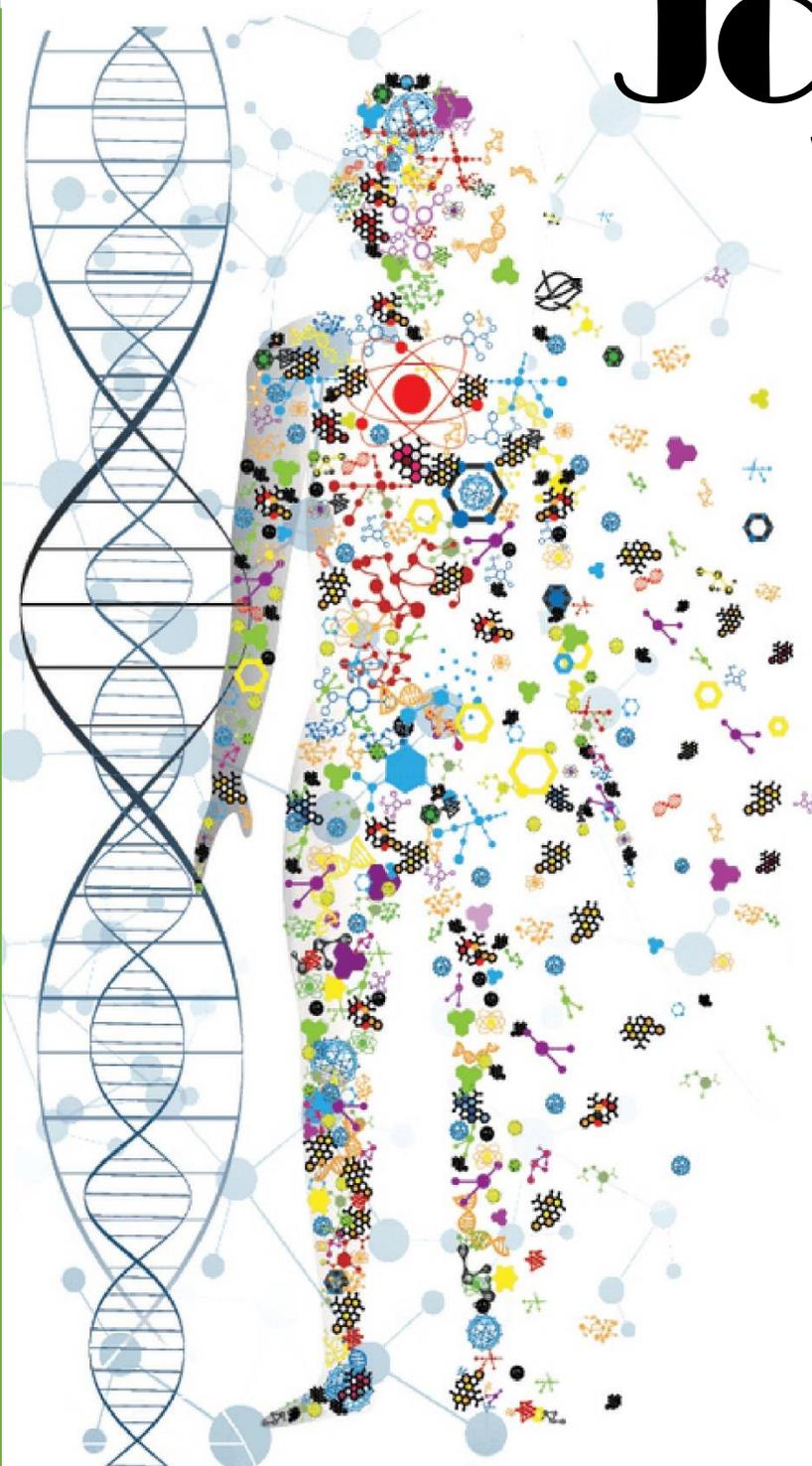




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TOXIC HEAVY METALS IN PROTEIN POWDERS: ASSESSING LEAD AND CADMIUM CONTAMINATION

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ABSTRACT

Heavy metal contamination of protein powders, especially lead (Pb) and cadmium (Cd), has become a significant issue from a public health perspective. Protein supplements are popular supplements for muscle gain, weight control, and general health purposes. These products have exposed people to toxic metals that can cause alarming issues of neurotoxicity, damage to the kidneys, carcinogenic effects, etc. With an emphasis on investigating the sources, prevalence, and health effects of lead and cadmium contamination in various protein powder formulas from plant-based foods rather than animal-based ones, this research explores further into which factors lead to contamination of these food products with these specific heavy metals. Limits and regulations are discussed with respect to mitigation strategies for ensuring industry compliance and consumer safety. Overall, the findings highlight the importance of regulatory control of dietary supplement products, manufacturing practices, and consumer education to reduce the amount of heavy metal exposure through the dietary supplement route.

INTRODUCTION:

Protein powders are popular dietary supplements that are widely consumed as a means of supplementing your muscle growth and recovery, as well as for additional nutritional support while training or competing for your sport. Catering to fans, athletes, and anybody else looking for an easy way to get their proteins in, these types of supplements have grown in popularity over time as a result of more accessible plant-derived and animal options, such as whey, casein, soy, pea, and rice. Despite the general popularity and the image of health benefits associated with the consumption of protein powders, in recent years, they have raised an alarm about contamination with heavy metals, especially lead (Pb), but also cadmium (Cd)^[1,2].

The main sources of heavy metal contamination of protein powders are related to environmental pollutants, soil pollution, and manufacturing^[3]. These contaminants can be incorporated during synthesis, as protein cells take in heavy metals that are present in the soil, water, and air^[4], or during industrial synthesis as protein powders can be contaminated with machinery, package and other external sources^[5]. The presence of lead and cadmium in such dietary supplements is of major public health concern because of their known toxicity.

Even low levels of lead exposure can result in lead-induced brain cell toxicity, affect cognitive ability, cause renal damage, and cause cardiovascular complications, according to the CDC (2019). "With time, lead exposure could inflict injury to soft and bone tissues^[6]. It is important to note that this research might have been limited by a small sample size, a short follow-up period, and heterogeneity of patient characteristics. Further studies with larger samples and longer follow-up are necessary to confirm the findings and to gain a better insight into the effects of GPMS exercises versus conventional physiotherapy practice for lumbar PIVD."

In this paper, we examine closely recent studies that have tried to determine what kinds of protein powders have the highest levels of lead and cadmium based on their methodology and results. The report also examines regulatory standards and industry approaches that aim to minimize dangerous exposure to heavy metals in nutritional supplements and examines the hidden risk of chronic exposure to heavy metal poisons. With these important points in mind, this review highlights the importance of rigorous quality control mechanisms to ensure the safety of protein powder supplements for consumers, manufacturers, and regulatory agencies.

Heavy Metals in Protein Powders:

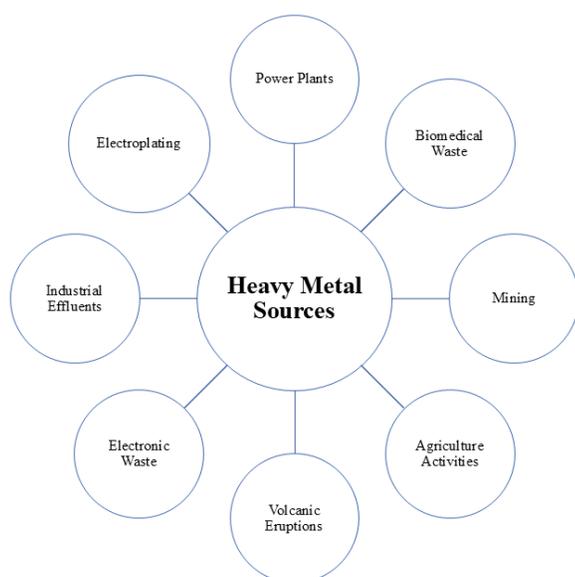


FIG-1. Sources of Heavy metals.

Protein powders are popular with many athletes, bodybuilders, and health-conscious people who want to make sure they're getting enough protein. However, some concerns have been raised recently about the heavy metal content of such items, including lead (Pb) and cadmium (Cd). The presence of heavy metals in protein powders may result from either raw material extraction, soil contamination, and industrial processing, all of which may be highly carcinogenic and toxic insults to the human body when chronically exposed. Both lead and cadmium have no known biological roles in humans, and have been linked to serious health effects including neurotoxicity, organ damage, and effects

of carcinogenicity [12]. Identification, presence, and risks associated with those contaminants are of fundamental importance to consumer protection and regulatory policies.

1. Lead (Pb) Contamination:

1.1 Sources of Lead in Protein Powders

There are many ways in which lead can find its way into protein powders. These are agricultural practices, processing and environmental contamination. There are, however, numerous incidents of lead in the soils resulting from anthropogenic lead sources such as mining, lead based fertilizers, industrial emissions and contamination amongst others [8]. As a result, plants grown in contaminated soil can hoard lead, which subsequently enters the protein powders derived from them. Additionally, lead can leach into protein products during manufacturing and packaging processes if contaminated equipment or materials are used.

1.2 Health Effects of Lead Exposure

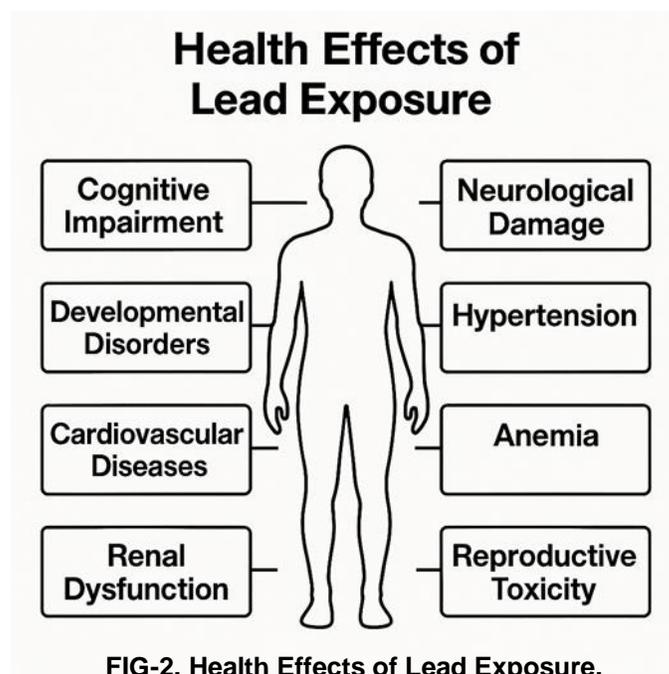


FIG-2. Health Effects of Lead Exposure.

Lead, a known neurotoxin, builds up in the body over time, mostly in bones and soft tissues. linked lead exposure over time to cognitive decline, developmental delays, heart disease, and kidney failure [8]. Particularly in developing brains, lead exposure during pregnancy

and in infants at even low concentrations may have devastating effects. Lead exposure in adults may cause harm to the reproductive system, anemia, and hypertension. Many regulatory agencies, including the FDA, have set maximum allowable levels of lead in dietary supplements; nonetheless, research shows that many protein powders surpass these limits [1].

1.3 Lead Levels in Protein Powders

According to studies, protein powders made from plants often have greater levels of lead than those made from animals. This is because plants take up lead from contaminated soil, and elevated lead accumulates in protein-based products from rice, peas, and hemp [1]. Consumer Reports once compared 134 samples of protein powder and discovered that plant-based protein powders contained, on average, three times the amount of lead as whey- and egg-based powders. Due to the popularity of these supplements, ongoing surveillance and increased regulation are necessary to reduce exposure to lead toxins.

2. Cadmium (Cd) Contamination

2.1 Sources of Cadmium in Protein Powders

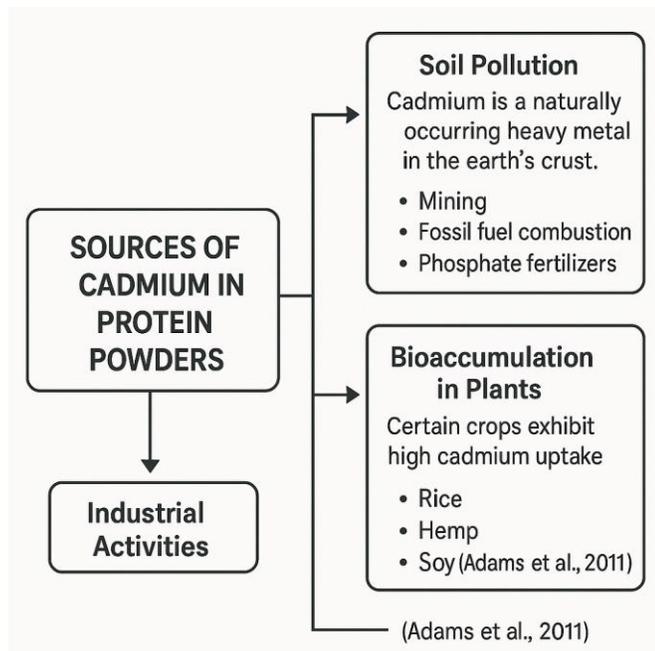


FIG-3. Sources of Cadmium in Protein Powders.

As a result of its toxicity and bioaccumulation in plants, industrial processes, and soil contamination, cadmium is a common element in protein powders. Nowadays, agricultural soils have much higher Cd concentrations than in the past as a result of anthropogenic activities [9], such as mining, use of fossil fuels, and phosphate fertilization. Protein powders derived from plants contain higher levels of cadmium due to the inherent ability of some plants, such as hemp, soy, and rice, to take up larger amounts of cadmium within the ground [10].

2.2 Health Effects of Cadmium Exposure

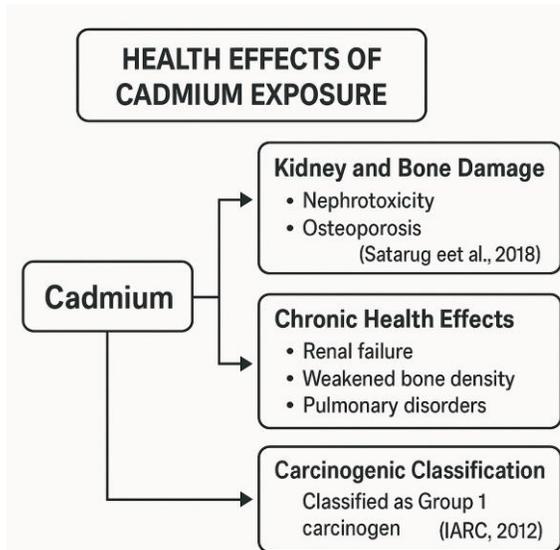


FIG-4. Health Effects of Cadmium Exposure.

“In humans, the half-life for cadmium, a toxic metal with a long biological half-life, is from 10 to 30 years. Accumulation of it in the body makes it carcinogenic, related to osteoporosis, and has been shown to have the risk of nephrotoxicity [9]. When people are exposed over a period to cadmium, it could potentially cause kidney damage, bone density problems, and lung problems, the research states. The International Agency for Research on Cancer (IARC) (2012) has concluded that there is good evidence that cadmium may cause cancer in people. The metal is known to be a Group 1 carcinogen. Because cadmium has such a long half-life, it is a very dangerous element to take in dietary supplements.

2.3 Cadmium Levels in Protein Powders

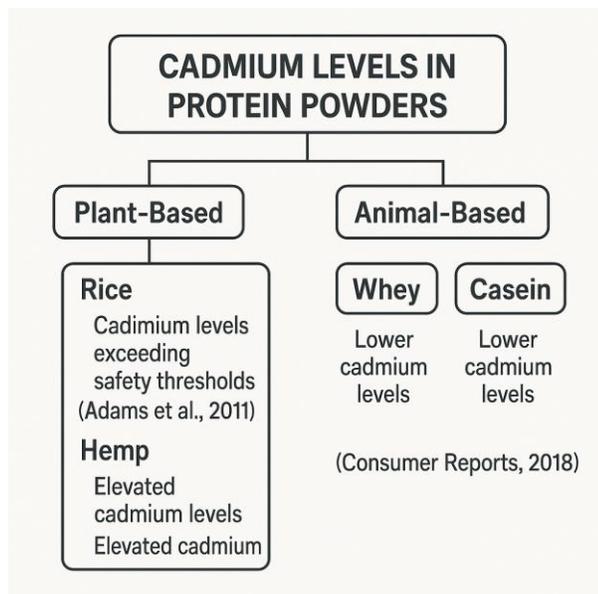


FIG-5. Cadmium Levels in Protein Powders.

Many studies have reported heavy cadmium levels in plant-based protein powders, particularly hemp and rice-based protein powder. Adams et al. (2011) have found rice protein powders to have cadmium levels that are above regulatory protective standards due to the crop having a high uptake of heavy metals from affected soil.” Similarly, cadmium in hemp-based protein powders was high, because cannabinoid plants are well known to be hyperaccumulators of heavy metals.

Since animals are better able to metabolize and excrete cadmium, animal-derived protein powders, such as whey and casein, usually contain lower levels of cadmium than plant-based protein powders. However, low levels of cadmium have been found to contaminate animal-based protein powders because of environmental contamination and ingredients in feed [1]. Our findings indicate that both consumer education and strict quality control are necessary steps to reduce the risk of heavy metal exposure related to dietary supplements.

3. Regulatory Standards and Consumer Safety

“The Food and Drug Administration, the European Food Safety Authority, and the World Health Organization are among the regulatory bodies that have established maximum limits for heavy

metals levels in food and dietary supplements sparked by lead and cadmium contamination of protein powders.” The PTWI for lead was set by the FDA at the amount of 25 ug per kilogram in body weight and for cadmium at 7 ug per kg in body weight as reported by World Health Organization (2011). However, independent research suggests that some protein powders not only surpass these limits, but do further than expected, highlighting the importance of stronger regulation, better testing methods, and transparency in labelling [1]. Because there is no standard governing the quality of protein powders, the safest method is to seek out protein powders tested for heavy metal contamination through third-party certification programs like the US Pharmacopeia (USP) and NSF International. In addition to consuming diversified protein sources, such as meat, eggs and dairy, buying goods from reputable manufacturers will be helpful in limiting the risk of exposure to heavy metal substances.

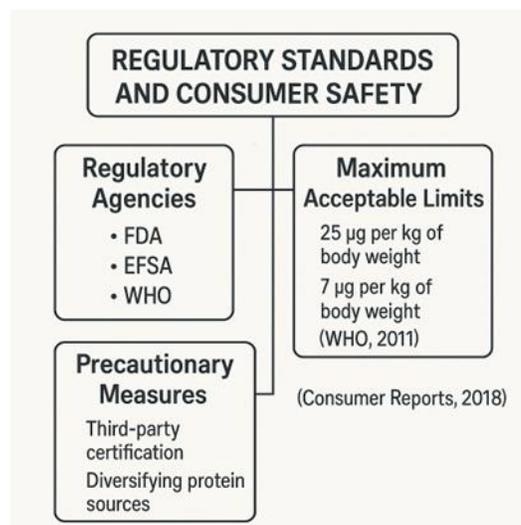


FIG-6. Regulatory Standards and Consumer Safety.

Highest Levels of Heavy Metals in Specific Protein Powder Varieties

According to recent research, plant-based proteins - such as pea, hemp and rice protein - are more likely to release heavy metals than an animal-based protein - such as whey or eggs. This difference can be attributed to a variety of factors: soil -

characteristics, agriculture practices, the ability of certain biological species to accumulate the toxin, etc [12,1]. Some of these protein powders contain heavy metals such as lead and cadmium that can build up over time in our bodies.

Rice Protein Powders: Elevated Cadmium Levels

Other research proved that the cadmium content is very high in rice protein powders. The heavy metals are believed to occur in waterlogged soils, and waterlogged soils are usually polluted with the introduction of pollutants from industries and agriculture, and rice is known for having the ability of metals absorption [13]. The anaerobic environment in paddy fields increases the solubility and bioavailability of cadmium, which in turn increases its uptake by rice [14]. In addition, rice cultivated from areas with high environmental pollution levels has been shown to have higher levels of cadmium and would increase contamination risk for protein powders sourced from such areas [15]. Kidney damage, bone demineralisation and the potential for cancer are but a few of the serious adverse health effects associated with cadmium, which might build up in humans given its long biological half-life [16].

Hemp Protein Powders: Heavy Metal Bioaccumulation

Hemp protein powders: Powder made from hemp has also been found to have elevated levels of heavy metals, most specifically lead and cadmium. Cannabis Sativa (also known as hemp) is a herbaceous plant with high phytoremediation abilities, which is a plant with a high affinity to bind contaminants such as heavy metals from the soil [17,18]. While this bioaccumulation of phosphorus and potassium is great for the purpose of soil detoxification, it is a challenge if hemp is being grown for use as a source for food-grade protein. Also, in some regions where hemp is produced, there are no strict heavy metal regulations that may increase the risk for contaminated soils [19]. Studies have shown that hemp cultivated in contaminated soils may result in high levels of lead and cadmium being retained in the plant parts, including protein powders [20]. Considering the effect of lead as a neurotoxin and cadmium as a nephrotoxin, hemp protein flour represents a product of concern for public health for consumers

who make of these commercial products a main protein source [7].

Pea Protein Powders: Variability in Heavy Metal Contamination

The peptide analysis did highlight that there could be significant variability in heavy metal (especially lead and cadmium) contents of pea protein powders, depending on processing, farming practices, and soil quality [21,22]. Pea (*Pisum sativum*) can also take heavy metals from polluted soils and its protein powders contain high levels depending on the place where they are grown [40]. Studies have indicated that certain samples of pea protein powders also contain lead levels higher than what has been defined as a safe level, as established by health authorities, further highlighting the concerns over whether they are safe to consume regularly. Besides, proteins derived from peas unavoidably contain heavy metals as a result of certain farming practices, including polluted irrigation water and fertilizers [40]. Since lead can lead to neurodevelopmental problems and cadmium can lead to renal toxicity, consumers should take care when choosing plant-based protein powders [23].

Comparative Perspective: Plant-Based vs. Animal-Based Proteins

Plant-based proteins might have more contamination by heavy metals than animal-based proteins, like egg whites or whey. This gap is likely due to the generally higher risk of accumulation in animal-based products, since the ability of heavy metals to bioaccumulate is generally much lower in dairy and eggs [24] compared to beef, pork and poultry. While eggs and whey may be a potentially lower risk factor for heavy metal contamination, concerns persist about contaminants such as hormones and antibiotics [39].

4. Health Implications of Lead and Cadmium Exposure

Heavy metals (lead and cadmium in particular) pose serious health risks when they are absorbed into the human body through food consumption or consumption of food products with heavy metal contamination through environmental exposure. Because these toxic chemicals bioaccumulate and are persistent, there is the potential for them to have serious and long-lasting health -

consequences. The presence of lead and cadmium in protein powders raises serious concerns, particularly for individuals who consume these products regularly for fitness and dietary purposes. The following sections discuss the major health implications associated with lead and cadmium toxicity.

4.1 Lead Toxicity and Its Health Consequences

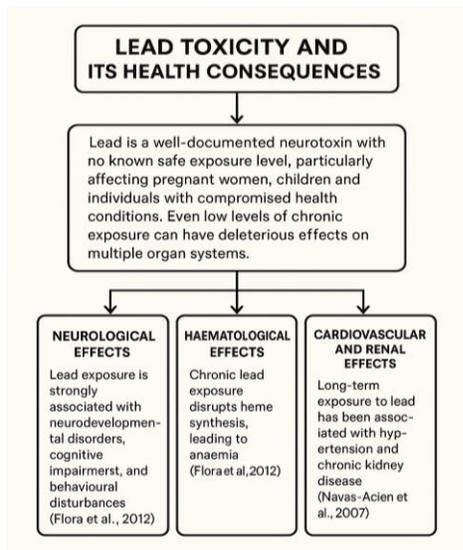


FIG-7. Lead Toxicity and Its Health Consequences

Particularly for youngsters, pregnant women, and individuals with prior health conditions, Currently, the optimal amount of lead exposure is unknown. Lead is a well-documented neurotoxic. The harmful effects on several organ systems may be felt even with low levels of prolonged interaction.

4.1.1 Neurological Effects:

There is considerable evidence linking lead exposure to neurodevelopmental problems, cognitive impairment, and behavioral issues. Lead impairs synapse function, neurotransmitter release, and brain plasticity, which in turn causes learning difficulties, attention deficit disorders, and lowered IQ in children [8]. Prenatal and early childhood exposure is particularly concerning, as the emerging brain is highly susceptible to the neurotoxic effects of lead.

4.1.2 Haematological Effects:

Chronic lead exposure disrupts heme synthesis, leading to anaemia. Lead inhibits key enzymes involved in the production of

haemoglobin, resulting in microcytic and hypochromic anaemia [8]. Additionally, lead exposure increases oxidative stress, exacerbating damage to red blood cells and reducing their lifespan.

4.1.3 Cardiovascular and Renal Effects:

High blood pressure and cardiovascular disease are two outcomes linked to lead exposure over the long term. Increased blood pressure and arterial stiffness are caused by lead-induced oxidative stress and endothelial dysfunction [25]. Furthermore, chronic contact with lead can impair kidney function, increasing the risk of nephrotoxicity and chronic kidney disease.

4.2 Cadmium Toxicity and Its Health Consequences

Heavy metal cadmium is similarly poisonous and serves no biological purpose in humans. The main ways it is absorbed are via food, second-hand smoke, and certain work environments. Chronic toxicity from cadmium builds up in bones and kidneys over time because of its very long biological half-life (up to 30 years) [9].

4.2.1 Renal Dysfunction:

The primary target organ for cadmium poisoning is the kidneys. Chronic exposure leads to tubular dysfunction, proteinuria, and a decline in glomerular filtration rate [9]. Prolonged accumulation of cadmium can result in irreversible kidney damage, increasing the risk of chronic kidney disease and hypertension.

4.2.2 Skeletal Effects:

Osteoporosis and an increased risk of fractures are caused by cadmium's disruption of calcium metabolism. In particular, postmenopausal women may be at a higher risk of fractures because to cadmium's potential to impair bone remodeling [26].

4.2.3 Carcinogenic Potential:

"The U.S.-based International Agency for Research on Cancer classifies cadmium as a Group 1 human carcinogen. A higher risk of kidney, prostate, and lung cancers has been associated with long-term exposure to cadmium, according to scientists. According to Satarug et al. (2018), cadmium mostly causes cancer via oxidative stress, DNA damage, and disruption of the-

cellular repair mechanism.”

4.3 Long-Term Exposure and Vulnerable Populations

Even at modest doses, lead and cadmium exposure over time may have negative effects on health. Women who are pregnant, newborns, young children, and those with established medical disorders are at a higher risk. Low birth weight, premature delivery, and developmental delays are some of the negative outcomes linked to lead exposure during pregnancy [23]. In a similar vein, prenatal growth restriction and placental malfunction may result from cadmium exposure.

Given the increasing popularity of protein powders as dietary supplements, the detection of lead and cadmium in these products is alarming. Consumers who rely on protein supplements for nutritional needs or athletic performance may unknowingly expose themselves to hazardous levels of heavy metals. Reducing heavy metal pollution and ensuring public health requires strict quality control and regulatory procedures.

Regulatory Guidelines and Industry Standards

There is rising worry about heavy metal contamination in food items, particularly protein powders. This is since being exposed to lead and cadmium for an extended period of time is known to create health problems. Max allowed levels of lead and cadmium in food have been determined by both the European Food Safety Authority (EFSA) and the Federal Drug Administration (FDA) in the US. However, regulatory oversight for dietary supplements, including protein powders, remains limited, as there are no specific federal regulations governing heavy metal content in these products [27].

The Food and Drug Administration (FDA) advises that adults not consume more than 12.5 micrograms of lead daily and that children not consume more than 3 micrograms per day as part of the Provisional Total Tolerable Intake (PTTI) for lead [27]. According to the EFSA (2009), the equivalent weekly intake (TWI) for cadmium is 2.5 micrograms per kilogram of body weight [28]. Brands and formulations may differ substantially in terms of contamination levels, despite the presence of some criteria, due to the lack of a uniform worldwide norm for the quantity of heavy metals in protein powders.

Protein powder contamination levels have been the subject-

of several studies conducted by third-party testing organizations, including the Clean Label Project (CLP). Some protein powder brands revealed detectable quantities of heavy metals, with a couple going past the allowed limits, according to a 2018 investigation by the Clean Label Project. Among the 134 popular protein powders that were tested, 70% included lead, 74% contained cadmium, and some brands had levels that were higher than what is allowed for food products [29,30]. There has to be more regulation and more education for consumers on the safety and efficacy of dietary supplements, as shown in this study.

Medical experts and organizations representing supplement consumers are worried about the absence of uniform rules pertaining to heavy metals in these products. Though the Food and Drug Administration (FDA) requires cGMPs for dietary supplements, these regulations primarily enforce practices for a product's processes and quality control; cGMPs do not restrict levels of certain contaminants [27]. This legislative gray area highlights the importance of comprehensive policies that specifically tackle heavy metal contamination in protein powders to ensure consumer safety.

Over time, the industry and several scientific communities have advocated for more regulations that will help reduce the exposure to harmful levels of heavy metals. The U.S. Pharmacopeia (USP) has proposed stricter contaminant hazard concentrations for dietary supplements; but manufacturers are still voluntary in complying with the proposal [31]. Consumer education and transparency are also crucial elements in combating this problem, as awareness campaigns can help individuals make informed decisions about the supplements they take.

Lastly, despite the national and international regulatory agencies having established tolerance values for lead and cadmium contents of food, there are no limits set on protein supplements (e.g., shakes), making the supervision of these products non-existent. The findings of independent testing organisations still demonstrate inconsistencies in-

contamination levels between brand sponsors and stress the necessity of tightening up controls and making consumers more aware. Improving regulatory frameworks and increasing compliance by industry with safety standards is an important step toward reducing heavy metal exposures from protein powders.

5. Strategies for Reducing Heavy Metal Contamination.

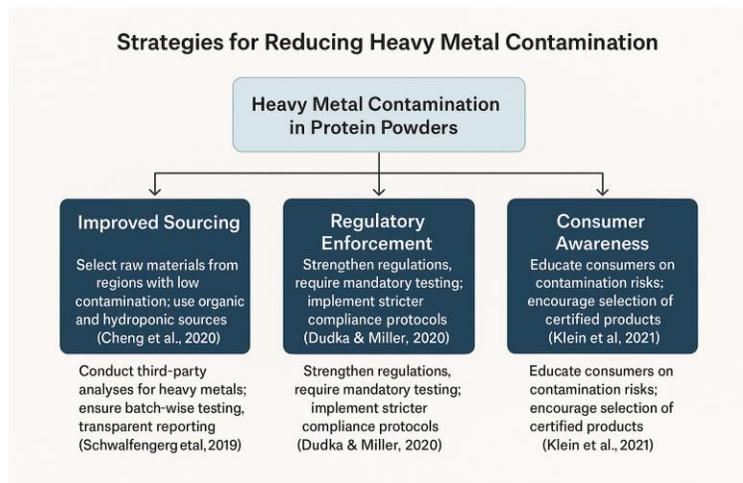


FIG-8. Strategies for Reducing Heavy Metal Contamination.

The high lead and cadmium in protein powders are very dangerous heavy metal pollutants to the consumers. From better sourcing of raw materials to better regulatory systems, there are a number of ways exposure can be mitigated and consumers protected. The following measures are crucial in addressing this issue:

5.1 Improved Sourcing

“Order picking of raw materials from an area with a low environmental contamination level is one of the most effective strategies for the prevention of heavy metal deposition. Heavy metals load in the water and soil because of agricultural and industrial application, this also affects the plant and animal protein sources [32]. Sourcing ingredients from suppliers who follow soil remediation practices and perform environmental monitoring can help reduce heavy metals in crops Furthermore, promoting plant-based proteins which are organic and/or produced by hydroponics proved to be a sensible alternative as such techniques have shown to decrease heavy metals accumulation into the plants from soils contaminated with heavy metals [33].”

5.2 Enhanced Testing

In addition, maintaining boundaries pricing on heavy metal content means protein powders need to be subjected to thorough third-party testing to be drafted as an approved option for the protein powder market. According to Schwalfenberg et al. (2019) monitoring of lead, cadmium, arsenic and mercury in elements from measuring by laboratories utilizing the latest technique of Inductively Coupled Plasma Mass Spectrometry (ICP-MS) [34]. Therefore, manufacturers should introduce batch-level testing to determine if contamination can occur at different stages of production. Reducing Ambiguity - Clear communication on the quantity of heavy metals present on product labels and company websites will help reinforce consumer trust and accountability. Certifications: Independent certifications like the Clean Label Project offer valuable assurance of adherence to rigorous heavy metal testing protocols [35].

5.3 Regulatory Enforcement

Dietary intake of heavy metals in supplemental forms is primarily a regulatory agency and governmental responsibility. “In 2022, the Food and Drug Administration (FDA), along with the European Food Safety Authority (EFSA) and some other organizations, set maximum allowable levels of lead and cadmium in food items [36].” In contrast to medications, nutritional supplements remain available under (at best) very loose regulatory scrutiny. Regulations: Enhancing regulations and mandating rigorous heavy-metal testing protocols, along with stricter compliance standards can play a significant role in decreasing exposure risks [37]. Further, coordination between international food regulatory agencies can serve to harmonize global standards and ensure that products which have been discovered to be contaminated do not enter markets recently opened to substantial levels of chronic contamination.

5.4 Consumer Awareness

It is important for buyers of protein powders to be educated on the risks of heavy metal exposure and make informed decisions. The research confirms that hemp products-

with a third-party certificate, such as NSF International or USP Verified, have been through extensive safety testing and should be the products of choice for consumers [38]. Public Awareness campaigns can help create consumer awareness of the possible sources of contamination, the importance of reviewing test results from laboratories, and how to read product labels. Furthermore, increased transparency among corporations regarding ingredient sourcing and testing may help to support consumers, who in turn can push the manufacturers for higher levels of safety.

CONCLUSION:

Lead and cadmium have been identified in protein powders and are a major concern when found in plant-based proteins. Since we understand there are health risks associated with chronic heavy metal exposure, regulatory controls and industry-user transparency are warranted. It is important for consumers to look for protein powders that have undergone rigorous third-party testing and meet established safety standards.

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