Name: _____ Date: _____

# Reading Lead with Carbon: Inside the Tethys Sensor

Reading level 13 · 1503 words

Take one liter of tap water. Through November 2026, the EPA's action level for lead is 15 parts per billion. A rule adopted in October 2024 lowers it to 10, with water-system compliance dates starting 1 November 2027. By our arithmetic, 15 parts per billion is about 15 millionths of a gram of lead in the whole liter. In October 2017, an 11-year-old named Gitanjali Rao won the Discovery Education 3M Young Scientist Challenge, and $25,000, for Tethys, a device built to find lead in water. Tethys used a disposable cartridge, a small processor and a phone, and it was meant for homes and for agencies alike. This book asks how a few millionths of a gram can become a message on a screen, and what it would take for anyone to trust that message.

The number needs careful reading. The 15 figure is an action level, not a safe line. The EPA says that if more than 10 percent of tap samples go over it, a water system must take more steps, while its health goal for lead is zero. The CDC says no safe blood lead level in children has been identified. The EPA first set the lead rule in 1991 and has revised it several times. The October 2024 version removes the old trigger level and lowers the action level to 10 parts per billion. So the number is a rule that people change, not a fact of nature. A court decision or a new EPA rule could move the dates again. The EPA names the most common sources of lead in water as pipes, faucets and fixtures that contain it, which release it as they corrode.

Before Tethys, a family had two routes, and each gave something up. The EPA says testing is the only sure way to know whether water has harmful lead. It points people to certified laboratories, at roughly $20 to $100 a test. The other route is a test strip, which a 2017 report called fast but not always accurate. Engineers call this kind of choice a trade-off among cost, speed and accuracy. Rao wanted a tool that would allow easy testing at home or by agencies, with quick results. She said, "I've got to do something to change this." Her answer was a sensor built on nanotubes, a material already used in gas sensors.

The sensing material is the carbon nanotube. A single-walled nanotube is a tube of carbon about 0.5 to 2 nanometers across, which one reference puts near a 100,000th the width of a human hair. Along its length, a tube acts either as a metal or as a semiconductor. The same reference says these tubes are sensitive to changes in their chemical surroundings, and that the change shows up as a rise or fall in electric current. In industry they already serve as gas and odor sensors, in a form called an electronic nose. By this book's reading, that makes them a natural candidate for a chemical sensor.

Reports of Tethys describe the sensing step briefly: the nanotubes are sensitive to changes in the flow of electrons, and they are lined with atoms that have an affinity for lead, which adds a

measurable resistance. Ohm's law gives the meaning: current between two points is proportional to the voltage, and resistance is the constant that links them, so at a fixed voltage, more resistance means less current. In clean water the flow stays the same, but when lead reacts with the atoms, resistance rises and a processor measures it. A chemical event at the surface of a tube becomes an electrical number. Real nanotube sensors depend on a coating to pick one target. A review says bare tubes have very limited selectivity. It also says a bound molecule can lower or raise the current. The 2017 reports give only the lead-raises-resistance version.

The rest of Tethys turns that number into a message. Its cartridge is disposable and holds chemically treated arrays of nanotubes. A signal processor built on Arduino technology reads the resistance, and a Bluetooth attachment sends the result to a smartphone app, which says whether the water is safe to drink. One tech article reported that the device warns above "15 parts per million," although the EPA's figure is parts per billion, and no page says how the cartridge was set or tested. By our arithmetic, the two units differ by a factor of one thousand, so a slip in a unit would change what the warning means. A threshold is only useful when its units are exact.

What would show that a sensor like this works? By this book's list, three things. First, sensitivity: the smallest amount of lead it can see, which should reach below the action level. Second, selectivity: it must answer to lead and not to the other minerals in tap water. The reports say the tubes are lined with atoms that have an affinity for lead, and that is the claim a test must check. Third, repeatability: the same sample must give the same answer on different days and on different cartridges. If the action level falls from 15 to 10 parts per billion, a sensor has to see even less lead. A sensor that fails any one of these can raise a false alarm or miss real lead. It passes when its readings match a certified lab's on the same water, sample after sample.

The 2017 news reports describe Tethys as a prototype. They say it was designed to detect lead faster than other techniques on the market, but no 2017 report describes a side-by-side test against a laboratory. In January 2019, NPR reported that Rao was working with a Denver Water lab manager. She was checking whether other chemicals, such as fluoride, could disturb the reading. That matters, because "faster" is a claim about measurement, and a prize recognizes a design and a demonstration, not a proven instrument. Rao said she planned to save some of the prize and use the rest to invest in the device, to make it commercially viable. She also said it could be expanded to test for other chemical contaminants, but those are plans. The road from a prototype to a trusted tool runs through the comparison above.

The challenge is built like a small research pipeline. Students in grades 5 through 8 send in a video of one to two minutes. It describes an invention or a solution to an everyday problem. Today, entries must come from one student, not a group, and the judges do not score production quality. Ten finalists are chosen. For the 2017 round, entries were due April 19.

Each finalist spends the summer building a prototype under a 3M scientist. In 2017 that took three months, and Rao's mentor was Kathleen Shafer, a research specialist who develops new plastics technologies. Under today's rules, the finals include a presentation and scored challenges on science knowledge.

Her account of the build is about failure. "I had so many failures when I was doing my tests," Rao said. She added, "I knew all these failures, which were learning experiences, would make my experiment better." In engineering terms, each failed run is information about one of three things: the cartridge, the electronics, or the way the result is read. The reports do not say which failures she had. What they show is the habit of changing one thing, testing again and keeping the result. Years later she gave the habit a name, a five-step process that she says she uses for everything now: observe, brainstorm, research, build, communicate.

The same method moved from chemistry to software. Kindly uses artificial intelligence to detect cyberbullying at an early stage. Rao said she first hard-coded in some words that could be considered bullying, and she also put out a survey to parents, teachers and students. UNICEF describes Kindly as an open-source API that uses machine learning to detect cyberbullying intent in text. It gives children real-time feedback so they can revise a message, and UNICEF says it is developing the tool as a Digital Public Good. MIT News described it in July 2025 as a UNICEF Digital Public Good service. Rao said the goal is not to punish. That is a design choice. The tool speaks to the writer before the message is sent.

The honors followed the work. In December 2020, TIME named Rao its first Kid of the Year. She was chosen from more than 5,000 nominees, in a field of five finalists ages 8 to 16. By then she had set a goal of mentoring 30,000 students, and she said she had reached it, through workshops that began as a simple presentation and lesson plans. TIME described her then as just 15 years old. In 2025 the Starmus Festival named her the first recipient of its Stephen Hawking Junior Medal for Science Communication, a new award. Whether a nanotube cartridge can match a laboratory on lead is a question that only a side-by-side test can answer.

## Questions

**1. Through November 2026 the action level is 15 parts per billion. Why does the book say it is not a safe line?**

A. It only applies to schools

B. It is where a water system must act, while the EPA's health goal is zero

C. It is the amount a child can safely drink

**2. At a fixed voltage, what happens to the current when resistance rises?**

A. It rises too

B. It stays the same

C. It falls

**3. A tech article said Tethys warns above 15 parts per million. How does that differ from the EPA's figure?**

A. It is the same figure
B. It is 1,000 times larger
C. It is 1,000 times smaller

**4. In the sentence "Second, selectivity: it must answer to lead and not to the other minerals in tap water," what does answer to mean?**

A. Respond to
B. Argue with
C. Report to

**5. What would show that a sensor like this works, by the book's list?**

A. Being small enough to carry
B. Winning a prize
C. Matching a certified lab on the same water, again and again

**6. What did Rao say she first did when building Kindly?**

A. Asked a 3M scientist to write it
B. Hard-coded in some words that could be considered bullying
C. Copied a lab report

## Words to know

nanotube: tiny carbon tube
resistance: opposes current
selectivity: answering only one
repeatability: same answer again
prototype: first model
corrode: wear away

# Answer key: Reading Lead with Carbon: Inside the Tethys Sensor

1. B. It is where a water system must act, while the EPA's health goal is zero
2. C. It falls
3. B. It is 1,000 times larger
4. A. Respond to
5. C. Matching a certified lab on the same water, again and again
6. B. Hard-coded in some words that could be considered bullying