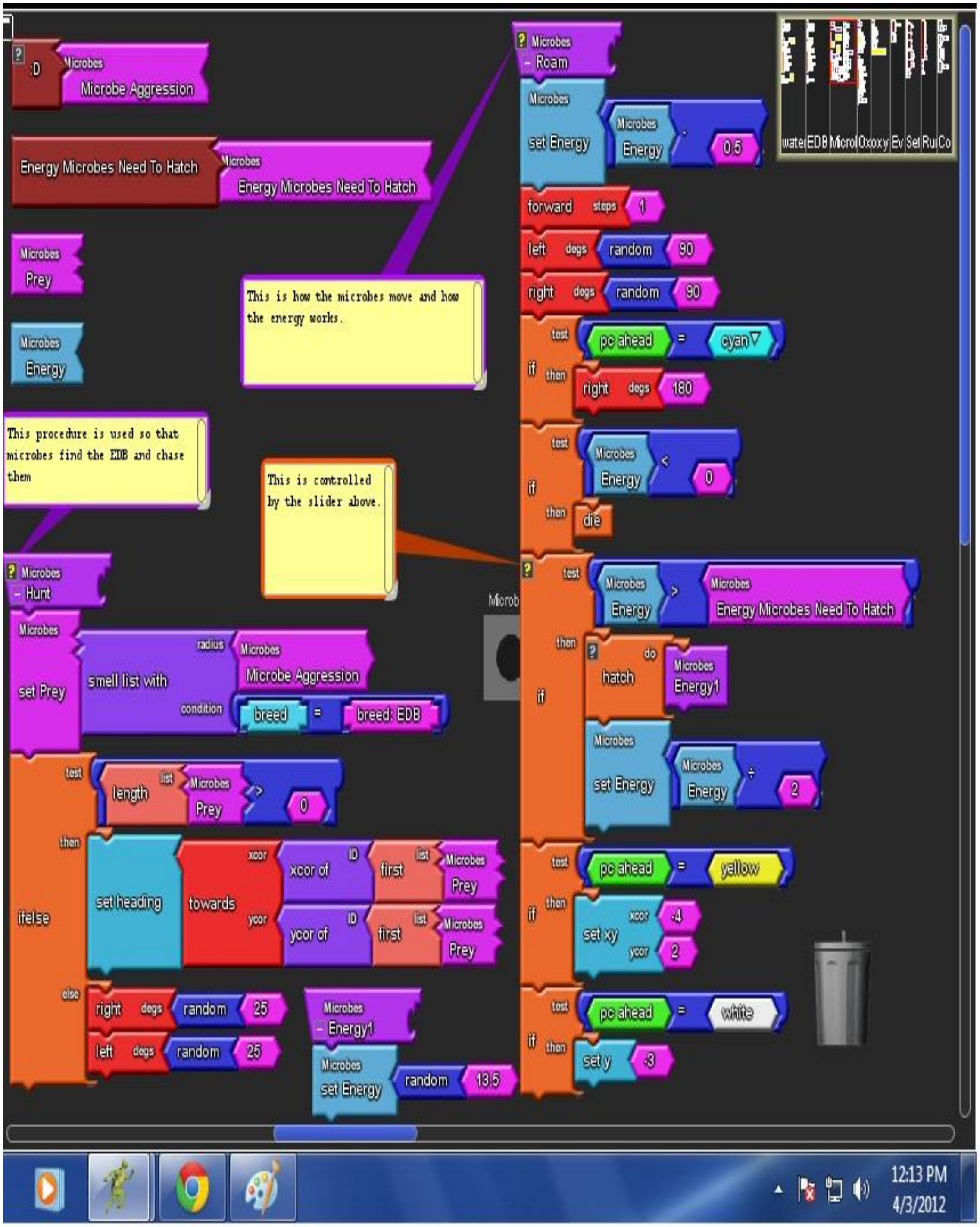

Figure 3 Microbe Agents

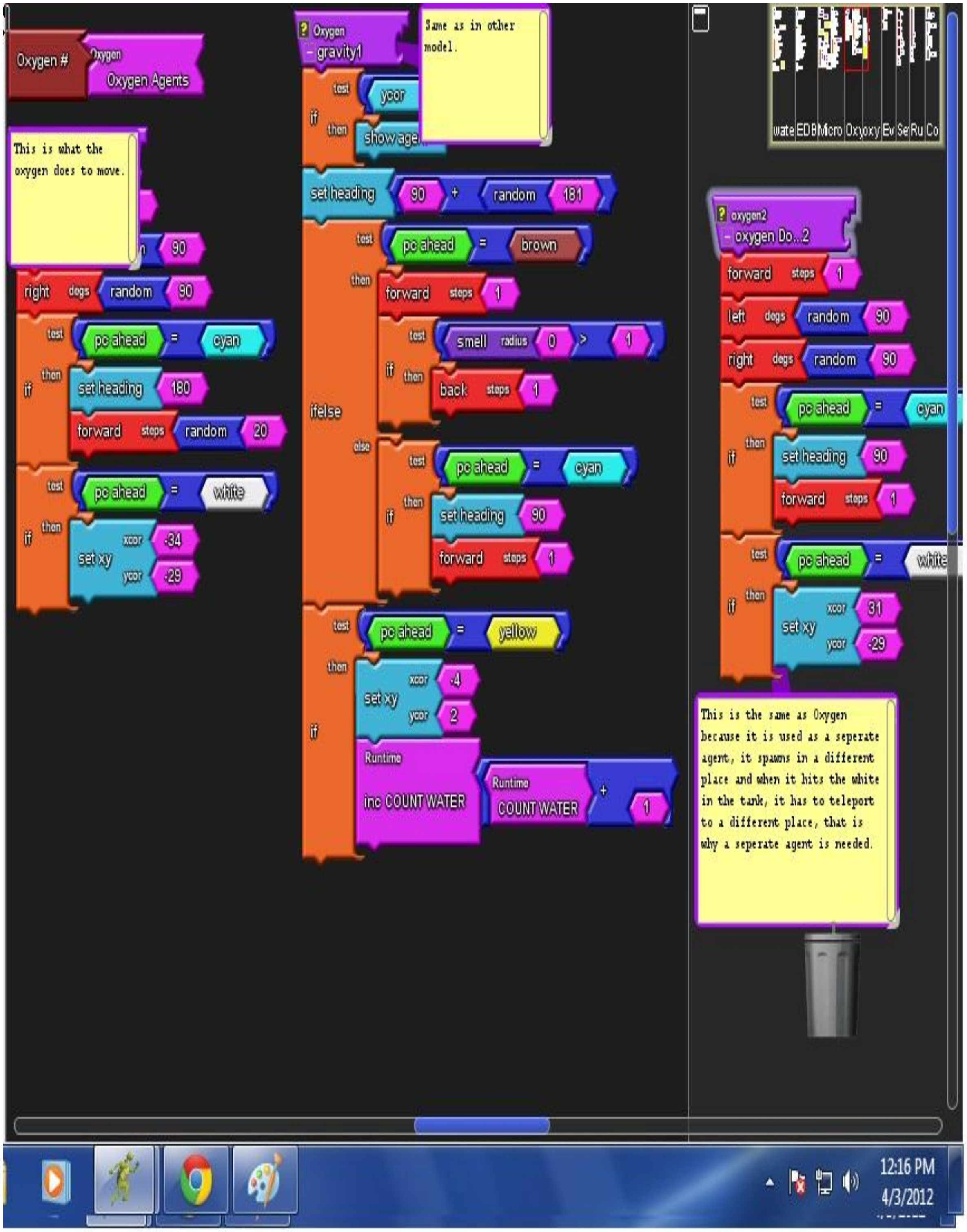

Figure 4 Oxygen Agents

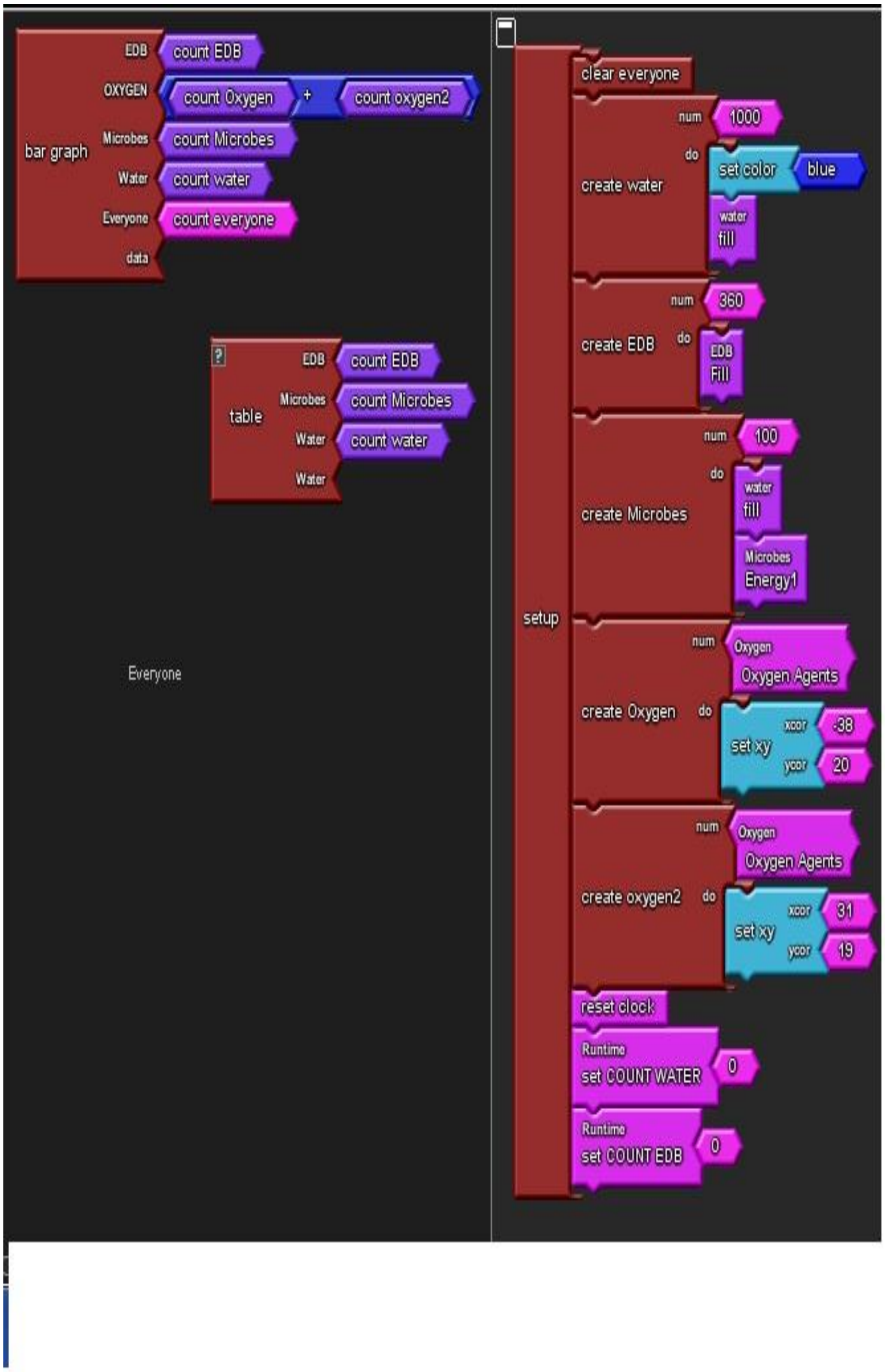

Figure 5 Setup

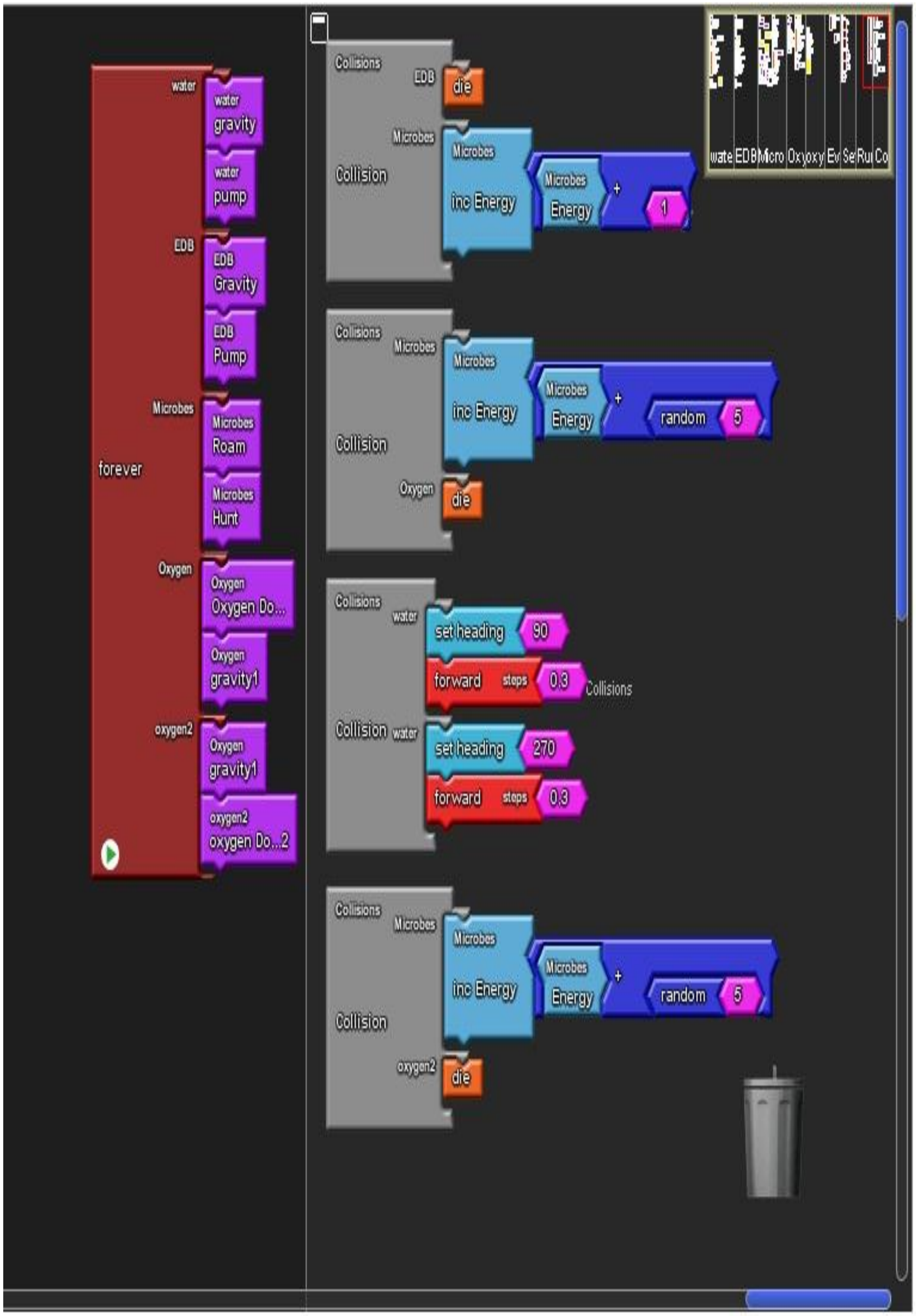

Figure 6 Runtime and Collisions