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ENVIRONMENTAL TOXICOLOGY: HOW POLLUTANTS LIKE LEAD IMPACT OUR HEALTH

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YOUNG REVIEWERS:

ANIKA
AGE: 10

ANUSHKA
AGE: 13

JOONSAH
AGE: 11

Every day, we interact with our environments. Many things in our environments are safe, but some might make us sick. How do scientists figure out which things make us sick? And when we find out what makes people sick, how do we clean up the environment to protect people? Environmental toxicology is the study of how pollution affects human, animal, and ecosystem health. The scientists working in this field study which chemicals make humans and animals sick, how we come into contact with them, and if there are safer chemicals that could replace those that are less safe. In this article, we use the metal lead as an example. We describe where lead comes from, how people are exposed to it, and why we must protect ourselves from lead exposure.

ENVIRONMENTAL TOXICOLOGY: STUDYING CHEMICAL POLLUTION

Everything around us is made of chemicals—from the water we drink to the clothes we wear. The news sometimes makes it seem like all chemicals are harmful, but the truth is *everything* is made from chemicals, and not all of them are bad. Our bodies need many chemicals, like water, food, and air. Although many chemicals are good for us, some can hurt the environment and our health. Your environment is everything around you. It includes your backyard, inside your house, your school, and any other places you go. When pollution gets into the environment, people and animals can be exposed to dangerous substances and become sick.

Sometimes pollution is something you can see, like cigarette butts or plastic bags on the beach. But sometimes pollution is invisible to the naked eye. Chemical pollution is when chemicals get into the environment where they can hurt either people or the plants and animals that live there. Who figures out which chemicals make us sick so that we can protect ourselves from them? **Environmental toxicologists** are professionals who study how chemicals in the environment affect the health of living beings, including humans. Environmental toxicologists do research to figure out if chemicals in the environment are harmful, and to figure out what needs to be done to protect ourselves from harmful chemicals.

ENVIRONMENTAL TOXICOLOGISTS

Scientists who study how chemicals in the environment affect the health of humans, animals, and our ecosystems.

WHERE DOES CHEMICAL POLLUTION COME FROM?

Pollution can come from many places. Chemical pollution can occur naturally, which means that the chemicals can come from the Earth, or they can be made by people, such as chemicals made in factories. Sometimes it is easy to see where pollution is coming from, like when you see a volcano erupt or waste being dumped somewhere. But sometimes we do not know where chemical pollutants are or how people get exposed to them. Some scientists dedicate their whole careers to being detectives for these "mystery" chemicals. They search our air, water, and even things in our houses (like our clothes, couches, or even frying pans) to find these chemicals.

One example of a chemical pollutant that is hard to see is the metal lead (with the symbol Pb^{2+} on the periodic table of elements). This article focuses on lead because it has been very well studied by environmental toxicologists, but it is important to note that there are many other chemicals around us that scientists still do not know much about yet.

Lead exists naturally in the Earth and has many uses. For example, some batteries contain lead. At one time, lead was used in the gasoline used to power cars. So much lead was used and released into the air

that, even now, dirt around some major roads contains lots of lead. In the past, some homes and even children's toys used lead-containing paints. People are still being exposed to lead particles from this paint as it chips away over time.

HOW DO CHEMICALS GET INTO OUR BODIES?

Chemicals in the air can get into our bodies when we breathe them in (called inhalation). Some chemicals can be absorbed through the skin (called dermal uptake). If toxic chemicals are present in food or drinks, they can get into our bodies when we eat or drink (called ingestion). Once inside our bodies, toxic chemicals can travel through the blood and harm our cells and organs (Figure 1A).

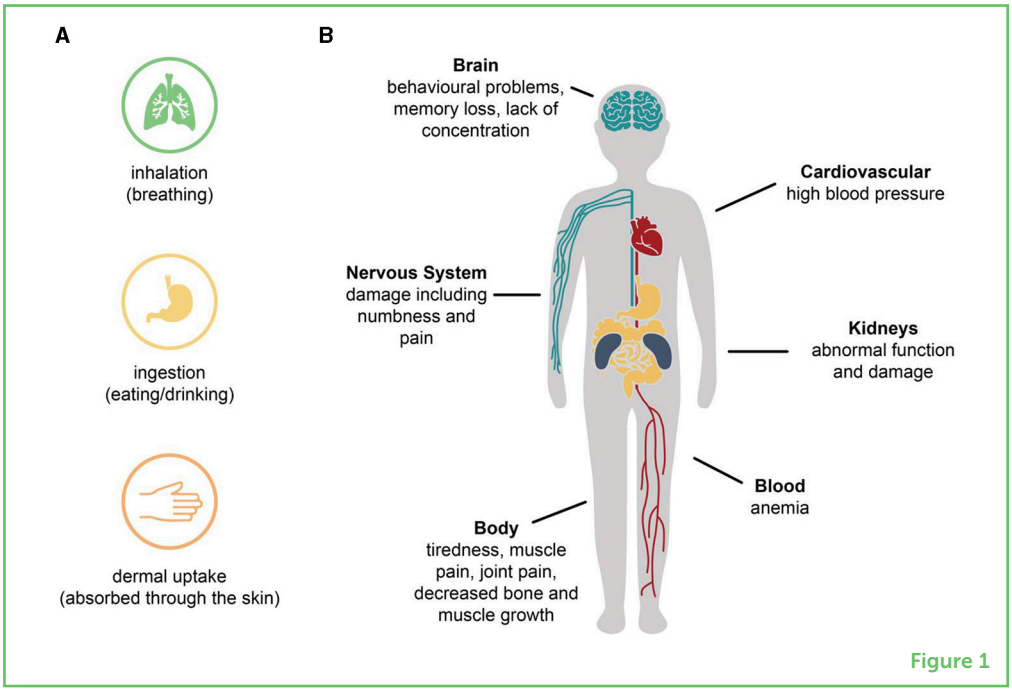

Figure 1

Paths by which chemicals get into our bodies and their effects on organs. **(A)** Inhalation (breathing), ingestion (eating/drinking), and dermal uptake (absorption through the skin) are three major ways chemicals enter our bodies and affect our health. **(B)** Once chemicals get into our bodies, they can go to various organs and cause toxic effects. Lead, for example, can damage organs including the brain, nervous system, heart, and kidneys.

A few years ago, many people in the city of Flint, Michigan were exposed to lead from pipes that carried their drinking water. Every time they took a sip of water, they were ingesting a little bit of lead. Lead ingestion can also happen when small children play in places where lead is present, because they often put their hands and toys in their mouths. People have also been exposed to lead just from inhaling it, such as when gasoline with lead was used to power cars. Luckily, lead is not easily taken up by touch.

WHAT DO CHEMICALS DO IN OUR BODIES?

Chemicals can have both positive and negative effects on the human body. For example, calcium is needed for strong bones,

and carrots contain vitamin A, which helps our eyesight. However, sometimes even beneficial chemicals in high amounts can cause bad things to happen. Every chemical can result in unique health effects, depending on what the chemical is, how the person was exposed to it, and how much of the chemical they were exposed to.

Lead is a **developmental neurotoxicant**. This means that it can cause harmful changes in the way the brain develops and functions. Lead can impact the brain by changing how brain cells communicate with one another. In a healthy brain, neurons release small chemicals to talk with each other. Lead can disrupt the release of these chemicals, so it impacts communication between cells [1]. This can make it harder to pay attention, learn language, and form memories. Lead exposure at low levels can also cause high blood pressure. Exposure to high levels of lead can cause nausea, tiredness, and in very bad cases can even cause death [2]. The variety of health effects of lead exposure are due to the many organs lead interacts with, ranging from the heart to the kidneys (Figure 1B).

THE DOSE MAKES THE POISON

The effect of any chemical depends on how much we are exposed to. The amount of a chemical that gets inside the body is called the **dose**. A **dose-response curve** is a tool used by toxicologists to show how increasing the dose changes the health effect being measured. Generally, a higher dose increases the effect the exposure has on someone's health (Figures 2A, B). Every chemical is different, and the **toxicity** of different chemicals can be determined by comparing dose-response curves. Some chemicals are more toxic than others, which a dose-response curve shows as a toxic response at a lower dose (Figure 2C).

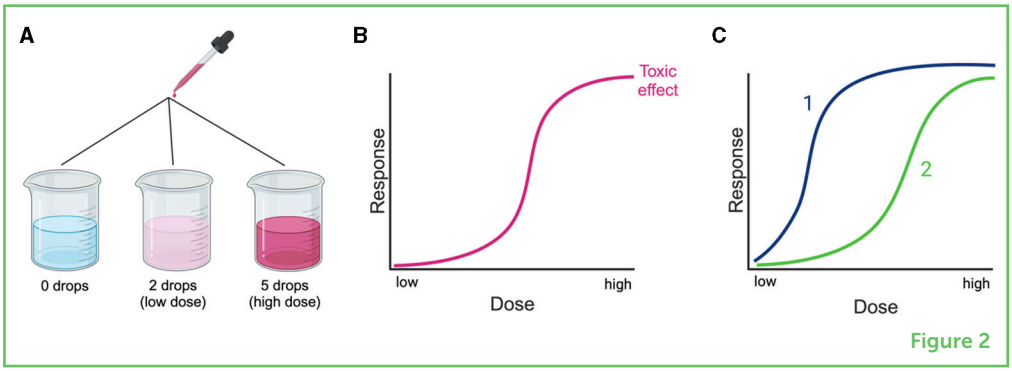

Figure 2

Usually, a toxic chemical is only harmful if you are exposed to a lot of it or if you are exposed to it for a long time. Toxicologists study

DEVELOPMENTAL NEUROTOXICANT

A chemical that can damage the brain and nervous system when they are developing.

DOSE

The amount of something a person gets exposed to.

DOSE-RESPONSE CURVE

A graph used by toxicologists to show how increasing the dose changes the health effect, or response, being measured.

TOXICITY

The adverse (harmful or dangerous) response of an organism to a chemical exposure.

Figure 2

(A) For colored chemicals like red food coloring, it is easy to see different doses. **(B)** If someone is exposed to a low dose of a chemical, there may be a smaller response. If they are exposed to a higher dose, the chemical will likely have a larger, possibly toxic, effect. **(C)** Some chemicals are toxic at lower doses than others. This can be seen as shifts in dose-response curves. In this example, chemical 1 is more toxic than chemical 2—a low dose of chemical 1 can do more harm than the same amount of chemical 2 (*Created with Biorender.com*).

two types of exposure: chronic and acute. **Chronic exposure** is when someone is exposed to a chemical over months or years. For example, a child might have a chronic lead exposure if they have toys coated in lead paint—they get exposed to a little every day. Thankfully, toys are no longer made with lead paint, so chronic exposures to lead are not common. **Acute exposure** is when someone is exposed to a chemical only for a short period of time. For example, someone might have an acute lead exposure from removing old lead-based paint if they make a lot of dust and inhale it while sanding the paint [3].

CHRONIC EXPOSURE

Long-term contact with a chemical, over weeks, months, or years, potentially leading to gradual health effects due to repeated or continuous exposure.

ACUTE EXPOSURE

Short-term contact with a chemical, often lasting minutes to hours, which can cause immediate health effects depending on the substance and exposure level.

When people are exposed to more than one type of chemical simultaneously, that also matters. These other chemicals can be toxic or non-toxic. Being exposed to two chemicals at the same time can change how our bodies respond, which can be helpful or hurtful. One example of how chemicals can interact and worsen health is that of lead and another metal, arsenic. Both lead and arsenic are toxic, and they are even worse for us when we are exposed to them together [4]. On the other hand, studies have shown that certain foods and drinks (such as milk, green tea, and vegetables) can actually reduce lead toxicity, which can lessen the harmful effects of the exposure [5].

WHO IS AT RISK FOR CHEMICAL EXPOSURE?

Environmental toxicologists do not only study which chemicals affect our health—they also study the people exposed. Contact with chemicals can be more common based on where you live, your job, your gender, and your race. For example, factories using toxic chemicals are often built in lower-income areas, so people living in these areas may be exposed to more chemicals. Another example is that, historically, there have been more studies of possible toxic effects of men's health and personal care products than women's, so women's health and personal care products might contain more harmful chemicals. Additionally, someone's job might make them more likely to be exposed to toxic chemicals, such as workers on farms who may need to use chemicals like pesticides, which are chemicals designed to kill insects. We see these differences in exposures to lead too—some people are more exposed than others. In the United States, Black children are exposed to higher levels of lead than white or Hispanic children [6].

When some groups have more exposure to higher levels of harmful chemicals than others, this can lead to more illnesses in those people. **Environmental justice** is a social and political movement that aims to make sure that everyone is treated fairly, so all people are equally protected from toxic chemicals. Environmental toxicologists all over the world advocate and stand up for equal access to a healthy environment.

ENVIRONMENTAL JUSTICE

A social movement that seeks to make sure everyone has equal access to a clean and healthy environment.

WHAT CAN WE DO ABOUT CHEMICAL EXPOSURES?

Environmental toxicologists have learned so much about which chemicals hurt our health and what doses are safe, so they can help us decide which places need to be cleaned up. For example, partly because of what toxicologists have learned about lead, the United States government is spending money to reduce exposure to lead from old paint and pipes. Also, it is important that we all take steps to protect ourselves from exposures, like being careful about what foods we eat and washing our hands. Other things you can do include talking to environmental toxicologists and other scientists who test these chemicals, reading more about these issues, and talking to your friends. You can also support environmental justice movements that champion equality, so everyone is equally protected. Maybe you will become an environmental toxicologist when you grow up! Finally, with our environment and climate changing every day, everyone can help, whether it is cleaning up places in your community or speaking up for a healthy environment.

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CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

ANIKA, AGE: 10

I am a 10-year-old girl and LOVE cats. I like to sing and dance in my free time. I like to sketch and do crafts too. I do not like slugs, snails, and bees. My favorite game is Brawl Stars and my favorite color is purple.

ANUSHKA, AGE: 13

I am a young individual interested in the field of science. Research has always been my passion from an early age. In my free time, I like to draw, read, dance, and sing. My favorite subjects are Math and Science. I wish to become a successful scientist when I get older!

JOONSAH, AGE: 11

Hi, my name is Joonsah. I am 11 years old. I like playing and watching soccer. My favorite subject at school is Science and English. I can play three instruments: piano, viola, and trumpet. I also speak four languages: English, Korean, Chinese and some German.

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Pooja Lalwani is currently a research assistant at the Precision Vaccines Program at Boston Children's Hospital. She graduated from Duke University in 2022 with a B.S. in biology, a minor in music, and a certificate in sustainability engagement. In her undergraduate years, she conducted environmental toxicology research, specifically

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