Fact or Fiction?

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Single Molecules

"In the case of 'single molecule theory' we should all be dead of cancer from the millions of molecules of arsenic, cadmium and chromium in each of our cells if the theory were valid."[1]

"One day we may recognize that there is something of everything in everything else and that a glass of water likely contains a molecule of every compound on earth."[2]

Each of us has billions of molecules of carcinogens naturally present in our bodies. These include radioactive carbon, a variety of metals including uranium (10,000 atoms per cell), metals that are considered pollutants, steroid hormones and numerous other carcinogens naturally present in food.[1] Part of the mix includes metals familiar to electroplaters—cadmium, chromium, cobalt, copper, iron, lead, nickel, tin and zinc. Our bodies have more of a metal mix than most common jobshops.

Table 1 lists some trace elements in the human body and their estimated content. The estimate for heavy metals in the human body ranges between 10^4 and 10^8 atoms per cell.

For discussion purposes, let's use arsenic, cadmium and chromium, all of which are considered to be carcinogenic. The approximate amounts of these elements present in the body, according to Jukes,[1] are 4.4 mg, 30 mg and 6 mg per person. If you compare these values with those in Table 1, which is from a different reference (Lenihan[3]) you'll note that Jukes' values are lower for arsenic and cadmium than Lenihan's, while both agree on chromium. Regardless of which numbers are correct, using Jukes' values, which are more conservative, will still show the relatively large quantities of these metals in the human body.

Arsenic, cadmium and chromium would supply respectively 1×10^5, 2×10^6 and 0.7×10^6 molecules per cell. Using a value of 4.4 mg as the arsenic content of a normal healthy human being, this translates to 9×10^{18} molecules or as As_4.[1]

Here's another example of big numbers. Ottoboni discusses benzpyrene in her book, *The Dose Makes the Poison:*[4]

"Benzpyrene is a naturally occurring and relatively potent carcinogen that is virtually omnipresent in our environment as a product of the cooking or burning of any organic material. It has been determined that there are 50 μg of benzpyrene in about 2 lb of charcoal broiled steak. A generous portion of steak would weigh about 1/5 of a kg (7 oz). That portion of steak would contain about 10 μg benzpyrene. Ten μg is a very, very small quantity, as demonstrated by the fact that there are over 28 million μg in 1 oz. But when one considers how many molecules are contained in 10 μg, that seemingly insignificant quantity takes on really formidable proportions. In 10 μg of benzpyrene there would be 24,000,000,000,000,000 molecules! To give this number a name, there would be about 24 quadrillion molecules of benzpyrene in a portion of charcoal-broiled steak."

Some folks subscribe to the theory that "one molecule" can cause cancer. The above calculations show that a "one-molecule" hypothesis for causing cancer is preposterous. Regardless, the one molecule theory was the reasoning behind the Delaney Clause, which was passed in 1958. Delaney was the so-called "zero risk standard." It stated that no substance that has been shown to cause cancer in laboratory animals may be added to our food supply in any amount, no matter how small.[5] Fortunately, the law did not apply the same standard to substances naturally present in food, because if it did, we would most likely starve. Naturally occurring substances that fail the same animal cancer tests have been found in many foods. One example: about 99.99 percent of all pesticides in the human

Trace Elements In the Human Body*

Element	Est. Human Body Content
Arsenic	10 mg
Boron	48 mg
Cadmium	50 mg
Chromium	6 mg
Cobalt	1 mg
Copper	70 mg
Fluorine	2.6 g
Iron	4 g
Iodine	20 mg
Lead	120 mg
Manganese	12 mg
Mercury	13 mg
Molybdenum	10 mg
Nickel	1 mg
Selenium	10 mg
Silicon	18 g
Tin	6 mg
Vanadium	100 ug
Zinc	2.3 g

** From Lenihan, ref. 3.*

diet are natural pesticides from plants. because plants produce toxins to protect themselves against fungi, insects and animal predators such as man.[6]

Last summer, new legislation removed pesticide residues from any association with the Delaney clause, replacing the scientifically untenable "zero discharge" requirement with a stringent but attainable standard of "reasonable certainty of no harm."[7] I would like to say more about the Delaney Clause, however, because it serves as a possible barometer for current issues. The Delaney Clause is a metaphor for the long-standing political problem that alarms are more easily turned on than switched off.[8]

When Delaney was passed in 1958, environmental exposures to synthetic chemicals were assumed to account for up to 90 percent of cancers and the abundance of naturally occurring toxins was not understood. Furthermore, in 1958, analytical techniques could find substances only to the parts-per-million range, levels at which the presence of a carcinogen is a clear danger.

Today, it is believed that synthetic compounds cause only a small percentage of cancers and modern analytical techniques allow us to measure to parts-per-quadrillion. "Delaney became ridiculous," says Linda Fisher, a former head of EPA's toxic substances office. "We were regulating extremely small amounts of synthetics in processed foods while having no controls for natural toxins in raw food, which research suggests is the greater problem. The situation made no sense."[8]

Contaminants that now cause public indignation and regulatory panic were not even detectable 25 years ago.[9] The improvement in analytical chemistry over the past few decades has been huge. Early on, we were detecting chemicals in water in the parts-per-thousand range. This is like finding one second in a 16-minute time span.

Today we can measure contaminants in parts-per-quadrillion, which is equivalent to finding that one second in a span of 32 million years![9] Or, put another way, one part-per-quadrillion is a single hair picked out of the heads of all humans on earth,[10] or one golf ball compared to the size of the earth.[11]

In 1990, Perrier™ bottled water was removed from the market because tests showed that samples of it contained 35 ppb of benzene. Although this was an amount so small that only 15 years prior it would have been impossible to detect, it was assumed that considerations of public health required withdrawal of the product.[12] A person would have to consume 2.5 million "bad" bottles each week to approximate the intake that had sickened rodents used to test it.[13] How's that for science fiction?

Shindell[5] has suggested that we may ultimately resort to counting molecules. When we do this, we immediately run into the law of diffusion. As described by scientist George Koelle, this means that:

"If a pint of water is poured into the sea and allowed to mix completely with all the water on the surface of the earth, over 5,000 molecules of the original sample will be present in any pint taken subsequently. The general conclusion to be drawn from these

calculations is that nothing is completely uncontaminated by anything else."[5]

At the smallest end of the spectrum, scientists at Oak Ridge National Laboratory detected a single atom of cesium in the presence of 10^{19} argon atoms and 10^{18} methane molecules.[14] Talk about finding a needle in a haystack! Obviously, these days one can find just about anything with the ultra-sensitive equipment currently available.

Conclusion

Each of us has billions of molecules of carcinogens present naturally in our bodies. So, of what practical value is it to learn that there is one part-per-trillion or one part-per-quadrillion of EDB or PCB or whatever in our muffins, bottled water or freshwater fish? All we're doing is showing how clever we are at analyzing things and chasing an ever-receding zero. We get alarmed by things this small, while 400,000 people die every year from smoking and another 100,000 die from drinking alcohol.

The Delaney Clause is proof of the dictum that alarms are more easily turned on than switched off. Once a piece of legislation is on the books, it can take years to turn it around, regardless of how bad it is. P&SF

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