A STUDY OF CHEMICALS EMERGING IN ENVIRONMENTAL EXPOSURES

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ABSTRACT

Contamination by chemicals from the environment is a major global food safety issue, posing a serious threat to human health. Tese chemicals belong to many groups, including metals/metalloids, polycyclic aromatic hydrocarbons (PAHs), persistent organic pollutants (POPs), Perfluorinated compounds (PFCs), pharmaceutical and personal care products (PPCPs), radioactive elements, electronic waste, plastics, and nanoparticles. Some of these occur naturally in the environment, whilst others are produced from anthropogenic sources. Tey may contaminate our food—crops, livestock, and seafood—and drinking water and exert adverse effects on our health. It is important to perform assessments of the associated potential risks. Monitoring contamination levels, enactment of control measures including remediation, and consideration of sociopolitical implications are vital to provide safer food globally. Nevertheless, only few of these compounds are toxicologically evaluated due to their vast numbers. Reliable analytical methods and toxicity assessment methods are the basis of either the management or the elimination of EPs.

KEYWORDS: chemicals emerging, environmental exposures, Contamination, food safety issue, human health, drinking water.

INTRODUCTION

Chemical contamination is a global food safety issue. Tere are many potentially toxic substances in the environment which may contaminate foods consumed by people. Tey include inorganic and organic substances and may originate from a wide range of sources (Figure 1 shows the pathway of contaminants through the environment). Tis review is restricted to chemical contamination of foods and does not address biological or physical hazards. In certain instances, the source of contaminants may be the environment. Tis is the case for metals such as lead and mercury, dioxins, and polychlorinated biphenyls (PCBs). Agricultural use of pesticides may lead to food contamination. Similarly, drugs used in both people and animals may contaminate waterways and pose a health risk to consumers. Additionally, food packaging methods may be a source of contamination, so-called “migrants” leaching from packing materials. Tese contaminants may cause acute or chronic toxic efects. Toxicity may relate to the route of exposure and dose, and personal characteristics such as age and health condition may afect the individual’s susceptibility. Due to the nature of contamination, some food products may be more contaminated than others. Tis may be due to several factors such as varying exposure to pesticides, differences in plant uptake mechanisms from the environment, or contaminants from food packaging [1, 2]. Dietary makeup will afect an individual’s exposure to these contaminants. For example, nursing neonates have a high intake of contaminants that are excreted in breast milk [3]. Exposure at diferent life stages may result in diferent toxic efects as well. For example, prenatal exposure to persistent organic pollutants has been linked to an increase in childhood obesity and increased blood pressure [4]. For many food items—including vegetables, fsh, and other seafood—human health risk assessment data is available afer analysis of available foods [5–7]. Urban farms and gardens may pose additional risks due to contaminants such as metals [8, 9]. Furthermore, drinking water may become contaminated [10, 11]. Xenoestrogenic compounds have even been detected in rainwater [12]. Water contamination may also result in pollution of marine biota, afecting suitability for consumption of seafood [13]. Consequently individuals with high consumption of seafood will intake higher levels of such contaminants. Occupational exposure will not be discussed in detail in this review, but workers may have increased risk of exposure to certain contaminants, for example, car repair workers with lead on their hands which they ingest afer hand-to-mouth contact [14].

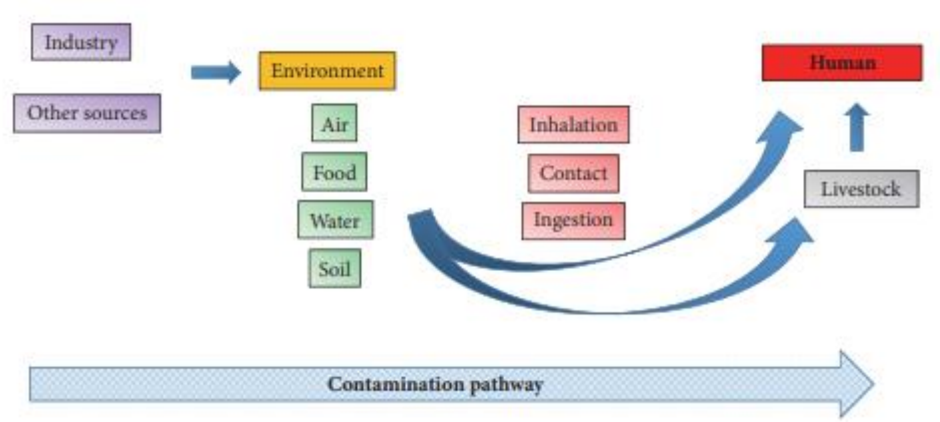

Figure 1: Sources of environmental contaminants in human foods

For most contaminants, there is no completely safe dose level. However, for many, acceptable levels have been calculated—levels below which signs of toxicity should not be evident. Toxic efects seen depend on the contaminant in question, the dose received, and the individual. For example, many contaminants have been linked to an increased risk of cancer. Skin cancer has been associated with longterm exposure to drinking water contaminated by arsenic, gastric cancer with lead contamination, and liver cancer with consumption of grain contaminated by mercury [15–17]. Our understanding of the health risks from combined exposures to more than one contaminant and the means by which we can assess such interactions is lacking [18]. Monitoring programmes are in place both nationally and globally to monitor such contamination in order to assess food safety. However, it is important to note that such monitoring cannot completely preclude supply of contaminated food to consumers. Te role of such programmes is to check that food and water contamination levels are below those deemed "unsafe." To this end, many governmental and nongovernmental organizations strive through risk assessments to ascertain what levels of contamination are acceptable for products destined for human consumption. In addition, national and international policies are in place to reduce contamination. For example, under the Stockholm Convention on Persistent Organic Pollutants, production and use of such substances are eliminated or restricted. Tis international treaty came into force in 2004 and currently has 152 signatories from 182 parties [19]. Te Codex Aliment Arius describes international food standards, setting permitted maximum levels (ML) for contaminants in foods based on risk assessment and scientific evidence. Te Codex Committee on Contaminants in Food (CCCF) is a global forum, but it can be difficult to compromise national legislations and harmonize global standards. Lists of contaminants also undergo risk assessment by the Joint FAO/WHO Expert Committee on Food Additives. Recommendations are made for standards such as provisional maximum tolerable daily intake (PMTDI) or provisional tolerable weekly intake (PTWI). Tese are usually calculated based on chronic toxicity data, and thus it may also be useful to consider acute reference doses (ARfDs). Te Codex Committee on Pesticide Residues (CCPR) has established maximum residue limits (MRLs) for over 5,000 pesticide residues. Tis committee also considers reports from the FAO/WHO Meeting on Pesticide Residues (JMPR), which estimates MRLs and acceptable daily intakes (ADIs) for people.

CONTAMINANTS FROM THE ENVIRONMENT TO FOOD AND WATER

It is useful to consider the sources of contaminants in order to understand their pathway into food and water sources for consumption. Factors such as soil properties, activities by people, and point sources affect the accumulation of metals in the environment. For example, mining may result in release of substances such as arsenic and mercury. Once in the environment, these substances may contaminate food and water and result in human health hazards, with toxic effects varying depending on the contaminant(s) ingested.

Metals and Metalloids.

Metals and metalloids in the environment have various sources. One source of mercury and lead is artisanal gold mining. For example, in the gold mining area of Tongguan, Shaanxi, China, concentrations of these metals in locally produced grains and vegetables exceeded governmental tolerance limits and posed a potential health risk to people from consumption. Lead and cadmium from an iron mine in Morocco resulted in concentrations of cadmium in livestock organs higher than acceptable limits. Likewise, in Spain, sheep near a mine were found to have lead contamination, with levels in 87.5% liver samples above European Union Maximum Residue Levels (MRL). Many fruits and vegetables have been shown to be contaminated by metals. For example, cadmium in soil was detected in navel oranges in China and lead and cadmium in soybeans in Argentina. Also in China, various metals were detected in edible seeds, with levels of copper sufciently high to show an increased health risk to people consuming them [68]. On the contrary, contamination levels of mercury in rice samples from a city in eastern China were below levels likely to afect human health. In the global arena, methylmercury has been detected in fsh and other seafood around the world. Fish tissues from Turkey were shown to be contaminated with copper, iron, zinc, and manganese. Various metals have also been detected in fsh from Sicily, with some concentrations exceeding European regulation limits. In Asia, food species of turtles have been shown to contain mercury. With regard to water, endemic arsenism from contaminated drinking water has been reported in China [11]. Monitoring has detected nickel in drinking water in New South Wales, Australia, but levels do not appear to pose any health risk for the local population. Further evidence of potential health risks to people from metals are surveys of human samples. Mercury and monomethylmercury were detected in human hair samples from French Guiana, associated with a diet rich in fish, with 57% of people tested having mercury levels higher than the WHO safety limit. In Spain, mercury, lead, and cadmium have also been detected in human milk samples, with increased levels of lead associated with higher consumption of potatoes.

Polycyclic Aromatic Hydrocarbons.

Polycyclic aromatic hydrocarbons (PAHs) primarily occur afar organic matter undergoes incomplete combustion or pyrolysis, or from industrial processes. Food contamination comes from the environment, industry, or home cooking (such as when using biomass fuels). Tese compounds appear to be genotoxic and carcinogenic. Oil spills from transporter ships in the ocean are all too common and will result in contamination of seafood. Besides the petroleum-related polycyclic aromatic hydrocarbon (PAH) compounds, chemical dispersants are ofen used to mitigate efects of oil in the ocean. Afer the BP Deepwater Horizon oil spill in Louisiana, USA, in 2010, the Federal government responded to seafood safety concerns by instigating protocols for sampling and analysis of food to determine its safety. Lessons learned afer this scenario included recognition of the need to improve risk assessments to adequately protect vulnerable populations, including pregnant women.

Industrial Chemicals.

Persistent organic pollutants (POPs) are synthetic organic chemicals; some are used in industry, some as pesticides, and some are by-products from industry or combustion. Tey include pesticides like aldrin, chlordane and DDT, industrial chemicals like PCBs and HCBs, and unintended by-products like dibenzodioxins and dibenzofurans. Tey persist in the environment, are distributed globally in air and ocean currents, and accumulate in animals in the food chain (including in humans). Teir side efects depend on the chemical and the contaminated species; for example, they may have effects on reproductive or immune systems, or increase cancer risks. Chlorpyrifos is an organophosphate pesticide that affects vision and causes other neurological toxic effects in humans. It has been detected in dietary samples, and foods have been shown to be responsible for approximately

13% of daily exposure to this chemical. Organochlorine pesticides such as DDT have been used in agriculture and vectortransmitted disease control for decades, though their use now is restricted due to known persistence in the environment and toxic effects such as neurological dysfunction and endocrine disruption. Pyrethroids such as permethrin and deltamethrin are widely used for control of vector insects and aircraf disinfection, as they are relatively safe for people. However, their use near foods can result in contamination and studies are ongoing to reduce potential toxic effects. Although neonicotinoids are widespread in the environment and contaminate consumable items, their toxic effects are still not yet well understood. Polychlorinated biphenyls (PCBs) have a variety of uses in industry, including in transformers, as heat exchange fluids or paint additives, or in plastics. Ingestion of PCB residuecontaminated food—especially meat, fish, and poultry—is the main source for people, with ready absorption from the gastrointestinal tract. Contaminated breast milk is a potential source for nursing infants. Chloracne is reported after extensive exposure to PCBs, but immune and carcinogenic effects may also result.

Electronic Waste.

Modern society has become encumbered with many electrical devices, and electronic waste (or e-waste) has become a major problem. Inappropriate processing, for example, incomplete combustion, of such products releases a variety of pollutants covered above, including PBDEs, dioxins/furans (PCDD/Fs), PAHs, PCBs, and metals/metalloids. In addition, contamination from such devices can enter drinking water and food.

Plastics.

In recent times, we rely more and more on packaging materials—in particular plastics—to transport and help preserve food. Tese materials are not inert and may themselves contaminate food and drinks as multiple chemicals are released into foods and beverages from food contact materials. Tese are termed “migrants” and include such chemicals as phthalate plasticizers which have been detected in bottled water. Factors such as higher storage temperatures and prolonged contact time with the packaging were linked to higher levels of contamination, but a health risk assessment showed that the risk for consumers was low.

Nanoparticles.

Another recent development is that of nanoparticles. Tese have one dimension less than 1×10^{-7} m, and engineered nanoparticles have been used in a wide range of products, such as paints, cosmetics, and pesticides. Pathways and effects of these in biota are as yet unclear, but they have been shown to travel in the food chain. Nanosized materials have been detected in foods such as wheat-based products.

RISK ASSESSMENT AND MONITORING

The possible contaminants in food can be linked to a variety of toxic effects. Any adverse effects seen depend on multiple factors, including whether exposure is acute or chronic, the dose received, the route of exposure, and details of the individual person such as age and health. As an example, lead toxicity affects almost all organs, but the most severely affected is the nervous system. In adults, long-term exposure results in reduced cognitive performance. More severe signs such as learning difficulties and behavioural problems are seen in infants and young children as they are more sensitive during this phase of neurodevelopment. High levels of contamination with lead may also cause kidney damage; chronic exposure may cause anemia and hypertension, and reduced fertility in males. In pregnant women, high blood lead levels are associated with premature birth or babies with a low birth weight, and this risk is increased in emaciated women. On an individual level, blood sampling is a quick and easy method of assessing circulating levels of lead and can be used to indicate recent or current exposure. However, this does not account for lead stored elsewhere in the body, particularly in bones. X-ray fluorescence can measure whole-body lead in bones, and x-rays may show lead-containing foreign materials. Treatment of clinical cases is by using chelating agents, which will reduce blood lead levels, yet neurological effects may remain.

On the other hand, at a community level, it may be more important to identify contaminated sites and assess health risks to the general population and thereafter aim to reduce or remove exposure to contaminants such as lead. Tus, monitoring plays a vital role in food safety. Such monitoring has identified contamination of many foods. In order to monitor efectively, samples should be analysed from a variety of sources: human samples to detect levels afer exposure, diverse foods from the total diet and drinking water sources, and also the environment itself (to identify the source of food contamination). Samples from people frequently include blood, urine, feces, breast milk, hair, and/or semen. Human bio monitoring is notably useful to facilitate risk assessment. A combination of environmental monitoring and bio monitoring may identify risk factors, such as detection of higher levels of cadmium in umbilical cord blood from mothers consuming more than two portions of fsh each week. In the case of metals, environmental sampling has shown hotspots of contamination around mining (such as gold, lead, and zinc), electronic waste sites, and industrial areas. Contamination in soils at these sites has been linked to bioaccumulation in agricultural crops and associated increase in human health risk.

Once sources of contaminants have been identifed, it is vital to minimize contamination of food. For this purpose, regulations are in place at both national and international levels to restrict contaminated food entering the human food chain. In some cases, legislation exists to assess levels of food contamination. For example, the Marine Strategy Framework Directive in Spain monitors for contaminants in edible tissues of seafood destined for human consumption, assessing levels against established EU standards for food safety. Te German Federal Environment Agency monitors both the environment—using the German Environmental Survey (GerES)—and human biomonitoring—using the German Environmental Specimen Bank (ESB). Amongst others, these have, respectively, been used to detect lead in drinking water and exposure to phthalates and bisphenol A. National monitoring systems may cooperate at an international level. To maintain and improve food safety globally, the Codex Alimentarius contains a set of international food standards, guidelines, and codes of practice [20]. Tese are based on science from risk assessment bodies or organized by consultations with FAO and WHO. Tese are voluntary but ofen form the basis of national legislation.

CONCLUSION

Attitudes in society towards food safety and contamination are often rooted in tradition and habit. Although consumers select their diet based on social and financial factors, the remit for food safety remains firmly with regulatory bodies. Tese bodies can monitor for contaminants and enforce legislation. Aspects of food contamination also have political implications. As mentioned above, food safety laws are necessary, with monitoring of food and water contamination, as well as enacting measures to reduce and eliminate exposure to environmental pollutants. Publicity after environmental pollution-related incidents behooves a government to have public health, legal, and ethical frameworks in place in a timely manner. Education of society regarding safer crop cultivation and livestock rearing, selection of a balanced diet, and safer cooking methods should also be encouraged. On a nationwide scale, governments also should endeavour to reduce urban disparities in environmental exposures. Although some contaminants have focal effects, many are transported globally. For this reason, an international stance on food safety is necessary by reducing environmental and food contamination and ensuring trade of safer food products on a global scale.

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