STM JOURNALS

International Journal of
Nutritions

https://journals.stmjournals.com/ijn/

ISSN: 3048-5576
Volume 3, Issue 2, 2026
July–December
DOI (Journal): 10.37591/IJN

Research IJN

Labeling Transparency and Heavy Metal Contamination in Commercial Protein Powders: A Case Study

Bavatharani V.[1], Amrita Shaw[2], A. Sunil[3], Jhinuk Gupta[4,*]

Abstract

With the recent surge in market demand, health supplements particularly protein powders, have become increasingly vulnerable to quality deterioration, adulteration, and unethical marketing practices. Non-compliance with labeling regulations is on a rise. Moreover, research indicates that heavy metals absorbed from contaminated soil often accumulate in the protein fractions of crops, thereby elevating the risk of heavy metal contamination in protein powders. These issues highlight the urgent need to systematically assess both mislabeling and heavy metal contamination in commercially available protein powders. In this study, 110 protein powders, available in India, were manually screened to check their compliance with Food Safety and Standards Authority of India (FSSAI) regulations and six of those, containing maximum number of violations, were assessed for heavy metal contamination through Microwave Plasma – Atomic Emission Spectroscopy (MP-AES). Target Hazard Quotients (THQs) and Hazard Index (HI) values were calculated to assess potential health risks of the heavy metal contamination. The findings revealed widespread mislabeling. Around 25% products lacked "how to use" instructions, increasing the risk of excessive protein intake and protein poisoning. 30% of products omitted mandatory warning statements and 42% failed to mention potential allergens. 75% of cocoa-based powder contained stevia, a sweetener regulated by FSSAI in cocoa based formulations. Additionally, 8% of the samples had incomplete ingredient lists. The MP-AES analysis revealed Arsenic to be the most abundant heavy metal present in the samples studied, followed by lead and mercury. The calculated Estimated Daily Intake (EDI) and Hazard Indices (HI) of all six protein powders revealed the severity of the health risk associated with the regular consumption of protein powders over a period. These findings highlight the critical need for stringent quality control measures in the dietary supplement industry and the implementation of sustainable strategies to prevent heavy metal contamination in protein powders.

*Author for Correspondence
Jhinuk Gupta
E-mail: jhinukgupta@sssihl.edu.in

[1]Student, Department of Food and Nutritional Sciences, Sri Sathya Sai Institute of Higher Learning, Vidyagiri, Prasanthi Nilayam, Andhra Pradesh, India
[2]Allied Ph.D. Research Scholar, Department of Food and Nutritional Sciences, Sri Sathya Sai Institute of Higher Learning, Vidyagiri, Prasanthi Nilayam, Andhra Pradesh, India
[3]Assistant Professor, Department of Chemistry, Sri Sathya Sai Institute of Higher Learning, Vidyagiri, Prasanthi Nilayam, Andhra Pradesh, India
[4]Assistant Professor, Department of Food and Nutritional Sciences, Sri Sathya Sai Institute of Higher Learning, Vidyagiri, Prasanthi Nilayam, Andhra Pradesh, India

Received Date: April 16, 2026
Accepted Date: April 30, 2026
Published Date: April 30, 2026

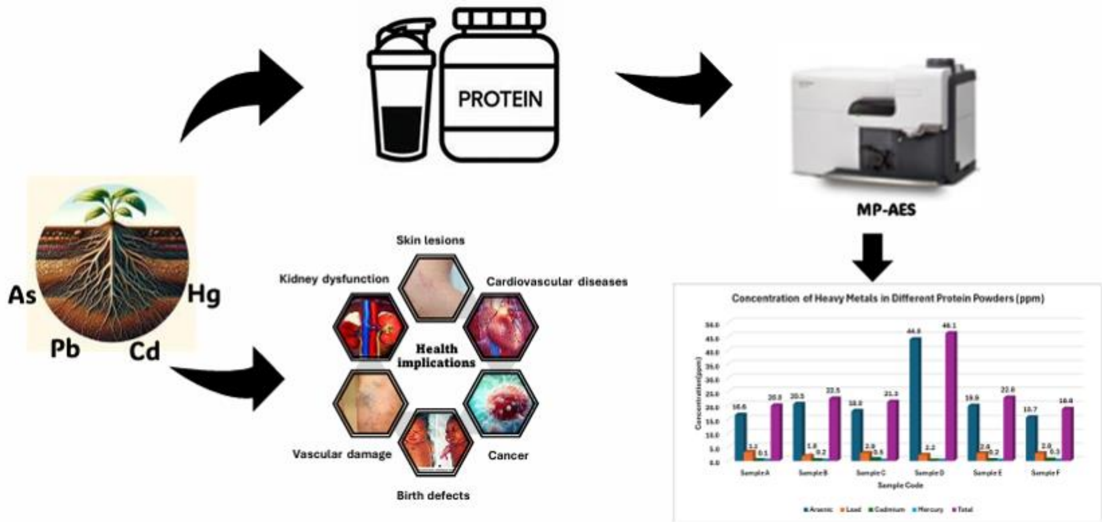
Citation: Bavatharani V., Amrita Shaw, A. Sunil, Jhinuk Gupta. Labeling Transparency and Heavy Metal Contamination in Commercial Protein Powders: A Case Study. International Journal of Nutritions. 2026; 3(2): 37–46p.

Keywords: Protein powders, Heavy metal contamination, Mislabeling, MP-AES, Market survey

INTRODUCTION

One of the fast growing and rapidly evolving food sectors in India is the health food sector. Its market value was US$ 11.85 billion in 2023 and is projected to hit US$ 28.70 billion by 2030 at a compound annual growth rate (CAGR) of 10.7% during the forecast period 2024–2032. Among the health supplements, protein supplements are one of the most important and prominent products [1]. It is available in the market in different types such as powders, isolates, concentrates, and hydrolysates [2]. Among those, protein powders are mostly consumed and have long been used for muscle growth and immunity building [3]. The popularity and consumption of protein supplements have increased especially in the post-Covid era. As the market for protein powders continues to expand, the sector becomes more vulnerable towards unethical practices, violation of safety regulations, quality depreciation, and adulteration.

The concept of food labels came into existence long back in history to satisfy the consumers' inquisitiveness about the food contents present inside a food package [4]. Functional food labeling allows consumers to make judicious choices about food. Labeling Regulations are set by national and international agencies to maintain food safety across the world. Mislabeling refers to the type of food fraud where label printed on the food package does not represent the true nature of the content present inside, hides risk information, claims unjustified health benefits, puts wrong expiry dates, etc. In recent past, some scattered incidents, studies, surveys conducted in different parts of the world have reported about mislabeled protein powders, with deceptive ingredients list, misguiding advertisements and compromised quality [5]. Study done on 36 popular protein supplements in India found that nearly 70% of the products were mislabeled, with 14% containing toxins [6]. The unavailability of enough literature, reports, and surveys conducted in India in this field highlights the need for conducting a comprehensive market survey to assess the labeling transparency/accuracy of the protein powders.



Highlights

- Mislabeling and heavy metals contamination in commercial protein powders is a less explored area in India.
- Mislabeling was detected in 55% of the samples.
- One or multiple heavy metals (As, Pb, Cd) were detected in 100% samples, exceeding the permissible limits.
- Findings are helpful for consumers, policy makers and manufacturers.
- Opens up new research area to prevent heavy metal contamination in protein powders.

Although the recommended daily usage for these protein powders is a maximum of 30 g/day for adults, yet a large section of protein powder users tend to use it in higher dosage to get quicker results. This makes protein powders a potential food source of many contaminants, including heavy metals. Heavy metals – such as arsenic (As), lead (Pb), cadmium (Cd), and mercury (Hg) – are considered under high-priority list of poisonous substances according to the US Environment Protection and the Agency for Toxic Substances and Disease Registry [7]. These are dangerous, even in low concentrations due to their non-biodegradability, and unavailability of effective removal mechanism [8]. Heavy metals can enter protein supplements through various pathways during both pre-harvest and post-harvest stages. Plant-based protein sources, such as peas and rice, can absorb heavy metals from contaminated soil and water. Stuadies have shown that heavy metals are often found in high concentrations in the protein fractions of contaminated crops, such as rice and wheat, where they bind to proteins of specific molecular weights [9]. Thus, daily consumption of protein supplements may contribute to an increased intake of heavy metal contents by the human body [10].

Heavy metals in protein supplements have been a global food safety concern in recent years. Heavy metals are detected higher in plant-based protein powders than other types of protein powders. A study by the Clean Label Project found that plant-based protein powders had higher levels of heavy metals than whey-based protein powders [11]. A human health risk assessment of heavy metal ingestion among protein powder supplements revealed that plant-based protein powder supplements tend to have a higher heavy metal burden than animal-based protein powder supplements [12]. Considering the potential risks associated with heavy metals in protein supplements, each country has set up its own regulations related to permissible limits of heavy metals [13]. In India, the Food Safety and Standards Authority of India (FSSAI) permissible limits for heavy metals in food products, in general, are given as 1.1 ppm for arsenic, 2.5 ppm for lead and 1.5 ppm for cadmium.

Plant-based supplements, which are often marketed as natural and safe, remain underrepresented in heavy metal contamination research in India. Existing few studies on heavy metal contamination of protein powders tend to focus more on well-established brands, leaving significant research gap for comparatively newer brands. The insights discussed above on mislabeling and heavy metal contamination of protein powders shows the necessity of carrying out a systematic study to assess the labeling accuracy and heavy metal contamination in protein powders available in India. In this project, 110 such products were tested for labeling accuracy through manual screening, and six selected products were tested for As, Pb, Cd, and Hg contamination through Microwave Plasma Atomic Emission Spectroscopy (MP-AES).

MATERIALS AND METHODS

Market Survey

An online market survey was conducted to gather data on different protein supplements for checking their adherence to regulatory standards set by FSSAI. The keywords used for searching the protein powders in online platforms, are “protein supplements”, “plant-based proteins”, “whey proteins”, “vegan proteins”, “pea protein”, and “soy protein”. A total of 110 products from the search results were manually screened for labeling compliance against the FSSAI regulation under Food Safety and Standards (Health Supplements, Nutraceuticals, Food for Special Dietary Use, Food for Special Medical purposes, Functional foods, and Novel foods) regulation, 2016 And Food Safety and Standards (Labeling and Display) regulations 2010.

HEAVY METAL ANALYSIS

Sample Selection

The samples for heavy metal analysis were chosen based on the protein source, country of manufacturing, brand popularity, customer review ratings, and extent of labeling compliance with the FSSAI guidelines. All six selected protein powders were either completely plant-based formulations (pea or soy) or a blend of plant and whey-based protein. All six products were manufactured in India, possessed the “Top brand” or “Best seller” logo in the e-commerce platforms, and achieved customer review ratings >4 (out of five stars). Most importantly, those were found to have the maximum number of FSSAI regulation violations during the screening of the packaging labels. The selected protein powders were procured from Amazon. in and Flipkart.com and labeled with sample codes (as listed in Table 1) to ensure unbiased results. The samples were stored in airtight containers in a cool, dry place to prevent chemical contamination and microbial growth.

Sample Preparation

Sample preparation for MP-AES was done according to the procedure reported by Ali, H. et al., with slight modifications [14]. Approximately 0.1 g of the sample was precisely weighed. 10 mL concentrated HNO_3 was added and digested on a hot plate at 100˚ C for 2 hours until an almost clear solution was obtained. Although no solid particle was observed, the digests were filtered using Whatman filter paper (no 44), and the filtrate was collected in a volumetric flask and diluted to 10 mL using ultrapure deionized water. This solution was used for MP-AES analysis without any further dilution. Each sample was prepared in triplicate.

MP-AES Analysis

All measurements were performed using an Agilent 4200 MP-AES with nitrogen plasma gas supplied via an Agilent 4107 nitrogen generator. The sample introduction system comprised a double-pass cyclonic spray chamber and a OneNeb nebulizer. An Agilent SPS4 auto-sampler was used to deliver samples to the instrument. The experiment was conducted using a OneNeb nebulizer with a flow rate of 0.75 mL/min) A double-pass glass cyclonic spray chamber was utilized, and the pump speed was set to 15 rpm. The analysis was performed in triplicate, each with a read time of 6 minutes. The system was stabilized for 30 seconds before sample introduction, with an uptake time of 45 seconds and a rinse time of 30 seconds to ensure accuracy and consistency.

RESULTS AND DISCUSSION

Market Survey

A market survey was carried out on commercially available protein powders as described in the materials and methods section to look for any violations of labeling regulations that are visually detectable, and the findings are summarized in Figure 1. Out of the 110 products surveyed, 54.5% of products violated one or multiple of the labeling regulations issued by National and International regulatory bodies. These violations ranged from improper labeling to the use of regulated additives, raising concerns about consumer safety and product transparency. A major area of non-compliance was the absence of critical consumer guidance information. Notably, 25% of the screened products did not provide instructions on "how to use" the product. This omission is particularly concerning as it may lead to improper consumption, potentially resulting in health risks such as excessive protein intake, digestive discomfort, or metabolic imbalances. Furthermore, 30% of the products failed to include the mandatory warning statements, further exacerbating the risk for consumers, particularly those with dietary restrictions or health conditions. Allergen declaration was also found to be a critical issue. 41.6 % of the products did not declare warning statements about the potential presence of common allergens such as dairy, soy, and nuts. This oversight is a direct violation of the food safety regulations and poses a significant health threat to individuals with food allergies. Allergen disclosure on the label of the product is a fundamental requirement for ensuring consumer safety, and the absence creates a gap in regulatory enforcement. Another major concern identified in the study was the inclusion of stevia glycoside in 75% of the surveyed cocoa-based products, despite the explicit FSSAI regulation prohibiting its use in cocoa-based formulations. These widespread violations indicated either a lack of awareness among manufacturers or deliberate non – compliance with the regulation. 10% of the surveyed products failed to provide a complete list of ingredients; only name and the protein percentage were mentioned, leaving the remaining constituents unaccounted for. This lack of full disclosure raises concerns about hidden additives. Despite claiming long shelf life, none of the surveyed products disclosed the use of a preservative. Given the perishable nature of protein powders, achieving long shelf stability without the use of preservatives is highly unlikely.

Additionally, the study revealed that many products have higher carbohydrate content in the nutritional label, despite being marketed as protein supplements. This misrepresentation may mislead consumers who rely on such products for specific macronutrient intake goals such as muscle building or weight management. These findings reveal multiple labeling violations in protein supplements and strongly recommend chemical testing for unpermitted additives.

Therefore, the findings of the current study underscore the need for enhanced regulatory oversight and stricter enforcement of labeling and formulation guidelines in the protein supplement industry.

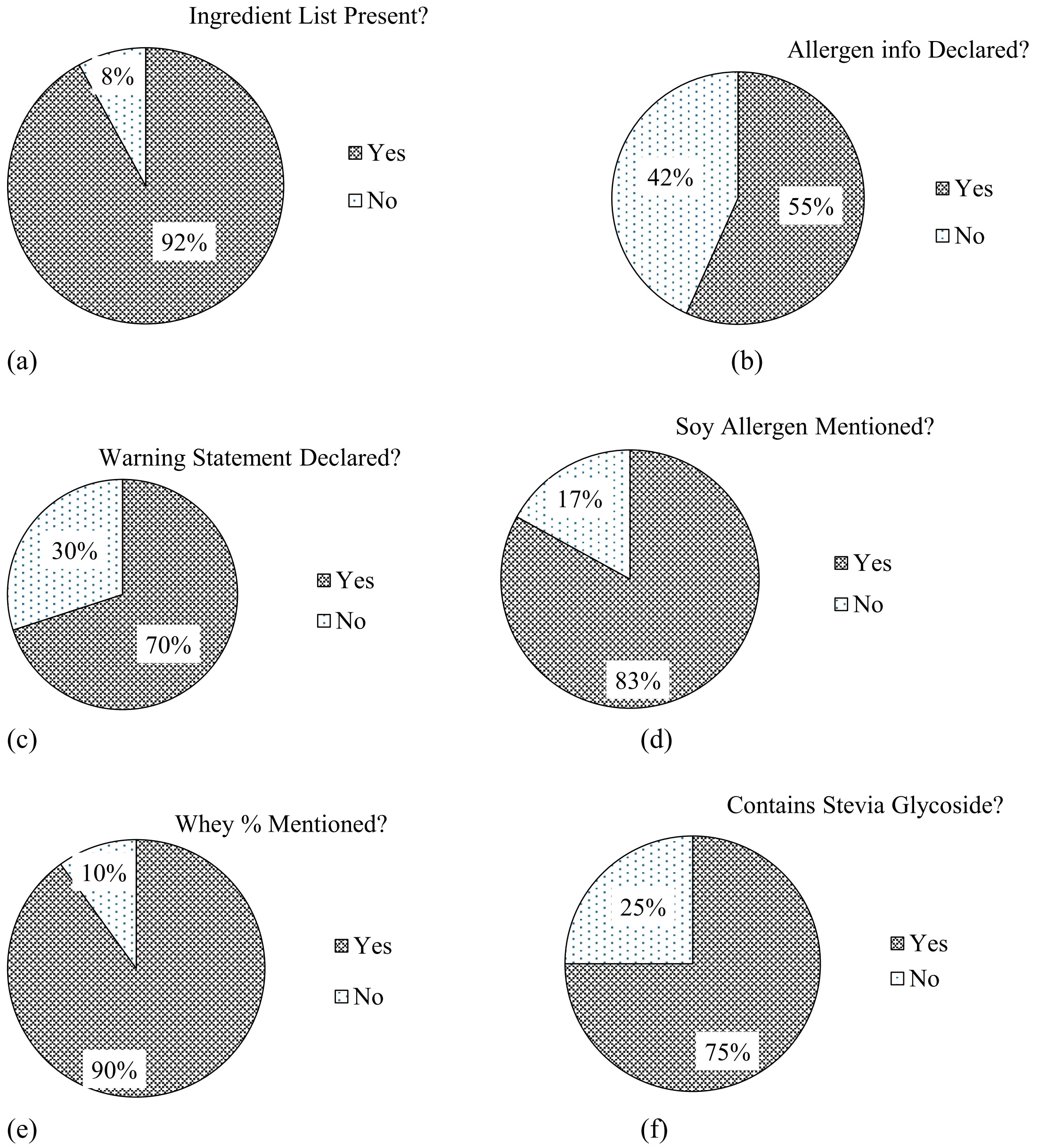


Figure 1. Findings from the screening of the package label of the protein powders. (a) presence of an ingredient list (b) presence of warning statements, (c) declaration of allergens (d) specific warning statements about the presence of soy in lecithin-containing products (e) disclosing the whey percentage in whey concentrate or whey isolate, (f) presence of stevia glycoside in chocolate-flavored protein powders.

Quantitative Analysis of the Heavy Metals Through MP-AES

Amongst the various analytical techniques available to quantify heavy metals in food, MP-AES gives the most accurate and reproducible results. The uniqueness of MP-AES is in its use of a magnetically excited microwave plasma source, which enables high sensitivity, low detection limits, and the ability to handle complex sample matrices such as food products. A total of six protein supplements were procured and analyzed for heavy metal contamination using MP-AES as described in the materials and methods section.

Seals were maintained on all procured products until they were used in the laboratory and were opened following standard operating conditions. The MP-AES instrument offers continuous wavelength coverage, allowing the selection of lines with optimal sensitivity for the required concentration range while minimizing interferences. Since most samples contain multiple elements at varying concentrations, special interferences can arise; the instrument was operated using powerful and user-friendly MP Expert software. This software enables precise wavelength selection from an extensive database, ensuring accurate analysis with minimal interference. The calibration range for the key elements was set as follows: As at 193.695 nm (0–5500 ppb), Hg at 253.652 nm (0–5500 ppb), Pb at 405.781 nm (0–5500 ppb), and Cd at 228.802 nm (0–5500 ppb). The findings of the heavy metal analysis through MP-AES are compiled in Table 1 and Figure 2. The results represent the average of three replicates done for each sample. All six samples were found to contain one or multiple heavy metals in significant quantities.

Among the four metals studied, Arsenic (As) was found to be the most abundant in all samples. Its concentration varied from 15.7 ppm to 43.9 ppm. Sample D had the highest level of As (43.9 ppm), followed by Sample B (20.5 ppm). The lowest Arsenic concentration was estimated in Sample F (15.7 ppm), which is also much higher than the permissible limit. The second most abundant heavy metal detected in the protein powder samples was lead (Pb).

The concentration of lead varied across different samples, with the highest level observed in Sample A with 3.2 ppm, followed by Sample E with 2.7 ppm. Out of the six tested samples, four exceeded the permissible limit, while the remaining two remained within the safe range, as represented in Figure 2. Cadmium (Cd) was the least prevalent heavy metal detected in the protein powder samples. The highest concentration was found in Sample C with 0.48 ppm, followed by Sample F with 0.3 ppm. Out of all the samples analyzed, three surpassed the permissible limit of Cd, whereas the remaining were within the acceptable levels. Surprisingly, mercury (Hg) was not detected in any of the six samples.

Table 1. Concentration of heavy metals estimated in the protein powders through MP-AES.

S.N.	Sample code	Nature	Arsenic (ppm)#	Lead (ppm)#	Cadmium (ppm)#	Mercury (ppm)#	Total (ppm)*
1	A	Whey	16.61 ± 1.66	3.20 ± 0.12	0.14 ± 0.05	ND	19.965
2	B	Plant	20.51 ± 1.43	1.80 ± 0.78	0.17 ± 0.09	ND	22.475
3	C	Plant	17.99 ± 1.89	2.88 ± 0.51	0.48 ± 0.28	ND	21.344
4	D	Plant	43.96 ± 1.71	2.16 ± 0.29	0.03 ± 0.01	ND	46.148
5	E	Whey	19.86 ± 1.79	2.78 ± 0.12	0.19 ± 0.05	ND	22.831
6	F	Plant	15.70 ± 1.76	2.76 ± 0.41	0.34 ± 0.02	ND	18.803

Note: #Average of triplicates. *Summation of As, Pb, Cd content.

The absence of detectable mercury in the tested protein powders is consistent with the previous studies, which report that mercury contamination in protein powders is uncommon [6], most likely due to low environmental contamination, processing methods, and nature of the ingredients. The highest total contamination of heavy metals was seen in Sample D with 46.1 ppm.

HEALTH RISK ASSESSMENT

Estimated Daily Intake (EDI)

The health risk associated with heavy metal-contaminated food not only depends on the level of contamination but also depends on the consumption rate of food. Heavily contaminated food may not always impose great hazard if consumed less frequently. Therefore, it is important to calculate the health risk associated with heavy metal contamination of the studied products. The estimated daily intake (EDI) was calculated according to Equation (1) given by Wu et al. and compared with the permissible limits [7].

$$EDI = (C \times F_{IR}) / Bwa \tag{1}$$

where C is the metal concentration (ppm) in the given food item, FIR is the food consumption rate (g/d) of the respective food item, and BWa is the reference body weight (60 kg). The results are shown in Table 2.

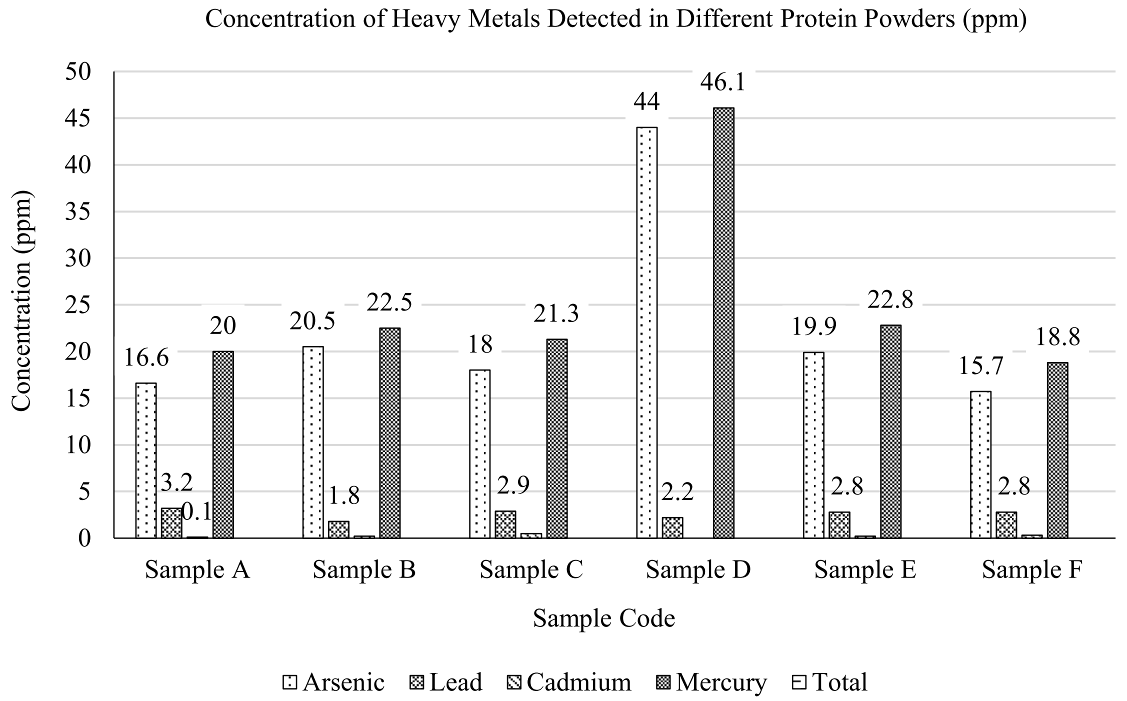


Figure 2. Concentration of heavy metals detected in different protein samples.

The results show that the level of As present in all six samples results in EDI exceeding the permissible limit, whereas the level of lead present in only two samples results in EDI exceeding the permissible limit. The cadmium level present in all samples resulted in EDI within the permissible limit. Comparison of the protein samples with rice (considering the rice to be contaminated with As, Pb, Cd) found that protein powders, despite being consumed in smaller quantities (30 g/day), had significantly higher EDI values compared to rice. This suggests a higher level of risk associated with protein powders, mainly for As contamination.

Table 2. Estimated daily intake (EDI) of heavy metals in protein supplements and common staple food (rice).

Sample	Consumption rate (g/person/day)	Arsenic (As)		Lead (Pb)		Cadmium (Cd)	
		EDI (mg/kg Bw/day)	Exceeding permissible limits* (yes/no)	EDI mg/kg Bw/day	Exceeding permissible limits** (yes/no)	EDI mg/kg Bw/day	Exceeding permissible limits# (yes/no)
A	30 g	0.00831	Yes	0.00160	Yes	0.000072	No
B	30 g	0.01026	Yes	0.00090	No	0.000084	No
C	30 g	0.00899	Yes	0.00144	No	0.00024	No
D	30 g	0.02198	Yes	0.00108	No	0.000015	No
E	30 g	0.00993	Yes	0.00139	No	0.000093	No
F	30 g	0.00785	Yes	0.00138	No	0.000169	No
Rice	400 g	0.00000921	Yes	0.00382	Yes	0.00025	No

Note:
* *Permissible limit of As (0.0021–0.003) mg/kg Bw/day [15].*
** *Permissible limit of Pb (0.0012–0.0015) mg/kg Bw/day [16].*
\# *Permissible limit of Cd (0.00036–0.001) mg/kg Bw/day [17].*

Target Hazard Quotient (THQ) and Hazard Index (HI)

To assess the comprehensive, long-term health risk posed by ingestion of heavy metal-contaminated foods, Target Hazard Quotient (THQ) and Hazard Index (HI) were calculated for the tested samples.

The results are shown in Table 3.

$$THQ = (E_{FR} \times Ed \times F_{IR} \times C \times 10^{-3}) / (R_{FD} \times BWa \times ATn) \quad (2)$$

where, E_{FR} is the exposure frequency to the trace element (365 days), Ed is the exposure duration (5 years), F_{IR} is the food consumption rate in g/d for the respective food item, C is the element concentration in the given food item, R_{FD} is the oral reference dose of the element in mg/kg/d, BWa is the reference body weight of 60 kg, ATn is the averaged exposure time (365 days, 5 years).

Table 3. Target hazard quotient (THQ) (non-carcinogenic risk) and Hazard index (HI) of heavy metals in Protein supplements and rice (staple food).

Sample	THQ			HI = ΣTHQ	Is HI>1?
	Arsenic (As)	Lead (Pb)	Cadmium (Cd)		
A	2.76	0.45	0.072	3.28	Yes
B	3.41	0.25	0.08	3.74	Yes
C	2.99	0.41	0.24	3.64	Yes
D	7.32	0.30	0.01	7.63	Yes
E	3.3	0.39	0.09	3.78	Yes
F	2.6	0.30	0.10	3.00	Yes
Rice	0.03	1.09	0.25	1.37	Yes

HI is the summation of THQs of all heavy metals present in contaminated food. An HI value greater than 1 makes the food a high-risk category. HI calculated for all six protein samples, considering 5 years of exposure, exceeded the safety value of 1, suggesting a potential non-carcinogenic health risk associated with the regular consumption of those protein powders. Particularly concerning was the dominance of arsenic and lead in contributing to the overall hazard index (HI).

CONCLUSION

The findings from this study are significant, as they reveal that a considerable portion of protein powders available in the Indian online market do not fully comply with labeling regulations. Several issues were identified, including the absence of ingredient lists, usage instructions and allergen warnings and use of regulated additives. These observations underscore the urgent need for ensuring regulatory compliance in the protein supplements industry to protect consumer welfare. The high levels of heavy metal contamination detected in the study highlights the vulnerability of protein powders to heavy metal contamination. The calculated Estimated Daily Intake (EDI) and Hazard Indices (HI) of all six protein powders revealed the severity of the health risk associated with the regular consumption of protein powders over a period. All these findings highlight the need for stringent quality control measures in this sector and finding sustainable measures to stop heavy metal contamination in protein powders, the most popular dietary supplements of current days.

Nonetheless, the study has certain limitations. The market survey screened only 110 products out of 1000 search results and the heavy metal analysis study was conducted only with a limited number of protein powders, which may not fully represent the wide range of products available in the market. To derive statistically significant conclusions and better validation of the findings, it is important that future research includes a larger and more diverse sample size, ideally analyzing over 100 products of various brands and formulations. Additionally, while the study effectively identified the presence of heavy metals, it did not explore the underlying causes of such contamination. Understanding the root causes, whether arising from raw material procurement, manufacturing practices, packaging materials, or storage conditions, is critical to develop effective prevention strategies. However, literature and data in this area remain scarce. Therefore, future studies should focus on tracing the contamination pathway and identifying specific stages in the production and supply chain where heavy metal exposure is most likely to occur. This would not only strengthen food safety regulations but also guide manufacturers in implementing better quality control measures.

Acknowledgments

The authors express their sincere gratitude to Sri Sathya Sai Institute of Higher Learning for providing this research opportunity. The authors extend their thanks to the Central Research Instruments Facility (CRIF) of Sri Sathya Sai Institute of Higher Learning for providing all necessary support to carry out the MP-AES analysis.

Author Contributions

JG: Conceptualization, Supervision, Formal analysis, Writing-original draft, Writing-review & editing. BV: Conceptualization, Writing-original draft, Investigation, Formal analysis, Visualization. A. Shaw: Investigation, Writing-review & editing. AS: Investigation, Formal analysis.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

REFERENCES

1. Al-Garory NH, Al-Kaabi WJ. Determination of some heavy metals concentration in some dairy products from three different regions of Basrah, Iraq. Basrah J Agric Sci. 2020;33(2):1–3.
2. Bethencourt-Barbuzano E, Gonzalez-Weller D, Paz-Montelongo S, Gutierrez-Fernandez AJ, Hardisson A, Carrascosa C, et al. Whey protein dietary supplements: Metal exposure assessment and risk characterization. Nutrients. 2023;15(16):3543.
3. Rodriguez-Lopez P, Rueda-Robles A, Sánchez-Rodríguez L, Blanca-Herrera RM, Quirantes-Piné RM, Borrás-Linares I, et al. Analysis and screening of commercialized protein supplements for sports practice. Foods. 2022;11(21):3500.
4. Thøgersen J. How does origin labelling on food packaging influence consumer product evaluation and choices? A systematic literature review. Food Policy. 2023;119:102503.
5. Shangguan S, Afshin A, Shulkin M, Ma W, Marsden D, Smith J, et al. A meta-analysis of food labeling effects on consumer diet behaviors and industry practices. Am J Prev Med. 2019;56(2):300–14.
6. Philips CA, Theruvath AH, Ravindran R, Chopra P. Citizens protein project: A self-funded, transparent, and concerning report on analysis of popular protein supplements sold in the Indian market. Medicine (Baltimore). 2024;103(14):e37724.
7. Wu W, Wu P, Yang F, Sun DL, Zhang DX, Zhou YK. Assessment of heavy metal pollution and human health risks in urban soils around an electronics manufacturing facility. Sci Total Environ. 2018;630:53–61.
8. Meng R, Zhu Q, Long T, He X, Luo Z, Gu R, et al. The innovative and accurate detection of heavy metals in foods: A critical review on electrochemical sensors. Food Control. 2023;150:109743.
9. Wong C, Roberts SM, Saab IN. Review of regulatory reference values and background levels for heavy metals in the human diet. Regul Toxicol Pharmacol. 2022;130:105122.
10. Li J, Zhang M, Sun J, Mao X, Wang J, Liu H, et al. Heavy metal stress-associated proteins in rice and Arabidopsis: Genome-wide identification, phylogenetics, duplication, and expression profiles analysis. Front Genet. 2020;11:477.
11. Sarip SH, Aziz R. Sensory evaluation and quantitative analysis of mineral and heavy metal content of protein supplement incorporated with herbal extract. Malays J Anal Sci. 2017;21(6):1299–306.
12. Horváth IL, Kajner G, Galbács G, Csupor D. Analysis of heavy metal content in protein powders available on the Hungarian market: A reassuring snapshot, but not a reassuring quality guarantee. J Nutr Sci. 2025;14:e49.
13. Bandara SB, Towle KM, Monnot AD. A human health risk assessment of heavy metal ingestion among consumers of protein powder supplements. Toxicol Rep. 2020;7:1255–62.

14. Regulation (EC) No. 1881/2006. EUR-Lex. 2023 [cited 2026 Apr 30]. Available from: https://eur-lex.europa.eu/eli/reg/2006/1881/oj/eng
15. Ali H, Khan E. What are heavy metals? Long-standing controversy over the scientific use of the term 'heavy metals'–Proposal of a comprehensive definition. Toxicol Environ Chem. 2018;100(1):6–19.
16. Kurzius-Spencer M, Burgess JL, Harris RB, Hartz V, Roberge J, Huang S, et al. Contribution of diet to aggregate arsenic exposures—An analysis across populations. J Expo Sci Environ Epidemiol. 2014;24(2):156–62.
17. EFSA Panel on Contaminants in the Food Chain (CONTAM). Scientific Opinion on lead in food. EFSA J. 2010;8(4):1570.

