REAL ecological and public health disasters in the modern age.

An extended essay cobbled from personal recollections and a bit of research.

Opinion: caution: severe tire damage

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Getting the lead out.

Even Dr. Seuss was in on the action (https://library.ucsd.edu/dc/object/bb8567598w) ... no one had ever seen a Karbo-Nockus before, a simian giant perched on your hood banging its fists on your engine. Modern synthetics offer better longevity than original oils, but NOTHING beat the combination of any-old-motor-oil and TEL (tetraethyl lead) added to gasoline. There is a bit of advertising fib here and time displacement, Seuss was pushing Standard Oil's Essolube product which is a motor oil, but TEL was an additive only appropriate for fuel.

The accepted definition of 'knocking' or 'plinking' is premature ignition, causing cylinders to stutter. Wikipedia says it best: *"Engine knock is caused by a cool flame, an oscillating low-temperature combustion reaction that occurs before the proper, hot ignition. Lead quenches the pyrolysed radicals and thus kills the radical chain reaction that would sustain a cool flame, preventing it from disturbing the smooth ignition of the hot flame front. Lead itself is the reactive antiknock agent, and the ethyl groups serve as a gasoline-soluble carrier."*

Also known as a 'dope' or less accurately an 'octane booster', the property makes engines run smoother by igniting right on the mark and increases available compression, also alleviates irregular detonation, the sudden terror to horses that had become cliché. Wikipedia says shamefully "beginning in the 1920s" but what kind of mumble is that supposed to be. I searched old newspapers and found the first public announcement of the substance by Thomas Midgley Jr. of General Motors on 05-Nov-1922. By 17-February-1923 a bottle of TEL was available to auto aficionados to mix with gasoline and was highly recommended. But TEL would never have become commonplace unless it came premixed at the pump. General Motors proceeded to do this quickly:

[22-Jul-1923 Tennessean] "The General Motors Chemical Co., Dayton, Ohio, is selling ethyl gas in Dayton, and in Cincinnati, and expects to get distribution all over the country. This is the only anti-knock gas I know of being sold at gas stations. Ethyl gas is technically known as tetra-ethyl-lead in solution with gasoline."

So there you have it from the original newspaper, the day the world changed. Dr. Seuss's Karbo-Nokus did not appear until 16-Apr-1933. But Standard Oil was supplying the gasoline and DuPont was licensing the technology. In 1924 five workers died at the TEL factory in New Jersey, who worked at "the loony gas building" that prepared the concentrate. It had actually been dubbed that by employees who had noticed a pattern of nervous breakdowns and strange behavior. They had collapsed and died of obvious acute lead poisoning. After some safety hullabaloo in various papers (the New York Times disagreed, claiming a better fuel is worth the risk) things escalated and in 1925 the U.S. Public Health Service declared a moratorium on TEL for one year to conduct a hazard assessment.

The moratorium was lifted the next day. In 1926 TEL was officially cleared of all suspicion of being a public health hazard, but with new guidelines for workers and gas station attendants. And despite unexpectedly finding lead in New York City dirt... nothing was said about what was escaping from the exhaust pipe. Them that sells the oil makes the rules.
The sleazy story is here: (https://archive.is/JNS1B)

Incredibly no one dared to move against TEL at the time and none would challenge TEL during WWII when high performance fighter planes demanded leaded grade 100-150 fuel. After the war America fell in love with muscle cars and leaded gas, and no one was testing the environment for lead.

And then, in one of the most amazing journeys of science ever... Clair Patterson, whose name should be a household word, SAVED THE WORLD as we know it.

Rome famously descended to madness because lead, the miracle metal that could be pounded flat to become dishes and cups and seal aqueducts for miles, poisoned their water and food. Our modern word plumbing and lead's symbol Pb is derived from Latin plumbum. This heavy metal danger was known in modern times. And yet from ~1930-1980 the US used cost-cutting and easily-bendable lead service lines between water mains to houses! When this sorry-ass practice was outlawed it required digging yards and streets to replace them with copper or brass, and yet when I worked for the City we were still occasionally finding lead service lines in 2010 that had been missed (which we dug and replaced as soon as we found them). Flint Michigan is notable for still having lots of lead lines, because a contractor hired to replace them kept pocketing the money and slow-walking the process for decades.

But in 1950 Patterson was uniquely qualified to investigate lead. He had been a physicist/chemist for the uranium refining project at Los Alamos and was familiar with isotopes and especially what has become known as U-Pb dating. Knowing that TWO separate decay chains led from uranium (U) isotopes to lead (Pb) isotopes... accurately measuring the amount and types of lead trapped in ancient zircons from when the Earth was formed... which could not have been put there directly and had to be the result of the U-Pb decay chains over time... one could theorectically 'triangulate' (I know triangles have 3 sides! Bear with me here!) the age of the Earth. The Age of the Earth was not just a schism between religion and science, within science it was a battleground of hand-waving assumptions.

In order to do this Patterson had to build a laboratory space without a trace of lead in it, so he could refine techniques for measuring lead isotopes. He had tried this before at Los Alamos but the results had been inconclusive and shocking. Now he repeated every isolation and meaurement procedure he knew and still did not succeed, until he brought himself to a terrifying conclusion that should make us shudder today. Patterson could not isolate his lab from lead in 1950 because atoms of lead were in EVERYTHING. In himself, the materials of the building and in the air. In the furniture and instruments, cloth and paper.

The metal was NOT supposed to be so pervasive. In the natural world there are many things that are pervasive like carbon but there is no natural process (like a volcano or ocean outgassing) which spews atom sized particles of elemental lead. If there had been the phenomenon would had been studied through history and if it had a source one would find incredible concentrations of it, a poisoned wastelend there. There was no such thing on record.

Having worked with heavy metal uranium as well as lead, Patterson knew full well the implications of such a discovery. There were lead particulates in the atmosphere that had been there for years, to

become part of things. Niel deGrasse Tyson told it well in Connections but Veritasium did a fine job explaining the journey in excruciating detail (https://www.youtube.com/watch?v=IV3dnLzthDA) ... the Ethyl Lead Corporation had evolved to become a worldwide juggernaut of corporate interests and patent users who were united by common interest not just to make money, but cover their collective asses.

Veritasium's title is a bit misleading. Patterson is not "the villain who accidentally killed the most people in history", he is the hero who saved countless more. The deadly villain is someone else we will get to in a bit. Aside from saving the world from a fate far worse than ancient Rome, Patterson did finally manage to calculate the age of the Earth. You will have to look it up yourself. I won't bother to say it here because you might read this tomorrow.

From the effort spearheaded by this one man, leaded gas was phased out in the USA starting in 1976 and gone from automotive gasoline by 1996. At the gas station the young may be mystified that all the pumps say "unleaded" now. Why would they say such a thing when that is all there is? The phase-out of lead began in 1978 and strict labeling appeared on gas pumps to give consumers a choice, and is still in effect today.

A 1994 study indicated that the concentration of lead in the blood of the U.S. population had dropped 78% from 1976 to 1991. Humans had scored a valuable environmental win.

Have you ever noticed that valuable and invaluable mean the same thing? Isn't it hilarious?

But lead is still the miracle metal whose softness and imperviousness to corrosion is invaluable. There was a persistent leak under a curving street at the flared 'bell' (junction between two iron pipes) because the pipes joined at a slight angle and the rubber seal inside had rotted away from water escaping past. The best remedy for this (and still is far as I know) was to place lead slugs into the space between the bell and the other pipe, and pound them until they flattened and spead out to fill the space between the pipes, sealing the leak. More permanent than any epoxy. A tiny bit of lead... in the real world one cannot always afford zero-tolerance solutions.

Zero tolerance such as, there are STILL engines spewing lead into the atmosphere today. NASCAR phased out lead gas in 2007, Formula One racing is required to use no more than 5mg/L lead in its fuel. Acute lead poisoning sets in around 6mg/L so don't be cute and drink it. But the main source today is aviation. 100 octane aviation fuel still contains TEL and not one of the little mice (the ones debating amongst themselves who will put the bell on the cat) have dared to speak up about that. They call it 'low lead' to salve everyone's conscience.

Algeria was the final country in the world to officially ban leaded gas for automobiles in 2021.

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Something to chill your heart

I promised you a supervillain and here he is: Thomas Midgley Jr. (https://en.wikipedia.org/wiki/Thomas_Midgley_Jr.) who developed the additive to gasoline in 1921. He did not set out to poison Earth with lead, so I guess you would have to call it planetslaughter. But Midgely had more mischief up his sleeve.

With the lead apocalypse under way in 1928, Midgely set sights on refrigeration technology. Easy to manufacture ammonia was the working fluid of the day and had been since Michael Faraday had built the first working vapor-compression prototype fridge in 1820. But ammonia was famously dangerous to work with, not strictly flammable but you could call it 'exitable'. Any gas with the right properties will work, and other gasses were used for large commercial freezers in Midgely's day such as propane. With its -44degF boiling point propane makes a fine heat pump. But all those hydrogens in it! We know what it really wants to do.

The problem was that most industrial gasses of the day were the product of petroleum processes with pesky explody hydrogens, or otherwise toxic to humans. Real chemistry was called for and Midgely set to work with a base of carbon, combined with atoms of chlorine and its violent cousin fluorine. But fluorines behave when bonded with chlorines and carbons. His goal was a stable gas with small molecules and a boiling point significantly below freezing, not flammable or toxic and did not react with air or common materials.

Midgely was actually continuing the work of Belgian scientist Frederick Swarts who in the 1890s had developed a technique starting with readily available carbon tetrachloride (CCl4) used in fire extinguishers. It is a carbon surrounded by a tight matrix of 4 chlorines, and Swarts's method replaced some chlorines with fluorines to make chemical compounds that (he guessed) were new and did not occur in nature. Swarts had synthesized samples of CClF3 (later known as CFC-11) and CCl2F2 (CFC-12).

So the first chlorofluorocarbons to threaten the ozone layer were emitted by a laboratory in Belgium. Let us declare war to avenge it and divert attention away from the lead debacle.

Midgely it was who refined the process of chlorine-fluorine replacement to scale its manufacture. CFC-12 marketed as R12 or 'Freon', with its boiling point of -26degF was a 'perfect match' to revolutionize the cooling industry. It was announed in 1928 to great acclaim because the industry already knew what it needed and this was it. Air conditioning for homes and cars would become practical and safe, small refrigerators efficient.

But while the stability of Freon was a prideful accomplishment of chemistry it was also a problem. These are long-lived non reacting molecules. Earth's atmosphere had always been a big place where the worst gaseous thing humans could do, even in elevators, would invisibly and eventually find its way out and away.

50 years later in 1974... F. Sherwood Rowland and Mario J. Molina, whose names should also be household words, were studying CFCs and building computer models to determine the fate and effects of them.

They were trying to estimate accumulated amounts from decades of use, working with air circulation models. There was no question that the molecules would disperse with weather, CFCs were surely already uniformly distributed above on the planet. And what would be the mechanism of eventual decomposition, if any? But there wasn't any. Fluorines and chlorines happily bound to a carbon do not want to react with anything already in atmosphere or even visiting particles of aerosols or pollution. They just get buffeted and shoved about (if you want to be dramatic). The CFC molecule in the troposphere is 'eternal'!

But the CFC would at least start to 'decompose' if it is hit by a photon of high energy such as UV-C from the sun which would break its weakest bond, the one between the carbon and a chlorine. This would leave CClF2 + Cl. But in the troposphere that is unlikely or ever to happen, because UV-C is blocked from above by the (you guessed it) stratospheric ozone layer. But now the researchers would have to consider this possibility and represent the stratosphere in their models.

When Joseph Fourier pondered in 1820 about a 'greenhouse effect' (and never called it that) he envisioned that the upper atmosphere was still and various compounds were stratified and stable. If you look at liquids of different densities it is easy to imagine this for air. And it is true to a large extent. But Earth has very violent weather with thermal and pressure gradients that can propel masses of air not just sideways but squeeze it upwards. Here is an image from 1999 which fits with this story nicely: (https://svs.gsfc.nasa.gov/829). Along the bottom is latitude so the sides are the poles and the middle is the equator. You are seeing what is called 'tropical upwelling' around the equator where air in the troposphere is propelled directly into the stratosphere. The image was produced from data by a spectrometer looking down at Earth, and the colors indicate calculated density of a single molecule — the CFC. So in this graph we are actually 'seeing' the ozone chomping monsters rising up to do their dirty work.

But in 1974 Rowland/Molina had just begun to include the stratosphere in their pursuit. If CFCs were driven into the upper reaches not only would they begin to receive high energy rays strong enough to break them apart, they or their products might interact with other things. I'm sure ozone was on the list.

Fourier's discrete layer idea did not pan out but people typically refer to an 'ozone layer'. It is actually the cross section where energetic reactions take place because there is unfiltered sunlight hitting dioxygen O2 and already-ozone O3. There's lots of other atoms and molecules there (nitrogen, argon, CO2 etc.), enough for physics teachers to whack students with a ruler if they say 'layer'.

Sunlight is energetic enough to split stable oxygen (O2 >zap> O1 + O1) into two 'free oxygen radicals' that each fly off and combine with stable oxygen to become ozone (O1 + O2 > O3). It also splits ozone (O3 >zap> O2 + O1) but the O1 soon finds another O2 to combine with. The exchange of free radicals between O2 and O3 in the stratosphere is sordidly and scandalously constant. During the day ozone is always being created and destroyed.

Yet remember that every time a photon of sunlight hits an ozone O3 molecule and splits it, that tiny bit of energy is absorbed and that photon never reaches the surface of Earth. And the collision/split only occurs if the energy is 'high enough' which is also to say is below a certain wavelength (<240nm for ozone). The statistical result of zillions of photons hitting zillions of O3s over time is that a wide spectrum of energy (<240nm) is 'absorbed'. So you can say "the ozone layer blocks sunlight wavelengths of 240nm and lower" or flip from wavelength to frequency terminology and say "the ozone layer blocks sunlight for part of the UV-B band and above."

Rowland/Molina would have focused on CFC effect on ozone production right away (I assume) because that is really the only thing happening up there that doesn't happen anywhere else. They are assuming a molecule of say CFC-12 has arrived there. What happens to it?

1. CCl2F2 + sunlight-zap! > CClF2 + Cl
2. Cl + O3 > ClO + O2
3. ClO + O > Cl + O2

or
1. CFC-12 is hit by a photon and a 'chlorine radical' Cl is separated because the carbon-chlorine bonds are weaker and carbon-fluorine bonds are stronger
2. When the chlorine radical Cl encounters an ozone O3, it steals the 'weaker' 3rd oxygen to become ClO. The ozone O3 becomes stable oxygen O2. It has been 'destroyed'.
3. When the ClO encounters a free oxygen radical O the oxygen-oxygen bond is stronger that the chlorine-oxygen bond, so its oxygen is stolen and a stable oxygen O2 is formed. The chlorine Cl is left by itself and becomes 'radical' again.

Are you screaming in terror yet? Let me help. Steps 2-3 begin and end with a free chlorine drifting around, so as long as there are ozones to react with the SAME free chlorine will 'destroy' as many of them as it touches. A free chlorine in the ozone layer can be called a 'destructive catalyst' in this sense because it is not consumed or changed by the interactions.

So CFCs are not strictly the problem, free floating atoms of chlorine are. And free chlorine is not strictly the problem either. Free bromine atoms were found to have the same ozone destroying properties.

F. Sherwood Rowland and Mario J. Molina described their results and this mechanism of ozone destruction in a paper that was published in Nature, 1974. They embarked on a long campaign of outreach and influence to convince world leaders to act quickly. They didn't of course, but it made great headlines and brought ozone to everyone's attention. NASA started monitoring ozone by satellite in 1979, and when the 'ozone hole' was spotted over Antarctica things really heated up. The Montreal Protocol treaty in 1987 to enforce by 1989 was a high-energy/low-wavelength response by human standards.

Rowland and Molina received the Nobel for Chemistry in 1995, and The American Chemical Society honored them with a commemorative booklet in 2017 (https://www.acs.org/content/dam/acsorg/education/whatischemistry/landmarks/cfcsozone/cfcs-ozone.pdf) that is a good read. The formulas I reproduced as steps 1-3 appear superimposed over their photograph on the cover, a testament to the simplicity and brilliance of their discovery.

With Freon, Thomas Midgely, Jr. had destroyed most life on Earth, AGAIN. He did not really set out to sterilize Earth by destroying our protection from the sun with zombie atoms that attack the ozone layer, so I guess you could call it planetslaughter.

China has been caught pants down manufacturing CFCs, and in 2008 India was the largest clandestine manufacturer smuggling them around the world. And news from the bromine front is not good. There may be many chemicals in use whose propagation to the stratosphere is yet unproven, or perhaps known and the companies are flying under the RADAR from the efforts of lobbyists and hush-men.

Please do me a favor. If you are ever presented with several issues such as:

1. something in use which "contributes" to "average global temperature" in the far future
2. something in use which can release free chlorines or bromines in the ozone layer
3. anything about CO2 besides how great it is for plants and how we want to feed the world

Choose #2 as your focus. You're less likely to be scammed and might actually save the Earth.

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DDT, banned by people who love childhood malaria. They STILL love it, apparently.

If anything, dichlorodiphenyltrichloroethane will get me canceled and lynched by a mob because I refuse to go with the program and declare its prohibition a no-brainer 'win'. Its properties discovered in 1939, by WWII's end it had become the go-to insecticide for crops and houses. Even Dr. Seuss touted it (https://www.humortimes.com/wp-content/uploads/2021/01/FlitSeuss1.jpg) and for the mosquitoes that carry malaria its action was nothing short of a miracle. Even a tiny particle adhering to a wall kills a mosquito that lands on it. DDT deserves sole credit for the complete eradication of malaria in the United States — by 1951.

And yet in enlightened 2023 malaria remains the world's third most deadly disease to children. I consider it to be the first because the other two cited (pneumonia and diarrhea) are multi-cause symptoms not diseases. It seems the word 'disease' has suffered as well.

What is essential to realize is that DDT on crops was applied in copious, even obscene amounts. In the days before Monsanto GMO and genetically engineered glyphosate-tolerant crops — (from 1970, don't get me started on that) — mid-century farmers were rendered incredulous, flabbergasted by the sight of 'pristine' fruits and vegetables for the first time in their lives. Ones they could easily take to market. Modern people are pampered but some remember when grocery produce was often disheveled and bruised with pocks and stains (some with grubs still inside! Score!). Dumpsters were popular meeting-places as people who didn't care (or liked grubs) found a wide selection of cast offs. Not only were insects prevalent in produce, but crops also suffered from being harvested early to avoid their full wrath.

It is also essential to realize that DDT was cheap, cheap in itself and cheap as compared to sorting, discarding and early harvest. I'm not saying it's as wholesome as mother's milk, but for better or worse it was in mothers' milk. And history does not record the extent, if any, DDT could have preserved this state of affairs (great veggies, and allowing children to survive) if its use had been scaled back to the least effective amount. That requires pragmaticism and a balanced approach, that not only watches for signals when something is introduced or claiming its effect with studies that can be replicated and we venture (to replicate them), but also the courage to spot the expected decline in signal if something is discontinued suddenly. And especially if at all possible, a decline in use under monitored conditions to ensure that the signal is responding to actual substance use or exposure.

No doubt the second half of the 20th century started to become the most carcinogenic period in US history, but its rise (https://acsjournals.onlinelibrary.wiley.com/doi/10.1002/cncr.11380) does not gain a modern slope until the 1960s and DDT was a BIG factor of exposure by 1950. Can we spot the 'DDT signal or spike? I can't, if it was a serious factor sudden prohibition in 1972 should have bent a knee then and later. The latest hit piece on DDT (https://www.publichealth.columbia.edu/news/ddt-exposure-tied-breast-cancer-risk-all-women-through-age-54) cites a frankly pedestrian 'three-fold risk increase' coupled with a dubious '40 year induction period' with practically-anectotal estimate of 'point of contact and amount of exposure in childhood'. Women's lives are important... at least as important as the lives of children, but it smells to me like a statistical pudding served to keep the nail in the coffin.

I also wonder about the calculated half-life estimate of DDT in humans '3-6 years' that is based on 'animal studies', whether that was crafted in part to keep the nail in the coffin. I would wonder what dosage, how much endocrine disruption was happening from sucky lab life or other factors to impair flush out, and how many routinely treatable disorders (for humans) were permitted to progress to arrive at this conclusion. This level of skepticism is similar, and inverse, to questioning the fatal-for-half validity of LD50 testing that establishes toxicity at very high levels (yet) does not hint at safe levels.

If you think there is no safe level of something, get ready to defend every death that it prevented or could have prevented. Don't do it... just get ready.

Paul Muller won the Nobel in 1948 for his discovery of DDT. And in 1962 Rachel Carson deserved a Pulitzer for leveraging what was surmised at the time about egg shell thickness into a grotesque vision of a DDT-infused world without birds. Such a thing is actually happening (https://news.cornell.edu/stories/2022/05/global-bird-populations-steadily-decline) and the latest "salve of conscience" is to blame Climate Change more so than wanton destruction of habitats, such as the leveling of Indonesia to plant oil palms for biodiesel. Ironically to combat Climate Change. But in 1962 DDT (not wind turbines) was the bird killer. It really worked. The book terrified everyone.

The crux here is, what is an 'endrocrine disruptor' (https://en.wikipedia.org/wiki/Endocrine_disruptor)? For the estrogen cycle it very well could affect eggshell thickness and in post-menopausal women it may indeed affect breast cancer rates. To what extent? And we can be sure hormone disruption will continue because these disruptors are also found in cosmetics, food and beverage packaging, toys, carpet, flame retardants, "caffeine". I scare-quote that because all stimulants disrupt hormones and scare is what is happening here. And pesticides, even 2023 ones. Of course the closer we get to eliminating all these things the better we will feel. Have I mentioned the half billion children dead of malaria and also the adults who suffer its effects for life, yet?

In 1951 I could get a witness for that, but malaria has been considered to be "collateral damage" that only happens to other people since 1972. I am a curmudgeon so I can say harsh things. Until it resurfaced in Florida recently (https://www.nbcnews.com/health/health-news/new-malaria-case-florida-brings-national-total-8-first-us-cases-20-yea-rcna94899) not from the Oxitec experiment releasing genetically modified male aedes aegypti (the females with little white socks carry dengue and other things). That is a temporary local solution at best because the gene change breeds females that will be unable to breed. Gene splicing can be hard.

Since 1957 some anopheline mosquitoes have evolved a degree of resistance to DDT (breaking some of it down to DDE). Why this happened is known (https://genomebiology.biomedcentral.com/articles/10.1186/gb-2014-15-2-r27) L119F if you must know. And the world is full of monsters who would never consider finding ways to reverse that.

Work on an effective antimalarial vaccine is continuing, a trial is ongoing in 2023. Its claimed efficacy is 75%, hopefully this is more based in reality than the COVID shot that was advertised at '91%' when it turned out to be negative (making one more likely to contract the disease than with natural immunity). There are mosquito strains under development that impair the plasmodium itself (https://www.genengnews.com/news/genetically-modified-mosquitoes-stunt-malaria-parasite-growth-prevent-transmission/). That kind of splicing, which introduces a new working mechanism, is hard.

But I'll wager that the mosquitoes they are studying for the gene approach are modern ones resistant to DDT. It would be child's play for child-lovers (genetically) to toss in a correction to the base pairs to

reverse the mutation conferring DDT resistance, the one that is obvious from 1950 specimens. Those genes are still "ready to go" and once that strain propagated it would work well if DDT (or a better alternative) was some day used again. How long would that work? Maybe longer than last time.

Whether or not you think I am directly advocating for DDT, presenting two sides of an issue is a valuable mental exercise. We are becoming a world of snake oil salesman and devoted but unthinking followers that move to crush what they perceive as 'dissent'.

Now let's move on to other endocrine disruptors and cancer causers I positively agree were withdrawn smartly. Because like some people love childhood malaria, I love wildfires.

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Polychlorinated biphenyls (PCBs), carbon tetrachloride (carbon 'tet') and the fire monster.

Have you ever noticed that flammable and inflammable mean the same thing? Isn't it hilarious?

A funny thing happens when carbons team up with chlorines that is not funny. It can be a carbon surrounded by chlorines (carbon tet, sorta 'chloroform') or chlorines surrounded by benzene rings of carbons (PCBs). They go scorched earth on the liver, which is unfortunate because chemically similar (+H) 'chloroform' was a widely used intoxicant/anesthetic in the 19th century... Both substances will turbocancer you and the level of endocrine and immune disruption from carbon tet is severe, the body has not had time to evolve a mechanism to endure or flush it out. Proven beyond DDT. But today I will not elaborate on creative ways to kill people.

Rather, they are un-inflammable and non-inconductive. Carbon tet is a supersolvent that became the dry cleaning fluid of choice for decades as many Superfund sites will attest. In the Virgin Islands we kept a covered pan of carbon tet on the roof, supplied by the local dry cleaner (which later became a Superfund site). If your circuit board had recent saltwater or spilled liquid exposure, the carbon tet would dive right in even under the chips and after a brief drying period, would be shiny and good as new. After hurricanes we restored many computers and hard drives and electronics that had been exposed to salt water or salt air. But we didn't breathe the stuff, hence the roof.

PCBs solved wildfires because practical transformers cannot be practically sized unless they are insanely huge and convection cooled, and even that doesn't work on hot days because the temperature has to be kept below the point at which enamel coating of the winding begins to fail and short circuits. So you need a liquid that is thermally conductive, not electrically conductive and carries away heat quickly. The champion for this had been mineral oil whose ignition point is high (but not really high). Also failure of an adjacent transformer or the crossing of wires downstream, or automatic disconnects that don't... may cause bursting regardless of liquid but oil spreads conflagration. It's just nature.

Along comes a freak of nature in 1929, a fluid with the right heat properties for transformers that could catch fire (anything with carbons can) but usually didn't and if it did, no conflagration from the ejected liquid. PCB transformers became the standard item for electrification of North America and places in the world that didn't favor oil for cost. It was known that a hot transformer burst open and exposed to air caught fire from its more volatile materials including PCBs, and released noxious vapors. Anything with chlorine will. The true chemical danger arose from the liquid's long term stability and resistance to

biodegrade. It stuck around long enough to get to the water table and work its way up the food chain (always seek and judge amounts. Just like DDT, relevant but also used as a scare tactic).

PCBs also had another property, the ability to be detectable in amounts too minuscule to pose harm to biology. This is true of many chemicals and most notably radioactive isotopes. That is a good thing for the species and demonstrates it is clever and can track risk, but I believe it is important to mention that detectability in modern times has been used as an indicator of harm and a bludgeon, a modern form of zero tolerance.

Zero-tolerance attitudes also promote infinite-tolerance attitudes as two sides of the same coin in my opinion. How often have you heard someone expressing zero-tolerance for something and you get the feeling that they would recommend an infinite cost solution to the problem, and expect there would be money left over?

PCBs were banned in 1978 and the world geared up to embrace mineral oil wildfires again. This has not gone strictly according to plan. They are difficult to research on the Internet because PCBs are printed circuit boards and some contain biphenyls. From a legal document (https://law.justia.com/cases/california/court-of-appeal/3d/197/1134.html) I learn that in 1988 "1.2 billion pounds of PCB’s were manufactured in the US since the late 1920’s" . Two broken apostrophes in the same sentence written by a lawyer. How aggravating is that?

Also what I already knew, "EPA in the Federal Register [said] that the use of PCB transformers for the rest of their useful lives did not present an unreasonable risk to public health or the environment." So much for the infinite cost solution. But the EPA does demand registration of those transformers since somedate and spills reported anydate, and remediation of contaminated material with extremely high temperatures that set loose the chlorines. Also interestingly, "Interestingly, the EPA estimated that in 1981 there were 39,600 utility PCB transformers and 91,600 in all other industries, while there were some 25 million mineral oil transformers in use nationwide. Thus, PCB transformers would account for approximately one-half of one percent of the transformers in use in 1981."

Someone's numbers are off unless millions of transformer types are misreported or were replaced 1978-1981, or there was some bum rush to replace 99.5% [or whatever] of them. That would have made quite a noise and I didn't hear anything.

And this recent 2019 project (https://www.epa.gov/sites/default/files/2019-09/documents/pcb_transformer_database.pdf) is a bizarre spreadsheet that accounts for [1713] sites totaling [9081] PCB transformers with additional sections of places with no number of transformers given. I searched for "Not Provided" (their tell phrase) to find 1537 more sites with presumably-but-who-knows at least [1] transformer each. So at least 10618 transformers are accounted for here. But most odd, their "Number Registered" and "Number Remaining" BOTH add up to 9018. So either there have never been any replacements or the whole thing is a steaming pile of bullslack.

So your guess is as good as mine, or the government's. Somewhere else (forgot where) dropped the titillating fact that "some ~40% of PCB transformers nationwide are still in service." That does not sound shocking to me at all, considering their ubiquity and reliability. I've seen working rusted transformers that must be from the 1940s on poles.

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It seems appropriate to end with this,

"What a piece of work is a man! How noble in reason, how infinite in faculty, In form and moving how express and admirable, In action how like an Angel, In apprehension how like a god, The beauty of the world, The paragon of animals. And yet to me, what is this quintessence of dust? Man delights not me; no, nor Woman neither; though by your smiling you seem to say so."

~William Shakespeare, Hamlet