frontiers for Young Minds

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REMOVING THE EXCESS OF FLUORIDE FROM WATER THROUGH ELECTRICITY: SAFE WATER TO SHARE WITH THE KITTENS

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YOUNG REVIEWERS:

ALI
AGE: 14

ELENA
AGE: 15

HASAN
AGE: 13

SAMAR
AGE: 8

Every living thing needs water—people, animals, and plants. But have you ever wondered if water is safe to consume? Unfortunately, water might be contaminated with tiny things we cannot see. One contaminant is a tiny particle called fluoride which, in excess, can harm your teeth and bones, even causing them to break or deform. Cleaning water to remove contaminants like fluoride is very important, but we have a guardian on our side: electrosorption! This amazing process uses nothing more than electricity and special materials that conduct it to remove harmful contaminants from water, making it safe for everyone to drink. This process is surprisingly simple. In fact, your cat has probably already shown you how it works, and you just did not realize it!

THE AMERICAN SCHOOL OF SALTILLO (COLAM)

AGES: 12–14

WHEN WATER HAS TOO MUCH OF A GOOD THING

In this story, kittens will be our heroes, as they help to explain how to get safe water for everyone. For this, meet Dr. Jona-Cat (orange cat) and Denny (black cat), brilliant and curious felines scientists who will guide us through the world of clean water!

Did you know that, by 2037, there will be nearly 9 billion people in the world? This huge population will make the demand for fresh water—one of the most important resources for life—enormous. However, even by 2040 there might not be enough water for everyone, and almost 40% of the global population might be at risk of running out of this vital resource. That means humans, and even our furry friends, might not have enough water to drink!

Do not panic because there is a solution—using underground sources of water called groundwater. In many dry regions, people already get their water from underground sources. Groundwater usually starts off clean, but unfortunately, it can pick up something called fluoride. Fluoride is a tiny, negatively charged particle that is okay (or even healthy) in small amounts but harmful in excess. Where does fluoride come from? As water flows through rocks and soil, fluoride dissolves into the water. Rain or farm irrigation can also carry fluoride from the soil into rivers, lakes, and even back underground, where it builds up over time. While groundwater is usually good for drinking, it sometimes needs to remove excess fluoride to make it safe for people. Then, our mission only focuses on removing the excess of fluoride from water.

You might be thinking, "If fluoride is in toothpaste, how can it be harmful"? The answer is all about how much there is. Fluoride is important for our bodies—it helps prevent cavities and makes our bones strong. But we only need a small amount, about 1 mg per liter, which we get from water or some foods. But too much fluoride can be a problem, making water unsafe. According to World Health Organization, if the water you drink every day has more than 1.5 mg of fluoride per liter, it can harm your teeth and bones, causing a condition called **fluorosis** [1]. To give you an idea of how small this amount is, it is like adding just one drop of ink to an Olympic-sized swimming pool!

FLUOROSIS

A health problem caused by drinking too much fluoride over time, which can damage teeth or bones.

REMOVING EXCESS FLUORIDE FROM WATER

There are several ways to remove fluoride from water. One method is by reverse osmosis, which is like a super-smart strainer, where the clean water slips through, but the fluoride and other stuff get left behind. This process works well but is very expensive. Another method, called coagulation-flocculation, is like making a net with glue: a substance traps the fluoride like crumbs in sticky dough, and the big

"clumps" sink or get filtered out easily. This method is cheaper, but it does not catch all the fluoride. Then there is adsorption, which uses solid materials to trap contaminants, like a powerful fishing net that grabs everything it touches as it moves through the water. The most popular material for adsorption is activated carbon, which is great at removing many pollutants. It is also affordable and easy to find but, unfortunately, it is not very good at removing fluoride [2].

Luckily, we can make activated carbon even better at removing fluoride, using an exciting new technology called **electrosorption**. Electrosorption combines adsorption with electrochemical principles to enhance fluoride removal. Think of it like a sponge: when a small electric current is applied, the activated carbon attracts and holds onto fluoride ions, keeping them out of the water. Although it is still an emerging technology, electrosorption shows great promise for water treatment and could play a key role in producing enough clean water in the future.

ELECTROSORPTION

A way to clean water, in which a material uses a tiny electric current to pull ions out of the water and hold them, almost like a sponge grabbing tiny charged particles.

HOW EXACTLY DOES ELECTROSORPTION WORK?

Electrosorption requires an electrochemical cell, which you can think of as a team with four key players: the anode, the cathode, the electrolyte, and the electrical connector (Figure 1), as indicated by Dr. Jona-Cat in Figure 1.

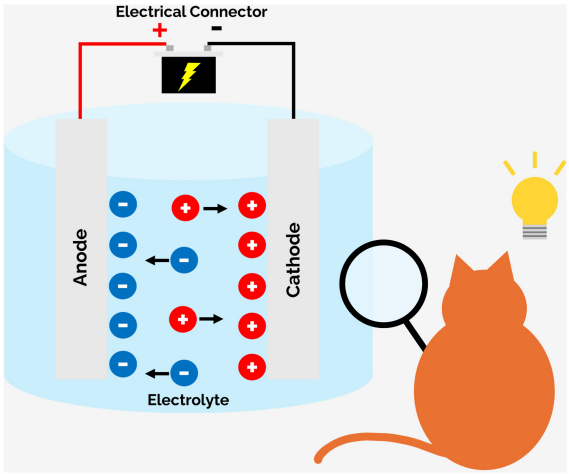

Figure 1

Figure 1

An electrochemical cell is made up of four main parts. The anode is a material that becomes positively charged when we apply electrical energy, while the cathode becomes negatively charged. The electrolyte is a liquid surrounding the anode and cathode, which contains tiny, charged particles that can move between the anode and cathode. The electrical connector links the anode and cathode, allowing the electric current to flow between them.

The anode is a material that conducts electricity. When we apply voltage (electrical energy) to the anode, it becomes positively charged. Meanwhile, the cathode becomes negatively charged. These two materials, called **electrodes**, are usually made of metals. The energy needed to charge them can come from a battery, for example.

ELECTRODES

Materials that allow electricity to enter or leave a system during a process.

The electrolyte is like a transportation system. It is a liquid that contains tiny particles with positive or negative charges. These particles move

between the anode (positive side) and the cathode (negative side), creating what we call an ionic current. The electrical connector, outside of the electrolyte, links the anode and cathode, allowing the electric current to flow between them (Figure 1).

Now, let us dive into the topic of electrosorption. When we apply voltage to the electrochemical cell, the ions in the water are drawn toward the electrodes. Why does this happen? Because opposite charges attract! Positive ions move toward the cathode, while negative ions—like fluoride—are pulled to the anode. This process cleans the water.

Here is a fun way to imagine it: Picture a box filled with tiny foam balls, representing fluoride. Now, let us introduce an orange kitten with short fur, called Dr. Jona-Cat. When you pet the kitten, its fur becomes electrostatically charged. Then, the curious kitten jumps into the box, and its charged fur starts attracting the foam balls, which stick to it. In this situation, the kitten acts as the anode, capturing the foam balls (fluoride) with its electric charge. By the end, our furry friend is covered in foam balls (Figure 2A)!

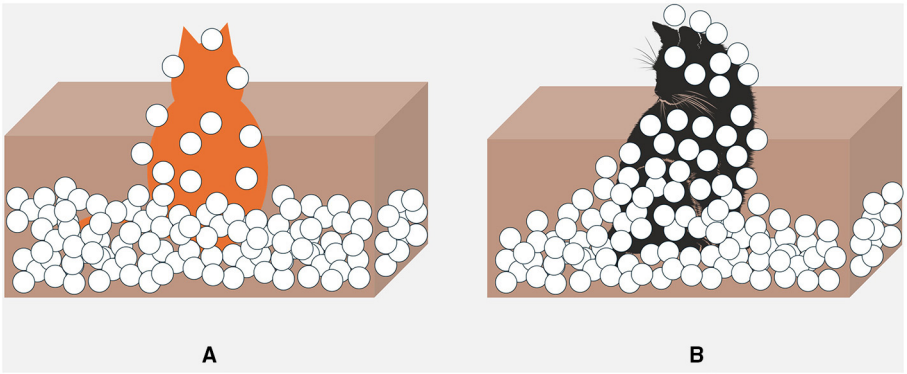

Figure 2

Figure 2

(A) Dr. Jona-Cat, a kitten with short orange fur, develops a positive electrical charge when petted. When the cat jumps into a box full of foam balls, it acts like an anode—the balls (representing fluoride ions) are attracted to the cat's fur and stick to it. **(B)** A cat like Denny, with longer, fluffier fur, has more surface area to hold the electrical charge and can thus attract even more foam balls.

It might seem logical to think that the more voltage we apply, the better the cell will be at capturing contaminants, right? But it is not that simple. If we use too much voltage, unwanted electrochemical reactions can occur, using extra energy and making the process less efficient.

Imagine a mixture of fluoride and water. If the voltage is too high, we might start breaking down the water, or even damaging the electrodes. This would make the cell less effective at retaining fluoride at the anode. It is like petting the kitten so much that, instead of attracting the foam balls, it becomes so charged it starts shooting sparks around the room, burning the foam balls!

HEY, WAIT... WHERE IS THE ACTIVATED CARBON?

POROUS

Containing tiny openings or cavities that allow gases or liquids to pass through easily.

CARBON FIBERS

Thin strands of carbon that are very strong and light, often used to make materials that conduct electricity.

CARBON NANOTUBES

Tiny tubes made of carbon atoms that are extremely small, strong, and good at carrying electricity.

To optimize fluoride removal, the material of the electrodes plays a crucial role. This is because the surface of the electrodes is where ions accumulate, separating the contaminant from water. To make this process more efficient, the electrodes must have a large specific surface area (measured in square meters per gram of material), which can be achieved if they have a **porous** structure. The pores allow the electrodes to store more ions, maximizing their interaction with the water and improving fluoride accumulation.

To meet these characteristics, carbon-based materials such as **carbon fibers**, **carbon nanotubes**, and activated carbon are used [3]. These materials stand out for their excellent electrical conductivity and their ability to be designed with an enormous specific surface area. Among them, granular activated carbon is one of the most popular options due to its high efficiency, low cost, and ease of production.

Using activated carbon is like swapping the short-haired orange cat, Dr. Jona-Cat, for a much fluffier one—Denny, the black cat (Figure 2B). This new kitty has more fur, which means there are more pores and surface area with a static charge to attract tiny foam balls (the fluoride). In this way, Denny could catch many more little balls from the box.

THE FINAL MISSION: CONTINUOUS WATER FLOW

The real challenge is to bring electrosorption to continuous-flow systems that can be used in large-scale water treatment plants.

How would it work? First, imagine a bunch of foam balls falling around our statically charged Denny sitting on his climbing tower. As the balls move, they become trapped in Denny's fur and few, if any, fall out (Figure 3A). An electrochemical reactor works similarly, as a stream of fluoride-contaminated water flows in. Inside, the positively charged activated carbon anode captures the fluoride as the water passes through. In this way, the water leaving the reactor is free of the contaminant (Figure 3B).

Although this might sound simple, operating such a reactor is not that easy. Many factors must be carefully adjusted, including water flow rate, electrode size, applied voltage, initial fluoride concentration, and water temperature. Scientists are currently working hard to overcome these challenges and make this technology a reality.

In addition to being important for science, improving electrosorption could be very beneficial for everyone's health. By helping to prevent diseases like fluorosis, we are working toward a safer future. And that is not all! Can you imagine using this technology to remove

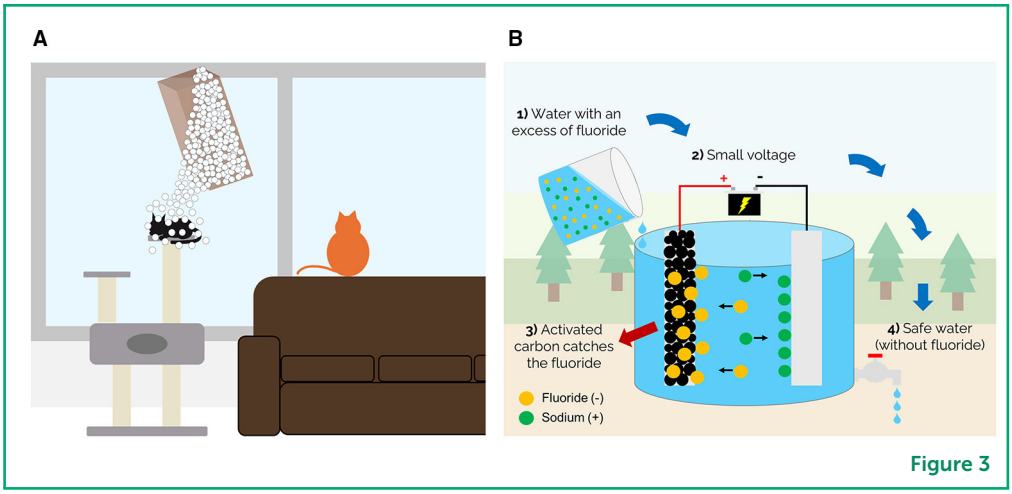

Figure 3

(A) In our analogy, an electrically charged fluffy cat captures foam balls as they pass over it. **(B)** In water treatment plants, water with too much fluoride enters an electrochemical cell, where activated carbon with a positive charge attracts fluoride ions. After this process, the water is safe to share with the kitten.

salt from seawater? This could be a revolutionary way to make seawater drinkable, helping to solve water scarcity problems. The best part is that this process could work with renewable energy, like solar power.

WHERE ARE WE? WHERE ARE WE GOING?

This project was created after reviewing many research papers on pollutant removal. Although the idea of electrosorption was not originally proposed by our research group, we are the first scientists trying to apply it to a continuous process—the same way water treatment plants work to produce safe water for humans (and their pets). Currently, this project is at the laboratory scale because we spent 2 years on the design and construction of the electrochemical cell. However, we hope it can be operated on an industrial scale within a few years. In fact, it might even be you, young reader, who makes it happen! Of course, this raises new questions: is it economically viable? Could it solve the global water crisis? While those answers are for another time, what is certain is that electrosorption is vast and exciting.

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AI TOOL STATEMENT

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REFERENCES

1. Thamarai, P., Deivayanai, V. C., Karishma, S., Yaashikaa, P. R., and Saravanan, A. 2024. Effective removal of fluoride ions from contaminated water using electrochemical techniques: a critical review on recent developments and environmental perspective. *J. Hazard. Mater. Adv*. 16:100483. doi: 10.1016/j.hazadv.2024.100483
2. Vences-Alvarez, E., Velazquez-Jimenez, L., Chazaro-Ruiz, Diaz-Flores, P., and Rangel Mendez, J. 2015. Fluoride removal in water by a hybrid adsorbent lanthanum–carbon. *J. Colloid Interface Sci*. 455:194–202. doi: 10.1016/j.jcis.2015.05.048
3. Wu, P., Xia, L., Dai, M., and Lin, L. S. S. 2016. Electrosorption of fluoride on TiO2-loaded activated carbon in water. *Colloids Surf. A Physicochem. Eng. Asp*. 502: 66–73. doi: 10.1016/J.COLSURFA.2016.05.020

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YOUNG REVIEWERS

ALI, AGE: 14
I am Ali, I am 14 years old, and I like playing video games and having fun with my friends and family. I am deeply interested in Science and Engineering, and I plan to pursue a doctorate in Chemical Engineering as my career inspiration and then teach kids through much simpler ways, may be through new innovations and tools and may be only using video games to do math and science.

ELENA, AGE: 15
My name is Elena. I love learning about biology, anatomy and medicine. My hobbies and favorite things to do include reading, making jewelry and rowing. I have competed at 2 National Championships and Head of the Charles Regatta, placing top 5. It is a great sport to combine scientific and critical thinking with athletics. My favorite classes are Biology and Anatomy and Physiology. In Anatomy, we learn about the organ systems and are even drawing a diagram of the human body by hand to express how the organs function together. I hope one day to work in the medical field and do medical research to contribute to my community.

HASAN, AGE: 13
My name is Hasan Nasar. I enjoy learning about science and how things work. I love to play basketball and hang out with my friends. I hope to one day be a scientist and find solutions to many of our day-to-day problems. I love figuring out ways to help others. Science makes me feel it is possible to find answers to all our questions.

SAMAR, AGE: 8
I am Samar, and I like playing with my friends and making friendship clubs. I am the president of a friendship forever club at my elementary school. I love going to my school library and looking at books. On weekends I always push my mom to take me to our neighborhood libraries as for me it is fun to just look at pictures in nice books about sea creatures and oceans. I am fascinated by living systems, particularly how life came into being in oceans and researching on Sharks and Whales. I love asking lots of questions to my teachers and parents. I also love Disney world and hope to continue visiting it every year, it is lot of fun and inspires me to dream.

THE AMERICAN SCHOOL OF SALTILLO (COLAM), AGES: 12–14
They are from Middle School and enjoy making funny figures with "Play-Doh".

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