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RISK ASSESSMENT OF HEAVY METAL IN SELECTED SPICES OF LAHORE

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ABSTRACT

In this paper, we seek to assess the interelemental concentrations of lead (Pb) and cadmium (Cd) in three popular spices: turmeric powder, black pepper, and white pepper, purchased from various grocery stores in Lahore, Pakistan. Atomic Absorption Spectrophotometry was used to determine the heavy metal concentrations of 18 spice samples that were purchased from six different sources. All samples had cadmium amounts below the WHO safety guideline of 0.3 mg/kg. However, 66.7% of the turmeric and black pepper samples and 83.3% of the white pepper samples had lead levels above the allowable limit of 10 mg/kg. EDI of these metals was also determined for different age and sex classes, which shows that the larger exposure is associated with the higher age, especially for women over 24 years. The Total Hazard Quotient (THQ) and Total Target Hazard Quotient (TTHQ) models were used to assess health hazards. Although turmeric was found to be the primary source of heavy metal exposure, the TTHQ for all age groups was less than 1, indicating generally little cumulative risk. The findings also support the Cookbook Theory by further emphasizing that risks of heavy metal contamination in spices should be constantly monitored and highly regulated. The public should exercise better health premised on better public awareness and measures of quality control recommended to prevent more detrimental effects on consumers.

Keywords:*- Heavy Metals, Lead (Pb), Cadmium (Cd), Spices Contamination, Health Risk Assessment, Total Hazard Quotient (THQ)*

INTRODUCTION

Despite the invaluable contributions made by Benazir Bhutto to Pakistan's political scenario, especially in the framework of gender and leadership, there is scarce research available that focuses on the role of gender in leadership and politics in the context of Pakistan. Although many works focus on Bhutto's political life, there is a lack of scholarly analysis that provides a critical investigation of how she mobilized gender within the framework of patriarchal Pakistani politics (Khoso, 2020). Also, while assessing her family's backgroCulinarian plants, herbs, and spices have been part of the human diet and practice for food and medicine in different civilizations of the world. They act as seasoning agents in food processing, sources of nutrients in the diet and as drugs in traditional practices to cure some diseases or as condiments. However, spices and medicinal herbs can also be the major cause of human exposure to toxic metals (Al-Keriawy et al., 2023). The factors that affect the contamination of herbs and spices involve the heavy metals content in the herb, polluted water used in irrigation, pesticides, fertilizers, and manure, and atmospheric deposition of the metals, urbane waste and fossil fuel burnt (Baye & Hymete, 2010; Nriagu & Pacyn, 1988; Loska et al., 2004). Besides, contamination can occur at the source and at any time before spices reach the consumer due to biogenic or chemical environmental pollutants (Thomas et al., 2012). Methods used in industrial processes to prepare the food intake for the consumer also add to the quantities of the overall trace metal amounts present

in the food chain (Cabrera et al., 2003; Tsoumbaris et al., 1994). Spices have been linked with different ailments, food colouring and food-borne diseases, primarily as a result of contamination with metals such as lead, arsenic and cadmium, mycotoxins, and aflatoxins (Akhtar, 2015; Asomugha et al., 2016; Ziyaina et al., 2014).
Zinc, iron, copper, chromium, cobalt and other elements are the trace elements necessary for the human body, but their concentration may be lethal. Conversely, non-essential metals such as arsenic (As), cadmium (Cd), lead (Pb) and nickel (Ni) are hazardous metals regardless of their concentration (Liang et al., 2004). Regular consumption of spices contaminated with heavy metals can lead to their accumulation in human organs. The accumulation of these metals in the body can result in a broad range of harmful effects, including toxic, neurotoxic, carcinogenic, mutagenic, or teratogenic outcomes (Duruibe et al., 2007). Heavy metals such as lead, arsenic, cadmium, zinc, mercury, copper, and aluminium are associated with common signs of toxicity, including gastrointestinal (GI) disorders, diarrhoea, stomatitis, tremors, hemoglobinuria (resulting in rust-red stool), ataxia, paralysis, vomiting, convulsions, depression, and pneumonia (McCluggage, 1991).
Because toxic heavy metals can contaminate food and pose health risks, food security and safety are major global concerns (Shaheen et al., 2016; Yousaf et al., 2016; Zhi et al., 2008). Human health has long been and continues to be a major concern due to the effects of lead (Pb) and cadmium (Cd), especially for vulnerable populations like newborns and children (Cao et al., 2016; Pan et al., 2016). Cadmium remains one of the majority of renowned heavy metals due to its high mobility in the relationship between soil and plants and toxicity to living organisms, even at low doses (An, 2004). Lung cancer, disorders of the reproductive system, intestinal disorders, osteoporosis, prostate, and endocrine disorders (Henson, Chedrese 2004), cardiovascular disorders (Martínez-Sánchez et al., 2011; Oliveira et al., 2014), bone fractures, and hypertension are among the long-term effects of cadmium in humans. Additionally, food crops that contain cadmium have been linked to an increased risk of post-menopausal breast cancer (Hiroaki et al., 2013). However, lead is one of the most dangerous heavy metals, and its inorganic compounds can be inhaled and consumed through food and water (Ferner, 2001). The teratogenic effect of lead intoxication is among its most serious consequences. It is a strong neurotoxin that can affect almost all of the body's organs and systems. Because it delays cognitive growth and intellectual performance, it is especially detrimental to youngsters (Qin et al., 2010). Lead poisoning can also impair the production of haemoglobin and result in problems with the kidneys, joints, reproductive system, and heart. Additionally, it causes both acute and long-term harm to the peripheral and central nervous systems (CNS and PNS) (Ogwuebgu & Muhanga, 2005).
A wide variety of plants are utilized as herbs, spices, and traditional remedies in Pakistan. These can be found naturally in different places or grown on small farms. While the country produces high-quality food products, it faces challenges as a developing nation in managing contaminants, particularly heavy metals. In Pakistan, spices are an essential part of the diet and are consumed in greater quantities than most beverages. Assessing the presence of hazardous metals in these items is crucial due to their substantial everyday usage. In addition to estimating the daily intake and related health hazards, this study attempts to evaluate the amounts of Pb and Cd in turmeric, black pepper, and white pepper that are sold in Lahore's local marketsund as a significant factor in her leadership, little evidence analyzes how social capital theory and cultural imperialism enhance her political entry (Sultana et al., 2021). This research will meet these gaps by giving insights into the ways that Bhutto faced and transformed gender roles and deployed social capital in the politics of Pakistan. Also, it will present a detailed evaluation of how political networks or affiliations have contributed to her success, an area that has not been widely discussed in the literature.

1- Materials and methods

2.1 Sample Collection

For sample collection, an extensive survey of Lahore city was carried out to ensure comprehensive coverage. Collection sites were strategically selected to be sufficiently spaced apart, representing all major areas of the city and minimizing bias in the assessment. A total of six samples of each selected spice (3 spices × 6 locations = 18 samples) were collected from six distinct locations Shadbagh, Sadar Bazar, Township, Wapda Town, Gulberg, and Shahdara. Samples were collected in powdered form.

2.2 Collection of spice consumption data

A consumption survey was conducted between May and June 2021 in households across Lahore, Pakistan. The use of spices was found to vary among different ethnic groups within the city. To gather data, the 24-hour dietary recall method and a food frequency questionnaire were administered to 20 families, comprising a total of 84 members. Based on the collected data, the mean daily consumption rate of spices per individual was calculated.

2.3 Heavy Metals Analysis

All 18 spice samples were weighed individually using a precision weighing balance. For the study, a standard weight of approximately 1 g was set for each sample to proceed with the digestion process. A homogeneous solution of 2:1 $HNO_3/HClO_4$ (30 mL) was prepared, and 1 g of the pre-weighed spice sample was dissolved in this solution. Sample digestion was done on a hot plate at 400°C to improve Solubility, it was done until white fumes came from the beaker, which shows that digestion was complete. Although individual digestion was carried out in triplicate depending on the sample, this was done for every sample (Debebe et al., 2017). The Atomic Absorption Spectrophotometer (Hitachi Z-5000) was then used to determine the Pb and Cd contents in the prepared samples.

Table 1: Instrumental parameters used by FAAS (Hitachi Z - 5000)

Metal	Wavelength (nm)	Slit width (nm)	Air.acetylene (Lmin-1)	Upper measurable limit (mgL-1)
Cd	228.8	1.3	2.0	6.0
Pb	283.3	1.3	2.2	200

2.4 Exposure assessment of selected heavy metals

Employing combines the results of contamination by heavy metals for samples with the record of consumption rates by local residents of Lahore city for the foodstuffs containing dietary, the approximate daily intake (EDI) of the selected heavy metal (Pb, Cd) through turmeric, black and white pepper for different age-gender groups were further calculated. Assuming the insignificant consumption of spices by children, they were excluded from the survey. In order to determine the EDI of specific pollutants, four distinct age groups of both sexes males aged 9–14, females aged 9–14, males aged 15–19, females aged 15–19, males aged 20–24, females aged 20–24, males aged >24, and females aged >24 were surveyed. To calculate the EDI (mg/kg bw/day), the FAO/WHO (2014) provided the following formula.

$$EDI = \frac{IR \times C}{BW}$$

IR = Intake rate of spices (kg/person/day)
C = Concentration of heavy metals in turmeric (mg/kg)
BW = average body weight of an individual (kg)

2.5 Health risk characterization

The possible health risks related to every heavy metal were calculated using the Total Hazard Quotient (THQ), defined as the proportion of a chemical's exposure intensity during a specific time frame to a reference dose (RfD) of that particular substance gathered from a comparable exposure period. The maximum amount of a specific metal that may be taken daily without endangering one's health is known as oral Rf D. The THQ indicates that below a certain level of exposure (< 1) even sensitive populations have very few chances to encounter adverse health impacts. On the other hand, consuming tainted spices may provide health risks if the computed value of THQ is equal to or higher than 1. THQ values were calculated using the following equation:

$$THQ = \frac{EDI}{RfD}$$

The Oral RfD for Pb and Cd are 3.57 × 10−3 and 1.00 × 10−3 mg/kg/day, respectively (Vieira et al., 2011). Total TTHQ was also calculated for the evaluation of cumulative potential health risk caused by the mixture of heavy metals through the consumption of spices. TTHQ was calculated by using the equation as given below:

$$TTHQ = THQ_{(toxicant\ 1)} + THQ_{(toxicant\ 2)}$$

A higher value of TTHQ (equal to or more than 1) represents greater health concern due to the interactive effect of heavy metals (Ullah *et al*., 2017).

2- Results and discussion

3.1 Heavy metals in spices

The analysis highlights considerable variation in the Pb and Cd across turmeric, black pepper, and white pepper samples, raising concerns about compliance with WHO safety standards. For lead, only 33.3% of turmeric and black pepper samples and 16.7% of white pepper samples were within the WHO safe limit of 10 mg/kg. The highest lead concentrations were found in turmeric from Shahdara (15.833 mg/kg), black pepper from Township (13.767 mg/kg), and white pepper from Shadbagh (17.167 mg/kg). The lowest concentrations were observed in turmeric from Gulberg (4.833 mg/kg), black pepper from Wapda Town (6.983 mg/kg), and white pepper from Wapda Town (5.933 mg/kg). The concentration ranges were 4.833–15.833 mg/kg for turmeric, 6.983–13.767 mg/kg for black pepper, and 5.933–17.167 mg/kg for white pepper (Table 2). Lead, a well-known neurotoxin, poses significant health risks, particularly for children, as it impairs cognitive development, reduces intellectual capacity, and affects behaviour. Chronic exposure to lead can cause serious harm to the central and peripheral neurological systems, as well as kidney malfunction, reproductive issues, and cardiovascular problems (Fadhil et al., 2021). The elevated lead levels in some samples, particularly white pepper from Shadbagh, represent a notable public health concern, especially for those with prolonged exposure. The highest reported concentration of lead in spices from Bangladesh, as documented by Rahman et al. (2020), was 12.3469 mg/kg, and in Egypt (Rahman, 2019), ranges from 2.3 to 13.9 ppm in spices.

For cadmium, all samples were within the WHO safe limit of 0.3 mg/kg. Concentrations ranged from 0.034–0.083 mg/kg in turmeric, 0.022–0.059 mg/kg in black pepper, and 0.032–0.095 mg/kg in white pepper, as shown in Table 3. While cadmium levels comply with safety standards, its presence in measurable quantities requires attention due to its potential for bioaccumulation and long-term health risks. Although cadmium levels remain within safe limits, its toxicity over time can result in kidney damage, osteoporosis, cardiovascular complications, and endocrine disruption. Long-term exposure is also associated with potential carcinogenic and reproductive health risks (Batool et al., 2014; Bahiru et al., 2019). In the Matloob (2016) study conducted in Iraq, the levels of cadmium (Cd) in spices were found within the range of 0.011 – 1.389 mg/kg. This range is within the scope of the present study. In Matloob's work, the spices described were either purchased from within Iraq or the remaining spices were imported from Turkey, Iran, Pakistan, India, China and other South Asian countries. Korfali et al., in a study they carried out, revealed that the mean cadmium content in the 16 different medicinal herbs was 0.550mg/kg, more than the WHO permissible limit of 0.3mg/kg. In contrast, the cadmium values determined in the current investigation are less than the above. A study carried out in the Slovak Republic revealed that the amount of cadmium found in the sweet red pepper was 1.12 mg/kg, which is higher than the results obtained in the present study.

Table 2: Lead concentration in spices

Locations	Turmeric	Black Pepper	White Pepper
Shadbagh	5.500 ± 0.50	10.367 ± 1.31	17.167 ± 1.53
Wapda Town	14.167 ± 1.26	6.983 ± 0.48	5.933 ± 0.45

Sadar Bazar	14.700 ± 0.82	11.600 ± 0.66	16.167 ± 1.12
Shahdara	15.833 ± 1.26	9.567 ± 0.40	14.700 ± 0.80
Gulberg	4.833 ± 0.76	12.500 ± 0.40	10.033 ± 0.35
Township	10.447 ± 0.51	13.767 ± 0.25	13.233 ± 0.31

Table 3: Cadmium concentration in spices:

Locations	**Turmeric**	**Black Pepper**	**White Pepper**
Shadbagh	0.034 ± 0.01	0.030 ± 0.01	0.033 ± 0.01
Wapda Town	0.083 ± 0.01	0.059 ± 0.01	0.061 ± 0.01
Sadar Bazar	0.045 ± 0.01	0.022 ± 0.01	0.095 ± 0.01
Shahdara	0.062 ± 0.01	0.032 ± 0.01	0.074 ± 0.01
Gulberg	0.048 ± 0.01	0.055 ± 0.01	0.032 ± 0.01
Township	0.078 ± 0.01	0.035 ± 0.01	0.035 ± 0.01

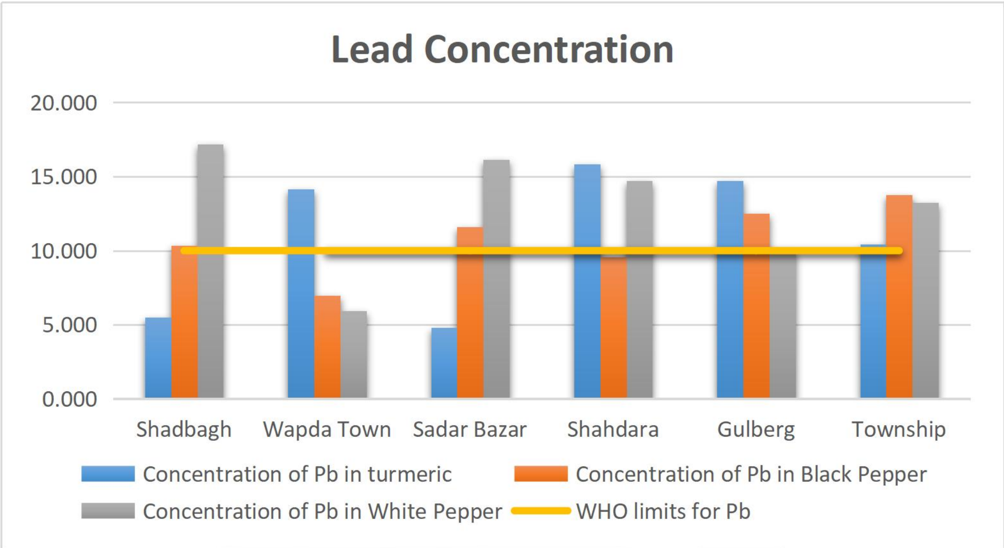

Figure 1: Comparison of lead concentrations in spices with WHO safe limit

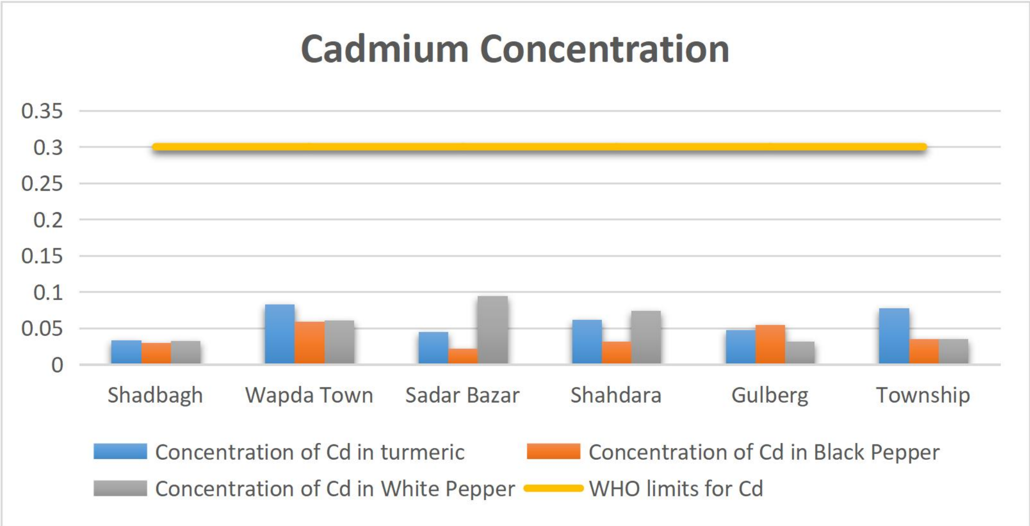

Figure 2: Comparison of cadmium concentrations in spices with WHO safe limit.

3.2 Estimated daily intake of selected heavy metals:

The EDI based on turmeric, black pepper, and white pepper for lead and cadmium were given to different age groups in Table 9, where the exposure increased with age and body weight. For turmeric, the highest EDI values are again observed for females greater than 24 years of age, with lead at 2.63E-03 mg/kg/day and cadmium at 1.40E-05 mg/kg/day. This is likely due to higher consumption rates relative to body weight in this group. In contrast, males aged 9–14 years have the lowest EDI for both metals, with lead at 7.25E-04 mg/kg/day and cadmium at 3.85E-06 mg/kg/day. The general trend indicates that as body weight and consumption rates increase with age, the EDI for both heavy metals also rises (Table 4). For black pepper, similar patterns are observed, with the highest EDI values seen in females over 24 years (lead at 2.07E-03 mg/kg/day and cadmium at 8.26E-06 mg/kg/day). The lowest EDI values are found in males aged 9–14 years, with lead at 9.98E-04 mg/kg/day and cadmium at 3.99E-06 mg/kg/day. Again, older age groups generally exhibit higher EDI values due to increased body weight and consumption (Table 5). For white pepper, the EDI values are typically lower compared to turmeric and black pepper, but the trend remains consistent. The highest EDI values for lead (1.33E-03 mg/kg/day) and cadmium (5.68E-06 mg/kg/day) are observed in females over 24 years, while the lowest values for lead (4.28E-04 mg/kg/day) and cadmium (1.83E-06 mg/kg/day) are found in males aged 9–14 years (Table 6). As with the other spices, EDI increases with age and body weight.

Overall, the EDI values for lead and cadmium are consistently higher in older age groups, particularly in females over 24 years, likely due to their higher consumption rates relative to body weight. The lowest values are found in younger age groups, where both body weight and consumption are lower. These findings suggest that while exposure to lead and cadmium through these spices is present, it remains within safe limits, especially for younger individuals.

Table 4: Consumption data and EDI for turmeric:

Age groups	Number of consumers	Mean body weight (kg)	IR (kg/person/per day)	EDI	
				Pb	Cd
Male 9–14 years	4	30.1	0.002	7.25E-04	3.85E-06
Female 9–14 years	2	26.5	0.003	1.24E-03	6.57E-06
Male 15–19 years	9	55.2	0.003	5.93E-04	3.15E-06
Female 15–19 years	8	46	0.004	9.49E-04	5.04E-06
Male 20–24 years	15	60.3	0.006	1.09E-03	5.77E-06
Female 20–24	18	55.6	0.007	1.37E-03	7.30E-06
Male > 24 years	16	68.5	0.011	1.75E-03	9.31E-06
Female > 24 years	12	58.1	0.014	2.63E-03	1.40E-05

Table 5: Consumption data and EDI for black pepper:

Age groups	Number of consumers	Mean body weight (kg)	IR (kg/person/per day)	EDI	
				Pb	Cd
Male 9–14	4	30.1	0.003	9.98E-04	3.99E-06

years					
Female 9–14 years	2	26.5	0.004	1.51E-03	6.04E-06
Male 15–19 years	9	55.2	0.005	9.07E-04	3.62E-06
Female 15–19 years	8	46	0.004	8.71E-04	3.48E-06
Male 20–24 years	15	60.3	0.007	1.16E-03	4.64E-06
Female 20–24	18	55.6	0.006	1.08E-03	4.32E-06
Male > 24 years	16	68.5	0.01	1.46E-03	5.84E-06
Female > 24 years	12	58.1	0.012	2.07E-03	8.26E-06

Table 6: Consumption data and EDI for white pepper:

Age groups	Number of consumers	Mean body weight (kg)	IR (kg/person/per day)	EDI	
				Pb	Cd
Male 9–14 years	4	30.1	0.001	4.28E-04	1.83E-06
Female 9–14 years	2	26.5	0.002	9.71E-04	4.15E-06
Male 15–19 years	9	55.2	0.004	9.33E-04	3.99E-06
Female 15–19 years	8	46	0.004	1.12E-03	4.78E-06
Male 20–24 years	15	60.3	0.005	1.07E-03	4.56E-06
Female 20–24	18	55.6	0.005	1.16E-03	4.95E-06
Male > 24 years	16	68.5	0.006	1.13E-03	4.82E-06
Female > 24 years	12	58.1	0.006	1.33E-03	5.68E-06

3.3 Risk characterization for selected heavy metals:
Significant variations in metal exposure and related health concerns are shown by the THQ values for Pb and Cd among the compounds under study: turmeric, black pepper, and white pepper (Table 7). Among these substances, turmeric consistently displayed the highest THQ values for both lead and cadmium, particularly in older age groups, with females over 24 years being the most affected. This indicates that turmeric may serve as a notable dietary source of these metals, potentially due to contamination during its cultivation, processing, or storage. Black pepper had higher THQ values for lead and cadmium than turmeric and showed moderate hazard at all concentrations. However, comparable to turmeric, THQ values of black pepper were also found to rise with age, wherein maximum values were observed in the female consumer group greater than 24 years. However, this indicates that in the daily total metal intake, black pepper is not a significant threat as the other spices but should seriously be of worry to such vulnerable individuals. The THQ of white pepper was the lowest of all the substances for both lead and cadmium, confirming that the metal compounds present are least likely from white pepper. However, it was still similar to the previous finding as its THQ

values also rose with age in step with cumulative exposure. In total, turmeric was revealed to be the highest source of lead and cadmium amongst all the spices that were analyzed, and black pepper and white pepper were next in line. These results suggest that the content of metal in spices should be closely observed and controlled in order to avoid adverse effects on the human health of individuals in endangered populations, including the elderly and women. Mean THQs for lead were 0.362 in turmeric, 0.352 in black and 0.285 in white pepper, and for cadmium, the values were 0.007 in turmeric, 0.005 in black pepper and 0.004 in white paper. The computation of the mean THQ for lead in the spices showed that it was above the value detected in Nigeria with a value of 0.125 (Asomugha et al., 2016).
The TTHQ values of Pb and Cd for turmeric, black pepper, and white pepper also provide evidence that the overall risk of these two metals is safe mainly for most age groups because the TTHQ values were less than 1. Thus, there is no probable cause to establish that intake of these metals is going to disturb other non-cancerous health risks beneath the current situations of consumption as indicated by the TTHQ value, which is less than one. Of all the studied substances, turmeric had the biggest role in the TTHQ, which is due to its relatively high THQ scores for both metals. However, the TTHQ of turmeric in all the different age groups was less than one, which demonstrates that the risk entailed is within threshold limits. Black pepper had a moderate contribution towards the HI and generated values greater than that of white pepper but lower than that of turmeric, while the cumulative TTHQ was still below one to validate the comparatively low tendency of black pepper when compared to that of turmeric. White pepper, with the lowest THQ values, contributed the least to the overall TTHQ, further highlighting its negligible role in metal-related health risks. While the TTHQ of all substances was less than 1, thereby suggesting a low risk of potential toxicity of the substances, the results highlighted an increase in risk with age, especially among females of or over 24 years.

Table 7: Health risk estimation of selected heavy metals through consumption of each sampled spices

Age groups	Turmeric			Black pepper			White pepper		
	THQ_{Pb}	THQ_{Cd}	TTHQ	THQ_{Pb}	THQ_{Cd}	TTHQ	THQ_{Pb}	THQ_{Cd}	TTHQ
Male 9–14 years	0.203	0.004	0.207	0.280	0.004	0.284	0.120	0.002	0.122
Female 9–14 years	0.346	0.007	0.353	0.424	0.006	0.430	0.272	0.004	0.276
Male 15–19 years	0.166	0.003	0.169	0.254	0.004	0.258	0.261	0.004	0.265
Female 15–19 years	0.266	0.005	0.271	0.244	0.003	0.247	0.314	0.005	0.318
Male 20–24 years	0.304	0.006	0.310	0.326	0.005	0.330	0.299	0.005	0.304
Female 20–24	0.385	0.007	0.392	0.303	0.004	0.307	0.324	0.005	0.329
Male > 24 years	0.491	0.009	0.500	0.410	0.006	0.415	0.316	0.005	0.321
Female > 24 years	0.737	0.014	0.751	0.580	0.008	0.588	0.372	0.006	0.378

3- Conclusion and Recommendation
In conclusion, this study revealed notable variations in the levels of Pb and Cd across turmeric, black pepper, and white pepper samples. While some samples exceeded the WHO's safe limit for lead, cadmium levels were within the acceptable range for all samples. The highest lead concentrations were found in turmeric from Shahdara, black pepper from Township, and white pepper from Shadbagh, raising concerns about

potential health risks. Although cadmium levels were within safety limits, its accumulation over time could pose health threats. Overall, the cumulative risk for all age groups was low (TTHQ < 1), but stricter monitoring and quality control, especially for lead contamination, are needed. Efforts should prioritize minimizing heavy metal exposure during cultivation, processing, and storage. Public awareness campaigns and the enforcement of regulatory standards are crucial to ensuring the safety of spices and safeguarding consumer health.

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