Persistent Organic Pollutants, Changing Food Consumption Habits, Science and Regulatory Response

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1 Introduction

Trends towards 2050 predict a steady population increase to 9 billion people, forcing an increased food/feed output from available agro-ecosystems resulting in an even greater pressure on the environment. Scarcities of agricultural land, water, forest, fishery and biodiversity resources, as well as nutrients and non-renewable energy are foreseen (FAO, https://www.fao.org/edible-insects/en/).

This increase in population, combined with increasing wealth and desire for improvements in human health are driving changes to traditional sources of food. There is a recognized need to avoid deforestation and destruction of more rain forest to maintain species diversity and to support efforts to minimize climate change, and there are efforts to find alternative protein sources to traditional farm animals which take a disproportionate amount of land, water and other resources to produce. The 'green agenda' set by governments and driven by NGOs has recycling and the minimization of waste as some of its core values. For reasons of health, there are several trends including a drive to move towards a plant-based diet and to increase the amount of food from marine sources.

Often, such changes are driven by very worthy factors, such as the need for sustainability, to support wildlife habitats and to improve human health, but this is only part of the picture, and it is important to consider any negative impacts of dietary changes in order to give a holistic view of any major changes. Potential negative consequences include any increased exposure to persistent organic pollutants, and other contaminants as a result of such changes.

As examples of changing dietary habits, two examples are given below, and the risk assessment and risk management process in relation to these is explored. These are related to increased consumption of algae produced from the marine environment, and the production of insect protein from food and other waste materials.

2 Algae

Seaweed has long been regarded as a staple food in Asia and has seen a significant rise in popularity amongst European and Western consumers over the last decade. Shifts towards a plant based more sustainable diet and also the perception of seaweed as a health food are likely to see this increase further (Holdt, 2021). It has been estimated that by 2050, as much as 0.1% of our oceans will be used for seaweed production, producing fifteen times more food of this type than current production. There are currently no specific regulations covering the safety and quality of seaweed outside Asia.

The reputation as a 'superfood' is associated with seaweed containing high concentrations of vitamin B12, dietary fibre, omega-3 fatty acids, polyphenols, sulphated polysaccharides and pigments that are all associated with health benefits. It is also known that seaweeds can bio-accumulate minerals and trace elements from their surrounding waters. Whilst many of these are also beneficial, some such as lead, mercury, and arsenic are known to be toxic in at least some of the forms in which they are found. Iodine is beneficial at a certain level, and is in fact essential for thyroid hormone synthesis, but high levels can trigger thyroid gland disfunction. The European Food Safety Authority (EFSA) recommends an upper level for iodine intake of 600 µg per day for adults, meaning that the high concentrations of iodine found in some species of seaweed can result in dietary exposure exceeding this amount even when only small amounts of seaweed are consumed. Mercury, lead, cadmium and arsenic have no beneficial effect and can be harmful in small amounts. Lead has been classified as a possible carcinogen and neurotoxic properties, and arsenic is a class I carcinogen.

Different types of seaweed have different properties in terms of bioaccumulation. Environmental factors such as geographical location, pollution status of water, season etc can all also have an impact on the amount of elements found within seaweed. Hijiki seaweed can contain so much arsenic that regulatory authorities have recommended that it is not consumed (Rose et al, 2007).

In 2018, the European Commission advised member states to monitor elements in seaweed with a view that limits may be needed, depending upon the results of evaluation by EFSA.

Whilst metals are the most obvious contaminant in algae, it has also been used of algae to accumulate organic pollutants from polluted aquatic ecosystems and is gaining popularity in environmental studies, where it may be considered an environmentally friendly bioremediation technique for decontaminating polluted sites. But this property demonstrates the potential for exposure when such products are consumed (A. El-Maradny et al, 2021).

Seaweed can be used to model aquatic organisms to assess the impact of pollution on an ecosystem. Some species accumulate more pollutants than others, indicating that specific accumulation activity depends on their morphology, including branching, size, and nature of the blades (Zokm et al, 2022).

Figure 1: Algae for food

3 Insect protein

Edible insects contain high quality protein, vitamins and amino acids for humans. Insects have a high food conversion rate, e.g. crickets need six times less feed than cattle, four times less than sheep, and half the requirement for pigs and broiler chickens to produce the same amount of protein. Besides, they emit less greenhouse gases and ammonia than conventional livestock. Insects can be grown on organic waste. Therefore, insects are a potential source for conventional production (mini-livestock) of protein, either for direct human consumption, or indirectly in recomposed foods (with extracted protein from insects); and as a protein source into feedstock mixtures FAO, https://www.fao.org/edible-insects/en/). Other high value products such as vitamins, minerals and chitin as byproducts of the protein production process make insect production particularly attractive.

The EU funded project PROTEINSECT (https://www.proteinsect.eu/) focused on five key areas in order to evaluate insects as a novel source of protein for animal feed and to ensure that methodologies are sustainable and economically viable. These included 'Determination of safety and quality criteria for insect protein products' and 'To build a pro-insect platform in Europe to encourage adoption of sustainable production technologies to include examination of the regulatory framework.'

Points to consider in a risk assessment framework for using insects as a food source include:

- Environmental contaminants such as: heavy metals, dioxins, PCB and PAHs
- Viruses and other human pathogens.
- Chemical residues (e.g. pesticides, veterinary medicines).
- Allergens
- Taints

In January 2021, EFSA published its first completed assessment of a proposed insect-derived food product (EFSA, 2021). It was found that consumption under the proposed uses and use levels did not contribute significantly to the overall exposure for the analysed undesirable substances through the diet. However, this considered only the dried yellow mealworm (Tenebrio molitorlarva) and production was according to a specific process. Other insect species may accumulate contaminants in a different way, but of greater potential concerns is perhaps the way in which the insects are raised. One proposal has been that insects could be raised on abitoir waste, which is likely to have a much higher level of dioxins and other POPs and therefore may give rise to much higher levels of contamination in food produced.

Figure 2: Insects for food

4 Specific concerns for risk assessment and risk management

Risk assessment is defined by IPCS as ‘a process intended to calculate or estimate the risk to a given target organism, system or (sub)population, including the identification of attendant uncertainties, following exposure to a particular agent, taking into account the inherent characteristics of the agent of concern as well as the characteristics of the specific target system’. When considering chemicals in food and drinking water, the term safety assessment is sometimes used, where the term safety is the ‘practical certainty that adverse effects will not result from exposure to an agent under defined circumstances’. Risk is defined as the ‘probability of an adverse effect in an organism, system or (sub)-population caused under specified circumstances by exposure to an agent’.

The risk assessment process is independent and well-established. It forms part of the overall risk analysis that also covers risk management and risk communication. It is increasingly seen as important to separate the activities of risk assessment from those of risk management. This is to ensure the scientific independence and objectivity of risk assessment which should be evidence based. Risk management and communication also need to take into account political and socio-economic considerations.

Risk managers will nevertheless need to communicate and interact with risk assessors during the process, particularly during the initial problem definition phase (‘framing the question’) to ensure that the outputs of the risk assessment are useful for them. Best outcomes are therefore achieved when the relationship between risk assessment and risk management is a dynamic, interactive, often iterative, process (Rose, 2015).

4.1 Mixtures or ‘cocktail’ effect

As demonstrated by the examples above, dioxins and other POPs are usually found in combination with other contaminants and are often not even the contaminant of most concern. For algae, the biggest concern is most likely to be exposure to heavy metals unless there is a specific contamination issue or location associated with production. Whilst risk assessment of mixtures is reaching the agenda of many risk assessment agencies and considerable progress has been made towards establishing fate-based risk assessment strategies for complex mixtures (e.g. Suehring et al., 2022), current methodologies tend to be limited to closely related compounds with similar modes of toxic action e.g PFASs, PCDD/Fs, PBDEs and so on. Exposure is normally to a wide range of contaminants, organic, inorganic and also biological. We are still some distance away of being able to assess true combined exposure to multiple contaminant classes.

4.2 Toxicity other than dioxin-like effects and mobility

Associated in some ways to the mixture effects discussed above, the dioxin-like toxicity, may not be overall the biggest concern when considering the overall picture. In addition to Ah-mediated toxicity, other effects such as endocrine, neurotoxity, and others may be more significant.

Likewise, the mobility of a substance, including its ability to move through wastewater treatment plants and into aquifers is being discussed as a property of high concern for drinking water safety (Hale et al., 2020). In fact, it has been argued that persistent, mobile, and toxic contaminants (PMTs) cause an equivalent level of concern as PBT/vPvB substances and should be regulated under Article 57 in REACH (Hale et al., 2020). Within North America, a recent study drew similar conclusions based on the low predicted retention in wastewater treatment plants of PMTs registered for use in Canada (Fries et al., 2022).

5 Conclusions

The drivers towards changes in dietary consumption are strong and usually arise from ideas of good intention, and have to capability of helping to address some major global issues such as increasing population, maintain diversity, sustainability, reduction of waste, recycling etc. However, the impact of such changes could result in an increase in exposure to some classes of contaminant, including dioxins and PCBs. It is important to balance any increased risk resulting from such exposure, with health benefits associated with nutritional components of new foods, and wider societal benefits.

6 References

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