Major Environmental Contaminants: Sources and Impact on health

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Abstract

Nowadays, people have been exposed to several types of contaminants which have broad spectrum. These different kind of contaminates are result of fast evolving technology. The problem of human health and environmental risks has become a key problem for all the world. The present chapter deals with major environmental contaminants, their sources and their impact on health and environment. These contaminants cause major effect on the human health and also toxic for environment due to their chronic toxicity and persistance. So, it's important to study about these contaminates and needed the efficient and ecological methods for their remedial from the environment. This chapter also provides a critical look at the major challenges posed by these emerging pollutants

Keywords: Contaminants, Environment, Pesticides, Pollution, Heavy metals, etc.

I INTRODUCTION

Environmental pollution is one of the most serious problem and global challenges of our earth today. Pollution of any kind is dangerous for human as well as for another living beings also. Pollution is curse for environment whatever It's kind of and we have to control the pollution in every possible way to save, prevent and protect our environment. Environmental pollution can be referred to undesirable and unwanted change in physical, chemical and biological characteristics of air, water and soil which is harmful for living organism. We are facing pollution of various types like water pollution, air pollution, noise pollution, plastics pollution, digital pollution. Being human, we made all the things which can comfort our life but we had not predicted the side effects [1-2].

Generally, contaminants are any chemical, physical and biological substances which have adverse impact on the environment. So, contaminants, can be defined as any substances, which are present above their permissible limit fixed by regulatory authorities and negatively affect the environment by creating it toxic to the human, animals and plants. The abundance of pollutants is mainly due to the industrialization and overuse of agrochemicals, plastics and chemical fertilizers. The common sources of contaminants are fossil fuels, industries, oil spills, chemicals used in our daily use product etc. The contaminants can be natural or man-made/synthetic. Accidental release of these contaminants in the environment causes many problems for the human health and as well as mass death of population. The biggest challenge is that the environmental contaminants also polluted our food through soil, water and air mode [3].

The major harmful pollutants of concern are heavy metals like Arsenic, Lead, Mercury, Cadmium, Perchlorates, radioactive materials, Benzene, Dioxins, persistent organic pollutants, pesticides, polyhalogenated byphenyls, hazardous solvents, airborne pollutants and per and Polyfluoroalkyl Substances (PFAS). The worldwide regulatory agency FDA regularly monitor the contamination levels in food commodities, do the risk assessment and also provide guidance to for the preventive measures to minimize the hazard to food and risk to health [4]. Environmental pollutants are now a great challenge for all the academicians and researchers all over the world [5]. Different categories of pollutants that impact on soil, air, water, animals, plants, microorganisms and humans are given in Figure-1.

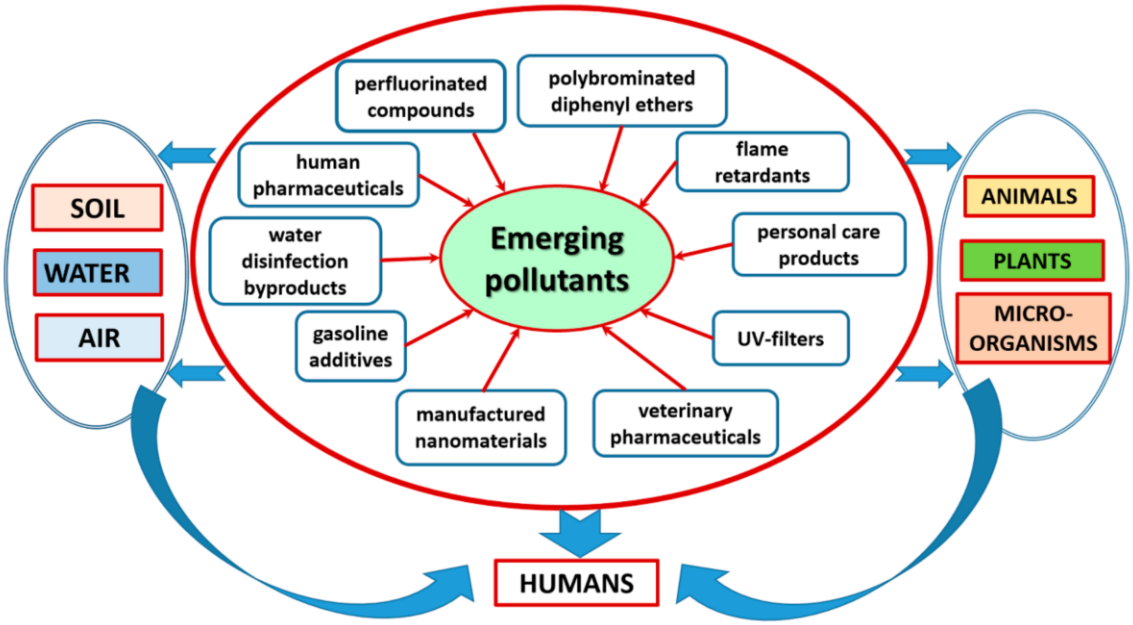

Fig. 1 Different categories of pollutants that impact on soil, air, water, animals, plants, microorganisms and humans [6]

II SOURCES OF CONTAMINANTS

Urbanisation led to the several industries that constrained the climate change crisis in spite of knowing the dangers caused by industrial effluents. Some important industries which are creating most pollutants are caustic soda, cement, brewery, dyes, fertilizers, iron and steel, oil refineries, paper and pulp, food, pesticides, pharmaceuticals, textiles, thermal power plants, leather etc. These all industries also producing harmful byproduct along with their main product. The chemical contaminants mainly are soil contaminants, environmental contaminants, disinfection by-products, personal care products and packaging materials. There are lots of chemical contaminants in our day-to-day care products such as disinfectants, plastics, detergents, deodorants and cosmetic. If we take the example of only energy industry which produce approximately 30% of greenhouse gasses [7], it clearly shows the picture. To make products like plastics and medicines, we also need oil and coal. The fashion industry also effect people directly and directly across the world. The carbon emissions produce by the wasted and dumped clothes wastes is very high.

In series of this, Agriculture and forestry industries contaminate environment by the use of Pesticides, nitrates, phosphates, greenhouse gases, and mineral salts. Mining and mineral processing industries generate heavy metals, cyanide and acids, hydrocarbon products resulting from spills and coal mining, and metallic salts. Hazardous chemicals such as sulphur dioxide, carbon dioxide, nitric oxide, acids, acid rain, ozone, polycyclic aromatic hydrocarbons, and volatile organic compounds are generated by Fossil fuel combustion. Approximately, every industry produces various organic and inorganic compounds, dioxins, heavy metals, hydrocarbons, chlorinated phenols, sulphides, surfactants, solvents, acids, bases, salts, pharmaceuticals, plastics, resins and explosives. However, for the development of our country, we required these industries, but in spite of all these, we should also limit the impending danger.

We should implement the green chemistry and green solution to overcome these problems. The green solutions are very much needed because with the increase in production and use of chemical compounds, man has become more exposed to the adverse effects and chemical toxicity, so remedies are needed to lower overall costs associated with environmental health and safety. Pollutants are categorized on the basis of their mode of action, toxicity, their chemical composition and their origin (natural/synthetic). Some of them is discussed in this chapter.

III Heavy metals

A. Brief Introduction

Heavy metals from natural and anthropogenic sources are released into aquatic ecosystems such as atmospheric precipitation, wastewater, and industrial discharge. In general, there are different sources through which metals and their ions come into the environment like geological weathering, industrial processing of ores, metallic compounds, animal and human excretions which contain heavy metals and also from leaching of metals from garbage and solid waste dumps [8]. Toxic heavy metals like cadmium, mercury, lead, copper, arsenic etc. enter

through the industries waste and contaminate the food. Zheng and his colleagues reported that an industrial area in China is heavily contaminated by heavy metals like zinc, copper, lead and cadmium and also contaminated the food [9]. Fishes being one of the main aquatic organisms in the food chain, may often accumulate large amounts of certain metals [10]. A nation-wide survey to monitor concentration of arsenic, copper, cadmium, chromium, lead, mercury and zinc in fish, shell fish and fishery products was conducted and the metals were detected in all the samples irrespective of the habitat [11]. Heavy metals from industrial areas enter into the food chain to infect the raw sources of food [12]. Heavy metals can be found in the form of hydroxides, oxides, sulphides, sulphates, phosphates, silicates and organic compounds. The most common heavy metals are arsenic (As), lead (Pb), nickel (Ni), chromium (Cr), cadmium (Cd), mercury (Hg), zinc (Zn) and copper (Cu).

B. Impact on health

Among the toxic heavy metals, Arsenic rank the first. Arsenic is a metalloid that is detected in many areas throughout the world. According to the 2011 and 2013 ATSDR rankings, inorganic Arsenic was ranked as the highest priority toxic substance to human health [13]]. Many studies reported that arsenic levels exceeding the WHO standards all over the world and affecting the health of people [14]. Short-term exposure of inorganic arsenic can result in nausea, lung irritation, vomiting, diarrhoea, fatigue and bruising whereas acute exposure can even result in death [15].

Lead (Pb) is a heavy metal that exists in organic and inorganic form. Lead exposure in environment causes a significant threat to human health [16]. Presence of very small concentration of lead can cause several unwanted effects, such as disruption of the biosynthesis of haemoglobin, rise in blood pressure, kidney damage, miscarriages, disruption of nervous systems, brain damage, declined fertility of men through sperm damage, behavioural disruption of children, such as aggression, impulsive behaviour and hyperactivity [17]. Lead can enter a foetus through the placenta of the mother, because of this, it can cause serious damage to the nervous system and the brains of unborn children [18].

Cadmium is a non-essential, highly toxic and ecotoxic metal. Chronic effect on human health may occur as a result of its accumulation in liver, bone, blood, kidney and muscles. About 50% of the cadmium that reaches the sea and river comes from human activities (Industrial waste, fertilizer containing phosphate of animal origin [19]. Cadmium can cause several health hazards like diarrhoea, stomach pains and severe vomiting, bone fracture, reproductive failure, damage to the central nervous system, damage to the immune system psychological disorders, possibly DNA damage or cancer development.

Mercury is a naturally occurring metal that exists in both organic, and inorganic forms. Mercury is the only metal which is a liquid at room temperature. Mercury is at the same time among the best known and most puzzling metal in the environment. The mercury species differ greatly in properties, but all are toxic [20]. The organic forms of mercury are generally more toxic to aquatic organisms than the inorganic forms. Mercury is present in common household items, medicinal and chemical products, Acute effects of metallic mercury exposure leads to difficulty breathing, lung and eye irritation, coughing, nausea, vomiting, diarrhoea and increased blood pressure [21].

IV Pesticides

A. Brief Introduction

Pesticides are an indispensable tool for the sustainable production of high-quality food, fodder and fibers. The use of pesticide helps to reduce the crop loses, provide benefits to farmer, reduce soils erosion and ensure the food safety and security for the nation. Excessive, non judicious and non-recommended use of pesticides heads to the possible adverse effect on human health, Pesticides are used approximately 3 billion kg every year around the world which poses a serious threat, as the chemicals contaminate the raw sources of food [22]. Pesticides helped in increased food production, but on the other side, the problems such as presence of pesticide residues in food and feed, environmental pollution, pest resistance, pest resurgence, outbreak of secondary pests, killing of non-targets including natural enemies, pollinators etc were also noticed. In spite of these, the presence of pesticide residues is a cause of serious concern for the wild life, ground water and over all environmental quality. This food safety issues are major concern for all consumers, and hence all National and International Governments are focusing on the monitoring of pesticide residues in various food commodities and environmental samples like soil and water.

The persistence of pesticides and their residues in food commodity at harvest or foods depends of several factors such as nature and amount of pesticide used, number of applications, type of crop, method of application, weather condition, interval between application and harvest etc. The pesticides residues in food are rigorously regulated in many countries to address the domestic food safety and trade issues / disputes under SPS Agreement of WTO. At International level, the Codex Committee on Pesticide Residues (CCPR) is responsible for

establishing maximum limits for pesticide residues in specific food items or in groups of food. Pesticides like insecticides, fungicides, herbicides and rodenticides are also classified on the basis of their chemical compositions such as Organochlorine, Pyrethroids, Organophosphorus, Carbamates, Phenoxy herbicides, Neonicotinoids etc [23].

B Health Effects on Non-target organism

The entry of Pesticide residues in food commodities has become a major cause of concern all-over the world. Its impact on non-target organism like human can be very dangerous. For humans, a pesticide exposure means acquiring pesticides in or on the body. The toxic effect of a pesticide exposure depends on the quantity of the pesticide involved and how long it remains there. Our body gets exposed to pesticides in four main ways:

- ***Oral exposures*** are often caused by either not washing hands before eating, drinking, smoking or chewing, accidentally applying pesticides to food, or splashing pesticide into the mouth by accident.
- ***Inhalation exposures*** are often caused by prolonged contact with the pesticides in closed ventilated spaces, breathing vapors from fumigants and other toxic pesticides without appropriate protective equipment, inhaling vapors present immediately after a pesticide is applied.
- ***Eye exposures*** are caused by spraying pesticides in windy weather without eye protection, rubbing eyes or forehead with contaminated gloves or hands, and pouring dust, granule, or powder formulations without eye protection.
- ***Dermal exposures*** are often caused by not washing hands after handling pesticides wearing pesticide contaminated clothing, applying pesticides in a windy weather, wearing inadequate personal protective equipment while handling pesticides, and touching pesticide-treated surfaces.

C The Safer alternative of Persistence and Synthetic Pesticides

The naturally formed Bio-pesticides are substances that biologically control harmful pests, especially among field crops. Bio-pesticides are living organisms (bacteria, virus, and algae), their products (bio-chemicals produced by them) and also plant byproducts. Advantages of bio pesticides are eco-friendly, affect only target pest groups, biodegradable and minimal quantity is enough. Some effective bio-pesticides are Bacillus thuringiensis, Bacillus sphaericus, Trichoderma viride, Trichoderma harzianum etc. The Bio-pesticides have the potential to control crop losses and reduce negative environmental externalities. Bio-pesticides constitute around 3 per cent of pesticide market in the country. In India, 14 bio-pesticides have been registered under the Insecticide Act 1968 in India.

There are some issues which need immediate attention to strengthen domestic pesticide industry and safe application of pesticides. Firstly, it is important to regulate and encourage the use of cost-effective and environmentally safe pesticides. The uniformity in testing procedures (parameters, labs, actors, etc.) and deregistration of outdated, hazardous pesticides are necessary for avoiding the adverse impacts. Secondly the consideration should be on promotion of safe application practices and awareness among farmers. The third issue relates to assessment of potential effects of strengthened patent regime on pesticide industry, particularly its likely effect on product prices. Now it become a major challenge in-front of agricultural scientist, farmers, pesticide industries and other stake holders to ensure the food availability from declining agricultural land so it is very crucial to know and assess the risk involved with use of chemical pesticide to ensure proper pest management, food safety, risk management, consumer safety, compliance with sanitary and Phyto-sanitary requirements on food hygiene and plant health has gained importance and such vital issues need attention of scientific community and whole world.

V Mycotoxin

Mycotoxins are fungal secondary metabolites generated by various species of fungi that contaminate food and causes severe public health hazards due to their carcinogenic and mutagenic properties [24]. They are naturally occurring and unavoidable so they can easily enter in food chain by direct (plant-based food components contaminated with mycotoxins) or indirect (growth of toxic mycotoxin on food and feed) contamination [25]. They are also chemically and thermally stable during all stages of food processing, including cooking, boiling, baking, frying, roasting etc. They also contaminate our food via meat, eggs, milk [26]. A lot of study revealed that mycotoxins are accumulate mainly in cereals and oil seeds not only in the field but also during storage and transportation. Generally, the crops which are not stored properly and kept under humidity for longed time can be subject to mycotoxin contamination [27]. Consumption of mycotoxin-contaminated food or feed can cause toxicity in human and animals. In addition to concerns over adverse effects from direct consumption of mycotoxin-contaminated foods and feeds, there is also public health concern over the potential ingestion of animal-derived food products, such as meat, milk, or eggs, containing residues or metabolites of mycotoxins. Mycotoxin contamination of food is an ongoing global concern.

Many national and international public health and governmental authorities such as the US Food and Drug Administration (FDA), World Health Organization (WHO), Food Agriculture Organization (FAO), and the European Food Safety Authority (EFSA), are paying serious attention to mycotoxin contamination in food and feed and addressed this global problem by adopting strict regulatory guidelines for major mycotoxin classes in food and feed [28]. Numerous research studies have been done in India and it shows that AFB1 is the most extensively encountered mycotoxin in food, followed by AFB2, with the occurrence of AFG1 and AFG2 being almost negligible. Aflatoxin poisoning is one of the main causes of cancer, kidney disorders, neonatal jaundice and many diseases.

VI Polycyclic Aromatic Hydrocarbons

Organic compounds which consist of two or more than two aromatic fused rings are considered to be polycyclic aromatic hydrocarbon like naphthalene, anthracene etc. They are lipophilic in nature [29]. Polycyclic Aromatic Hydrocarbons are found in coal tar, mineral oils and in various products used in construction. Mainly PAHs enter the environment through anthropogenic sources [30]. The people working in the coal melting, combustion, and coal product combustion industries are exposed to high levels of PAHs through inhalation or dermal contact [31]. Exposure to high level of PAHs or mixtures of PAHs can gives skin, and eye irritation, difficulty with breathing, nausea, vomiting, diarrhoea, and, in extreme cases, death. Sustained exposure to PAHs includes immunosuppression, teratogenicity, cytotoxicity, and genotoxicity [29]. Polycyclic Aromatic Hydrocarbons are an area of concern for researchers working in the field of environmental pollution due to its widespread exposure and detrimental health effects.

VII Polyfluoroalkyl Substances (PFAS)

Perfluorinated chemicals are a broad class of hydrocarbon compounds in which all the hydrogens have been replaced with fluorine molecules [32]. Perfluorinated chemicals includes perflurooctane sulfonate (PFOS), perfluorooctanoic acid (PFOA), Gen X, and many others [33]. These compounds have fluorine atoms attached to alkyl group. Perfluorinated chemicals are used in cookware, textile industry, construction, electronic industry and many more product. PFAS has been reported to contaminate food and water because PFAS break down very slowly and persist in the environment. Due to its persistence and impact on health of people and animals, it comes under the category of toxic pollutant and needs an immediate concern of the researchers and scientists [34]. Structure of PFOA is given in Figure 2.

Per and polyfluorinated chemicals can harm health by hormone imbalance, increases in hepatic enzyme and increased cholesterol levels [36]. In more exposed populations to these chemicals, prostate, kidney, liver, and bladder cancer has also been observed in [37].

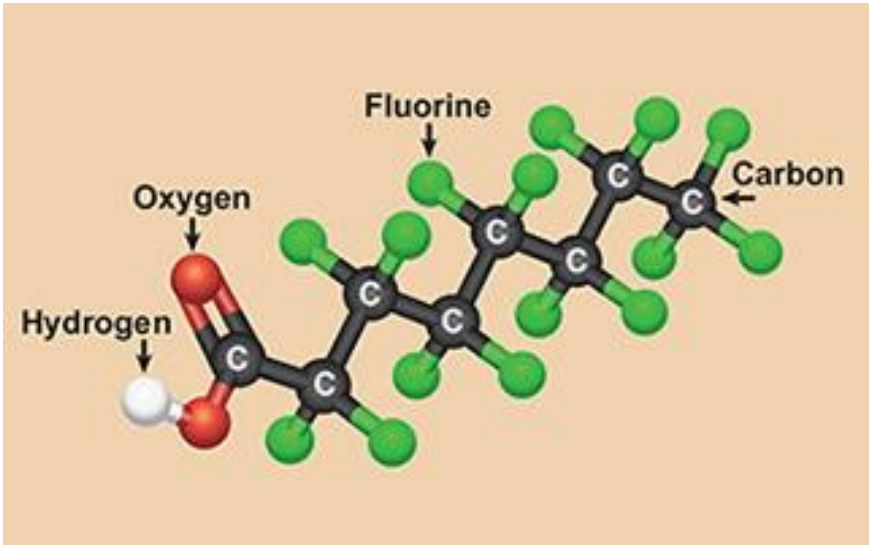

Fig. 2 Structure of PFOA [35].

VIII CONCLUSIONS

The present chapter has given a brief overview of the various types of contaminants and their impact on human health. The presence of contaminates in the environment is always being a matter of concern for human health. The impact of persistent and toxic contaminants is significant on environment and health and they all need considerable attention due to their impacts on environment and people health. More studies on the Persistence, dissipation, consumer risk assessment and also on their remedial and elimination is much needed. New methods and technologies need to be effective and environmentally friendly. Keeping in mind the long-term health hazards contaminates, it is advisable to regularize the monitoring programmes of the contaminants. A joint effort including the participation of government agencies, non-government agencies, industries stake holders and the people is needed to overcome this problem.

References

1. Bunke, D.; Moritz, S.; Brack,W.; Herráez, D.L.; Posthuma, L.; Nuss, M. Developments in society and implications for emerging pollutants in the aquatic environment. Environ. Sci. Eur. 2019, 31, 32.
2. Caliman, F.A.; Gavrilescu, M. Pharmaceuticals, personal care products and endocrine disrupting agents in the environment—A review. Clean (Weinh) 2009, 37, 277–303.
3. https://www.fda.gov/food/chemical-contaminants-pesticides/environmental-contaminants-food.
4. https://www.epa.gov/report-environment/exposure-environmental-contaminants
5. Herawati N, Suzuki S, Hayashi K, Rivai IF, Koyoma H. Cadmium, copper and zinc levels in rice and soil of Japan, Indonesia and China by soil type. Bulletin of Environmental Contamination and Toxicology. 2000; 64:33-39
6. https://www.mdpi.com/2073-4441/13/2/181]).
7. https://ecojungle.net/post/the-most-polluting-industries-in-2021
8. Singh, G. (2020). Comparative Study of Lead and Cadmium Levels in Freshwater Fishes. International Journal of Plant and Environment 6(4): 315-320.
9. Zheng, N., Wang, Q., Zhang, X., Zheng, D., Zhang, Z., and Zhang, S. (2007). Population health risk due to dietary intake of heavy metals in the industrial area of Huludao city, China. Sci. Total Environ. 387, 96–104. doi: 10.1016/j.scitotenv.2007.07.044.
10. Mansour, S. A. and Sidky, M. M., *Food Chem*., 2002, 78, 15–22
11. CIFT. (2006). National risk assessment programme for fish and fish products for domestic and international markets, Final Consolidated Report. December, 2006.
12. Krishna, A., and Govil, P. (2006). Soil Contamination due to heavy metals from an industrial area of Surat, Gujarat, Western India. Environment Monitoring Assessment. 124, 263–275. doi: 10.1007/s10661-006-9224-7
13. ATSDR. The ATSDR 2013 substance priority list. Atlanta: Center for Disease Control; 2013.
14. Uddin R, Huda NH. Arsenic poisoning in Bangladesh. Oman Med J 2011;26(3):207.
15. ATSDR. Toxicological profile for arsenic. Atlanta: Center for Disease Control; 2007. http://www.at sdr.cdc.gov/toxprofiles/tp.asp?id=22&tid=3.
16. Landrigan PJ, Schechter CB, Lipton JM, Fahs MC, Schwartz J. Environmental pollutants and disease in American children: estimates of morbidity, mortality, and costs for lead poisoning, asthma, cancer, and developmental disabilities. Environ Health Perspect 2002;110(7):721–8.
17. ATSDR. Toxicological profile for Lead. Atlanta: Center for Disease Control; 2007. http://www.atsdr. cdc.gov/toxprofiles/tp.asp?id=96&tid=22.
18. Lanphear BP, Dietrich K, Auinger P, Cox C. Cognitive deficits associated with blood lead concentrations <10 microg/dL in US children and adolescents. Public Health Rep 2000;115(6):521–9.
19. Sepe, A., Ciaralli,A., Ciprotti,M., Giordano, E. Funari and Costantrini,S.(2003) Determination of Cadmium,Chromium, lead, vanadium in six fish species from the Adritic sea. Food and Additive contaminates,20,6,543-552
20. Gochfeld, M. (2003). Case of mercury exposure, bioavailability and absorption. Ecotoxicology Environment Safety, 56:174-179.
21. WHO. Guidance for identifying populations at risk from mercury exposure. Geneva: United Nations Environmental Program, Division of Technology, Industry, and Economics: Chemicals; 2008.
22. Pimentel, D. (2005). 'Environmental and economic costs of the application of pesticides primarily in the United States'. Environ. Dev. Sustain. 7, 229–252. doi: 10.1007/s10668-005-7314-2.
23. El-Shahawi MS, Hamza A, Bashammakhb AS, Al-Saggaf WT. An overview on the accumulation, distribution, transformations, toxicity and analytical methods for the monitoring of persistent organic pollutants. Talanta. 2010;80:1587-1597.
24. Alshannaq, A.; Yu, J.H. Occurrence, toxicity, and analysis of major mycotoxins in food. Int. J. Environ. Res. Public Health 2017, 14, 632.
25. Ukwuru, M.U.; Ohaegbu, C.G.; Muritala, A. An overview of mycotoxin contamination of foods and feeds. J. Biochem. Microb.Toxicol. 2017, 1, 101.
26. Richard, J.L. Some major mycotoxins and their mycotoxicoses—An overview. Int. J. Food Microbiol. **2007**, 119,3–10.
27. Kumar, P.; Mahato, D.K.; Kamle, M.; Mohanta, T.K.; Kang, S.G. Aflatoxins: A Global Concern for Food Safety, Human Health and Their Management. Front. Microbiol. 2017, 7, 2170.
28. Bennett, J.W.; Klich, M. Mycotoxins. Clin. Microbiol. Rev. **2003**, 16, 497–516.
29. Kim KH, Jahan SA, Kabir E, Brown RJ. A review of airborne polycyclic aromatic hydrocarbons (PAHs) and their human health effects. Environ Int 2013; 60:71–80.
30. NTP. 12th Report on Carcinogens. Research Triangle Park (NC): U.S. Department of Health and Human Services; 2011.
31. IARC. Some non-heterocyclic polycyclic aromatic hydrocarbons and some related exposures. In: WHO, editor. IARC monographs on the evaluation of carcinogenic risks to humans. Lyon: World Health Organization Press; 2010.
32. Lindstrom AB, Strynar MJ, Libelo EL. Polyfluorinated compounds: past, present, and future. Environ Sci Technol 2011;45(19):7954–61.
33. Corsini, E., Luebke, R. W., Germolec, D. R., and DeWitt, J. C. (2014). Perfluorinated Compounds: Emerging POPs with Potential Immunotoxicity. Toxicol. Lett. 230, 263–270. doi: 10.1016/j.toxlet.2014.01.038
34. Kurtz, A. E., Reiner, J. L., West, K. L., and Jensen, B. A. (2019). Perfluorinated Alkyl Acids in Hawaiian Cetaceans and Potential Biomarkers of Effect: Peroxisome Proliferator-Activated Receptor Alpha and Cytochrome P450 4A. *Environ. Sci. Technol.* 53, 2830–2839. doi: 10.1021/acs.est.8b05619.

35. https://www.niehs.nih.gov/health/assets/images/pfoa.jpg.
36. Post GB, Cohn PD, Cooper KR. Perfluorooctanoic acid (PFOA), an emerging drinking water contaminant: a critical review of recent literature. Environ Res 2012; 116:93–117.
37. Lau C, Anitole K, Hodes C, Lai D, Pfahles-Hutchens A, Seed J. Perfluoroalkyl acids: a review of monitoring and toxicological findings. Toxicol Sci 2007;99(2):366–94.