Modeling Groundwater Flow Experiment

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Abstract - There are commercial groundwater flow models that can be used to teach students about groundwater flow. However, involving students in building their own groundwater flow models experiment increases their enthusiasm and learning. The purpose of this experiment was to enable students to conceptualize and understand the workings of an aquifer, contamination of groundwater sources and mathematical concepts of measurement and unit conversions.

Groundwater flow modeling experiment is done in science classes. However, this experiment was done by six graders taking math therefore mathematical concepts of measurement and unit conversions had to be incorporated in the experiment. The students were fully involved in building a group groundwater flow model using locally available materials. They brought different types of soils and two liter plastic soda containers for their models to be built in school. GK 12 program provided syringes and food dyes used as contaminants in the experiment.

Students were divided into groups of four before the experiment. The experiment was started by first building the groundwater flow model. Thereafter, the model was used to demonstrate the workings of an aquifer and contamination of groundwater. This paper gives a brief description of aquifers, saturated and unsaturated ground zones, contamination of groundwater, soil horizons and learning about groundwater flow. The procedure for the experiment, the materials required and learning outcomes are outlined.

Modeling groundwater flow experiment simplified the explanation of aquifer recharge and depletion, and contamination of groundwater sources for six grade students.

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*Keywords***:** Groundwater flow model, contamination, aquifer, soil horizons

INTRODUCTION

Importance of protection of ground water

Many households have private drinking water wells in their property in rural areas. In these areas local water utility companies also rely on groundwater as their source of drinking water. Groundwater sources can potentially be contaminated by human activities. To ensure protection of groundwater from contamination United States Environmental Protection Agency (EPA) has developed several programs to meet this objective. These programs include: Underground injection control program, groundwater rule and source water protection [EPA, 8]. The Safe Drinking Water Act requires that the States develop EPA approved programs to carry out assessments of all source waters in the state [EPA, 10].

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Aquifers

Aquifers are water yielding formation that may contain sufficient groundwater to be a practical source of potable water. There are two types of aquifers, confined aquifer and unconfined aquifers. Confined aquifers are those where the rocks surrounding the aquifer confines the pressure in the porous rock and its water. Unconfined aquifers are those which are not confined by any rocks [EPA, 11].This can be seen in in figure 1 below.

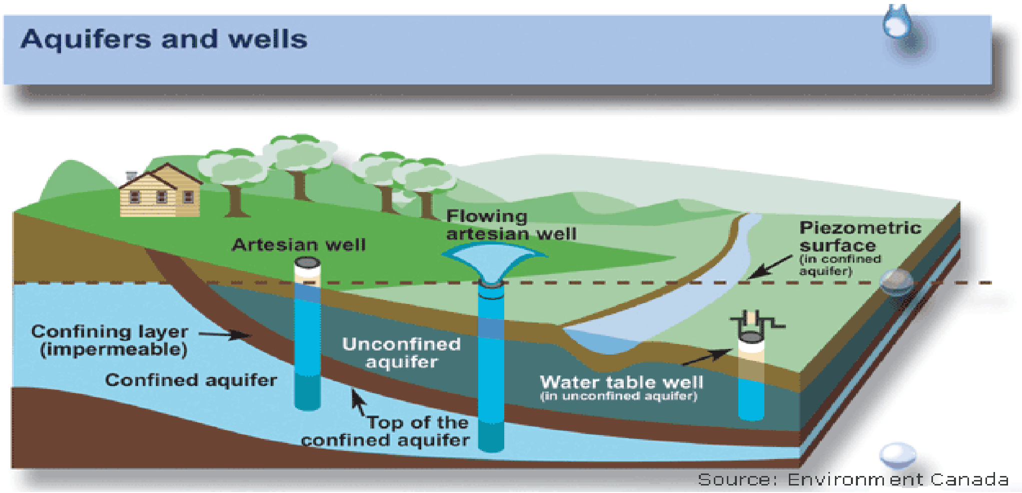

Figure1: Sectional view of aquifers and wells [EPA, 11]

Saturated and unsaturated zone

Groundwater is found in two zones. The unsaturated zone, immediately below the land surface, contains water and air in the pores. The saturated zone, a zone in which all the pores and rock fractures are filled with water, underlies the unsaturated zone. The top of the saturated zone is called the water table [EPA, 10]. Figure 2 shows the sectional view of unsaturated and saturated zones in the ground.

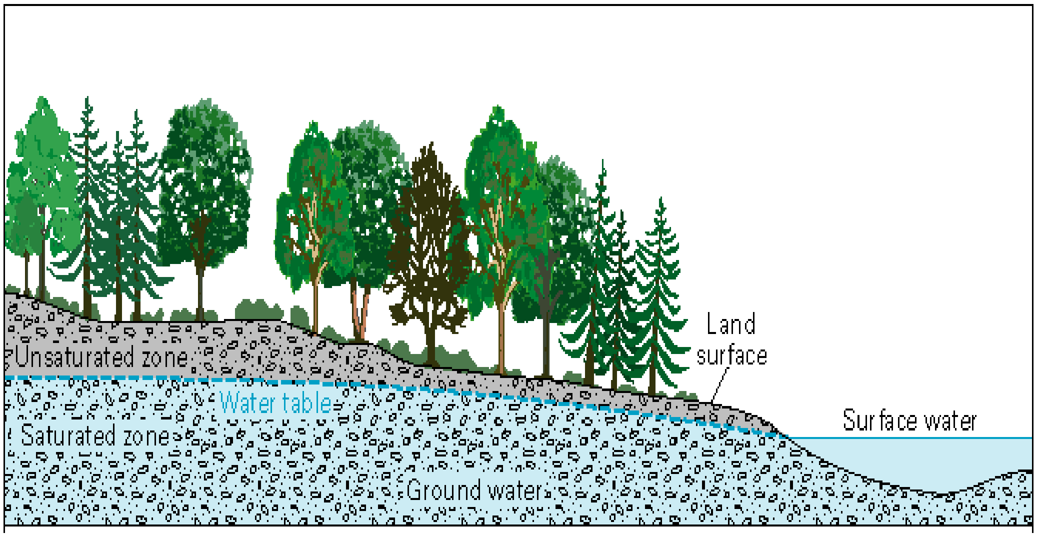

Figure 2: Sectional view of unsaturated and saturated zones [EPA, 11]

Contamination of groundwater

Groundwater can be contaminated in many different ways. Pollutants injected underground and contaminated surface water percolation may contaminate groundwater. This was demonstrated in the groundwater model experiment. Figure 3 shows the dispersal of contaminated groundwater from waste disposal site.

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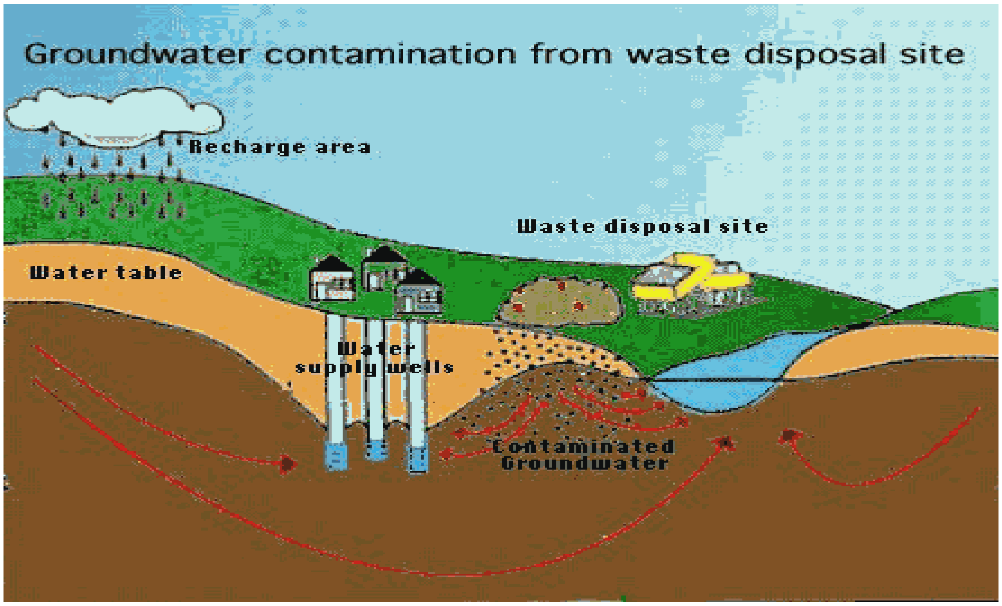

Figure 3: Shows sectional view of groundwater contamination from waste disposal site [Groundwater, 2].

Soil Horizons

There are five main soil horizons in a soil structure, namely O-horizon, A-horizon, E-horizon, B-horizon, and C-horizon. Figure 2: shows the soil horizons.

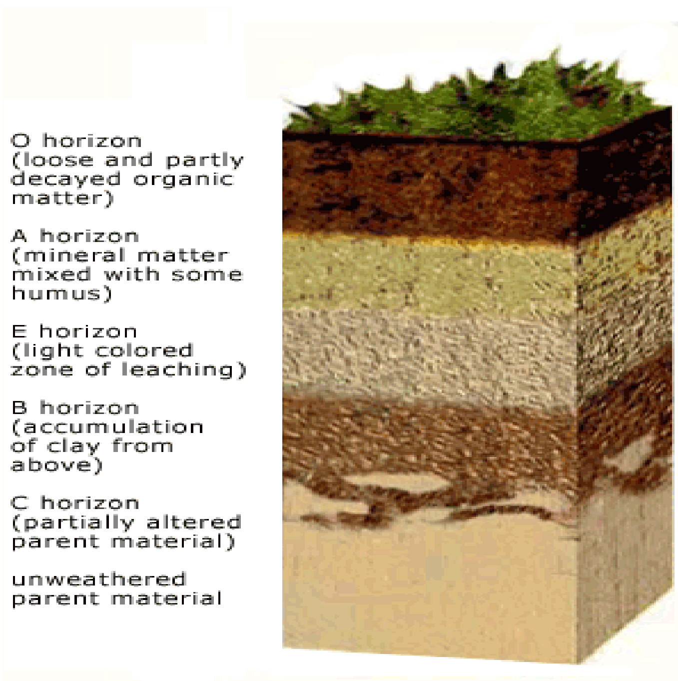

Figure 2: The cross-sectional view of soil horizons [The University of Vermont, 7]

Firstly, O-horizon consists of loose and partly decayed organic matter. This horizon was represented in the experiment by loose top soil collected from the locality of the school. Secondly, A-horizon consists of mineral matter mixed with some humus. It was represented by clay soil in the experiment. Thirdly, E-horizon consists of light colored mineral particles. Fourthly, B-horizon consists of accumulated clay transported from top horizons. In

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the experiment E-horizon and B-horizon are combined together and was represented by sand soil. Fifthly, C-horizon consists of partially altered parent material. This horizon was represented by gravel in the experiment.

Learning about groundwater flow

Groundwater is the water found underground which is stored in spaces between rocks and soil particles [EPA, 10]. There are many sources of groundwater contamination for example septic systems, waste landfills, hazardous waste sites and agricultural chemicals.

The students learned about different soil properties of the soils used in the experiment. They learned about soil texture, color and water percolation rates.

To demonstrate the operations of an aquifer, 200 ml of water was added onto the groundwater flow model. Thereafter100ml of water was pulled out using a syringe. The students observed and recorded what happened to the aquifer when this was done.

To demonstrate how contaminants reach the groundwater sources, a contaminant (food coloring) was injected onto the model. Students observed and recorded what happened when this was done. The contaminants seeped through the soil and contaminated the groundwater when they came in contact.

The following experiment was handed out to the teacher.

Groundwater Flow Model

(Activity time, approx. 40min)

Goal of groundwater flow model

The goal of the groundwater flow model experiment was to help six grade students conceptualize and understand the working of an aquifer and contamination of underground water sources. To achieve this goal, the students applied soil science and mathematical concepts in carrying out the experiment. The mathematical concepts applied included length and volume measurement, unit conversions, multiplication and division operations.

Pre-Activity Lesson

The students were taught how to apply mathematical concepts of measurement and unit conversion before they could build their own groundwater flow models.

1. Measurement. Each student was given a ruler with two units of measurement, centimeters and inches. They were taught how to use a ruler to take measurement using centimeters. The students were also taught and practiced how to measure different volumes of water using graduated cylinders.
2. Unit conversion. Students were taught how to convert units using International system of units (SI). Unit conversions involved using multiplication and division operations. Students were given units conversion problems for practice after the lesson. Table 1 shows length and volume units' conversions.

Length	**Volume**
1 centimeter = 10 millimeters	1 centiliter = 10 milliliter
1 meter = 100 centimeters	1 liter =100 centiliters
1 kilometer = 1000 meters	1 kiloliter = 1000 liters

Table 1: Shows length and volume units' conversions

Required Materials (Per Group)

2 liter clear plastic bottle

Two long transparent straws

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100ml graduated cylinder

30ml plastic syringe

Sand soil, Clay soil, topsoil and gravel

Procedure for the experiment

1. The teacher or aid should cut the top off the two liter bottle.
2. Place 5 centimeters of gravel on the bottom of the 2 liter plastic bottle. Use a ruler to measure that you have 5 centimeters from the bottom of the bottle.
3. One member of the group should hold two straws inside the container on the opposite sides while the other member pours sand soil into the container. The sand added should measure 6 centimeters from the level of gravel.
4. Add 5 centimeters of clayey soil on top of the sand. Use a ruler to take measurement.
5. Add 3 centimeters of topsoil on top of the clayey soil. Take measurement using a ruler.
6. Add 200ml of water to the model slowly to saturate the sand and gravel layers.
7. Draw off 100ml of water using the syringe through one of the straws. What happens when the water is drawn off? Record your observation.
8. Using the other straw on the opposite side, draw off 20ml of water. Record your observation.
9. Add 100ml of water onto the model.
10. Using a beaker mix food coloring with 20ml of water.
11. Inject the mixed food coloring solution into one of the straws. Observe and record what happens when the food coloring enters the groundwater.
12. Draw 50ml of water from the other straw opposite the straw used for injecting the food coloring. Observe and record what happens. Is the water drawn contaminated by food coloring? Why do you think this happened?

Post-Activity lesson

The review of the activity will be done after the students have completed the experiment. The questions asked when doing the experiment will be discussed to enable students to have a clear picture of what happens in actual groundwater flow. These questions are:

i. What happens when the water is drawn off?
    a. The level of the water is reduced.
ii. What happens if we had several straws and draw water off each straw?
    a. The water could be depleted in the aquifer.
iii. What happens when the food coloring enters the groundwater?
    a. The groundwater becomes discolored.
iv. Is the water drawn contaminated by food coloring?
    a. Yes the water is contaminated by the food coloring.
v. Why do you think this happened?
    a. This is because water discharged from the surface of the soil ended up in the same aquifer underground. Therefore we have to be careful not to contaminate surface water since it can end up contaminating groundwater.

RESULTS

Student Enthusiasm

The students enjoyed the activity greatly. After the pre lesson activity, the students were eager to work on their groundwater models. The teacher built the model along with the students enabling them to follow along easily. The students enjoyed pulling water using syringes from the groundwater model and did not want to stop. The teacher told them to stop so that they could complete the remaining procedures.

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Student Learning

The students were actively engaged in learning throughout the activity. The activity was well received by students since it was hands-on activity. They were able to learn how to measure length and volume using a ruler and graduated cylinder respectively.

Students learned about the properties of different soil types and soil horizons where the soil can be found.

Students learned how to apply mathematical operations of multiplication and division to perform unit conversions of length and volume measurements using international system of units (SI).The students were able to conceptualize the workings of an aquifer and contamination of groundwater sources.

Working in groups enabled students to learn team work. The students had to communicate and agree on how they were going to work together as a team to build a groundwater model.

CONCLUSIONS

This activity enabled students to understand that they can apply mathematical concepts practically. Most students had not learned how to use a ruler to take measurements. They were fascinated when they learned how to do it. They enjoyed taking measurements of both length and volume. This module can be used to teach 6^{th} and 7^{th} graders Life Science and Math classes.

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