Safety and Regulatory concerns of seaweed contaminants in food

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The use of seaweed as a food ingredient has become increasingly popular. However, by its nature seaweed has a higher propensity to absorb contaminants including heavy metals and microplastics. This article reviews the latest science in discussing the potential benefits of seaweed, the substances that could pose a contamination risk and the relevant regulatory limits.

Increased popularity of seaweed as a food

The use of seaweed as a food has increased over the last decade, due in part to growing awareness and interest on sustainable and alternative food sources, changes in dietary patterns and increased emphasis on a healthier lifestyle.

Seaweed has a high nutritional value and is considered as an alternative source of protein and source of potential bioactive compounds [1]. Compared with traditional agriculture that requires the use of arable land or hydroponic cultivation, seaweed cultivation requires seawater that is available in the open ocean.

Seaweed has been found to be a source of many bioactive compounds and is low in fat, high in protein, and has a high concentration of dietary fibre, omega-3 and omega-6 fatty acids.

Harmful components detected in seaweed

Seaweed has a high absorption and accumulation capacity and thus has potential to be compromised by a high concentration of potential and harmful components including [2-4]:

- Chemical contaminants [cadmium (Cd), lead (Pb), mercury (Hg) inorganic arsenic (iAs) and aluminium (Al)]
- Micronutrients [iodine (I)]
- Persistent organic pollutants [organochlorine pesticides (OCPs), polychlorinated biphenyl (PCB), polybrominated diphenyl ether (PBDE) and polychlorinated-dibenzo-*p*-dioxin (PCDD)],
- Micro and nanoplastics [polyethylene-polypropylene, polyamide, cellophane, rayon, and polyethylene terephthalate].

We go into more detail on each of these components below.

Chemical contaminants in seaweed

Studies have observed several chemical contaminants and heavy metals to be present in seaweed.

- *Cadmium (Cd)* is a toxic element with high accumulating characteristics and its toxicity depends on the chronic exposure. Long-term exposure can lead to accumulation in the kidney, contributing to renal tubular dysfunction and damage [5]. The amount of cadmium in seaweed-related products was observed to be **0.038-1.044 µg/g DW** (dry weight) [6].
- *Lead (Pb)* is associated with toxic effects on humans including neurotoxicity and nephrotoxicity and has been classified as carcinogenic for humans [7]. The average range levels of lead in seaweed products was observed to be **0.078-0.956 µg/g DW** [6].
- *Mercury (Hg)* is a highly toxic element classified as one of the top ten chemicals or groups of chemicals of major public health concern [8]. The toxicity is related to the chemical form in which mercury is found in the food. Methylmercury (MeHg) has been shown to have a significant impact on the digestive tract and can

also affect the nervous system [9]. The level of mercury (Hg) in seaweed was observed to be **0.007-0.019 μg/g DW** [6].

- *Arsenic (As*) present in food can be catagorised as organic (OAs) and inorganic (iAs). Inorganic arsenic was observed to have a toxicological effect on human body. Chronic arsenic exposure is associated with cardiovascular problems, nervous system dysfunction, various cancers including lung, skin, kidney, liver, prostate, bladder and many more [10]. The average concentration of arsenic in seaweed was observed to be in the range of **3.39-30.26 μg/g DW** [6].

- *Aluminium (Al)* is known as a neurotoxic element that can be accumulated in the brain, bones, liver and kidneys. Prolonged exposure to high levels of aluminium have been observed to lead to neurodegenerative diseases such as Alzheimer's disease [11]. The mean concentration of different seaweed samples observed in studies across Europe and Asia was **15.5-57.7 μg/g DW** [9].

Micronutrients in seaweed

- *Iodine (I)* is a trace element in the human body required for the synthesis and function of thyroid hormones that are important for growth, development and metabolism, particularly vital during earlier stages of life [12]. Seaweed can contain excessive iodine concentration that can impair thyroid function due to a high level of exposure. The iodine concentration found in different seaweed product is **18.97-2302.5 μg/g DW** [9].

Regulatory framework of contaminates in seaweed

The toxicological profile of seaweed has been viewed as a concern by several international food authorities. The regulations on the acceptable levels of chemical contaminants for edible seaweed and seaweed products differ by country or region.

The maximum levels of contaminants in seaweed for human consumption is not regulated in the US and Canada [13]. However, in Europe, China, Australia and New Zealand, regulations are already in place determining the maximum level of contaminants in seaweed as a food [6, 14-17].

Schedule 19 of the Australia New Zealand Food Standards Code (**Food Standards Code**) sets out maximum levels for contaminants and toxicants for various food types, including seaweed. Food Standards Australia New Zealand (**FSANZ*)*** has also published advice on the risk of the excessive iodine concentration in brown seaweed, establishing a maximum tolerable iodine level in dry seaweed of ***1000 mg/kg DW of Iodine***. In regards to the other chemical contaminant only ***inorganic arsenic*** has set permitted concentration of maximum ***1 mg/kg*** calculated at 85% hydration and only regulated for Hijiki seaweed [18].

The contaminant regulations in seaweed are shown in table 1.

Table 1 Contaminant regulation in seaweed from different part of the world.

	Australia/New Zealand	**European commission**	**China**	**France**
Cadmium	N/A	3mg/kg	1 mg/kg	0.5 mg/kg
Mercury	N/A	0.1 mg/kg		0.1 mg/kg
Inorganic Arsenic	1 mg/kg	N/A	1 mg/kg	3 mg/kg
Lead	N/A	3.0 mg/kg	1 mg/kg	3 mg/kg
Iodine	1000 mg/kg (max tolerable level)	N/A	N/A	2000 mg/kg

Persistent organic pollutants in seaweed

- Seaweed can also absorb persistent organic pollutants that can have a negative effect on human health. Several studies have analysed the level of organic pollutants in seaweed. The concentration of OCPs in red, green and brown seaweed was observed to be in the order of endosulfan > endrin > HCH > DDT > aldrin >

heptachlor > methoxychlor, and was found to exceed relevant residue limits [19]. A study that observed the level of persistent organic pollutants in edible seaweed found that samples exceeded the screening levels or international limits for PCBs [3].

Microplastic pollutants in seaweed

Microplastic contamination in commercially-sold seaweed was observed in several published studies. A study on seaweed products sold at ethnic food stores in Mexico confirmed average abundance of microplastics in seaweed samples of approximately 24.0 particles/g. The roasted seaweed contained higher microplastics levels than dried and seasoned goods and the identified polymers included polyethylene-polypropylene, polyamide, cellophane, rayon, and polyethylene terephthalate [21].

Another study observed the presence of microplastics in dried seaweed (3.3 particles/g) and raw seaweed (2.6 particles/g) [22]. The amount of microplastics analysed in the seaweed samples was observed to be lower if the seaweed is washed before consumption.

The commercially packed nori seaweed had a microplastics range of 0.9-3.0 particles/g. The polymers identified in commercially packed nori samples were polypropylene, polyethylene and poly (ethylene-propylene) copolymers as detected by μ-FT-IR spectroscopy and microscopy [23]. An example of the plastic particles that were observed in the nori samples is shown in figure 1.

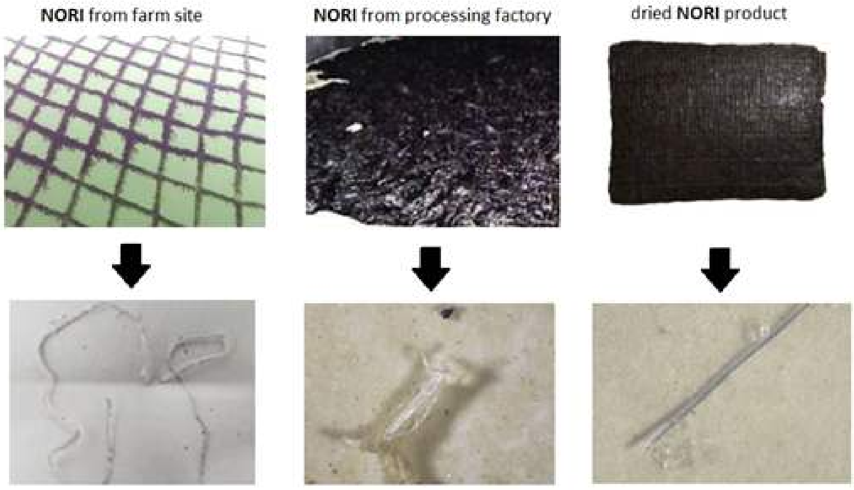

Figure 1. Microplastics observed in NORI seaweed samples in different stage of the production process. Adapted from Li et al., (2020)

The abundance and the composition of microplastics in seaweed products is dependent on the microplastic concentration and the ambient environment in which the seaweed is found. Furthermore, there are no set regulatory limits on the micro and nanoplastics present in seaweed products and careful attention should be paid on the presence of the plastic particles in the seaweed products and to assess the human health risks. As at the date of this article (March 2024), there were no set regulatory limits for nanoplastics in seaweed.

If you have any questions on the contents of this article, please feel free to contact us.

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