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Detection of Heavy Metal Levels in Branded and Unbranded Chilli Samples in Hyderabad by using ICP-MS Technique

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ABSTRACT
Samples of chili powders were screened for macro, micro, and heavy metals in and around Hyderabad, Telangana, India. 3 branded samples and 28 unbranded (loose) samples were collected and analyzed. Inductively coupled plasma mass spectroscopy is employed in this work to examine the concentrations of heavy metals like Al, Cr, Mn, Fe, Ni, Cu, Zn, As, Se, Ag, Cd, Ba, Pb, Ca, and Mg. There is a growing emphasis on developing various macro-, micro-, and heavy metal studies to identify contamination levels and safeguard public health. Inductively coupled plasma mass spectroscopy is employed in this work to examine the concentrations of heavy metals. This study aims to determine the level of heavy metals in commonly used spices sold at stores and open markets, as well as estimate health hazard concerns associated with heavy metal intake through spice consumption. Given the significance of this research and its significant connection to human health, a few heavy metals (Al, Mn, Fe, Cu, Zn, Ar, Se, Cd, Ba, Ca,Mg)were observed to be higher than the recommended limits that the FSSAI had authorized.
KEYWORDS: *Chilli powder, heavy metals, ICPMS, FSSAI, human health, and branded and unbranded chili powder samples.*

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I. INTRODUCTION

The term "heavy metal elements" describes metals such as Au, Hg, Pb, and Cr that have a density of more than 4.5 g/cm3. Based on global guidelines, the primary heavy metal elements are Cu, Cd, Pb, Hg, and As.According to reports, metals like magnesium (Mg), manganese (Mn), copper (Cu), iron (Fe), chromium (Cr), molybdenum (Mo), nickel (Ni), zinc (Zn), and selenium (Se) are necessary nutrients for a variety of physiological and biochemical processes (WHO, 1996). Inadequate supply of these micronutrients results in a variety of deficiency diseases or syndromes (WHO, 1996).However, heavy metals can accumulate hundreds of times under the biomagnification of the food chain before entering the human body and actively interacting with proteins and enzymes to render them inactive. Heavy metals cannot be biodegraded. The term "heavy metal elements" describes metals such as Au, Hg, Pb, and Cr that have a density of more than 4.5 g/cm3. Based on global guidelines, the primary heavy metal elements are Cu, Cd, Pb, Hg, and As.Organs and tissues may also accumulate it, leading to a variety of poisoning symptoms. Furthermore, copper plays a significant role in several physiological processes in the human body .The term "heavy metal elements" describes metals such as Au, Hg, Pb, and Cr that have a density of more than 4.5 g/cm3. Based on global guidelines, the primary heavy metal elements are Cu, Cd, Pb, Hg, and As. nd is one of the essential trace metals. The lack of Cu will cause a decrease in brain cytochrome oxidase, which can lead to thinking disorders, slow responses, and dyskinesia. (Wanyue Chen et. al., 2022).Due to the necessity and toxicity of heavy metals, their frequent contamination of food has drawn attention from researchers throughout the past ten years (Al-Eedet et al., 2002). The body needs essential metals like copper, iron, and zinc for proper development, but excessive concentrations are harmful and seriously endanger the health of people and animals. In extremely low quantities, even certain metals like lead, cadmium, etc. are hazardous (A. Marian and C. Opoku Amoako, 2010). The human body won't be harmed by minerals or heavy metals as long as they are present in amounts that are within permissible bounds. But eventually, when they build up to a certain point, the human body will unavoidably suffer irreversible damage. (Guan et al., 2021).Significant investigation is needed to address this matter because these heavy metals may have negative effects on human health, including neurological diseases, immunological defenses, and growth retardation (Mubeen et al., 2009). Overindulgence in heavy metals can have negative effects on human health, including illness in fetuses, mental impairment in youngsters, and premature labor (Inam, Farhin, et al., 2013). Dried plant pieces called spices have been added to food to improve its flavor, color, and agreeableness (Sattar et al., 1989). When heavy metal-contaminated spices are added to food to improve its flavor, these metals may accumulate in human organs and have an adverse effect on health (Singh, K.P., 2004). Important flavor compounds in spices are shown in Table 1. Among all the spices that India exported in 2022–2023, the most was chili powder, presented in Table 2.

Important flavour compounds in spices	
Spice	**Flavour compounds**
Allspice	Eugenol. b-caryophyllene
Anise	(E)-anethole, methyle, chavicol
Bay laurel	1.8-cineole
Black pepper	Piperine, S-3-Carene, b-caryophyllene
Caraway	d-carvone, carone deri vati yes
Cardamom	a-terpinyl acetate. 1-8-cineule. linalool
Cinnamon,cassia	Cinnamaldehyde,eugenol
Chilli	Capsaicin,dihydro capsaicin
Clove	Eugenol, eugeneyl acetate
Coriander	d-linalool. C10-C 14-2-alkenals
Cumin	Cuminaldehyde. p-l.3-mentha-dienal
Dill	d-carvone
Fennel	(E)-anethole, fenchone
Ginger	Gingerol,Shogaol, neral,geranial
Mace	a-pinene,sabinene, 1-terpenin-4-ol.
Mustard	Ally isothiocynate
Nutmeg	Sabinine,a-pinene, myristicin
Parsley	Apiol
Saffron	Safranol
Turmeric	Turmerone,Zingeberene, 1,8-cineole
Vanilla	Vanillin, p-OH-benzyl-methyl ether

Table 1: Flavour Compounds in Spices. **Source: https://www.indianspices.com/spices-development/properties/flavor-profile-spices.html**

ITEM-WISE EXPORT OF SPICES FROM INDIA							(QTY. IN TONNES & VALUE IN Rs. LAKHS)					
	2017-18		2018-19		2019-20		2020-21		2021-22		2022-23(*)	
ITEM	QTY	VALUE	QTY	VALUE	QTY	VALUE	QTY	VALUE	QTY	VALUE	QTY	VALUE
PEPPER	16,840	82,078.48	13,540	56,868.00	17,000	57,370.94	19,980	57,068.74	21,863	75,331.23	17,958	72,686.41
CARDAMOM(S)	5,680	60,908.15	2,850	35,625.00	1,850	42,537.15	6,486	110,346.58	10,571	137,566.95	7,352	87,514.87
CARDAMOM(L)	760	5,646.60	860	6,106.00	1,310	7,090.17	1,220	9,635.74	1,981	15,448.21	1,883	13,720.19
CHILLI	443,900	425,632.74	468,500	541,117.50	496,000	671,039.53	649,815	924,126.56	557,138	858,180.26	516,177	1,044,412.31
GINGER	22,605	21,607.49	18,150	19,602.00	60,410	52,905.00	145,974	84,982.34	147,677	83,651.76	50,885	43,246.06
TURMERIC	107,300	103,567.63	133,600	141,616.00	137,650	128,690.53	183,868	172,264.56	152,758	153,442.05	170,085	166,699.49
CORIANDER	35,185	27,274.96	48,900	35,208.00	47,135	39,831.38	57,359	49,627.93	48,656	48,247.51	54,481	66,501.19
CUMIN	143,670	241,798.78	180,300	288,480.00	214,190	332,806.00	298,423	425,154.66	216,971	334,367.40	186,509	419,359.76
CELERY	6,480	5,950.30	6,100	6,649.00	6,230	6,903.85	7,438	9,815.24	7,579	9,854.19	5,248	7,755.76
FENNEL	34,550	25,906.35	26,250	24,412.50	24,220	23,162.14	33,742	29,396.40	40,139	41,197.20	21,201	31,437.42
FENUGREEK	29,280	12,688.57	27,150	13,846.50	26,570	15,690.38	40,340	26,703.34	32,402	26,285.83	35,055	26,680.17
OTHER SEEDS (1)	22,175	16,045.55	29,740	18,736.20	37,580	22,080.72	68,266	42,629.21	47,167	40,445.48	57,431	48,089.08

GARLIC	46,980	30,936.38	29,500	17,110.00	22,280	17,182.52	17,643	14,971.04	22,135	18,575.04	57,346	24,579.64
NUTMEG & MACE	5,500	22,094.31	3,300	15,015.00	2,900	13,280.00	3,812	19,115.33	3,597	21,798.86	3,447	22,127.57
OTHER SPICES (2)	38,305	65,253.17	43,300	61,486.00	37,235	66,545.96	54,908	88,958.81	109,375	160,236.06	116,269	193,701.29
CURRY POWDER/PASTE	30,150	61,619.55	33,850	74,470.00	38,370	81,278.66	51,347	117,064.38	52,479	115,836.50	57,924	141,689.27
MINT PRODUCTS (3)	21,500	322,834.86	21,610	374,933.50	24,470	383,202.24	27,519	366,713.38	36,254	444,144.18	26,708	357,386.49
SPICE OILS & OLEORESINS	17,200	266,172.39	12,750	219,300.00	13,000	244,682.74	16,997	340,568.76	21,920	447,823.73	18,398	408,551.25
TOTAL(incl others)	1,028,060	1,798,016.24	1,100,250	1,950,581.20	1,208,400	2,206,279.91	1,758,985	3,097,331.96	1,530,661	3,032,432.44	1,404,357	3,176,138.22
VALUE IN MILLION US $		2,789.35		2,805.50		3,110.63		4,178.80		4,068.45		3,952.60

(*) Provisional

(1) INCLUDE BISHOPS WEED(AJWANSEED), DILL SEED, POPPY SEED, ANISEED, MUSTARD ETC.

(2) INCLUDE ASAFOETIDA, CINNAMON, CASSIA, CAMBODGE, SAFFRON, SPICES (NES) ETC.

(3) INCLUDE MENTHOL, MENTHOL CRYSTALS AND OTHER MINT OILS.

SOURCE : DGCI&S., CALCUTTA/DLE FROM CUSTOMS/EXPORTERS' RETURNS UPTO 2019-20. Note:2020-21 onwards figures are taken from DGCIS/MoC only

Table 2: Item-wise Export of Spice from India Source :https://www.indianspices.com/

II. EXPERIMENITAL-MATERIAL AND METHODS

Sample Collection: Different samples of chili powder with a weight of 500 grams were collected from various locations, which included both branded samples and unbranded samples that were given sample numbers 1 to 31, respectively. Among the 31 samples, 3 are branded samples, collected from supermarkets, and 28 are unbranded samples, collected from various open markets in which loose chili powder was obtained. Figure 1 shows the study area, and Table 1 summarizes the location of branded and unbranded samples, respectively. The labeling and location of the collected branded and unbranded chili powder samples are presented in Table 3.

Figure 1: Study Area and Sample Locations

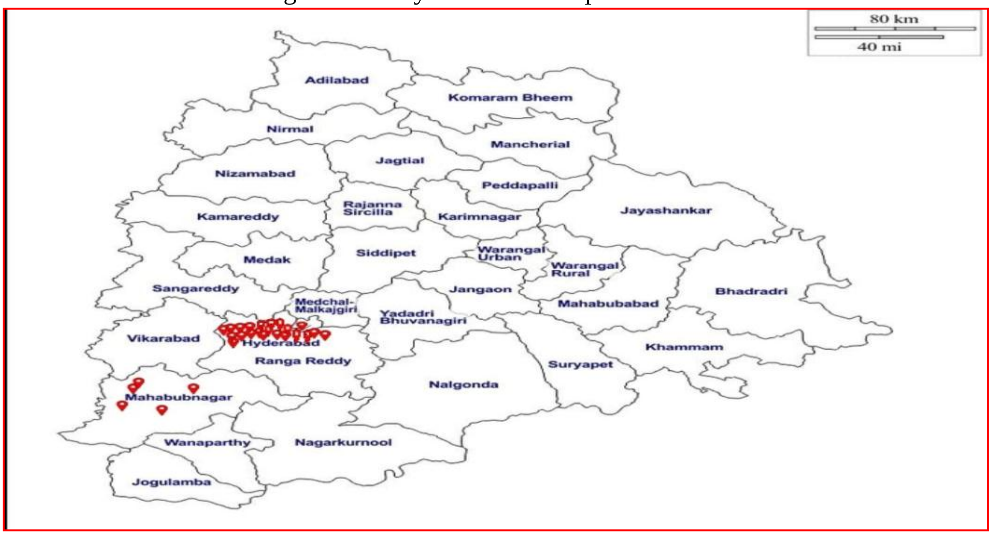

Table 3: Labeling and Location of the Collected Branded and Unbranded Chili Powder Samples

Branded Samples			Unbranded Samples (Loose Chilli Powder Samples)		
Sl.No	**Sample No.**	**Location**	**Sl.No**	**Sample No.**	**Location**
1	6	Sanjay Super Market, Dilsukhnagar	4	1	Mandi,Jiyaguda ,Hyderabad
2	21	Sanjay Super Market, Dilsukhnagar	5	2	Mandi,Jiyaguda ,Hyderabad
3	29	Sanjay Super Market, Dilsukhnagar	6	3	Mandi,Madannapet,Santhoshnagar, Hyderabad
			7	4	Santosh Mirchi Grounding Mill, Mangalhat, Hyderabad.
			8	5	Srinivasa Kirana & General Store, Mangalhat, Hyderabad.
			9	7	Vegetable Market, Mahabubnagar.
			10	8	Puranapul Mandi,Charminar,Hyderabad
			11	9	Mangalhat Mandi,Hyderabad
			12	10	Puranapul,Charminar,Hyderabad
			13	11	Mangalhat,Kamatipura Mandi,Hyderabad
			14	12	Madannapet Mandi,Hyderabad
			15	13	Miralam Mandi,Charminar,Hyderabad
			16	14	Jiyaguda Open Merchant Jiyaguda,Hyderabad
			17	15	shop,Jiyaguda ,Hyderabad
			18	16	New Gunj,Mahabubnagar
			19	17	Rhythu bazar,Mahabubnagar
			20	18	New Gunj ,Malakpet ,Hyderabad
			21	19	Open Merchant,Dilsukhnagar,Hyderabad
			22	20	Miralam Mandi, Charminar,Hyderabad
			23	22	Miralam Mandi, Charminar,Hyderabad
			24	23	Madannapet Mandi, Santoshnagar,Hyderabad
			25	24	Flour Mill, Madannapet X Road, Hyderabad
			26	25	Mandi Open Merchant,Madannapet ,Hyderabad
			27	26	Mandi Open Merchant,Madannapet ,Hyderabad

			28	27	Miralam Mandi, Open Merchant, Charminar,Hyderabad
			29	28	New Market,Mahabubnagar
			30	30	Open Market,Bhoothpur,Mahabubnagar .
			31	31	Open Merchant, Begumbazar, Hyderabad

II. Methodology:

Using the apparatus with a cross-flow nebulizer for Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and the standard operating procedure outlined in the Perkin Elmer NexION 2000 handbook, the samples were examined for multiple elements. Multi-elemental standards were used to analyze the digested samples. High purity, high purity nitric acid, and high purity are checked at 3200 VA using argon gas, whereas helium is used in a collision cell for purity checks. Hydrochloric acid is used in addition to thirty percent hydrogen peroxide. The ICP-MS is calibrated using an HNO3 tuning solution containing 0.5% HCL in order to assess the purity of trace elements. establishing work standards and developing standards with multiple components.Table 4 displays the maximum allowable levels of heavy metals in chili powder.

Table 4. Maximum Heavy Metal Limit Values in Chili Powder

Sl.No	Heavy Metal	FSSAI Max Permissible Limit (PPM)
1	Aluminium	5
2	Chromium	5
3	Manganese	5
4	Iron	5
5	Nickel	5
6	Copper	5
7	Zinc	25
8	Arsenic	0.1
9	Selenium	0.1
10	Silver	0.1
11	Cadmium	0.1
12	Barium	0.1
13	Lead	10
14	Calcium	10
15	Magnesium	10

III. RESULTS AND DISCUSSION

Heavy Metal (Al) Concentration in Chilli Powder as Per FSSAI Standards

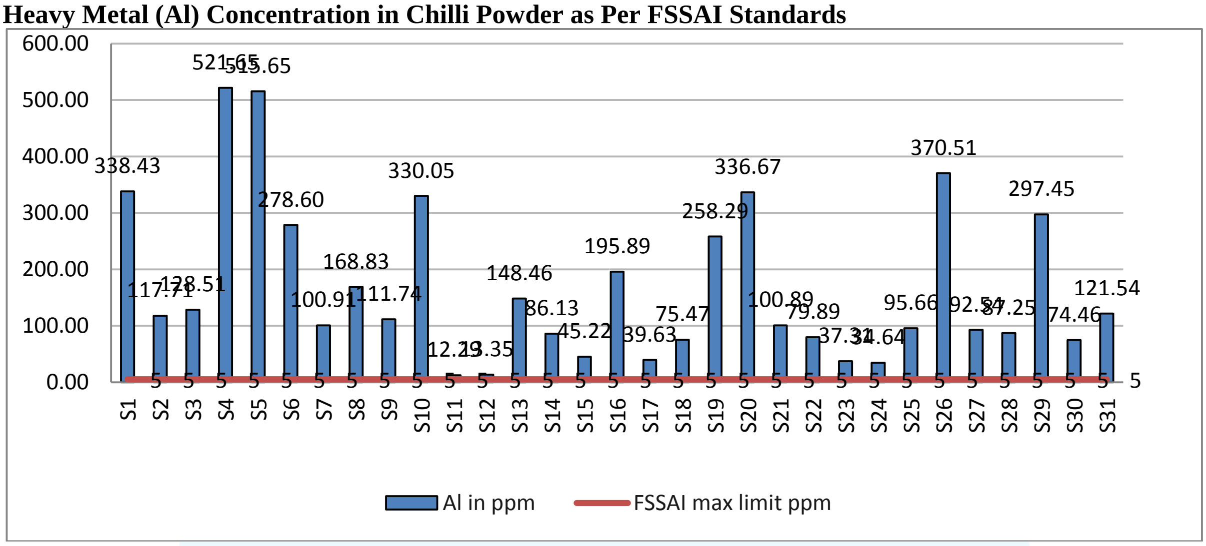

Figure 2: The concentration of heavy metals (Al) in 31 powdered chili samples.

Aluminium (Al): Figure 2 illustrates the prescribed limits provided by the FSSAI Standards, which were found to be exceeded by the aluminum amounts in all thirty samples.

Heavy Metal (Cr) Concentration in Chilli Powder as Per FSSAI Standard

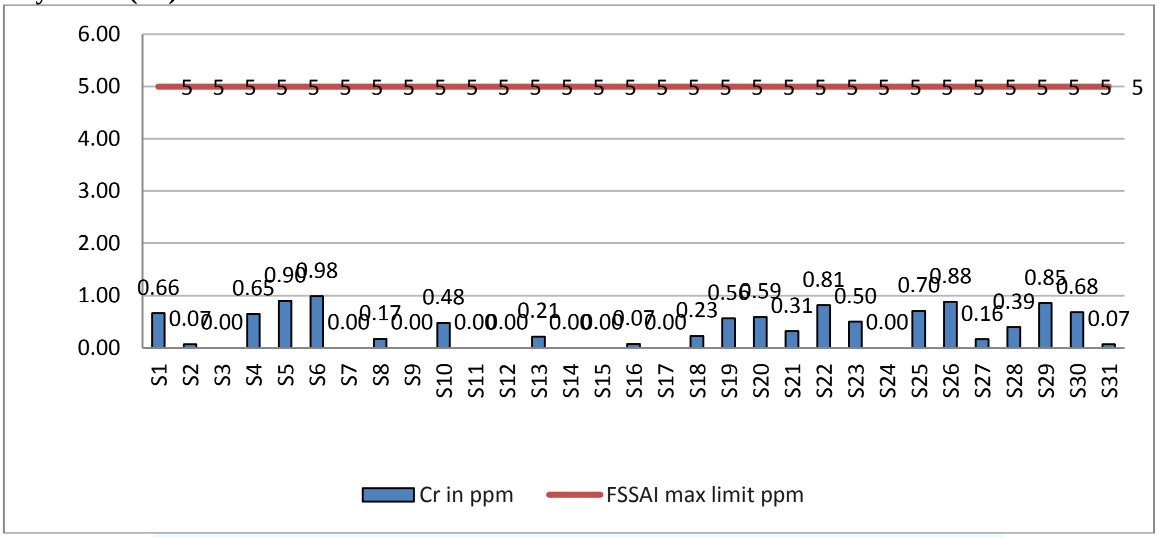

Figure 3: The concentration of heavy metals (Cr) in 31 powdered chili samples.

Chromium(Cr): It has been determined that each of the thirty-one examined samples falls inside the acceptable upper bound. Consequently, none of the study's spice samples are regarded as harmful to health; rather, because there are numerous ways to be exposed, it is believed that the heavy metal levels in chili powder should be carefully checked.

Heavy Metal (Mn) Concentration in Chilli Powder as Per FSSAI Standard

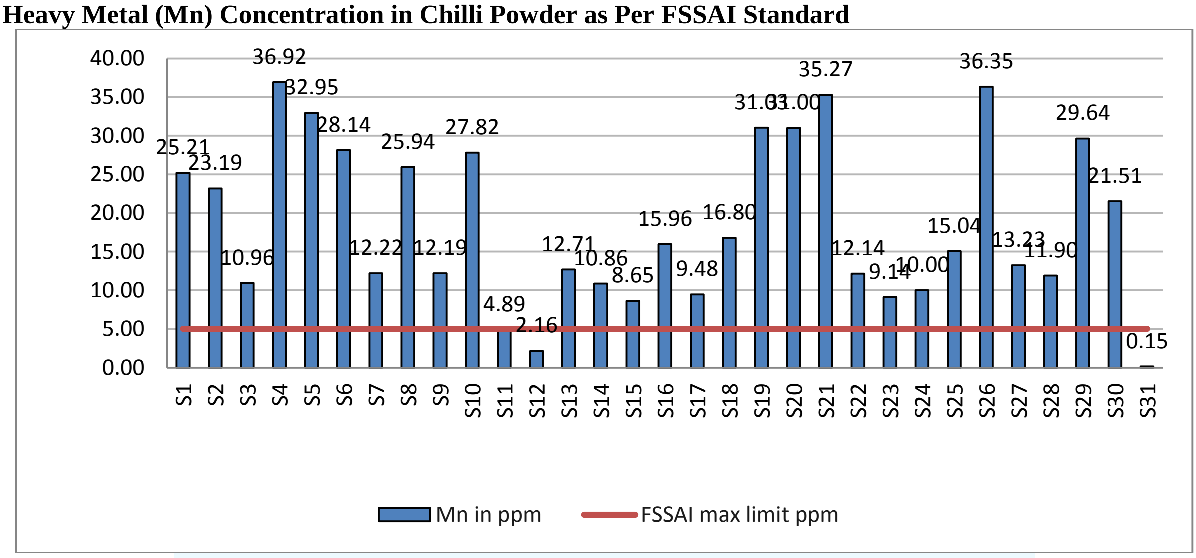

Figure 4: The concentration of heavy metals (Mn) in 31 powdered chili samples.

Manganese(Mn): With the exception of two samples, all thirty samples had manganese amounts over the recom mended limits set forth by the FSSAI Standards, as seen in Figure 4.

Heavy Metal (Fe) Concentration in Chilli Powder as Per FSSAI Standard

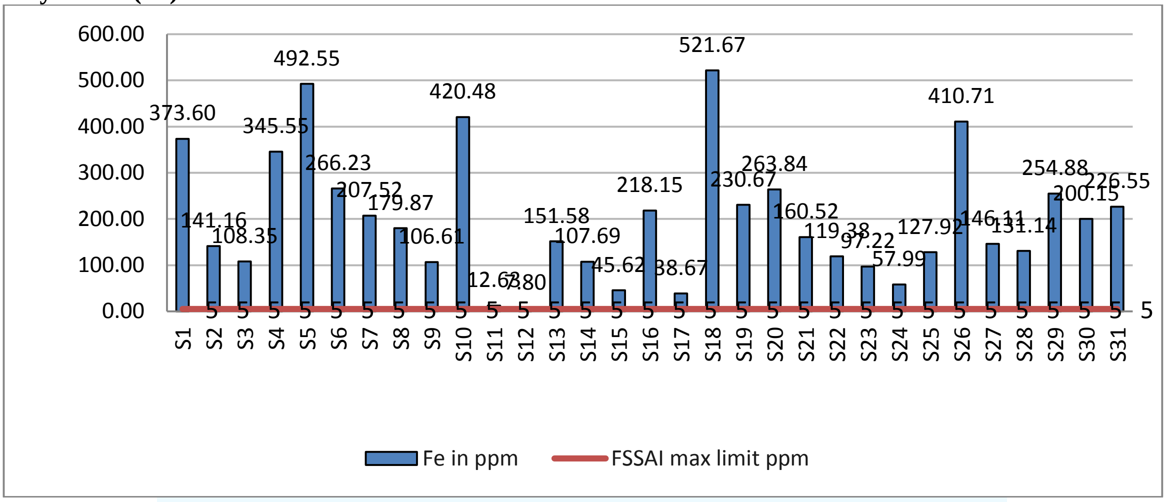

Figure 5: The concentration of heavy metals (Fe) in 31 powdered chili samples.

Iron (Fe): The iron concentrations of all thirty-one samples exceeded the top limits suggested by the FSSAI Standards, as depicted in Figure 5.

Heavy Metal (Ni) Concentration in Chilli Powder as Per FSSAI Standard

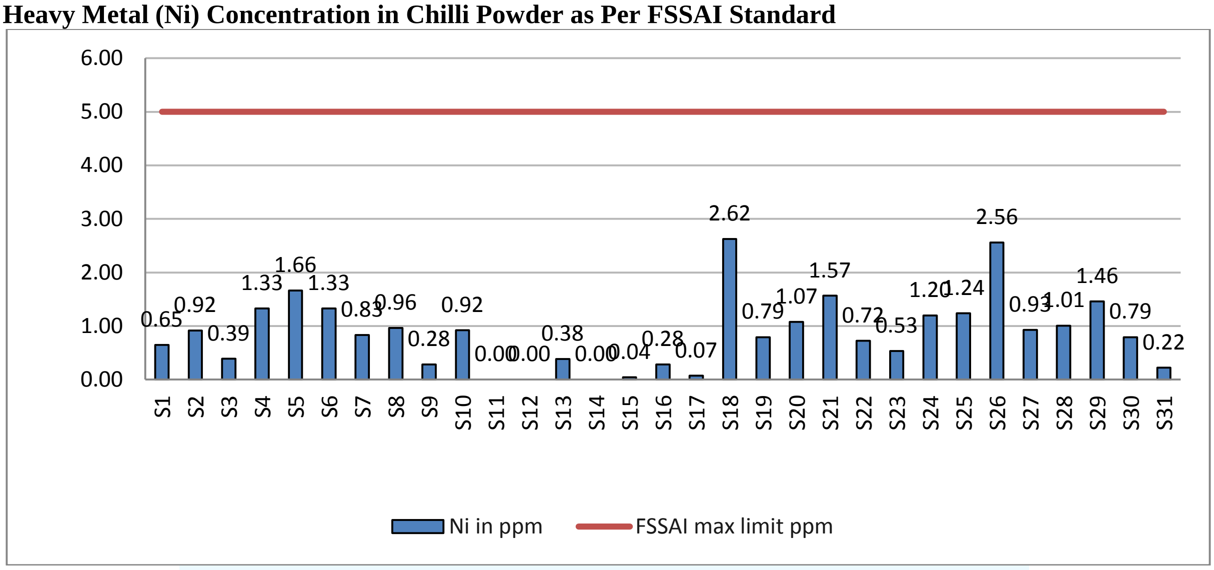

Figure 6: The concentration of heavy metals (Ni) in 31 powdered chili samples.

Nickel(Ni): As shown in Figure 6, the amounts of nickel in all 31 samples were within the FSSAI allowed limits.

Heavy Metal (Cu) Concentration in Chilli Powder as Per FSSAI Standard

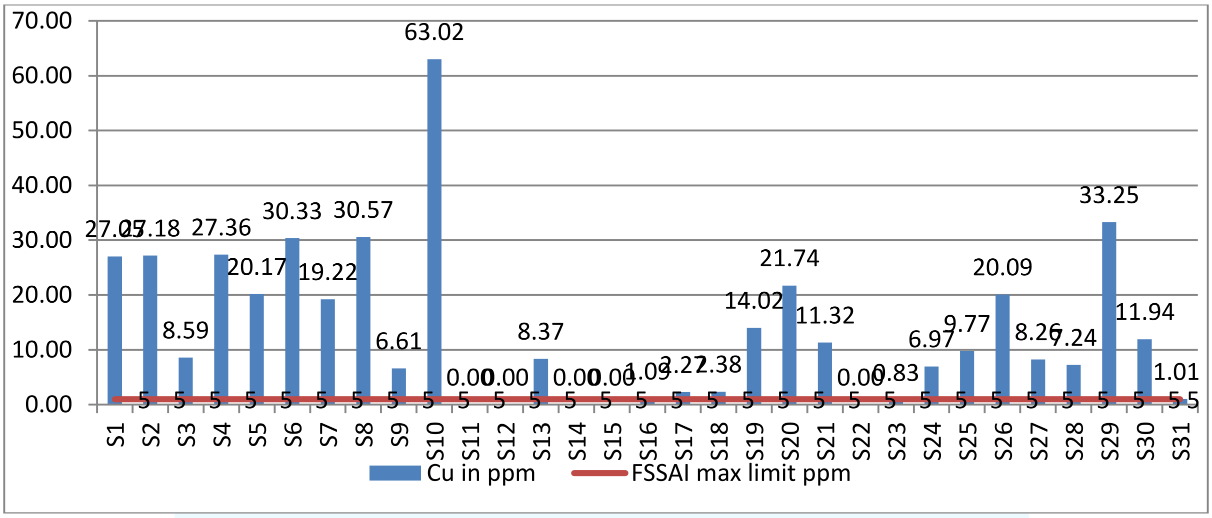

Figure 7: The concentration of heavy metals (Cu) in 31 powdered chili samples.

Copper (Cu) The findings, which are shown in Figure 7, show that, with the exception of Sample Numbers 11, 12, 14, 15, 16, 17, 18, 22, 23, and 31, the copper contents in all thirty-one samples were greater than the recommended limits established by the FSSAI Standard.

Heavy Metal (Zn) Concentration in Chilli Powder as Per FSSAI Standard

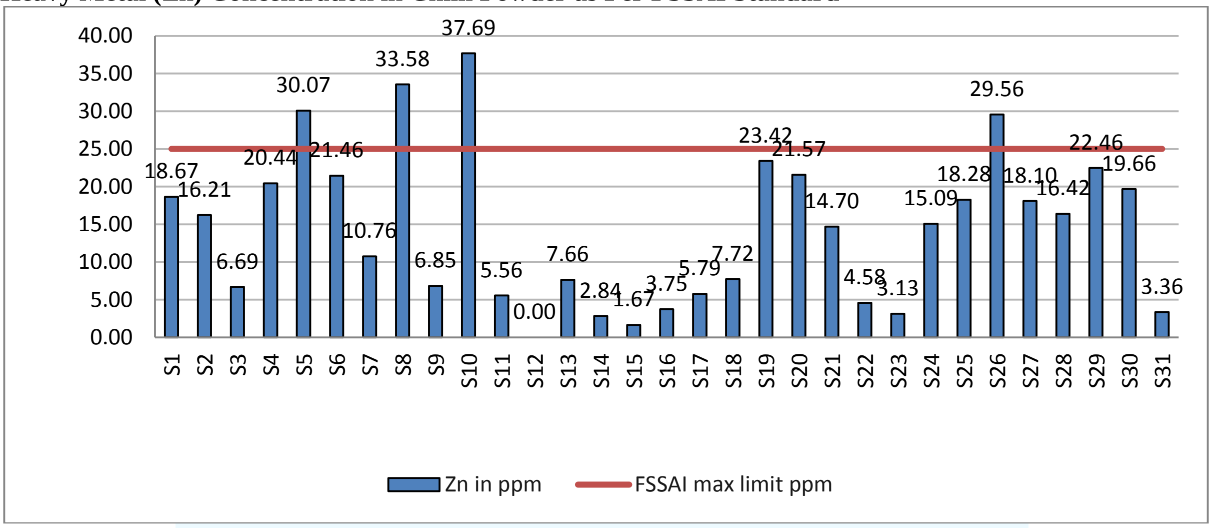

Figure 8: The concentration of heavy metals (Zn) in 31 powdered chili samples.

Zinc (Zn) : Only four of the 31 chili powder samples that were examined—sample numbers 5, 8, 10, and 26—had zinc concentrations that were above the allowable limit as specified by the FSSAI Standards, as illustrated in figure 8.

Heavy Metal (As) Concentration in Chilli Powder as Per FSSAI Standard

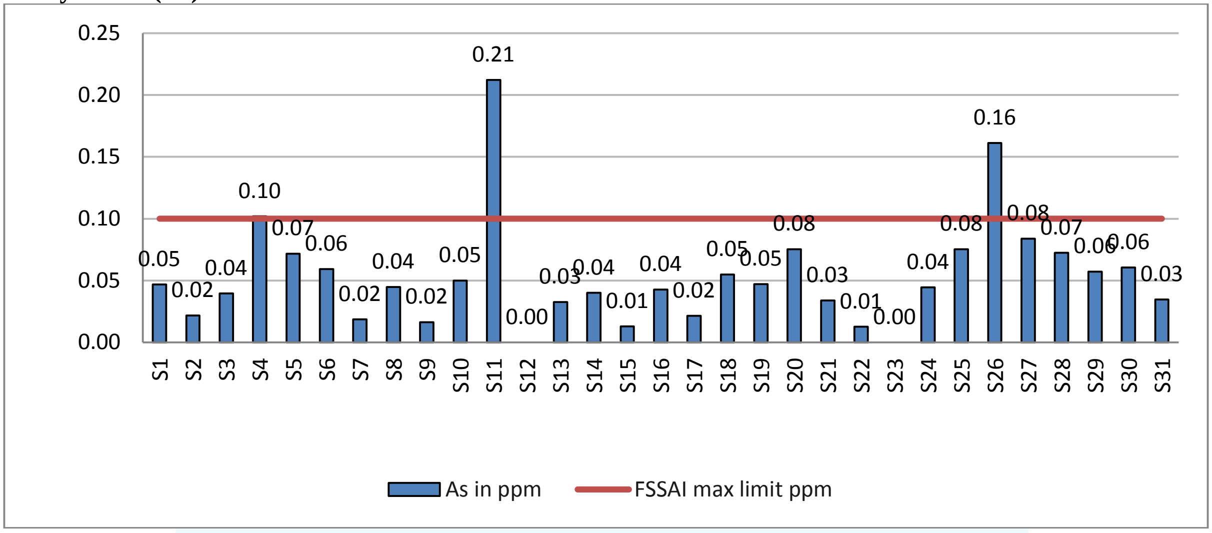

Figure 9: The concentration of heavy metals (As) in 31 powdered chili samples.

Aresenic(As): Of the thirty-one samples that were examined, only two (Sample Numbers 11 and 26) were found to contain arsenic levels over the allowable limit, as indicated by the FSSAI Standards displayed in Figure 9.

Heavy Metal (Se) Concentration in Chilli Powder as Per FSSAI Standard

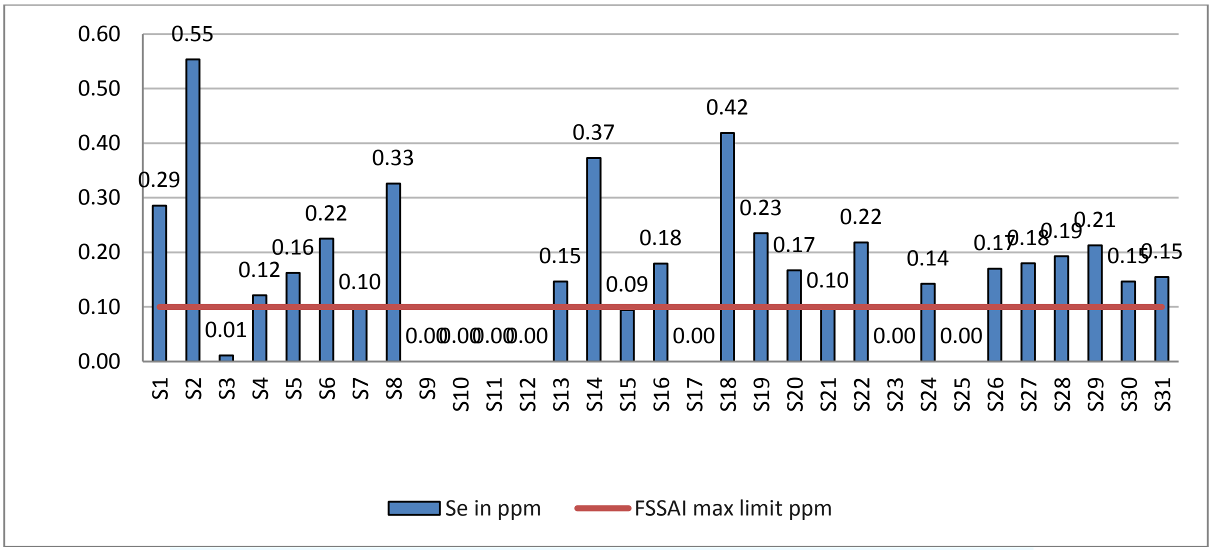

Figure 10: The concentration of heavy metals (Se) in 31 powdered chili samples.

Selenium(Se): Figure 10 shows that twenty of the thirty-one samples have a selenium concentration that is higher than the FSSAI's allowable limits.

Heavy Metal (Ag) Concentration in Chilli Powder as Per FSSAI Standard

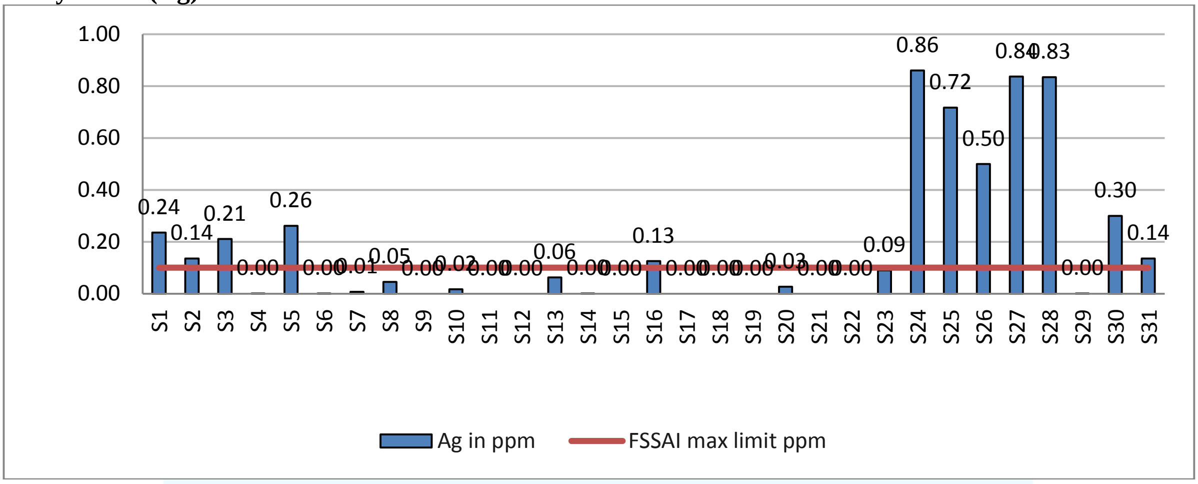

Figure 11: The concentration of heavy metals (Ag) in 31 powdered chili samples.

Silver(Ag): The levels of silver in all thirty samples were found to exceed the FSSAI Standards' specified limits, as depicted in Figure 11.

Heavy Metal (Cd) Concentration in Chilli Powder as Per FSSAI Standard

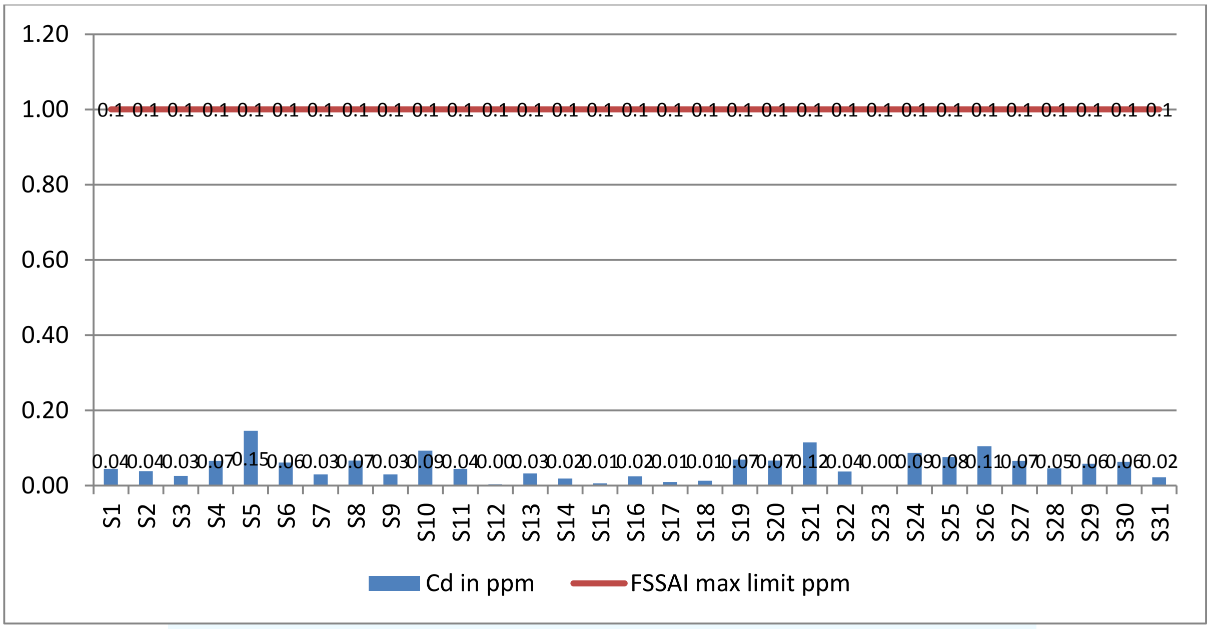

Figure 12: The concentration of heavy metals (Cd) in 31 powdered chili samples.

Cadmium(Cd): As indicated by the FSSAI Standards, all thirty-one of the samples were determined to be within the allowed limit (Figure 12)

Heavy Metal (Ba) Concentration in Chilli Powder as Per FSSAI Standard

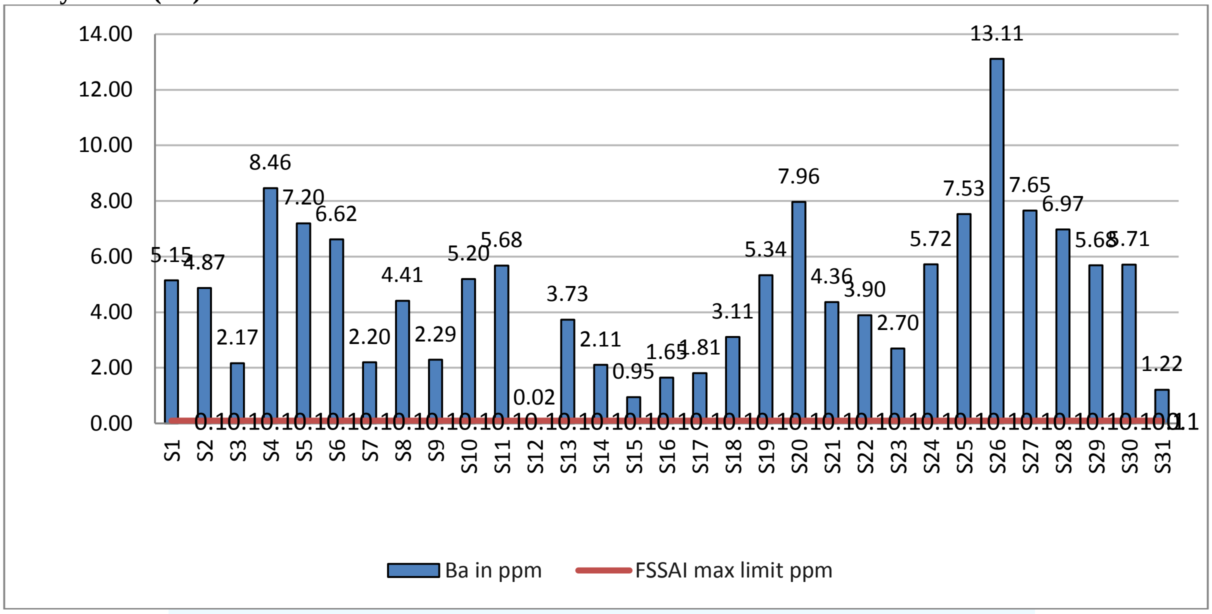

Figure 13: The concentration of heavy metals (Ba) in 31 powdered chili samples.

Barium(Ba): It is clear from Figure 13 that the barium contents in all thirty samples were greater than the recommended upper bounds specified by the FSSAI Standard.

Heavy Metal (Pb) Concentration in Chilli Powder as Per FSSAI Standard

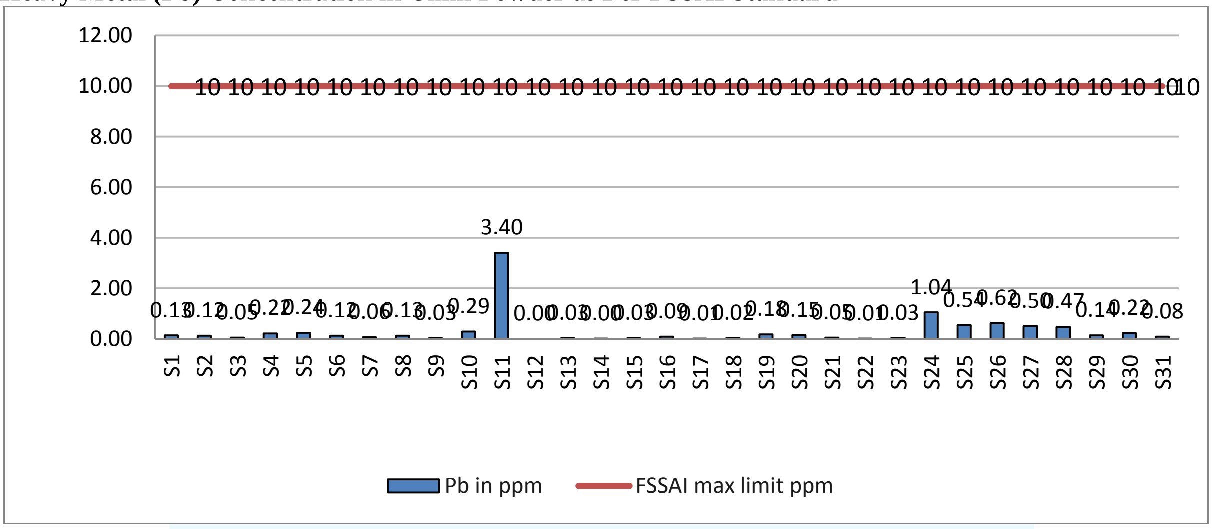

Figure 14: The concentration of heavy metals (Pb) in 31 powdered chili samples.

Lead(Pb): As shown in Figure 14, all 31 samples were determined to be below the allowable level specified by the FSSAI Standards.

Heavy Metal (Ca) Concentration in Chilli Powder as Per FSSAI Standard

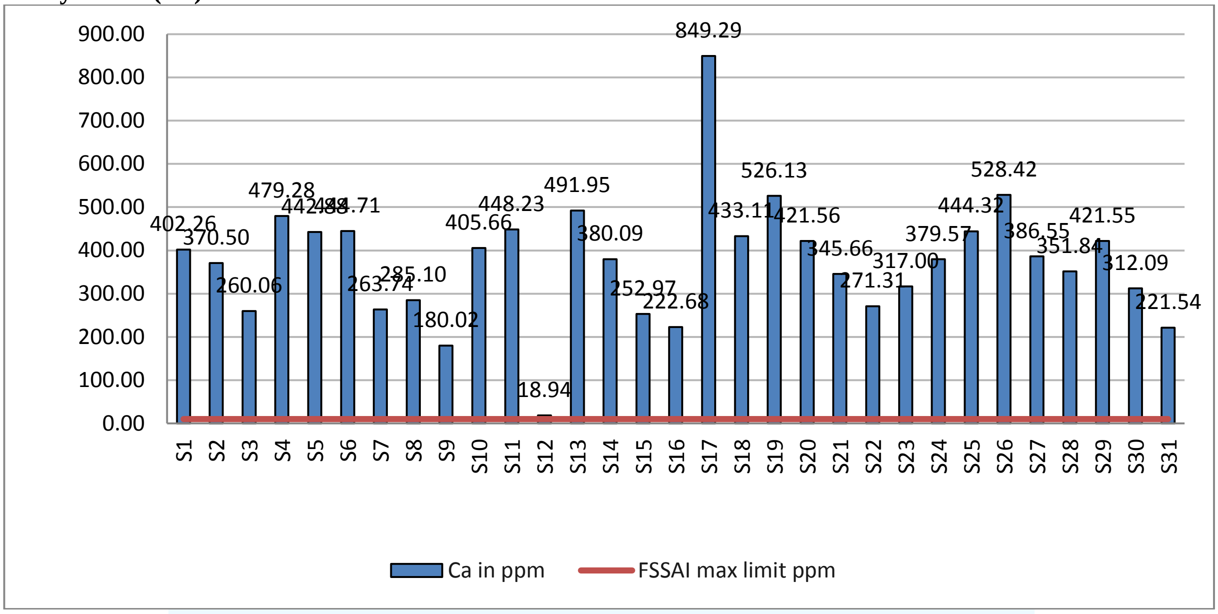

Figure 15: The concentration of heavy metals (Ca) in 31 powdered chili samples.

Calcium(Ca): Figure 15 shows that the quantities of calcium discovered in all 31 samples were greater than those advised by the FSSAI Standard.

Heavy Metal (Mg) Concentration in Chilli Powder as Per FSSAI Standard

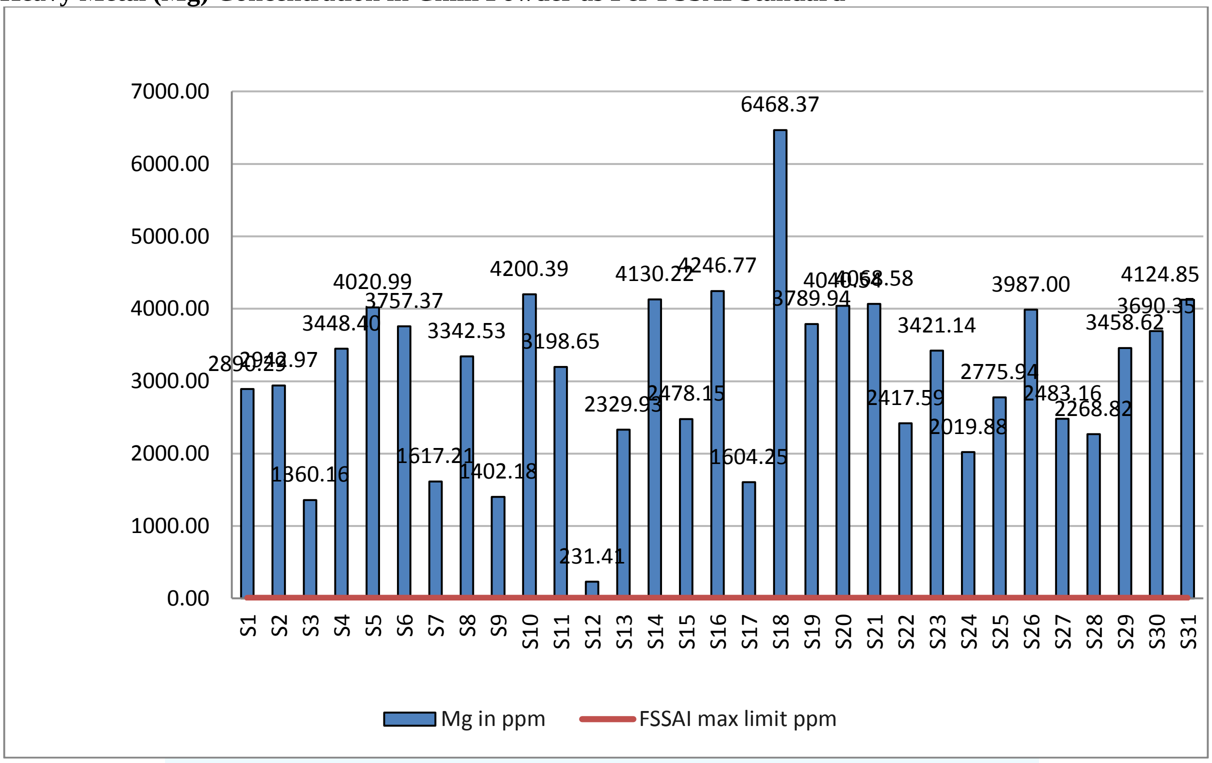

Figure 16: The concentration of heavy metals (Mg) in 31 powdered chili samples.

Magnesium (Mg): All thirty-one of the samples had magnesium concentrations more than the recommended upper bounds established by the FSSAI Standard (Figure 16).

Summary of the Number of Branded and Unbranded Samples That Exceed the Permissible Limit of Heavy Metal Concentration

Heavy Metal	Number of samples that exceed permisible limit of Heavy metal Concentration (in ppm) in Branded Samples	Number of samples that exceed permisible limit of Heavy metal Concentration(in ppm) in UnBranded Samples
Aluminium (Al)	3(S6, S21, S29)	28(S1,S2,S3,S4,S5,S7,S8,S9,S10,S11,S12,S13,S14,S15, S16,S17,S18,S19,S20,S22,S23,S24,S25,S26,S27,S28,,S 30,S31)
Chromium (Cr)	0	**0**
Manganese (Mn)	3(S6, S21, S29)	25(S1,S2,S3,S4,S5,S7,S8,S9,S10,S13, S14,S15,S16,S17,S18,S19,S20,S22,S23, S24,S25,S26,S27,S28,S30)
Iron (Fe)	3(S6, S21, S29)	28(S1,S2,S3,S4,S5,S7,S8,S9,S10, S11,S12,S13,S14,S15,S16,S17,S18, S19,S20,S22,S23,S24,S25,S26,S27,S28, S30,S31)
Nickel (Ni)	0	0
Copper (Cu)	3(S6, S21, S29)	18(S1,S2,S3,S4,S5,S7,S8,S9,S10, S13,S19,S20,S24,S25,S26,S27,S28,S30)
Zinc (Zn)	0	4(S5,S8,S10,S26)
Arsenic (As)	0	2(S11,S26)
Selenium (Se)	2(S6,S29)	18(S1,S2,S4,S5,S8,S13,S14,S16,S18 ,S19,S20,S22,S24,S26,S27,S28 ,S30,S31)
Silver (Ag)	0	12(S1,S2,S3,S5,S16,S24,S25,S26,S27,S28,S30,S31)
Cadmium (Cd)	1(S21)	2(S5,S26)
Barium (Ba)	3(S6, S21, S29)	26(S1,S2,S3,S4,S5,S7,S8,S9,S10,S11, S13,S14,S16,S17,S18,S19,S20,S22, S23,S24,S25,S26,S27,S28,S30,S31)
Lead (Pb)	0	0
Calcium (Ca)	3(S6, S21, S29)	28(S1,S2,S3,S4,S5,S7,S8,S9,S10,S11 ,S12,S13,S14,S15,S16,S17,S18,S19, S20,S22,S23,S24,S25,S26,S27,S28 ,S30,S31)
Magnesium (Mg)	3(S6, S21, S29)	28(S1,S2,S3,S4,S5,S7,S8,S9,S10,S11,S12,S13,S14,S15, S16,S17,S18,S19,S20,S22,S23,S24,S25,S26,S27,S28,S3 0,S31)

Table 5: Summary of the Number of Branded and Unbranded Samples That Exceed the Permissible Limit of Heavy Metal Concentration

The total number of samples that surpass the FSSAI-established acceptable limits for both branded and unbranded samples is summarized in Table 5. Aluminum, manganese, iron, copper, silver, cadmium, barium, calcium, and magnesium heavy metals surpass the FSSAI standards in branded samples, which is harmful to consume. These findings are based on an ICPMS analysis of thirty-one samples. Aluminum, manganese, iron, copper, zinc, esenic, selenium, silver, copper, barium, calcium, and magnesium are over the bounds of detection in the unbranded samples.

IV. DISCUSSION

There were significant differences in the results of the examination of 31 samples of chili powder, including higher levels of heavy metal contamination than what the Food Safety and Standards Authority of India (FSSAI) recommended. The potential health impacts of the samples were also examined in the analysis. According to the ICP-MS data shown in the aforementioned graphs, some macrometals like calcium (Ca) and magnesium (Mg) are present at significantly higher concentrations than other dangerous heavy metals, such as iron (Fe) and aluminum (Al). Heavy metals can accumulate in human bones or adipose tissues through diet, which can compromise immune system performance and result in the body losing essential nutrients. Additional research suggests that certain heavy metals, including Pb, Mn, Al, and Cd, could cause development retardation in utero (Iyengar and Nair, 2000; Turkdogan et al., 2003; Khan et al., 2010; Rai, 2018a).

The results show that, out of the thirty-one samples that were tested, three (S6, S21, S29) were branded samples and twenty-eight (S1, S2, S3, S4, S5, S7, S8, S9, S10, S11, S12, S13, S14, S15, S16, S17, S18, S19, S20, S22, S23, S24, S25, S26, S27, S28, S30, S31) were unbranded samples that exceeded the FSSAI's permissible limits for aluminum concentration. Al has been connected to Alzheimer's disease (AD) via inducing amyloid senile plaques and neurofibrillary tangles in brain tissue. Long-term exposure to elevated aluminum levels can lead to physiological imbalance and deteriorate cognitive function, memory, and reasoning (Chen et al., 2011a).

The analysis has shown that none of the branded or unbranded samples have chromium levels over the recommended range. Hexavalent chromium can cause cancer in humans. Indeed, a substantial amount of evidence suggests that cancer may be linked to chromium (VI) (Locatelli et al., 2014).Cr has an impact on the body's metabolism of fat and sugar.

It is also essential to a healthy metabolism of cholesterol and will cause issues with hepatic lipid metabolism. Obesity and problems with lipid and glucose metabolism have been related to low chromium levels (Yang et al., 2015). Humans with intentionally or unintentionally ingesting extraordinarily high amounts of chromium (VI) compounds have had serious consequences to their neurological, hepatic, renal, gastrointestinal, hematological, and respiratory systems. Thanks to medical intervention, these consequences have been documented to result in survival in certain cases and death in others (ATSDR, 2008). The precise mechanism by which chromium causes cancer is still unknown, despite the fact that there seems to be strong evidence connecting the mineral to cancer in humans and other land animals. (Tang TL and others, 2009).

Thirty-one samples were tested, and the results show that three branded samples (S6, S21, and S29) have higher manganese concentrations than allowed, and twenty-five unbranded samples (S1, S2, S3, S4, S5, S7, S8, S9, S10, S13, S14, S15, S16, S17, S18, S19, S20, S22, S23, S24, S25, S26, S27, S28, and S30) have higher than allowed levels of manganese. People require the element manganese (Mn), yet it has been found that excessive Mn concentrations can affect fetal development during pregnancy by passing via the placenta (USEPA 1999). Mn, Zn, and Cu control not just enzymatic reactions but also the creation of tissues, cell division, and immunity. Zinc is the sole metal present in every category of enzyme (Broadley, M.R. et al. 2007).

Mn is a metal auxiliary group necessary for the activity of superoxide dismutase and a crucial part of the liver antioxidant system.Furthermore, Mn directly affects reproduction; it can enhance human development and growth, enhance reproductive health, and stimulate the formation of cholesterol (Yu et al., 2015).

The outcome demonstrates that none of the branded or unbranded samples exceed the acceptable levels of nickel.The results show that, out of the thirty-one samples that were tested, three (S6, S21, S29) were branded samples that had an aluminum concentration above the allowable limit, and twenty-eight (S1, S2, S3, S4, S5, S7, S8, S9, S10, S11, S12, S13, S14, S15, S16, S17, S18, S19, S20, S22, S23, S24, S25, S26, S27, S28, S30, and S31) were unbranded samples that exceeded the FSSAI's limits. Iron is a mineral that the human body need for hematopoiesis, growth and development, the manufacture of cytochrome, myoglobin, hemoglobin, and other enzymes, and the circulation of nutrients and oxygen (Guo et al., 2015). Apart from being an essential element, iron (Fe) plays a crucial role in controlling body weight, which is essential in certain illnesses (diabetes). In smaller amounts, Fe also aids in the oxidation of lipids, proteins, and carbohydrates (Selim, A. I. et al., 1994).

Three branded samples (S6, S21, and S29) out of the thirty-one tested samples have exceeded the permissible limit for copper concentration, according to the results, and eighteen unbranded samples (S1, S2, S3, S4, S5, S7, S8, S9, S10, S13, S19, S20, S24, S25, S27, S28, and S30) have exceeded the FSSAI's limits. Copper (Cu) is another essential metal involved in several metabolic processes. However, copper is dangerous at higher amounts and mostly harms the kidneys and blood (S. Lakshmanasenthil et al., 2013; X. Guoqiang et al., 2011). At higher levels of deposition, copper results in liver and renal problems; at lower amounts, however, it causes nausea, vomiting, headaches, and diarrhea. As to USEPA (1999), copper has a role in the oxidative defense system. The oxidative stress-related enzymes ferroxidases, catalase, superoxide dismutase, peroxidase, cytochrome c oxidases, monoamine oxidase, and dopamine β-monooxygenase all require copper as a necessary co-factor.

From the results, it can be seen that, out of the thirty-one samples that were tested, none of the branded samples had zinc concentrations over the allowable limit, and four of the unbranded samples (S5, S8, S10, and S26) had levels above the FSSAI-established threshold. An essential element is zinc. More than 300 enzymes have been found to be impacted by zinc, which participates in their structural processes and is important for their growth as well as their catalytic and regulatory roles. Zinc insufficiency has been related to hypogonadism and growth retardation. There are numerous theories as to how growth retardation and hypogonadism are brought on by a zinc deficiency.

Out of the thirty-one samples that were tested, none of the branded samples had zinc amounts over the permitted limit, and four of the unbranded samples (S5, S8, S10, and S26) had levels above the threshold set by the FSSAI, according to the results. Zinc is a vital element. Zinc has been shown to affect over 300 different enzymes. Zinc has a structural role in many enzymes as well as being critical for their proliferation, catalysis, and regulatory functions. Hypogonadism and growth retardation have been linked to zinc deficiency. Many ideas exist on the mechanism by which a zinc deficit causes hypogonadism and development retardation. Zinc has an effect on growth hormone (GH) metabolism.On the other hand, growth hormones have an effect on zinc metabolism. Other possible impacts of zinc deficiency include gonadal and bone metabolism (Nishi, 1996). Zinc is an essential component of many other enzymes in the human body and aids in the synthesis of DNA and RNA polymerase. It has a major role in maintaining the integrity of the skin and mucosa and aids in the healing of wounds. It can also increase lymphocyte function and remove oxygen-free radicals from the body. It has anti-cancer properties as well as the ability to prevent viral and bacterial infiltration. According to Wang and Jin (2018), exposure to zinc causes epithelial cells to become carcinogenic, while insufficient zinc in the body causes immune system degradation and tissue cell aging. As one of the necessary trace elements for both humans and animals, zinc (Zn) can cause copper shortage at high quantities and provoke nausea, vomiting, diarrhea, and stomach pain at low concentrations (Maria C. Linder et al., 1996). Zinc is an essential element for human growth and development. It can help to fortify the immune system in people. Increased quantities of zinc can cause anemia, sterility, skin rashes, diarrhea, vomiting, nausea, and problems with the gastrointestinal, respiratory, and blood systems... However, abnormal physiological issues like as anemia, hypogonadism, and dwarfism might result from a zinc deficit (GG. Ibrahim et al., 2012; B. Abera et al., 2017).

Twenty-one of the unbranded samples (S11, S26) had amounts of arsenic over the FSSAI-established threshold, but none of the thirty-one branded goods had concentrations above the permissible range, according to the results. Arsenic inhibits a number of mitochondrial enzymes, which hinders cellular respiration.It also breaks the link between oxidative phosphorylation and arsenic poisoning. Most of the toxicity of arsenic comes from its ability to replace phosphorus in a variety of metabolic processes and interact with the sulfhydryl groups of proteins and enzymes (Wang Z and Rossman TG, 1996). Overexposure to arsenic (As) in food crops, soil, and groundwater can cause a host of health problems, including cancer, dermatitis, respiratory disorders, and neurological, hematological, hepatic, renal, neurological, developmental, reproductive, and immune system disorders (Chiou et al., 1995; Kapaj et al., 2006; Hartley and Lepp, 2008; Hu et al., 2013; Lin et al., 2013; Liu et al., 2013; Zhou et al., 2016; Islam et al., 2017; El-Kady and Abdel-Wahhab, 2018).

Based on the test results, it can be observed that out of the thirty-one samples tested, two (S6,S29) branded samples have been found to have a selenium concentration above the permissible limit, and eight (S1,S2,S4,S5,S8,S13,S14,S16,S18,S19,S20,S22,S24,S26,S27,S30,S31) unbranded samples have exceeded the FSSAI's limits.Se is a crucial part of red blood cell antioxidant glutathione peroxidase, which is a non-specific antioxidant. Its primary job in the human body is to eliminate peroxides and free radicals. It also helps treat diabetes, heart disease, cancer, and other illnesses. Liver damage and illness can quickly result from a shortage (Zhao et al., 2017a).

The results show that, out of the thirty-one samples that were tested, none of the branded samples had silver concentrations over the allowable limit, while 12 unbranded samples (S1, S2, S3, S5, S16, S24, S25, S26, S27, S28, S30, S31) had levels above the FSSAI's guidelines. Human Ag poisoning causes severe harm to the central nervous system and paralyzes the limbs. Huo et al. (2016) claim that exposure can result in varied degrees of cirrhosis, fibrosis, liver damage, and even liver cancer. In severe cases, it may cause cardiac failure and even death.

The results show that, out of the thirty-one samples that were tested, one branded sample (S21) has a cadmium concentration that is above the allowable limit, and two unbranded samples (S5, S26) have a concentration that is over the FSSAI's guidelines. Cadmium is a dangerous heavy metal and a non-essential trace element in the human body. The majority of the time, plants take it in exchangeable and water-soluble forms, which are then either boosted directly into the human body through the respiratory and digestive systems or through the food chain, where it accumulates over time and compromises the organs' ability to function. Some of the specific signs include lung injury, kidney failure, gastrointestinal stimulation, cardiovascular and cerebrovascular disorders, bone pain, muscular soreness, and bone atrophy. Long half-lives in the body, mutagenic and carcinogenic effects, and irreversible damage are additional symptoms(Guan et al., 2021).

Cadmium is toxic if ingested or inhaled, irritating the lungs and digestive tract. According to Baselt RC and Cravey RH (1995), symptoms of acute intake typically appear 15 to 30 minutes after ingestion and include burning feelings in the belly, nausea, vomiting, salivation, muscle cramps, vertigo, shock, loss of consciousness, and convulsions. Acute cadmium poisoning can also cause unconsciousness, lung, hepatic, or renal damage, as well as gastrointestinal tract erosion, depending on the route of poisoning (Baselt RC and Cravey RH, 1995; Baselt RC, 2000). Long-term cadmium exposure lowers levels of norepinephrine, acetylcholine, and serotonin (Singhal RL et al., 1976).Cadmium exposure over time causes lung adenocarcinomas, according to rodent study (Waalkes MP et al., 1995; Waalkes MP et al., 1996). Furthermore, prostatic proliferative lesions, including adenocarcinomas, may arise from systemic or direct exposure (Waalkes MP et al., 1992).

The results indicate that, out of the thirty-one samples that were tested, three—the S6, S21, and S29 branded samples—have a barium concentration above the allowable limit, and twenty-six—the S1, S2, S3, S4, S5, S7, S8, S9, S10, S11, S13, S14, S16, S17, S18, S19, S20, S22, S23, S24, S25, S26, S27, S28, S30, and S31—the unbranded samples—have exceeded the FSSAI's limits. Large doses of barium compounds that dissolve in water or the stomach can be consumed by humans and result in paralysis or abnormal cardiac rhythms. (The profile of barium and its compounds in terms of toxicity.) Animal studies provide the majority of the information about potential health effects of barium exposure. This information encompasses metabolic, neurological, cardiovascular, and kidney issues (Peana, M., et al., 2021).

The analysis has shown that all of the branded and unbranded samples do not exceed lead requirements. Many illnesses, such as low IQ, neurological problems, reproductive problems, irreversible brain damage, and severe anemia, have been related to lead exposure. According to the United States Public Health Service's Agency for Toxic Substances and Disease Registry, fruits, vegetables, and grains are the primary food sources of lead exposure for the general population (McNamara, 2008).

Pb has the ability to cause apoptosis in brain cells and block the function of brain cell enzymes, which can disrupt calcium metabolism, protein kinase activity, and neurotransmitter metabolism. Postural coordination deficits may result from exposure to lead (Shen et al., 2017). Chronic poisoning from prolonged arsenic exposure can cause leucopenia or anemia, as well as skin pigmentation, hyperkeratosis, or verrucous hyperplasia (Huo, T. et al., 2016).Age and physiological state are the two elements that affect lead absorption. The human body absorbs lead first from the kidneys, with the liver and other soft tissues such as the brain and heart following suit. However, the bulk of lead in the body is located in the skeleton (Flora SJS et al., 2006). The nervous system is the organ system most vulnerable to lead toxicity. Headache, short attention span, irritability, memory loss, and dullness are among the early indicators of lead exposure's effects on the central nervous system (CDC) (ATSDR, 1999).

Out of the thirty-one samples that were tested, the results show that three branded samples (S6, S21, and S29) have exceeded the allowable limit for calcium concentration, and 28 unbranded samples (S1, S2, S3, S4, S5, S7, S8, S9, S10, S11, S12, S13, S14, S15, S16, S17, S18, S19, S20, S22, S23, S24, S25, S26, S27, S28, S30, and S31) have exceeded the FSSAI's guidelines. Ca is a necessary element for mammals. It is essential for maintaining the physiological function of the liver in addition to supporting blood coagulation, nerve conduction, and the activation of specific body enzymes(Yu and colleagues, 2015).

Out of the thirty-one samples that were tested, the results show that three (S6, S21, and S29) branded samples have a magnesium concentration that exceeds the allowable limit, and 28 (S1, S2, S3, S4, S5, S7, S8, S9, S10, S11, S12, S13, S14, S15, S16, S17, S18, S19, S20, S22, S23, S24, S25, S26, S27, S28, S30, and S31) unbranded samples have higher than the FSSAI's guidelines. Magnesium aids in the contraction of muscles, the production of proteins, the excitability of neurons, the integrity of nucleic acid structures, and the regulation of body temperature. Moreover, it can activate a wide range of enzymes. Magnesium is an essential trace element that the body needs to function. It binds to proteins, enzymes, hormones, and vitamins to control a variety of bodily functions. Yu and colleagues, 2015).According to Khadi et al. (1987), the ascorbic acid level may be impacted by an excess of magnesium (Mg) present in all the samples.

V. CONCLUSION

The findings indicate that, with the exception of a small number of metals in both branded and unbranded samples, the majority of spices available at Hyderabad's local market are not significantly polluted with heavy metals. As long as people take spices in moderation, there are no negative consequences; nevertheless, excessive use of spices increases the risk of health problems. Regularly testing spice samples is also advised.It is advised to regularly test spice samples because chili powder is the Indian spice that is exported the most.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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