Heavy Metals: Why Supplier Responsibility is Critical in Astaxanthin Production

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Abstract

Heavy metals such as arsenic, cadmium, lead, and mercury pose a threat to human health. Consequently, both finished products and their ingredients should be routinely screened for these metals, and their associated compounds.

Human activities are a major driver of heavy metal pollution worldwide, having a negative impact on water resources. In many parts of the world heavy metal concentrations in water exceed maximum permitted levels. Heavily dependent on water, microalgae cultivation and astaxanthin production are vulnerable to heavy metal contamination. Therefore, these metals must be strictly and routinely monitored for during the production process.

It is important for suppliers and manufacturers to understand what heavy metals are, the breadth of their impact on human health and global water quality, and why heavy metal controls must be present in microalgae cultivation and astaxanthin production.

Heavy Metals and Their Effects on Human Health

Warnings about heavy metals in foods, beverages, and dietary supplements have been in the media for years. Informed consumers are apprehensive about these safety concerns, and want evidence that the foods they consume are safe.

The term “heavy metal” is ubiquitously associated with toxicity, although numerous dense metals, which is the formal classification of a heavy metal,[1] such as iron, cobalt, and zinc, are nutritionally essential. However, there is a general consensus that certain heavy metals pose a threat to human health, namely; arsenic, cadmium, lead, and mercury **(Figure 1)**.[2]

The intake of these metals should be minimized, and all dietary supplements should therefore be routinely screened for these metals, and their associated compounds. Arsenic is included, although formally a metalloid, due to its similar link to potential toxicity or eco-toxicity (**Table 1**). These elements are also listed by the World Health Organization (WHO) as part of the “Ten chemicals of major public concern.”[13]

Because heavy metals are so detrimental to human health, the best astaxanthin suppliers are committed to going above and beyond guidelines in an effort to eliminate the presence of dangerous heavy metals completely.

Figure 1. *The four heavy metals that pose the greatest risk to human health.*

Table 1. *Primary exposure pathways to four heavy metals, their target organs, as well as signs and symptoms of exposure.*

Heavy Metal	Primary Exposure	Target organs	Symptoms
Arsenic[4]	Water / Food	Gastrointestinal, kidneys, cardiovascular, central nervous system, respiratory system	Cancer, headaches, drowsiness, vomiting, hair loss, convulsions, death[5]
Cadmium[6]	Water / Air / Food	Kidneys, bones, respiratory tract, liver	Cancer, renal failure, osteoporosis, pulmonary edema, death[7]
Lead[8]	Water / Food / Air	Central nervous system, eyes, gastrointestinal, kidneys	Headaches, irritability, renal failure, coma, death. Diminished intellectual capacity in children[9]
Mercury[10]	Food	Lungs, kidneys, central nervous system	Peripheral neuropathy, skin discoloration, paresthesia, tachycardia, coma, death[11]

Impact of Heavy Metal Pollution on Global Water Purity

Organic and inorganic pollutants, such as heavy metals, are of growing concern for human health. Natural weathering of rock and soil contribute to heavy metal pollution, although human activity is the primary culprit of heavy metal contamination of the environment.[12] Industrial emissions, wastewater, and solid waste are a few of the ways humans add to the heavy metal contamination of air, soil, water and eventually food (**Figure 2**).[13]

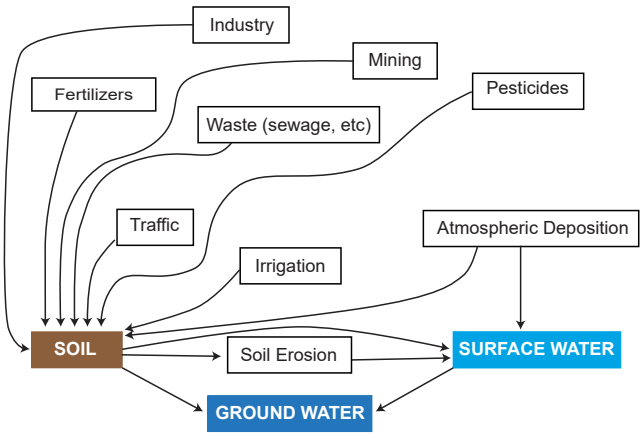

Figure 2*. Human activity that affects soil, and consequently surface and ground water. Figure reproduced based on review article by Ram Singh and Steinnes.*[14]

A recent review by Chowdhury and co-workers summarizes global heavy metal pollution of drinking water, and the associated health effects.[15] A schematic overview of scientific articles covering heavy metal contamination shows that human activity clearly impacts water purity, and illustrates how heavy metal levels globally can range dramatically (**Figure 3**).

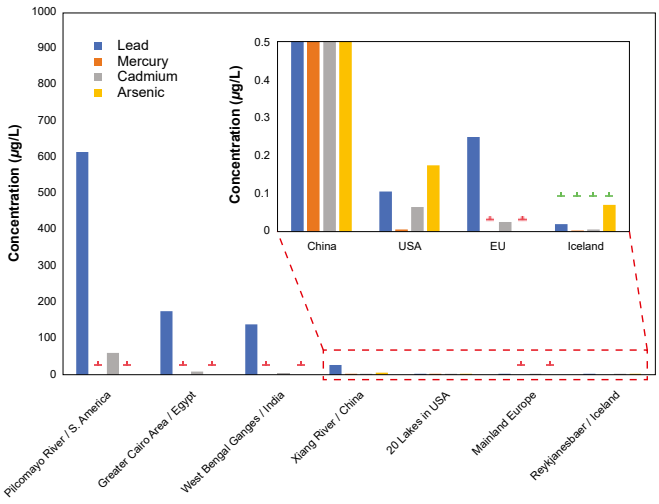

Figure 3. *Heavy metal pollution around the world. Data retrived from research and review articles for all but Icelandic data.*[16–21] *Values from literature used as presented. Red asterisk denotes missing data-sets. Icelandic data is based on a 12-month series of elemental analysis of tap water at Algalif's site in Reykjanesbaer, Iceland. The data correlates with the national measurements of water quality in Iceland.*[22] *Green asterisk denotes that the highest detected level is reported, or in case no heavy metal was detected, the limit of detection.*

Low heavy metal pollution in Iceland comes as no surprise. The country has one of the most pristine environments on Earth and is committed to preserving it. Iceland ranked second in the latest Yale Environmental Performance Index, a biennial, data-intensive ranking that evaluates how 180 countries protect ecosystems and human health.[23] The country has also some of the cleanest, contaminant-free air in the world, ranking fourth on air quality among all OECD-countries. Glaciers, rivers, and lakes cover 13% of Iceland's area, resulting in abundant freshwater supplies.[24] Naturally filtered through layers of volcanic rock, Icelandic water is extremely clean, low in minerals and unchlorinated.[25]

Heavy Metal Controls in Microalgae Cultivation and Astaxanthin Production

As the primary input for microalgae cultivation, the importance of water purity and heavy metal controls cannot be overstated. Due to the high biosorption capabilities of microalgae any trace amount of heavy metals present in water will accumulate and magnify in microalgae cultures. [19,26] Therefore, continual elemental analysis of water should be carried out to ensure that minimal (if any) heavy metal contamination is present, as is standard procedure by Algalif in Iceland.[22]

Additional controls can be implemented to reduce heavy metal contamination risk in microalgae cultivation. In addition to using exclusively high-end nutrients (food grade, or preferably pharmaceutical grade), the exclusion of external pollution risks can be achieved by cultivating microalgae in completely enclosed photobioreactor systems (PBRs) (**Figure 4**). An additional benefit of indoor enclosed PBRs, is perfect control of all cultivation parameters, such as lighting and temperature, which dramatically increases the efficiency, and subsequently the sustainability of microalgae cultivation.

***Figure 4**. A fully enclosed photobioreactor cultivation system under perfect climate and contamination control at Algalif´s site in Reykjanesbaer, Iceland.*

Without an abundance of pure water, the cultivation of pure microalgae and production of astaxanthin is not an easy task. However, simply having pure water, the highest grade of nutrients, and full contamination control is not entirely sufficient. Due to the severity of heavy metal poisoning, continual determination of heavy metal content of any high-end product must be carried out. The analysis should ideally use internationally approved methods and accredited laboratories. This is why Algalíf sends samples of every lot of Astalíf™ (5% and 10% astaxanthin oleoresin) to an external accredited laboratory to evaluate the heavy metal content (**Table 2**).

The United States Pharmacopoeia suggests to use either inductively coupled plasma-atomic (optical) emission spectroscopy (ICP-AES / ICP-OES) or inductively coupled plasma-mass spectrometry (ICP-MS) to evaluate the heavy metal content of astaxanthin oleoresin. It also states, however, that any validated procedure that gives equivalent or better results can be used. In addition to these methods, the Astalíf oleoresins have been analyzed by graphite furnace atomic absorption spectrometry (GF-AAS), hydride generation atomic absorption spectrometry (HG-AAS), and cold-vapor atomic apsorption spectrometry (CV-AAS), always giving the same result:

To date, no Astalíf product has ever had a quantifiable amount of the heavy metals listed!

Conclusion

Microalgae cultivation and, therefore, astaxanthin production are particularly vulnerable to heavy metal contamination through water due to the biosorption capabilities of algae. Although guidelines are in place to limit the exposure to consumers, the goal for astaxanthin producers must be to surpass the guidelines and eliminate the presence of heavy metals entirely.

Ask Your Astaxanthin Supplier

1. What are the heavy metal specifications they use?
2. What are the actual heavy metal values measured?
3. Which detection methods are used?
4. How frequently is the material tested for heavy metals?
5. What is the local water quality, regarding heavy metal content?

***Table 2.** The maximum permitted levels (MPLs) of heavy metals as defined in the relevant USP guidelines and European regulations, the USP-recommended test methods, and actual values for Astalíf 5 and Astalíf 10, Icelandic astaxanthin oleoresins, as measured by an independent 3rd party laboratory.*

Heavy Metal	MPL		Test Methods	Astalíf 5	Astalíf 10
	USP	EU*			
Arsenic	2.0 ppm	n/a	ICP-AES or ICP-MS, as described by: USP <231>, <232>, <233>, and <2232>	< 0.100 ppm	< 0.100 ppm
Cadmium	1.0 ppm	1.0 ppm		< 0.010 ppm	< 0.010 ppm
Lead	1.0 ppm	3.0 ppm		< 0.050 ppm	< 0.050 ppm
Mercury	1.0 ppm	0.1 ppm		< 0.005 ppm	< 0.005 ppm

**Based on Commission Regulation (EC) No 1881/2006 and subsequent amendments (EC) No 629/2008 and (EU) No 488/2014.*

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About Algalif

Algalif is a microalgae-ingredient supplier from Iceland. We produce Astalíf™ Astaxanthin, a powerful natural antioxidant with multiple health benefits and a solid scientific foundation, extracted from *Haematococcus pluvialis*. Manufactured to rigorous quality and sustainability standards at a state-of-the-art, cGMP-compliant, indoor facility, Astalíf™ is a specialty ingredient for nutraceuticals with applications in brain health, eye health, healthy aging, cardiovascular health, muscle endurance/recovery, and skin health. For more information, please visit **algalif.com** or contact us at **sales@algalif.com**.

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