Nitrogen Contamination in Groundwater

New Mexico High School Supercomputing Challenge

Final Report

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Team Number 068

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Diffusion Model

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Executive Summary

Dairies have become an essential part of New Mexico's economy. Last year, dairies had an economic impact of $1,593,520,524. This impact was the direct result of the milk produced, feedstock purchased, labor needed to manage the dairies, as well as other factors. While this economic impact to the state is important, it is also important for the state to assist the industry in finding ways to effectively manage the waste produced by the dairies, particularly with respect to the potential impact on groundwater.

Ground water resources are important to the long-term sustainability of the state. Research indicates that almost 90% of the total population of the state is dependant on ground water for drinking purposes. Of this population, 78% get their water from public systems and another 10% from private wells. Overall, the quality of the state's ground water is pretty good. However, if not protected, the state could lose a vital source of water.

In order for us to sustain both the dairy industry and groundwater, it is important that manure and other dairy wastes are managed effectively. Both cow manure and urine contain nitrogen (N_2), which in turn has the potential to be converted to nitrate (NO_3). In 1974, the U.S. Congress passed the Safe Drinking Water Act. This law requires the Environmental Protection Agency to determine safe levels of chemicals and arsenics. The maximum contaminate level of nitrate allowed is 10 part per million.

Our team chose to identify the relationship between nitrate excreted from dairy cows in the form of manure and urine and the impact on groundwater supply. We modeled this by creating a Java program that shows the worst-case scenario that could occur if the entire nitrate from the manure seeped into a given aquifer. We feel that we have effectively created a program that models the diffusion of nitrogen as nitrates into groundwater through a shallow water table. We feel that we are able to reflect the relationships between our respective variables and constants. Our results indicate that, if left untreated and/or unmanaged, nitrogen excreted from dairy cows can have negative impact on groundwater in a quick period of time.

Nitrogen Contamination in Groundwater

Introduction

Dairies have become an essential part of New Mexico's economy. Last year, dairies had an economic impact of $1,593,520,524. This impact was the direct result of the milk produced, feedstock purchased, labor needed to manage the dairies, as well as other factors. According to a report we obtained from New Mexico State University, in the year 2000, the state had over 249,000 dairy cows, with an estimated increase of another 40,000-60,000 cows over the next two years. While this economic impact to the state is important, it is also important for the state to assist the industry in finding ways to effectively manage the waste produced by the dairies, particularly with respect to the potential impact on groundwater.

Ground water resources are important to the long-term sustainability of the state. Research indicates that almost 90% of the total population of the state is dependant on ground water for drinking purposes. Of this population, 78% get their water from public systems and another 10% from private wells. Overall, the quality of the state's ground water is pretty good. However, if not protected, the state could lose a vital source of water.

As of 1998, the New Mexico Environment Department reported approximately 155 diaries held permits to discharge wastewater under ground water discharge permits. According to the state Environment Department, ground water contamination identified at dairy operations is generally characterized as nitrate, chloride, and/or TDS concentrations which exceed the water quality ground water standards. In New Mexico, the acceptable level of nitrate is 10 ppm.

One of the greatest waste management issues facing the dairy industry is finding ways to effectively manage the large amounts of manure produced by the cows. Failure to do so could result in the conversion of nitrogen (N_2) into nitrate (NO_3) that then seeps into the groundwater. Drinking this contaminated water can cause illness or even death. According to the state Environment Department, 1,907 water sources have become contaminated in New Mexico, of which 27 come from Dona Ana County. The largest number of contaminated wells can be found in Bernalillo County, 513 wells. However, according to the state Environment Department, only 2.4% of point source ground water contamination is contributed to the dairy industry. The majority is from underground storage tanks.

A common source of nitrate pollution is discharges of dairy waste to unlined or manure lined lagoons. Dairies use the manure from these lagoons to fertilize crops. Another source is from the urine excreted from the cows. Dairies use different management techniques to deal with manure and other waste produced within the dairy.

Through our hypothetical dairy, we plan to be able to show one scenario of the potential increase in nitrate contamination of ground water if manure management techniques are not used. This would be a worst-case scenario, but it would show how quickly the groundwater can become contaminated. We recognize that the majority of the state's dairies use some type of manure management, but we wanted to stress the importance of sustaining the quality of ground water.

As we previously stated, dairies are a major source of income for New Mexico's economy. However, as time goes on and if the contamination increase, it could result in some of the dairies being shut down which could seriously impact the state's economy.

Description

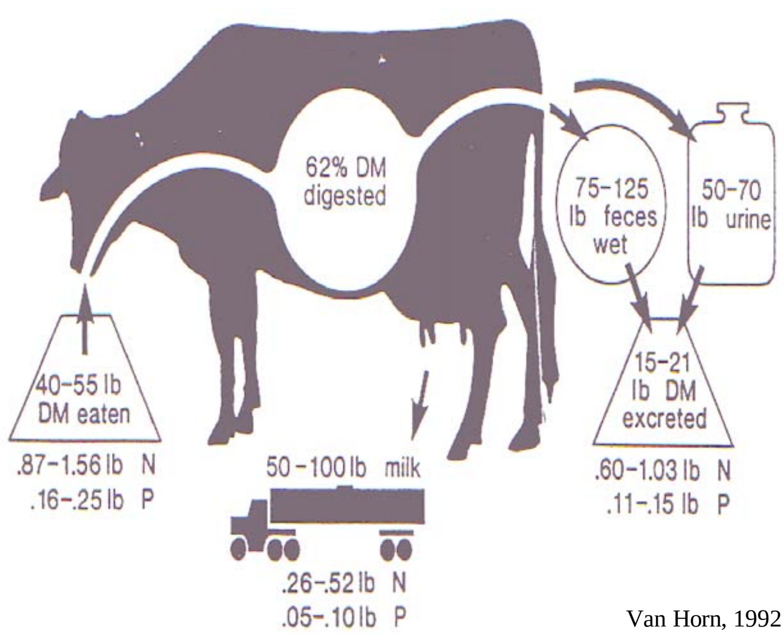
In order to determine the potential for ground water contamination by nitrogen, we conducted background research on dairy operations and nitrogen contamination in ground water. We divided the project into several areas such as internet web searchers, interviews with dairy producers, web page designing, and Programming. We also met with our mentors at New Mexico State University.

We wanted to create a diffusion model based on a hypothetical dairy operating within southern New Mexico. While conducting our research, it became very clear that we were going to have to make several assumptions in our hypothetical dairy in order to keep our program manageable. The intent of our final program was to determine the concentration of nitrate in a given aquifer over a period of time for a specific dairy.

The main variables used in developing our program were the size of the herd, the amount of time, and the aquifer size. The size of the herd was important because the more cows confined within the dairy, the more manure that will be produced, therefore creating more nitrogen and contamination. The amount of time was important because we wanted to determine how quickly the concentration would increase over time. If left undetected for too long a time, nitrogen contamination may become so great that either it can't be cleaned up or it would be very expensive to clean. The size of the aquifer is important because the larger the aquifer the more nitrogen it can allow to seep into it without having major nitrogen contamination problems. We assumed that the aquifer we modeled was confined. We made this assumption because an unconfined aquifer would require extensive variables that were beyond our ability to obtain data as well as model in a manageable way.

In order to develop the relationships between the different variables, we had to do a lot of conversions to make sure that our units were consistent. This was important in making sure that our model results were accurate. Some of the conversions we did involved converting pounds of nitrogen to moles of nitrate, pounds of manure and urine to mg, and acre feet of water to liters. We had to learn to use molecular weights and conversion tables to complete this process.

Some information that we found very useful when programming was that the average dairy operates with about 1475 cows. This is important because the amount of manure produced is directly dependent on the number of cows. The cows excrete about 2.5 tons of dry manure solids per year of which 195 pounds are nitrogen. This is important because we needed to know the amount of nitrogen excreted per cow per year. Urine goes into the ground water faster than manure because it is already in a liquid form. About 20% of urine turns to ammonia and the remaining 80% stays straight nitrogen, which 40% of that turns to nitrate. Most manure is dumped into one area and nitrogen stays in that area.



Van Horn, 1992

Some of the assumptions we made had to do with the aquifer size and the depth of the water table. We assumed an aquifer of one million acre feet of water. We used a confined aquifer because otherwise there would be too many variables to factor into our program. We put the water table at 12 feet deep. The water table depth is important because that will determine how long it takes the nitrate to get into the ground water. We also looked at the types of soils found in southern New Mexico in order to determine if the nitrates would leach fast are slowly. The soil types found were mostly sand with small amounts of clay. Since the water table is about 12 feet and the soil is mostly sand, we assumed a worst-case scenario of 100% hydraulic conductivity. Our research told us that the average hydraulic conductivity for soils in southern New Mexico was about 80%, but again, we wanted to look at a worst-case scenario.

Results

The results of our program confirmed our beliefs that over time the level of nitrate contamination, if not treated or managed, will increase. We ran our program using four different time periods; years one, five, ten, fifteen, respectively. The constants utilized throughout the program were as follows:

- Number of cows = 1475
- Size of aquifer = 1,000,000 acre feet

We assumed that the shallow ground water was in a confined aquifer and that the water table was about 12 feet. We also assumed that the hydraulic conductivity was 100% meaning that all of the nitrate produced from the manure and the urine would go directly into the ground water. We made these assumptions to try and model a worst case scenario for this hypothetical situation.

By developing this model we planned to show the impact that an average herd of dairy cows can have on the shallow ground water found in southern New Mexico. The program we created made various assumptions that showed the relationships between the point source and the ground water. While writing this program we gained a better understanding of the importance of manure management, protecting our ground water, the economic contribution of dairies to the state of New Mexico, as well as improving our ability to program in Java.

Table 1 shows the results of our program

	Year 0	Year 5	Year 10	Year 15
Nitrate from manure	863.04	863.04	863.04	863.04
Nitrate from urine	27,714.00	27,714.00	27,714.00	27,714.00
Total amount of nitrate (mg)	1.2797397×10^{10}	1.2797397×10^{10}	1.2797397×10^{10}	1.2797397×10^{10}
Initial concentration of nitrate	.0105479480	.0105479480	.0105479480	.0105479480
Concentration of nitrate over time	.0105479480	9.568307×10^{13}	$1.91366148 \times 10^{14}$	$2.870492225 \times 10^{14}$

Note: Constants include number of dairy cows at 1475 and aquifer size of 1,000,000 acre feet

Conclusion

In conclusion, we feel that we have effectively created a program that models the diffusion of nitrogen as nitrates into groundwater through a shallow water table. We feel that we are able to reflect the relationships between our respective variables and constants. Our results indicate that, if left untreated and/or unmanaged, nitrogen excreted from dairy cows can have a negative impact on the ground water in a quick period of time. This worst-case scenario made us realize that ground water is something that we need to protect. It also made us realize that the loss of dairies in the state due to environmental issues would have a big impact on the economy, especially in southern and southeastern New Mexico.

Recommendations

Some recommendations we would make would be to obtain more data that would reflect an existing dairy operation. By doing so, we could have compared our worst-case scenario with an average working dairy and determined the effectiveness of manure and waste-management on ground water contamination. We would recommend to other teams to visit some of the dairies and see first-hand how they operate. This would provide a better understanding when making assumptions because they would be based on discussions with working dairies.

Acknowledgments

We would like to thank our mentors Dr. Abbas Ghassemi, and Dr. Zohrab Samani. Dr. Samani helped us identify our project and provided us with our initial background information on the potential for groundwater contamination from nitrogen produced by dairies. Our project wouldn't have been completed without the assistance of Dr. Ghassemi, and the research done by the WERC program. Dr. Ghassemi helped us create our math equations for the final program and worked with us to understand the conversions and relationships needed for our model. He also provided us with background information that was developed through different WERC sponsored research projects. Additional assistance was provided by Jerry Smith, a Senior Researcher at the NMSU Physical Science lab and NMSU student Justin Culp, both of whom helped get us

going with the JAVA programming, Mike Looper, NMSU dairy specialist, also provided us with the industry specific data that we needed to complete our model. Mr. Looper helped us to understand the importance of the dairy industry on the state's economy. Last but not least, we would like to thank Ms. McCray for providing us the opportunity to participate in this project. So, thank you all very much and we couldn't have done it without you.

References

1. Ground Water Quality in New Mexico, Chapter 5, New Mexico Environment Department, pages 87-98.

2. Assessing the Risk of Groundwater Contamination from Animal Manure Management Facilities, Water Quality Initiative publication WQ657, University of Missouri, October 1995.

3. McQuillan, Dennis and Jennifer Parker, Ground-Water Contamination and Remediation in New Mexico: 1927-2000, New Mexico Environment Department, Ground Water Quality Bureau, July 2000.

4. Flynn, R.P. , W.C. Lindemann, J.P. Flores-Margez, and M. Remmenga. Total Nitrogen Content of Dairy Manures in New Mexico, New Mexico State University, Agricultural Experiment Station, Bulletin 785. February 2002.

5. Dr. Abbas Ghassemi, Executive Director, WERC: A Consortium for Environmental Education and Technology Development, New Mexico State University.

6. Dr. Zohrab Samani, Professor, Civil Engineering, New Mexico State University.

7. Jerry Smith, Senior Researcher, Physical Sciences Laboratory, New Mexico State University.

8. Justin Culp, student, New Mexico State University.

9. Mike Looper, Extension Dairy Specialist, New Mexico State University

Appendix 1: JAVA Program Code

```
import java.lang.Object;
import java.lang.Math;
public class NitrogenContamination6 {
  public static void main(String[] args) {
    int numCows = 1001; // size of herd
    int aquiferSize = 1000001; // acre-feet
    int period = 1; // years
    double galNum = 0;
    double manaq = 0;
    double uraq = 0;
    double totalaq = 0;
    double ca;
    double cf = 0;
    double cb = 0;
    if (args.length == 1 && args[0].equals("help")) {
      System.out.println("");
      System.out.println(
     "java NitrogenContamination6 number-of-cows aquifer-size period-of-
time");
      System.out.println("");
     return;
    }
    if (args.length == 3) {
      numCows = Integer.parseInt(args[0]);
      aquiferSize = Integer.parseInt(args[1]);
      period = Integer.parseInt(args[2]);
    }
    System.out.println("");
    System.out.println(
      "Nitrogen Groundwater Contamination in Southern New Mexico");
    System.out.println("");
    System.out.println("Number of Cows: " + numCows);
    System.out.println("Aquifer Size(in acre feet): " + aquiferSize);
    System.out.println("Period of Time (in years): " + period);
    System.out.println("");

    galNum = 7.481 * 43560 * aquiferSize;
    System.out.println("Number of liters in aquifer: " + galNum);
    manaq = (13.92 * 62) * numCows;
    System.out.println("Nitrate from manure in aquifer: " +manaq);
    uraq = ((1652/14) * 62) * numCows;
    System.out.println("Nitrate from urine in aquifer: " + uraq);
    totalaq = (manaq + uraq) * 454 * 1000;
    System.out.println("Total amount of nitrate, in mg: " + totalaq);
    ca = (totalaq) * numCows;
```

```
    System.out.println("Concentration of Nitrate in the ground water: " +
ca);
    cb = totalaq * period  *numCows;
    cf = (cb + ca) / 1.23E12;
    System.out.println("Concentration of nitrate over time: " + cf);

  }
}
```