Introduction to Toxicology Lesson Plan

This lesson plan serves as an introduction to toxicology for the high school classroom. This lesson utilizes students' prior knowledge and engages them in the study of toxicology. Students will explore the differences between man-made and natural toxic substances. Students will learn the basics of the dose-response principle and obtain information they can use in the future to make wise decisions for themselves and their families. This lesson plan is useful in chemistry, physical sciences, and biology as you begin to talk about all things chemical and the importance of chemical reactions in our everyday lives, as well as the effects of chemicals on all living organisms.

Primary Learning Outcomes

- Students will gain appreciation for the fact that life is dependent on an ongoing series of chemical reactions.
- Students will learn how government regulations protect our health**.**
- Students will learn that toxic substances in our environment can affect *all* organisms.
- Students will understand that we are surrounded by both natural and manmade toxic substances and be able to differentiate between the two.
- Students will be able to define a "toxic substance."
- Students will be able to define the "science of toxicology."
- Students will analyze toxicological risks versus benefits with the understanding of basic toxicological principles.
- Students will be able to calculate chemical concentrations in water.
- Students will understand the dose-response principle.

Secondary Learning Outcomes

- Students will obtain a basic understanding of toxicology that will provide them with more knowledge about choices they make in their everyday lives.

Assessed Georgia Performance Standards

<u>Habits of Mind</u>

SCSh1. Students will evaluate the importance of curiosity, honesty, openness, and skepticism in science.

SCSh2. Students will use standard safety practices for all classroom laboratory and field investigations.

SCSh3. Students will identify and investigate problems scientifically.

SCSh4. Students use tools and instruments for observing, measuring, and manipulating scientific equipment and materials.

SCSh5. Students will demonstrate the computation and estimation skills necessary for analyzing data and developing reasonable scientific explanations.

SCSh6. Students will communicate scientific investigations and information clearly.

The Nature of Science
SCSh7. Students analyze how scientific knowledge is developed.

SCSh8. Students will understand important features of the process of scientific inquiry.

Biology
SB4. Students will assess the dependence of all organisms on one another and the flow of energy and matter within their ecosystems.

Chemistry
SC1. Students will analyze the nature of matter and its classifications.

SC5. Students will understand that the rate at which a chemical reaction occurs can be affected by changing concentration, temperature, or pressure and the addition of a catalyst.

SC7. Students will characterize the properties that describe solutions and the nature of acids and bases.

Physical Science
SPS2. Students will explore the nature of matter, its classifications, and its system for naming types of matter.

SPS6. Students will investigate the properties of solutions.

Background
Everything in the environment is made of chemicals. Both naturally occurring and manmade (synthetic) substances are chemical in nature. People and other animals are exposed to chemicals by ingesting them, inhaling them, or absorbing them through their skin or mucousa. Protection from harmful chemicals can only occur by blocking these *routes of exposure*.

Students often have many misconceptions about chemicals. When asked what a chemical is, rather than providing a definition (any substance that has a defined molecular composition), they tend to give examples of synthetic, toxic chemicals like pesticides. It is important to begin with an exercise asking students to name some things made of chemicals. This will help you gauge the understanding of your students. Often, they do not realize that all natural substances are also made of chemicals.

Procedures/Activities

Step 1: Duration ~10 minutes *Activity/Discussion*
Ask students what a chemical is and to name some things made of chemicals. List the responses on the board. After generating a list, go through the list with students and identify listings as: synthetic (manmade), natural, toxic, nontoxic, good, or bad. Relay the fact that all substances are made of chemicals. This is an important concept that many students do not fully appreciate. This is an important first step in understanding the science of toxicology.

Option: You may choose to bring in examples of items for them to classify at the beginning instead of listing things made of chemicals on the board. In this exercise you could have them group the items into the above categories as well as things made of chemicals and things not made of chemicals. Naturally many students will place items such as food and clothing into the 'not made of chemicals' category and this will help you address the misconception, stated above, that is possessed by many students.

Step 2: Duration ~10 minutes *Reading/Lecture/Discussion*
Have students read the introduction to toxicology handout or provide this information in a lecture style. This will provide the background information for discussions, demonstrations, and lab activities.

Step 3: Duration ~10 minutes *Dose Demonstration*
This is a demonstration to relay the importance of the amount of dose. Fill three 400mL beakers about ¾ full with water. Place one drop of food coloring in the first beaker, five in the second, and fifteen in the last beaker. Stir each beaker and discuss the change in color as a response to increased dose (amount of food color) in each beaker. Use white paper as a backdrop for easy visualization. The human body is about 75% water, thus the beakers represent the amount of water in a human. Explain how some chemicals, like caffeine, are able to distribute throughout the body, just like the food coloring they witnessed in the water.

Step 4: Duration ~5minutes *Size Demonstration*
Fill one 400mL and one 100mL beaker about ¾ full with water. The large beaker represents an adult and a child is represented by the small beaker. Put the same amount of food coloring in each beaker (1 or 2 drops). The small beaker will be darker than the larger one. Use white paper as a backdrop for easy visualization. This is a demonstration on the importance of size or weight of the organism/human. Children may be more severely affected than an adult by the same dose. For example, a child who drinks one caffeinated soft drink will likely have a greater response than an adult who drinks the same amount.

Step 5: Duration ~55minutes *Lab Activity—Day 1*
This activity will allow students to become toxicologists in your laboratory and determine the effects of various chemicals on the germination of radish seeds. They will construct a dose-response curve for the effect of their chosen chemical on the germination of radish seeds. Radish seeds are used in this experiment because of their rapid time to germination (1-3 days). For solid chemicals, make a saturated solution in about 50mL of water.

Step 6: Duration ~ 10minutes *Lab Activity—Day 2*
Students will observe the seeds and record the number that have germinated and the number that have not.

Step 7: Duration ~ 10minutes *Lab Activity—Day 3*
Students will observe the seeds and record the number that have germinated and the number that have not.

Step 8: Duration ~ 10minutes *Lab Activity—Day 4*
Students will observe the seeds and record the number that have germinated and the number that have not. Students will answer questions and construct a dose-response curve for their data.

Materials/Equipment

<u>Demonstrations</u>: 3-400mL or bigger beakers; 1-250mL or 100mL beaker; dark food coloring (red, blue, green)

<u>Lab activity per group of students</u>: 6 7-ounce plastic cups, 1-50mL graduated cylinder, 1-10mL graduated cylinder, 50mL of chemical for testing, water, plastic pipet, masking tape, permanent marker, safety equipment (aprons, goggles, gloves), 6 Ziploc plastic sandwich bags, 12 paper napkins, bag of fast germinating seeds (~60 seeds, radish seeds will work), laboratory tray (for organization of the sample bags since the experiment spans over several days)

Example chemicals for testing (you may want to have a variety for the students to choose from): plant food, sucrose, artificial sweetener, liquid laundry detergent, shampoo, carbonated beverage, household all-purpose cleaner, disinfectant, salt, etc. *Note: If you a solid phase chemical, make sure to make a dissolved, concentrated solution of it in 50mL of water.*

Total Duration
Introduction, demonstrations, discussions : *~35 minutes*
Laboratory Activity: *~55 minutes* on day 1, *~10 minutes* on day 2, *~10 minutes* on day 3, *~30 minutes* on Day 4

Assessment
Students will be assessed based on their participation in the classroom discussions as well as the completion of the laboratory exercise. Students should write clear coherent sentences that precisely describe the responses observed during the seed toxicity test. Students should exhibit knowledge of <u>dose-response</u> and why toxicity tests are necessary.

Extension
Long-term project possibility: After reviewing the basic principles of toxicology in this lesson, you may wish to assign a long-term project in which they design their own experiment to test the toxicity of another chemical.

Introduction to Toxicology

Background

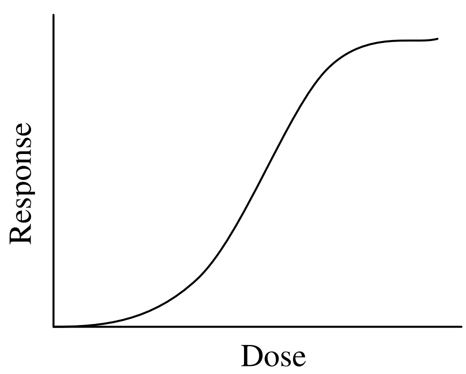
We are all made a variety of carbohydrates, proteins, nucleic acids, and other chemical compounds. For each of us, life is a series of ongoing chemical reactions which allow our bodies to function. The food we consume, the air we breathe, along with the water we drink provide the raw materials for the chemical reactions in our bodies. Within our bodies, chemical reactions take place in order to maintain homeostasis and provide us with the necessary nutrients for life.

The food, air, and water we consume are important for everyday life. Within the past century concern has risen about the possibility of toxic substances contaminating the necessities of life. Are these concerns valid? What is a toxic chemical and what type of risk may it pose to human health? Are the toxic chemicals man-made or natural? Can our bodies cope with exposure to toxic chemicals? Are all toxic chemicals the same, if not, how do they differ?

The simple answer is that all chemicals, natural and man-made, can be toxic. Paracelsus, the Father of Modern Toxicology, once stated that "the dose makes the poison." The science of **toxicology** aims to quantify the effects of toxic substances on living organisms (humans, plants, insects, etc.). Toxicology incorporates many aspects of science including chemistry, biology, biochemistry, physiology, microbiology, ecology, pharmacology, statistics, etc. **Toxicologists** work to determine how much of a chemical will cause adverse effects (harm) as well as how much of a chemical can you be exposed to without seeing adverse effects, a generally safe dose.

<u>The Dose-Response Principle</u>

Dose is the amount of exposure to an agent. Response is the reaction to the dose. For example, drinking one glass of milk may be fine, but drinking a gallon of milk will produce a very undesirable response! In general, increased dose produces more effects. The same is true for many chemicals (natural and manmade)—but remember the governing principle "the dose makes the poison."



The classic "S-shaped" dose-response curve. As the dose increases, the response (adverse effects) increase, too.

The effect of a chemical depends on the dose (amount of chemical that enters the body) but also on the resulting concentration (amount of chemical compared with body size/volume), the length of exposure to the chemical, and the route of exposure.

Toxic effects of chemicals vary from species to species. This explains why the well known herbicide, 2,4-D, is able to kill dandelions while allowing grass to grow. So, in many cases, the specific action of chemicals can be useful when applying pesticides or even administering antibiotics (killing the harmful bacteria and not hurting the helpful bacteria in your body).

In addition to toxic effects varying from species to species, they can also vary between individuals within a species. The effects of a chemical on your body may be very different from the effect it would have on your friend's body. Some people experience side effects to administered drugs, while others appear to have no adverse reaction to the same drug. Side effects associated with pharmaceutical drugs are useful in looking at another aspect of toxicology—**risk versus benefit**. A risk-benefit analysis is performed to determine if the risks associated with the drug/chemical exposure outweigh the disadvantage of adverse effects. We all perform risk-benefit analyses in our everyday lives, though we rarely think of it in those terms. For example, did you choose to drive or ride in a car/bus to school today? What risk did you take? What was the benefit; why did you take that risk? Many homeowners must also weigh the risks of applying an herbicide versus the benefit of a weed-free lawn. This type of analysis will likely result in different conclusions for various individuals and controversy may arise.

Many governments try to reduce risk by a variety of methods. New food and drug products must be tested for safety and usefulness. Consumers must be provided information to make decisions on their own; this information includes food labeling of contents, warnings on cleaners and pesticides, as well as directions for use and side effects associated with pharmaceutical drugs. Environmental regulations govern against serious pollution of our water, land, and air.

With all this information, if we are to live safely in a chemical world, we need to be well informed. All chemicals have the potential to result in harm if they are used carelessly or abused. We need to know how to evaluate the television, radio, newspaper, and magazine reports so that poor science or reporting does not cause an unnecessary panic. We also need to know how to react when a real problem or threat arises.

Questions

1. What is the science of toxicology?
2. What is a dose?
3. What is a response?
4. Explain the dose-response principle.
5. What is a risk-benefit analysis and how is it used?
6. How can you help decrease your risk associated with exposure to a toxic substance?

Name ________________________________

Student Handout: Toxicology Testing on Radish Seeds

In this exercise, you and your teammates are toxicologists. Your project manager has assigned you to construct a dose-response curve for the effect of a substance on the germination of seeds. First, you must decide what substance you will be testing for seed toxicity. Next you will make several concentrations of this solution and finally apply the solution to the seeds. Over the next couple of days, you will determine the effects of the substance on the rate of seed germination.

Part I: Making Solutions for the Toxicity Test

Materials

6 7-ounce clear plastic cups, clean and empty
1 50-mL graduated cylinder
1 10-mL graduated cylinder
100 mL of water
50 mL chemical substance for testing
disposable plastic pipette
permanent marker
safety goggles
protective latex gloves

Procedure

1. Put on protection for your health (safety goggles and latex gloves).
2. Using the information in the Table 1, determine the % Concentration of the Chemical and complete the table.

$$\%\ \text{Concentration of Chemical} = \frac{\text{Amount of Chemical}}{\text{Totoal Volume of Liquid}} * 100$$

3. Using the permanent marker, label each of the 6 plastic cups with the **Beaker #** and **% of Chemical Concentration** as shown in Table 1.

Table 1. Solutions for Toxicity Testing

Beaker #	Amount of Water	Amount of Chemical	Total Volume of Liquid	% Concentration of Chemical
1	20.00 mL	0.00 mL	20 mL	
2	18.75 mL	1.25 mL	20 mL	
3	17.50 mL	2.50 mL	20 mL	
4	15.00 mL	5.00 mL	20 mL	
5	10.00 mL	10.00 mL	20 mL	
6	0.00 mL	20.00 mL	20 mL	

4. Use the 50-mL (for beakers #1-4) and 10-mL (for beaker 5) graduated cylinders to measure the correct amount of water. To make minor adjustments to your measurements, use the eyedropper. *Remember, you read a graduated cylinder at the bottom of the meniscus, with eyes level with the meniscus.* Pour the water into each of the labeled cups according to Table 1.
5. Use the 10-mL (for beakers 2-4) and the 50-mL (for beaker 6) graduated cylinders to measure the correct amount of chemical. Pour the chemical into each of the labeled cups according to Table 1.
6. When you have completed Steps 3-5, check to make sure that the cups contain the same amount of liquid. If they are not equal, repeat the steps for the solution that is not equal.

Name ________________________________

Part II: Seed Toxicity Testing

Materials

6 Ziploc plastic sandwich bags with tight seals
6 cups of chemical solution (made in Part I)
permanent marker
protective latex gloves
12 paper napkins
1 bag of seeds (~60 seeds)
safety goggles
laboratory tray (if available)

Procedure

1. Develop and record your hypothesis. Do you think you'll see a difference in the effect on seeds of a high dose of chemical versus a small dose. Predict what you think will happen to the seeds as the dose increases.

2. Put on protection for your health (safety goggles and latex gloves).

3. Label all six bags with the beaker #, % concentration of chemical, and all of your teammates initials. For example: #1, 0%, EM, AR, CW, JP for the first bag; #2, 6.25%, EM, AR, CW, JP for the second bag; and so forth.

4. Place one paper napkin on top of another and fold them in half so that they fit into the bag. Do this for each of the six bags.

5. Slowly pour the entire chemical solution into the bags. **Make sure you match the beaker number and % concentration of chemical with the correct bag!!** Each bag should contain 20 mL of solution, which should be absorbed by the paper napkins.

6. Count out 10 seeds. Place these seeds, making sure to space them evenly, onto the paper napkins in Bag #1. Seal the plastic bag and push out as much air as possible as you seal.

7. Repeat Step 5 for bags 2-6.

8. Carefully stack the bags, lying flat with the seeds up, aside in the classroom as directed by your instructor. Keep them on a tray if possible to avoid confusion.

9. Over the next couple of days, observe your seeds and record the information in Table 2.

Name ___________________________________

Results

Table 2. Results of Seed Toxicity Tests

Bag #	**Dose (% Concentration of Chemical)**	**Response**					
		Day 1		**Day 2**		**Day 3**	
		# of seeds germinated	# of seeds *not* germinated	# of seeds germinated	# of seeds *not* germinated	# of seeds germinated	# of seeds *not* germinated
1	0%						
2	6.25%						
3	12.50%						
4	25%						
5	50%						
6	100%						

Construct a dose-response plot for your data using the space below.

Discussion and Conclusion Questions

Directions: Answer on a separate piece of paper in complete sentences—or complete a lab report if requested by the project manager)

1. What chemical did you test? Why did you choose to test this chemical? Describe any knowledge you have about this chemical. (Harmful? Beneficial? Neither?)
2. What is the potential for human exposure to the chemical substance you tested?
3. What was the highest dose tested (% concentration of chemical)? Which bag of seeds was treated with the highest dose?
4. What was the response that you were observing? How can a test like this be used?
5. After this test, how would you classify your chemical? Harmful, beneficial, or neither? Provide evidence to support your classification.