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NARRATIVE REVIEW

An Introduction to Chemical Pollution and Its impact on Human Life

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ABSTRACT

Currently there are roughly 300 million chemicals identified in the World for which there are little to no data to determine the environmental and/or human health impact(s). Furthermore, when data is available, regulatory agencies tend to disagree with toxicologist making it unclear as to what concentration(s) can be considered safe to use. These discrepancies appear to be related to differences in the toxicological method used to calculate the potential health impact(s). Most agencies use a "threshold" theory which is based on a specific external exposure level below which no adverse reactions are thought to occur. This is deceptive because the concentration of a chemical outside an organism is very different from the concentration that is inside the organism. For this reason, "toxicokinetics" modeling - understanding the absorption, distribution, metabolism and excretion of a chemical - for a specific organism is a more accurate model to predict toxicity. After reviewing numerous regulatory assessments on a variety of toxic chemicals there appears to be four critical factors that are commonly omitted from the regulatory risk assessment process: (1) most do not review all the available toxicological data before selecting a reference dose which is then used to determine an "safe" level of exposure; (2) few consider a chemical's lifecycle and/or half-life; (3) potential bioaccumulation and/or biomagnification is ignored; and (4) chemical synergies with similar and/or different chemicals is frequently not taken into consideration. This paper compares the toxicity of several known problem chemicals (forever chemicals, pesticides, ultraviolet filters/sunscreens, fragrance ingredients and heavy metals) and outlines the differences between how regulatory agencies and toxicologist determine acceptable levels of exposure.

Introduction

THE TERM CHEMICAL POLLUTION HAS BEEN USED OVER THE CENTURIES BY MANY TO EXPLAIN

The concept of contamination of the environment by human activity. The current understanding of pollution began to take shape post War War II, with increasing awareness of how various chemicals contaminate the environment harming ecosystems and human health. As environmental science developed, the term became more widely used to describe the introduction of harmful chemicals into ecological systems. Fast forwarding to today, there are roughly 300,000,000 chemicals identified in databases like the American Chemical Society who assigns "unique identification numbers to every chemical substance described in the open scientific literature." This group also has a smaller database of" common and frequently" used chemicals which consist of only 500,000 chemicals[1]. Although the numbers are somewhat overwhelming to wrap one's head around, the larger concerning point is that "little to no toxicological" information is available on the majority of chemicals with respect to the negative impact(s) of these substances to human and/or environmental health.

How did we get to this point? Global industries and governments began to see the financial value of marketing chemicals to consumers with phrases like the "miracle of science" and" better living through chemistry"[2]. These phrases happen to be part of DuPont's marketing history which brought us numerous toxic chemicals including the class known as Per- and polyfluoroalkyl substances or PFAS for short. The first PFAS chemical, polytetrafluoroethylene (PTFE) commonly known as Teflon, was developed in 1938's and used in the "Manhattan Project". When its financial value became clearer, chemical companies started making as many variations of these substances as possible. With that said, the Organization for Economic Co-operation and Development (OECD) expanded their database to include over 7,000,000 PFAS chemicals[3]. This is how we got from a few hundred chemicals to roughly 300,000,000 chemicals in less than 100 years!

IMPACTS OF CHEMICAL POLLUTION

Air: We have all seen photos of dense atmospheric pollution, where the air quality is so bad people cannot go outside due to respiratory concerns. Images of places like Beijing before the 2008 Olympics or Los Angles before the State of California instituted a number of clean air policies via the Clear Air Resources Board (CARB).

In a 2022 update published in Lancet relating to air quality and health, "pollution remains responsible for approximately 9,000,000 deaths per year globally, corresponding to one in six deaths worldwide[4]." The authors go on to state … "it is increasingly clear that pollution is a planetary threat, and that its drivers, its dispersion, and its effects on health transcend local boundaries and demand a global response."

Likewise, we have all heard climate deniers clearly state that there is no such thing as global climate change. The release of various chemicals into the atmosphere - like carbon dioxide, methane, nitrous oxide, and chlorinated/fluorinated gases – all contribute to a variety of human health impacts. The World Health Organization (WHO) perhaps said it best … "Climate change is impacting health in a myriad of ways, including by leading to death and illness from increasingly frequent extreme weather events, such as heatwaves, storms and floods, the disruption of food systems, increases in zoonoses and food-, water- and vector-bome diseases, and mental health issues.[5]"

"Climate Change and Air Pollution" are byproducts of Chemical Pollution"

Land and Water: Atmospheric deposition plays a significant role in the chemical pollution of land and water. This is a major way chemicals get from one location to another. For example, chemicals like Mercury are emitted into the air from mining operations and burning fossil fuels. Globally mercury emissions, which are estimated to be 2220 metric tons per year, have no boundaries; once released into the air mercury can travel thousands of miles before it deposits back to the earth[6,7].

Other than atmospheric deposition, chemical pollution of the land and water appears to be associated mostly with agricultural runoff of fertilizers/pesticides (which includes biosolids/ sewage sludge); improper waste disposal by consumers and industries; accidental release of industrial waste and/or "permitted" industrial waste by local regulatory agencies. With respect to the latter, permitting industrial waste to be released into bodies of water and/or landfills is problematic because most regulatory agencies do not consider at least four critical risk factors: (1) most do not review the available toxicological data before determining "acceptable" levels of exposure; (2) consider a chemical(s) lifecycle/half-life; (3) bioaccumulation or biomagnification issues; (4) chemical synergies. For example: let's look at how one Department of Health in the United States calculated an "acceptable" level of exposure for a Forever Chemical in fish tissue called Perfluorooctane Sulfonate (PFOS)[8].

In order to calculate the "acceptable concentration of PFOS in edible portions of fish" the Health Department devised a formula that includes a toxicity reference dose (RfD), body weight, time period, average fish meal and allowable meals per month. There are numerous calculations used to determine this information. However, these are the things that were not taken into account that significantly impact the assessment(s).

Department of Health Conclusion: "When the average PFOS concentrations in fish range from 10 parts per billion (ppb) to 20 ppb, the Department of Health recommends limiting consumption of contaminated species to two (8 ounce) meals per month per adult."

(1) First, "10 ppb to 20 ppb" is 10,000 to 20,000 times above the "known carcinogenic" dose" of 1 part per trillion (ppt) that produces pancreatic and liver cancers in animals[9]. Additionally, the RfD selected which represents "the daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime" was 1.8×10^{-6} mg/kg-day or 1.8 parts per trillion (ppt)/day. The RfD selected relates to the 2 ppt dose that is known to cause an "increase in total cholesterol in humans"[9]. This cholesterol statistic is an important one, especially since roughly 200,000,000 people use Statins globally to control this risk[10]. Note, with respect to significant human impact – the 1 ppt dose that causes pancreatic and liver cancers should have been use as the RfD instead of "total cholesterol" because cancer is significantly more disruptive to human life than elevated levels of cholesterol.

Globally, elevated cholesterol levels are thought to be responsible for 3,600,000 deaths per year[11], however, this pales in comparison to approximately 10,000,000 cancer deaths AND 20,000,000 new cancer cases annually.[12]

(2) Another point that appears not to be taken into consideration is the "toxicokinetics" or simply the absorption, distribution, metabolism, and excretion of PFOS in the body after exposure. Very simply, once PFOS enters the body via eating contaminated fish tissue (absorption) it is distributed throughout the body where it binds to protein in the blood for roughly 5 years – meaning that you only remove (metabolize and excrete) about 20% of the PFOS in your body a year.

(3) Taking all of the information that the Department of Health took into consideration to calculate an "acceptable level of PFOS in fish tissue" and used it to determine "actual" blood levels in humans one would see that an 80 Kg adult eating 2 - 8 ounce servings of fish per month containing 20,000 ppt of PFOS - the level of PFOS in a person's blood after 5 years (one half-life) would be roughly 3,663 ppt and after 10 years (2 half-lives) would be 4,863 ppt. Taking into account that cancer has a 10 to 20 year latency period, the levels of PFOS in the body would be roughly 5,000 times higher than the "known" dose that caused pancreatic and liver cancers. This is what bioaccumulation and biomagnification looks like in a real world setting and why the US National Health and Nutrition Examination Survey (NHANES) reports on average 5,000 ppt of PFOS in peoples blood[13].

(4) Regardless of using toxicokinetics - very few regulatory groups take into account the interaction of chemicals (synergy) that can cause greater toxicity then the sum of their individual effects[14-17]. Why is this information important – Table 1 below depicts data collected in fish tissue in fresh water streams, rivers, lakes and ponds. Out of approximately 36,862 fish caught/evaluated from several hundred different bodies of water over 16 years, 28,372 or 77% had all 3 toxic chemicals present in the edible tissue portion of the fish evaluated … mean values equaled 186 ppb of PCBs, 14 ppb of Chlordane, and 21 ppb of DDT per fish. This is very problematic , especially since all 3 of these chemicals have been banned in the US since the 1970's/1980's and Globally in the 2001 Stockholm Convention on Persistent Organic Pollutants. According to the Agency for Toxic

Substances and Disease Registry (ATSDR) – neurobehavioral effects are seen at 0.03 ppb PCBs[18], 0.6 ppb for Chlordane[19] and 0.5 ppb for DDT[20]. So what is the toxicological impact from eating 2 – 8 ounce servings per month of these fish for 10 years – no one has any idea! "Coincidentally", more than 3,000,000,000 people worldwide are living with a neurological condition … what role does eating contaminated fish daily, weekly, twice-a-month play … no one knows, but every food agency in the world claims that the food supplies are safe! Are they?

Additionally, loopholes that permit the use of "banned" chemicals simply needs to stop. This process has clearly been abused by many industries and has gone unchecked by regulatory groups worldwide. On a positive note, many of these adverse reactions are reversible. The WHO states "For example, around 1.5 million lives could have been saved, largely from cardiovascular disease, in 2021 by implementing simple measures to reduce exposure to lead. Moreover, tackling other hazardous substances, like highly hazardous pesticides and mercury, offers additional significant public health benefits"[21].

Similarly, Cunha et al[22] looked at "62 seafood samples commercialized in Europe Union (EU) from several representative species – mackerel, tuna, salmon, seabream, cod, monkfish, crab, shrimp, octopus, perch and plaice – were analysed for residues of 21 personal care products (PCPs), including 11 UV-filters (UV-Fs) and 10 musk fragrances (musks)." They concluded that exposure to UV-filters and musks estimated from the concentration values found in seafood were "far below toxicological reference values". This is somewhat misleading because toxicokinetics where not done to demonstrate what transfers to humans, where it goes in the body and for how long it stays there. Additionally, no account is made to understand what other chemicals were present in the same fish and no attempt is made to understand any potential synergies of these chemicals. The thing that no one wants to say, is that these chemicals are present in all fish regardless if they are sold in cans, caught fresh or raised via aquaculture. This is one of the clearest points that needs to be understood by the consumer about "chemical pollution" … it is everywhere and in everything and the regulatory agencies do not know had to handle the problem that they caused.

As a side note, therapeutic values and doses of many drugs (antibiotics, anticoagulants, antipsychotics … etc.) are determined based on the amount of protein binding that occurs. If substances like PFOS are "already" bound to human blood proteins, it causes a shift in the distribution, metabolism, excretion and benefit(s) of these drugs as well as increases the adverse reaction potential.

Table 1: Fish Containing More Than One Toxicant in US Waterways

Year	Total Fish Collected/Tested	Total PCBs (ppb)	Total Chlordane (ppb)	Total DDT (ppb)	Total Fish Tested with All 3 Toxins
1993	1127	95	5	18	1127
1994	21	396	30	56	21
1995	542	43	4	14	542
1996	698	325	17	15	698
1997	1603	97	18	20	1603
1998	3574	120	8	16	3574
1999	1673	479	11	25	1673
2000	2607	126	11	16	2607
2001	2808	135	12	18	2808
2002	2147	219	12	17	2147
2003	3671	161	9	22	3671
2004	2994	229	20	0.4	989
2005	2584	227	13	20	2574
2006	3711	166	3	5	136
2007	3127	63	5	39	3127
2008	3975	92	45	33	1075
Totals	36,862	Mean - 186 ppb	Mean = 14 ppb	Mean = 21 ppb	28372

Notes:
(1) Historical Data Obtained from Department of Environmental Quality (DEQ) Fish Tissue Monitoring Site - Historical fish tissue data (1993-2023) https://www.deq.virginia.gov/water/water-quality/monitoring/fish-tissue-monitoring
(2) PCB data continued to be collect through 2023; however, fish tissue samples for Chlordane and DDT were stopped after 2008?

Conclusions

We have too many chemicals in our world and have no regard to their potential environment and/or human health impact. For example, the organophosphate pesticide chlorpyrifos took nearly 14 years for the US Environmental Protection Agency to "ban". In 2017 the US government overturned the ban and the chemical is currently being used today despite clear evidence of its toxic effects in children[23]. Similarly, the EU requires representatives from all 27 member states to unanimous agree, one chemical at a time, before banning a substance. Banning one chemical at a time at a rate of 14 years per chemical with 300,000,000 chemicals to evaluate … do the math!

The second part of the conclusion is that regulatory agencies mainly use a "threshold" theory to calculate "acceptable" levels of exposure. This is based on "selecting" a specific exposure dose "thought" to be below the "threshold" of toxicity. Unfortunately, based on the current condition of the "World's" environment and the current human health record it should be clear that "threshold" theory is not working … one must look deeper into the biochemical mechanisms of action and use toxicokinetic modeling to give a "clear" picture of what the real toxicity potential of a chemical(s) is by understanding what is transferred to our bodies from the environment.

"Chemical Pollution cannot be handled one chemical at a time"

Conflict of Interest Statement:

The author has no conflicts of interest to declare.

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