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Research Article

Evaluated Daily Intake and Health Risk Assessment of Some Toxic Heavy Metals in Baby Powder for Various Brands Marketed in Benghazi, Libya

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ABSTRACT

Baby powder is a popular baby care product that is used to keep the baby's skin dry and prevent the development of dermatological conditions. Recently, there has been growing scientific interest about the presence of toxic heavy metals in baby powder that has led to concerns regarding its potential effects on human health and the environment. In this study, sixteen baby powder brands that are widely in demand at various pharmacies located in Benghazi were collected in November 2024. First, metals, including aluminium, cadmium, chromium, copper, lead, and nickel, were analyzed in the selected samples using atomic absorption spectrophotometry after a suitable digestion process, followed by the evaluation of health risks across the age groups for infants by the calculation of the chronic daily intake (CDI) that is measured in mg/kg/day from dermal absorption, target hazard quotient (THQ), hazard index (HI), and carcinogenic risk (CR). In regard to heavy metal toxicity, Al, Pb, Ni, Cu, Cr and Cd in all examined baby powders were above the permissible threshold established by the United States Food and Drug Administration (FDA). The findings indicate that periodic monitoring and quality control of baby powders is necessary to meet safety standards and protect infant health. Further, the result of non-carcinogenic and carcinogenic risk estimates was lower than the limits of safe risk (HQ and HI > 1 and cancer risk CR < 1×10^{-4}), suggesting no potential lifetime cancer risk.

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1. Introduction

The widespread daily use of personal care products and cosmetics that may contain heavy metals as impurities in its ingredients such as lead, chromium, and cadmium represent a growing public health concern [1]. Cosmetic products are part of everyday personal care practices and encompass a broad spectrum of formulations, including skincare formulations, personal hygiene products, fragrances, and talcum powders. These products are routinely applied directly to the skin and face with the aim of enhancing or altering physical appearance, in consequence increasing the chance of repeated and prolonged human exposure to potentially toxic constituents. The presence of metals in cosmetics can be attributed to three possible sources: the primary ingredients themselves, color additives, or metal-coated equipment utilized during manufacturing [2].

According to the United States Food and Drug Administration (FDA), cosmetics are defined as products intended for external application to the human body for cleansing, beautifying, promoting attractiveness, or altering appearance, without affecting the structure or physiological functions of the body [3]. This broad definition requires the safety of all ingredients used in cosmetic products. The United States researchers identified approximately 10,500 industrial chemicals, that used to prepare cosmetic products, including pesticides, carcinogens, reproductive toxins, endocrine disruptors, surfactants, degreasers, and plasticizers [4]. Among these substances, toxic heavy metals such as lead, nickel, arsenic, chromium, cadmium, and mercury were detected in various cosmetic products, showing toxic effect on human health, even at low concentrations [5,6,7].

Exposure to heavy metals in cosmetics can vary depending on the product type and usage patterns. While some products, such as shampoos and toothpaste, are rinsed shortly after application, others including lipsticks, body lotion, and talcum powders are often applied over large surface areas and remain in contact with the skin for particular amount of time [8], which increase the potential for dermal absorption and may also facilitate inhalation or incidental ingestion. The primary route of exposure for heavy metals in cosmetic products is through dermal absorption, with ingestion and inhalation being the secondary routes. Consequently, long-term or intensive use of contaminated cosmetics may lead to cumulative exposure and pose significant risks to human health and the environment. [9]. The baby talcum powder is a cosmetic product that, commonly used for infants and children to prevent diaper rash and maintain skin dryness due to its moisture absorbing properties and its ability to reduce friction [9] where talc is the primary ingredient of baby powder and it is produced by finely grinding talc, an extremely soft mineral derived from magnesium rich rocks through multiple processing stages. Heavy metals are naturally occurring elements on the earth, which are constituents of groundwater or soil. Due to industrialization and an increase in living standards, several anthropogenic sources have made water and soil polluted, thus containing heavy metals. Through mining and processing of talc, the powder may become contaminated with heavy metals.

Infants represent a highly vulnerable population owing to the incomplete development of their immune and detoxification systems, making them more susceptible to toxic effects. Furthermore, talc products contaminated with heavy metals are believed to be associated with increased carcinogenic risks, as these metals can act as carcinogenic agents [10].

Most of the studies have investigated heavy metal contamination in cosmetic products, most have focused primarily on determining heavy metals concentrations rather than assessing associated health risks. For instance, Omenka and Adeyi (2016) analyzed levels of heavy metals in a variety of cosmetic and personal care products, the result showed that the content of cadmium, lead, and nickel were above the permissible limits in cosmetic products [11]. Similarly, studies in Libya, focused on examine heavy metals in cosmetic products. For example, Rahil et al. (2016) examined heavy metals concentration including Fe, Cu, Cr, Zn, Pb and Cd in 25 cosmetic samples marketed in Benghazi, based on their

study, the results demonstrated that the concentrations of Pb in one sample and Cd in twenty samples were above permissible limits in cosmetic products by certain companies [12]. Another, study in Tripoli (2023) analyzed selected cosmetics (including only three brands of baby talcum powder) was marketed in Tripoli, Libya, detected varying levels of heavy metals such as lead (Pb), arsenic (As), cadmium (Cd), and nickel (Ni). Base on their study that all samples possessed high amount of Pb prohibited by European regulation [13]. On the other hand, a few studies were focused primarily on determining heavy metals concentrations in baby powder, where in 2010 and 2016, the U.S.A. court found asbestos and heavy metals such as lead and cobalt in Johnson and Johnson baby powder and talc-based body powder, and ordered Johnson and Johnson to compensate for the danger of their products. [6]. In 2019, the U.S.A. Food and Drug Administration (FDA) found that Blyif-Kor powder and a line of Johnson's Baby Powder, manufactured in 2018, were contaminated with heavy metals such as arsenic, cadmium, chromium, and lead. However, the ingredient declaration label of the product only states "Talc", so the fenestration testing technology for monitoring the talcum mineral and heavy metal powder of cosmetics urgently needed to be established [7]. Atomic Absorption Spectroscopy (AAS) is used to analyze the heavy metals in baby powder products. The method is capable of measuring total recoverable amounts of heavy metals down to the parts per billion level. Quality and accuracy can be maintained by using standard method performance requirements for each heavy metal analysis. The limit of detection is calculated using low-level calibration standards and the instrument blank measurement, giving a value that can be associated with the specified lower calibration level of the method. [10,11,12].

Despite the plenty of studies about detection of heavy metals in cosmetic products in the Libyan, here is an absence of research addressing heavy metal contamination in baby powders or talcum powders within the Libyan scientific literature. Furthermore, there have been no efforts made investigate the health risks associated with toxic elements in baby powder across different infant age groups. Therefore, the present study aims to determine the heavy metals concentration (including aluminum, cadmium, chromium, copper, lead, and nickel) in baby powder using Atomic Absorption Spectroscopy (AAS). Also assess age-specific health risks among infants by estimating daily metal intake, evaluating non-carcinogenic risks associated with heavy metals, and assessing carcinogenic risks through the calculation of chronic daily intake (CDI, mg/kg/day) via dermal absorption, target hazard quotient (THQ), hazard index (HI), and cancer risk (CR) for commonly used baby powders in Benghazi. The findings obtained from the health risk assessment are subsequently assessed in relation to the standard reference thresholds prescribed by the United States Environmental Protection Agency (USEPA) [14]. Measured heavy metal concentrations are evaluated against permissible limits defined by the FDA.

2. Material and Methods

2.1 Reagent and Instrumentation:

BDH Chemicals Ltd, UK supplied chemicals and reagents (Alchohol) of analytical grade, from which all other ingredients were obtained. Concentrated Aqua Regia (composition of concentrate of conc.) HNO_3, along with conc. H_2O_2. The digestion of the samples was performed using conc. 97% HNO_3 with 35% H_2O_2 with the metal salts [$Pb(NO_3)_2$, $NiCl_2.6H_2O$ and $Cr(NO_3)_3$] being utilized as standards.

The prepared digests were analyzed using a GBC Scientific Equipment Ltd. - 932 Plus - Atomic Absorption Spectrometer. This advanced instrument offered accurate and reproducible results, effectively determining the metal ion concentrations in the samples.

2.2 Sample collection

In this study, a total of sixteen commonly used baby talc powders were collected from various pharmacies located in Benghazi Libya. The sampling was conducted using a systematic random approach, with samples chosen from the same month of production but from different locations. Table 1 summarizes

the characteristics of the baby powder samples examined in this study, including their corresponding identification codes.

Table 1. Samples of Baby Powder retrieved from markets located in Benghazi.

No.	Code of Sample	Brand of baby talcum powder	Country of Origin
1	P1	Johnson's (baby powder)	Thailand
2	P2	Johnson's (sleep time)	Thailand
3	P3	Johnson's (baby powder)	Indonesia
4	P4	Johnson's (milk + rice)	Indonesia
5	P5	Johnson's (blossoms)	Indonesia
6	P6	Johnson's (bedtime)	Indonesia
7	P7	Nunu (baby powder)	Saudi Arabia
8	P8	Nunu	Saudi Arabia
9	P9	Chicco	Italy
10	P10	Chicco	Italy
11	P11	Baby Roz	Turkey
12	P12	Baby rose	Tunisia
13	P13	Petrova	United Arab Emirates
14	P14	Felce Azzurra (Talco Classico)	Italy
15	P15	Felce Azzurra (Talco Fresco)	Italy
16	P16	Dalin	Turkey

The systematic methodology for sample collection aims to provide reliable data for subsequent analysis of heavy metal content in these products.

2.3 Quality Control

Chemical analysis necessitated internal validation guidelines, which were aligned with the quality control procedures implemented in chemical analysis, resulting in an improved controlled quality. All reagents were used to test the chemical properties of glass, so that glass was not contaminated with metals. The reagents were packed tightly in glass sample containers to prevent any contamination with reagents. Prior to analysis, the performance of instruments was tested for daily calibration using standard solutions of the investigated elements and multi-level calibration standards to verify their linearity, with the results published in Analytical Techniques – The Performance of Instruments being verified before the analysis. To ensure the accuracy of the results, all samples were analyzed in triplicate (n = 3) and method precision was measured using the relatiometry method precision was evaluated using the relative standard deviation (%RSD), which was required to be less than 20% as an acceptable criterion for repeatability.

The linear range was considered a useful indicator of the analytical method's efficiency, as demonstrated by calibration curves that displayed a correlation coefficient ($R^2 > 0.99$) across the instrument's linear response, highlighting high sensitivity and good linear response of the instrument. The objective sample was analyzed for interference-free selective screening to ensure the absorbance of the target elements was pure and free of any absorbance bias. Similarly, to achieve a precise and consistent result, every glass of utensil was cleaned thoroughly with a cocktail of 10% nitric acid solution for 24 hours, followed by a thorough cleaning with deionized water for the full cleaning. Prior to analysis, laboratory contamination was eliminated and all subsequent analyses were analyzed using standard and blank measurements to ensure the integrity of the analysis and prevent laboratory contamination.

2.4 Experiment:

Collected of Baby Powder Samples were analyzed in the Food Chemistry Laboratory, Department of Nutrition, Faculty of Public Health, University of Benghazi. Where this experiment employed a systematic approach to the wet digestion of baby powder samples, ensuring precise analysis of their elemental composition [15]. A researchers weighted (2 g) of each type of baby powder into cleaned digestion flasks, 10 ml of concentrated nitric acid (97%HNO_3) has been added. This strong oxidizing agent facilitated the breakdown of organic matter while releasing metal ions for analysis. The flasks content is heated on a hot plate at a controlled temperature range of 70–80 °C for 30 minutes. This step enabled the effective dissolution of the sample matrix. After heating, the flasks were left to cool to room temperature.

Following the initial digestion, 5 ml of hydrogen peroxide (35%H_2O_2) has been added to each flask. Hydrogen peroxide promoted the oxidation of residual organic material. The mixture was vigorously heated until white fumes appeared, signifying the release of nitrogen oxides and the complete oxidation process. After completing the digestion and allowing the solution to cool, deionized water was then used to top up this volume to a predetermined final volume. All the previous steps of sample preparation are repeated with blanks After digestion, the samples were allowed to sediment overnight and then filtered using No. 42 Whatman filter paper to prepare for Atomic Absorption Spectroscopy.

2.5 Statistical Analysis

Statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS), version 20.0 (IBM Corp., New York, USA). Experimental data were reported as mean values accompanied by their corresponding standard deviations, and inferential comparisons were performed using the t-test with a 95% confidence interval to evaluate differences between groups.

2.6 preparation of standard curve

After setting the atomic absorption spectrophotometer to optimal conditions, measure the absorbance of a variety of standard metal solutions. To perform flame analysis, the standard solution has been diluted with 0.1 M HNO_3 to create a series of standards that involve the concentration of the elements to be measured. Each sample was analyzed in triplicates. Absorption is plotted against mg of metal/L solution. All data will be coded before being entered into a computer.

2.7 Health Risk Assessment of Toxic Elements Baby Powder

Human health risk assessment evaluates potential adverse health effects resulting from exposure to chemical substances, including both carcinogenic and non-carcinogenic agents, following methodologies outlined by the United States Environmental Protection Agency.. The risk of carcinogenic and non-carcinogenic carcinogenicities in Libya remains unregulated, as there is no consensus on an acceptable maximum risk level currently in place. In this study health risk assess was determined based on of the chronic daily intake (CDI) that is measured in mg/kg/day from dermal absorption, target hazard quotient (THQ), and hazard index (HI), and carcinogenic risk (CR).

Infants and children are more vulnerable to environmental contaminants due to the physiological differences between infants and children, making them more susceptible to higher doses of exposure. Infants have less developed protection mechanisms in their system, including an incompletely developed blood–brain barrier, limited plasma protein binding capacity, reduced hepatic and renal metabolic clearance, and an underdeveloped immune response, which are often underestimated [14,16]. Infants are especially sensitive to dermal contact contaminants due to their higher specific surface area [17].

This study conducted in partnership with the EPA utilized the agency's own health risk assessment (EPA-TCME) approach to evaluate the potential health effects of exposure to metals, which is associated with different types of health risks, such as cancer-causing and non-cancerous contaminants. CR is used to assess carcinogenic potential risks, while non-CR can cover both carcinogenic and non-carcinogenic contaminants. Firstly, the concentration of each contaminant was measured, and then

qualitative and quantitative estimations of the health risks associated were made to achieve this. In this study, the possibility of toxic heavy metal hazards was investigated for Al, Cd, Cr, Cu, Pb, and Ni, which could cause health issues. The human health risks are measured through exposure pathways that include dermal contact of polluted media. In each sex babies (0.5–3 years), health risks from these routes were evaluated based on their age and health in this study.

2.7.1 Estimated Chronic Daily Intake of Heavy Metals (CDI)

When contaminants are absorbed through the skin, they are referred to as dermal exposures. People who come into direct contact with baby powder are particularly at risk for exposure to this pathway. Estimated daily intake levels were calculated by combining the quantified metal concentrations with average body weight (Bw) parameters for male and female infants. The WHO [18] assessed the P95th percentile of the weight for girls and boys at for 0.5,1, 2 and 3 years, taking into account the child-growth standard table. The mean Bw was determined based on the standardized method of measuring child growth and development.

Equation (1) from the Environmental Protection Agency (USEPA) was used to calculate the chronic daily intake (CDI) that is measured in mg/kg/day from dermal absorption [35,36,39].

$$\text{Chronic daily intake } (CDI) = \frac{Cs \times SA \times AF \times ABS \times EF \times ED \times 10^{-6}}{BW \times AT} \quad (1)$$

Where, Cs: measured concentration of heavy metals in samples (mg/kg); while the default value for each parameter in the health risk calculation is described as the following, SA: Surface area of skin exposed (cm²); AF: Adherence factor (0.07 mg/cm²); ABS: Dermal absorption factor (0.001, unitless); EF: Exposure frequency (350 days/year); ED: Exposure duration (0.5, 1, 2 or 3 years); BW: Body weight (kg); AT: Averaging time (days). Table 2 indicated BW, SA, and AT parameters that used separately of girls and boys for these calculations and listed them here.

Heavy metal Concentration in the sample was determined in this study, while other factors were set to the default value [19].

The effect of the daily intake of heavy metal on the toxicity of heavy metal to humans varies according to the estimated daily intake saw a significant increase in funding for research and development initiatives [16].

2.7.2 Non-Carcinogenic Risk of Heavy Metals for Babies

The hazard quotient of each metal in the analyzed baby powder samples was used to calculate the non-carcinogenic hazard quotient (HQ) of the metals in the samples due to the presence or absence of carcinogenic carcinogenic infant formulas. The RfD values for children are seen in Table 3, which were used to calculate noncarcinogenic risks based on their respective RfD values and CDI values, respectively. The chronic reference dose (RfD) of a toxicant and chronic daily intake (CDI) of the toxicant (mg/kg/day) are related in relation as shown in Equation (2):

$$\text{HQ} = \frac{\text{CDI dermal}}{RFD\ dermal} \quad (2)$$

Where RfD is the estimated maximum permissible dose for human through daily exposure [20], as shown in Table 3.

Table 2: The parameters BW, SA, and AT for boy and girl their ages 0.5,1,2 and 3 years.

Age (years)	**0.5**		**One**		**Two**		**Three**	
Gender	**Boy**	**Girl**	**Boy**	**Girl**	**Boy**	**Girl**	**Boy**	**Girl**
BW (kg)	7.93	7.30	9.65	8.95	12.15	11.48	14.34	13.85
SA (cm²)	4500	4150	5750	5500	8000	7500	10000	9250
AT=EF×ED	350×0.5=		350×1=		350×2 =		350×3=	
(days)	175		350		700		1050	

Table 3: Reference doses (RfD) of six heavy metals [21-24].

Age (years)	0.5		1		2		3	
Gender	**Boy**	**Girl**	**Boy**	**Girl**	**Boy**	**Girl**	**Boy**	**Girl**
***RFD* (Al)**	0.012	0.009	0.018	0.015	0.031	0.025	0.053	0.045
***RFD* (Cd)**	0.0008	0.0007	0.0011	0.001	0.0014	0.0012	0.0017	0.0015
***RFD* (Cr)**	0.002	0.0018	0.003	0.0027	0.0045	0.004	0.006	0.0055
***RFD* (Cu)**	0.031	0.028	0.046	0.042	0.062	0.056	0/083	0.075
***RFD* (Pb)**	0.0004	0.0003	0.0005	0.0004	0.0006	0.0055	0.0008	0.0007
***RFD* (Ni)**	0.012	0.011	0.018	0.016	0.031	0.028	0.053	0.047

Most baby powder samples with different metals contained a hazard quotient, HQ carcinogenic risk and non-carcinogenic quotients, which was calculated. If the HQ values is more than one, the exposed babies are likely to experience adverse health effect. [16].
The potential health risks associated with exposure to toxic elements in infants aged 0.5 to 3 years were evaluated through the calculation of the estimated chronic daily intake (CDI), target hazard quotient (THQ), and hazard index (HI).The HI values were obtained by using the total THQ corresponding to each body weight at different ages, as demonstrated in equation (3) [25].

$$HI = \Sigma HQ = HQ\ Al + HQ\ Cd + HQ\ Cr + HQ\ Cu + HQ\ Pb + HQ\ Ni \quad (3)$$

2.7.3 Carcinogenic risk

Carcinogenic risk refers to the incremental likelihood that an individual may develop cancer over a lifetime as a consequence of exposure to chemical agents under defined exposure conditions. [24,25].
The carcinogenic risk value of mix trace metals was calculated to estimate whether the consumers are likely to suffer from cancer, and this can be evaluated from equation:
Carcinogenic risk=CDI ×SF [26,27,28].
Where CDI is the chronic daily intake of carcinogens ($mgkg^{-1}d^{-1}$) and SF is the slope factor of hazardous substances. The reported slope factor for Al, Cd, Cr, Cu, Pb and Ni are 0.0014, 6.300, 0.500, 0.017, 0.0085 and 0.91 $(mg/kg/d)^{-1}$, respectively [16,19].

3- Results and discussion

3.1 Levels of toxic heavy metals in baby powder samples

The results obtained, shown in Table 4, indicated the initial measurements in ppm, while Table 5 shows the calculated concentrations in mg/kg, along with the average concentrations and standard deviations for each element.
The assessment of heavy metal concentrations in consumer products, such as baby powder, has become essential due to the associated health risks posed to the population, particularly infants. These toxic elements, measured in parts per million (ppm) using atomic absorption spectroscopy (AAS).

3.1.1 Aluminum Content

The range concentrations of aluminum in all investigated baby powder samples were found to be from 12.32 mg/kg in Johnson's "Sleep Time" powder from Thailand to 275.475 mg/kg in "Baby Roz" powder from Turkey, as presented in Table 5.
Figure 1, illustrates these with the mean average of 113.183 mg/kg across samples. It has to be noted that the U.S. Food and Drug Administration (FDA) established a maximum safe limit for aluminum in baby powder at 0.400 mg/kg [16]. In the current study all samples are above the U.S. Food and Drug Administration (FDA), suggesting potential health risks.

Table 4. The measured concentration of heavy metals (ppm) in baby powder, values Mean ± SD.

Code of Sample	Metals contente (ppm)					
	Aluminum (Al±SD)	**Cadmium (Cd±SD)**	**Chromium (Cr±SD)**	**Copper (Cu±SD)**	**Lead (pb±SD)**	**Nickel (Ni±SD)**
P1	3.061±0.004	0.091±0.130	LDL	1.164±1.012	LDL	0.280±0.009
P2	0.493±0.007	LDL	LDL	1.091±0.005	0.358±0.0004	0.229±0.008
P3	5.254±2.200	LDL	LDL	0.317±0.007	0.511±0.0004	2.005±0.032
P4	9.997±1.040	0.118±0.007	1.079±0.001	0.755±0.006	0.259±0.0014	LDL
P5	4.652±0.009	0.133±0.008	1.062±0.002	0.561±0.001	LDL	0.546±0.004
P6	1.999±0.007	0.202±0.018	0.200±0.0005	1.238±0.016	0.180±0.0008	LDL
P7	2.926±0.007	0.297±0.003	0.555±0.009	0.319±0.008	LDL	0.631±0.081
P8	1.018±0.007	0.252±0.008	0.062±0.0001	2.205±0.250	LDL	0.155±0.006
P9	3.409±0.009	0.379±0.008	1.999±0.008	0.768±0.005	0.026±0.0017	0.219±0.006
P10	8.506±0.035	0.775±0.019	1.106±0.008	0.301±0.005	0.042±0.0006	LDL
P11	11.019±0.03	LDL	0.233±0.0004	3.099±1.008	0.312±0.0013	2.188±0.022
P12	2.608±0.006	LDL	1.606±0.007	1.084±0.008	0.418±0.0006	0.599±0.016
P13	0.881±0.004	LDL	0.770±0.008	0.922±0.015	LDL	0.027±0.007
P14	7.590±0.046	0.904±1.031	LDL	0.441±0.006	LDL	LDL
P15	1.568±0.004	0.113±0.0002	1.868±0.006	1.930±0.006	0.209±0.0020	LDL
P16	7.456±0.024	0.457±0.005	0.989±0.006	1.402±0.009	0.623±0.0008	0.346±0.006
Mean	4.530	0.491	1.429	1.099	0.294	0.417

Table 5. The concentration of heavy metals (mg\Kg) in baby powder, values mean.

Code of Sample	Metals contente (mg\Kg)						
	Aluminum (Al)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Lead (Pb)	Nickel (Ni)	Total Metals
P1	76.525	2.275	LDL	29.1	LDL	7.000	114.900
P2	12.325	LDL	LDL	27.275	8.95	5.725	39.600
P3	131.350	LDL	LDL	7.925	12.775	50.125	202.175
P4	249.925	2.950	26.975	18.875	6.475	LDL	298.725
P5	116.300	3.325	26.550	14.025	LDL	LDL	160.200
P6	49.975	5.050	5.000	30.95	4.5	LDL	90.975
P7	73.150	7.425	13.875	7.975	LDL	15.775	118.200
P8	25.450	6.300	1.550	55.125	LDL	3.875	88.425
P9	85.225	9.475	49.975	19.2	0.65	5.475	170.00
P10	212.65	19.375	27.650	7.525	1.05	LDL	337.150
P11	275.475	LDL	5.825	77.475	7.8	54.700	351.325
P12	65.200	LDL	40.150	27.1	10.45	14.975	132.450
P13	22.025	LDL	19.250	23.05	LDL	0.675	65.000
P14	189.750	22.600	LDL	11.025	LDL	LDL	223.375
P15	39.200	2.825	46.700	48.25	5.225	LDL	142.200
P16	186.400	11.425	24.725	35.05	15.575	8.650	257.600
Min.	12.325	LDL	LDL	7.525	LDL	LDL	39.600
Max.	275.475	22.600	49.975	77.475	15.575	54.700	351.325
Mean	113.183	5.814	18.014	27.495	4.591	10.436	179.533
FDA	0.400	3.000	5.000	13.000	0.100	0.600	

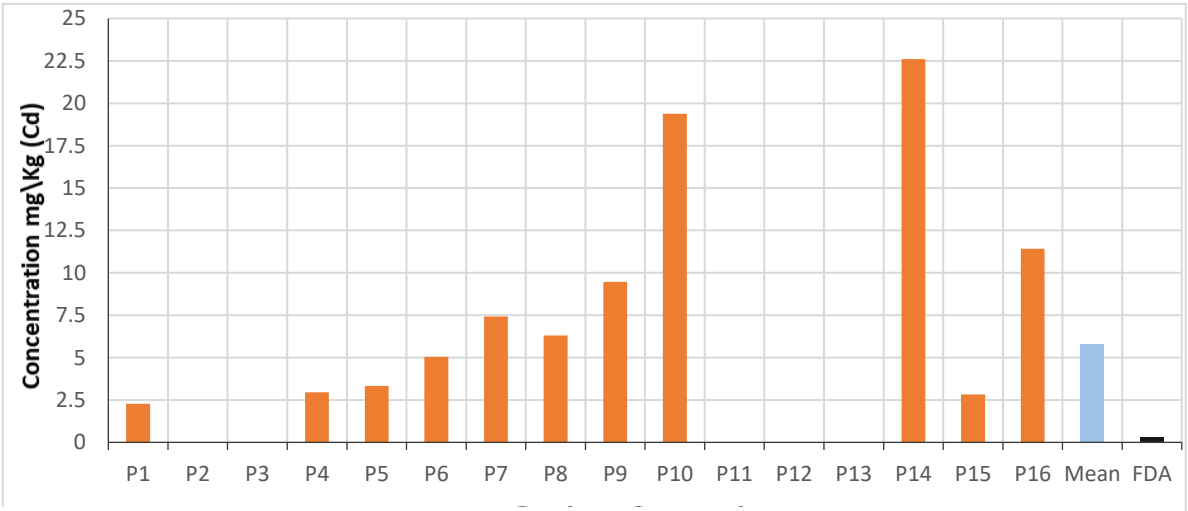


Figure 1. Aluminum concentrations (mg/Kg) in Baby Powder samples.

Infants with underdeveloped renal systems are particularly vulnerable to aluminum exposure [16,17]. That, might be led to weakened bone structures and increased health risks in individuals with renal insufficiency [18]. Also, this are linked to Alzheimer's disease and can negatively affect the nervous system [19,20,21].

3.1.2 Cadmium Content

Figure 2, shows the Cd concentration, where five out of sixteen baby powder samples tested was undetectable, with the mean average of 5.814 mg/kg. The lowest concentration was identified in Johnson's baby powder from Thailand, containing 2.275 mg/kg, while the highest concentration was found in Felce Azzurra (Talco Classico) from Italy, which contained 22.900 mg/kg.

Looking at all baby powder samples in Table 5, shows concentration more than 3.00 mg/kg, which above the permissible limits of FDA [26].

This result contrasts with previous studies that reported lower concentrations of cadmium in baby powder. Where K.S. G. Rehman *et al*., observed Cd levels ranging from 0.001 to 0.080 mg/kg in 30 different baby powder brands in Pakistan [22], also a study in Malaysia [23] documented Cd levels between 3.4 and 4.7 ppb (0.0034–0.0047 mg/kg).

Once Cd enters the human system, it accumulates predominantly in the liver and kidneys and is subsequently excreted very slowly through urinary and fecal pathways, leading to potential long-term retention and

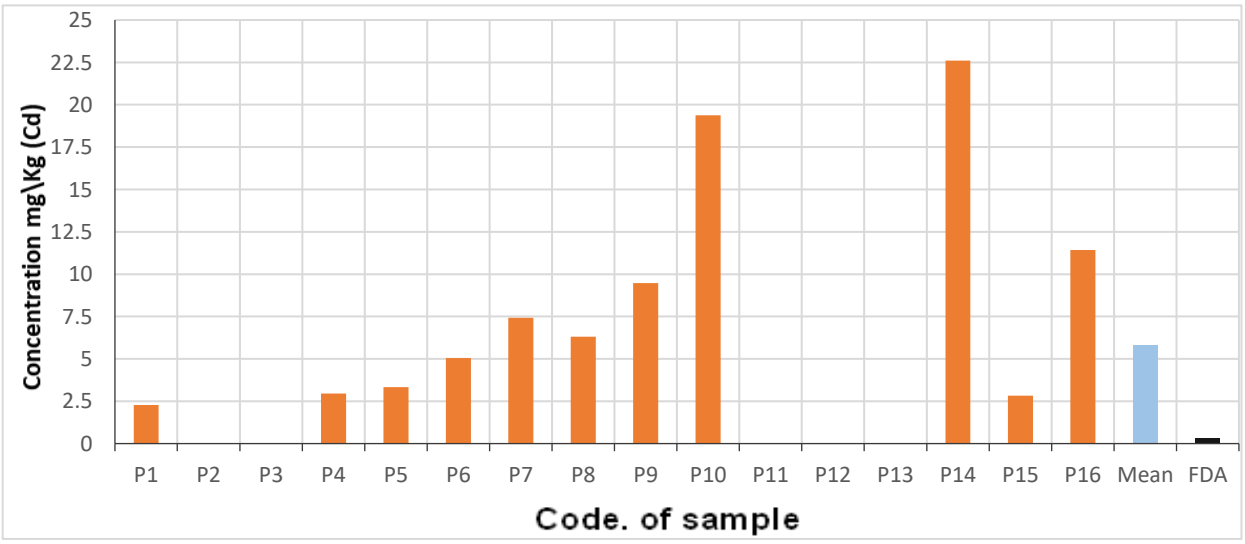


Figure 2. Cadmium concentrations (mg/Kg) in Baby Powder samples.

bioaccumulation [24].

The International Agency for Research on Cancer (IARC) has classified Cd as a Group 1 carcinogen due to its confirmed carcinogenic effects, particularly following inhalation, which can induce lung cancer [24]. Moreover, cadmium exposure has been associated with tumorigenesis in other organs, notably the prostate and kidneys [25]. However, the health risks associated with Cd, particularly in consumer products such as baby powder, are significant [26].

3.1.3 Chromium Content

Table 5, demonstrates that the Cr content within the baby powder samples with an average of 18.014 mg/kg, Since the FDA has outlined the safe limit of 5 mg/kg for Cr as an impurity in baby powder, [26] it can be concluded that all baby powder samples under the present study are above the safe limit recommended by FDA. While, Chromium was undetectable in four samples, as shown in Figure 3. However, the lowest detected concentration was 1.550 mg/kg in the Nunu sample from Saudi Arabia. In contrast, the highest detected amount was 49.975 mg/kg in the Chicco sample from Italy.

levels in Pakistani talcum powders ranging from 0.08 to 0.35 mg/kg, which are lower than those observed in this study [22]. S. Jamali *et al*. were reported a Cr concentration of of 0.3 to 0.3883 mg/kg in talc product [27], while K. S. Almugren et al. documented significantly higher concentrations in Malaysian samples, ranging from 4.883 to 5.846 mg/kg (4883.0 to 5846.0 ppb), [23] which exceed both this study's.

Both forms of (Cr III) and (Cr VI), can trigger immune responses associated with contact allergies, especially in infants [28]. This is particularly concerning as infants may be exposed to chromium through talcum powder application or inhalation, which poses additional risks due to their developing systems [29]. Many European Union countries and Canada have restricted chromium use in cosmetics due to these risks. Chromium's highly corrosive nature can exacerbate allergic reactions in the skin and respiratory tract, and chronic inhalation exposure may increase the risk of lung, nasal, and sinus cancers [41].

3.1.4 Copper Content

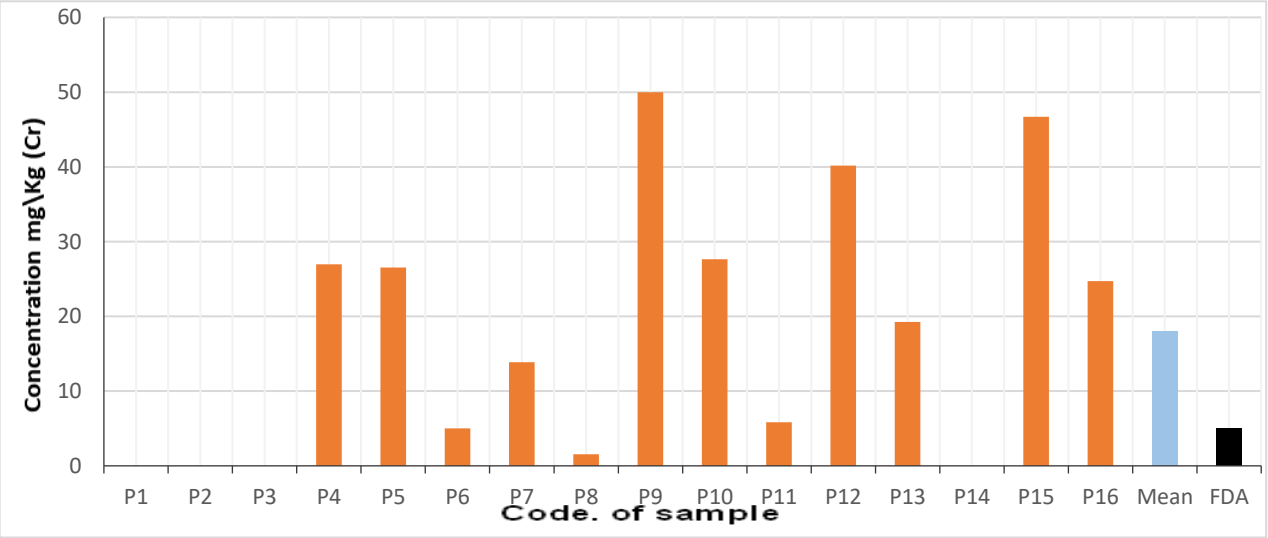


Figure 3. Chromium concentrations (mg/Kg) in Baby Powder samples.

Figure 4, demonstrates that the Cu content within the baby powder samples is ranging from, 7.525 mg/kg in Chicco powder manufactured in Italy, to 77.475 mg/kg in Baby Roz powder produced in Turkey. As shown in Table 5 the average Cu concentration across all tested baby powder samples was 27.495 mg/kg. The FDA has set a safe limit of 13 mg/kg for Cu as an impurity in baby powder products [26], it

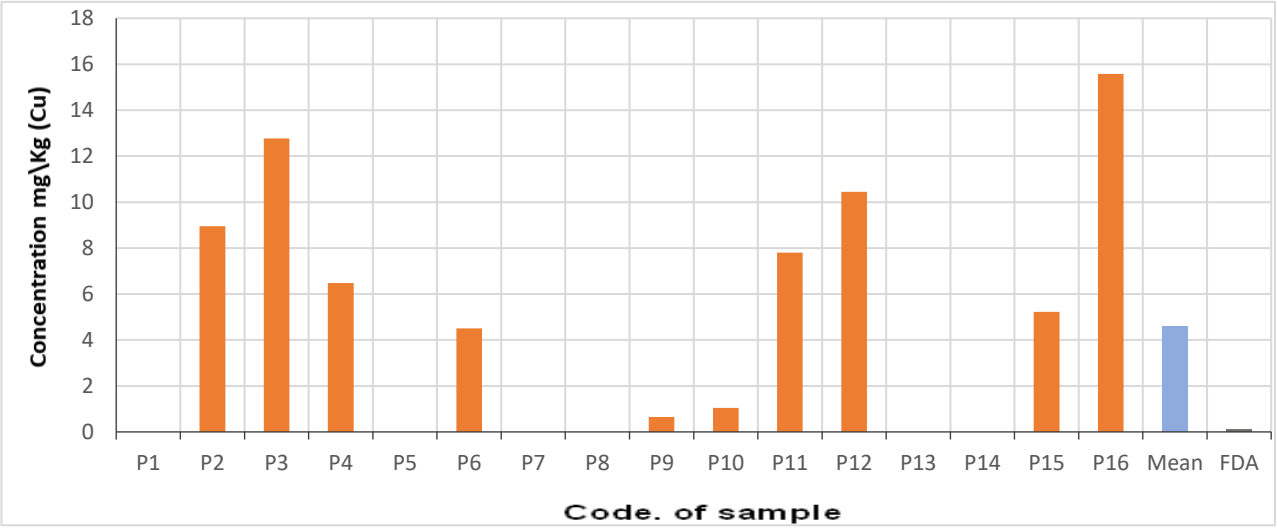


Figure 4. Copper concentrations (mg/Kg) in Baby Powder samples.

can be concluded that all baby powder samples under the present study are above the allowable safe limit thus pose significant risk to human health due to Cu toxicity.

In contrast to earlier findings by Ghana Rehman et al. [22] and by K.S. Almugren et al. [23], which are both lower than present study.

Copper is a vital trace element in the human body, essential for red blood cell production and iron metabolism. Its effects are dose dependent, with minimal amounts needed for optimal physiological functions [43].

3.1.5 Lead Content

Figure 5 also revealed that the cadmium content within all the baby powder samples appeared to be in the range of 4.500 to 15.575 mg/kg. When the results were compared with the 0.1 mg/kg permissible limits in baby powder recommended by Food and Drugs Administrative (FDA) [35]. The investigated baby powders in this study exceeded the permissible limits, which could potentially pose health risks to consumers from dermal exposure.

In contrast, lead content was undetectable in approximately half of the samples, with two samples presenting lower concentrations of 0.65 and 1.05 mg/kg. The average lead concentration across all baby powder samples 4.591 mg/kg, as indicated in Table 5. Other researches show variable lead content in baby products, such as 0.0006 to 1.05 mg/kg found by [36] and a range of 2585.0 to 1944.0 ppb (2.585 to 1.944 mg/kg) reported by [37]. Interestingly, the lead levels in baby powder samples analyzed in this study were unexpectedly higher than safety limit set by the FDA, warranting further investigation.

Lead exposure is linked to severe health risks,

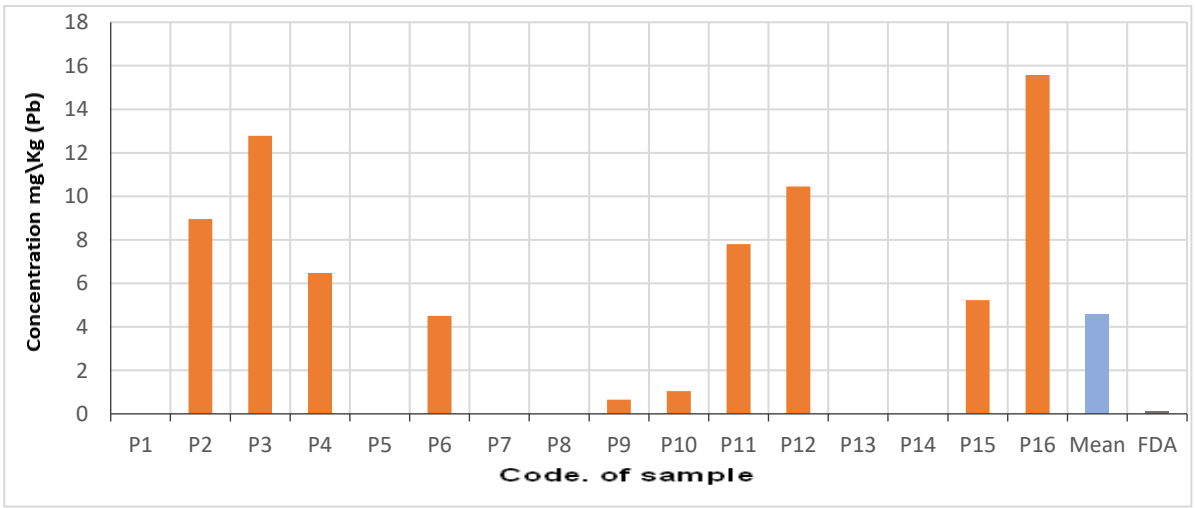


Figure 5. Lead concentrations (mg/Kg) in Baby Powder samples.

including disruptions in hemoglobin synthesis, elevated blood pressure, renal damage, miscarriage, and neurological impairments [31]. The U.S. Food and Drug Administration recommend not containing lead in consumer products like baby powder due to its toxicity and severe health impacts [3]. Lead is one of the top four heavy metals threatening human health, and studies on animal models suggest that lead compounds, such as lead acetate and lead phosphate, may have carcinogenic properties, as highlighted in a recent Department of Health and Human Services (DHHS) report. U.S. [45].

3.1.6 Nickel Content

The FDA has established a maximum permissible limit of 0.6 mg/kg for nickel concentration in products [26]. Analysis of baby powder samples revealed that most products were above this threshold, with nickel levels undetectable in seven samples. However, two samples exceeded the permissible limit. These included Johnson's Baby Powder from Indonesia, with a nickel concentration of 50.125 mg/kg, and Baby Roz from Turkey, with a concentration of 54.700 mg/kg. The lowest concentrations ranged between 0.675 and the highest concentration 50.125 mg/kg, as detailed in Table 5 and as shown in Figure 6. The average nickel concentration across all samples was 10.436 mg/kg .Interestingly, findings from Ghana Rehman *et al*. indicated that nickel concentrations in baby powder ranged from 3.102 to 2.207 mg/kg [36], which is significantly lower than the results obtained in the current study. Nickel (Ni) plays a dual role in biological systems. While it is an essential element for the growth and enzymatic functions of specific microorganisms and plants, excessive exposure to nickel poses health risks [46]. Notably, concentrations as low as 0.5 mg/kg (500 ppb) have been implicated in triggering contact dermatitis [47].

The elevated concentrations of Al, Pb, Ni, Cu, Cr, and Cd observed in all baby powder samples above FDA permissible limits strongly indicate contamination originating primarily from raw talc materials, which are known to naturally contain heavy metals depending on their geological source. Insufficient purification and refining during raw material processing likely contributed to the persistence of these metals. In addition, manufacturing-related factors, including inadequate quality control, contaminated processing equipment, and environmental exposure during production, may have further increased metal concentrations. These findings underscore the necessity for stricter regulatory control, improved manufacturing practices, and systematic monitoring of raw materials to prevent heavy metal contamination in baby powder products.

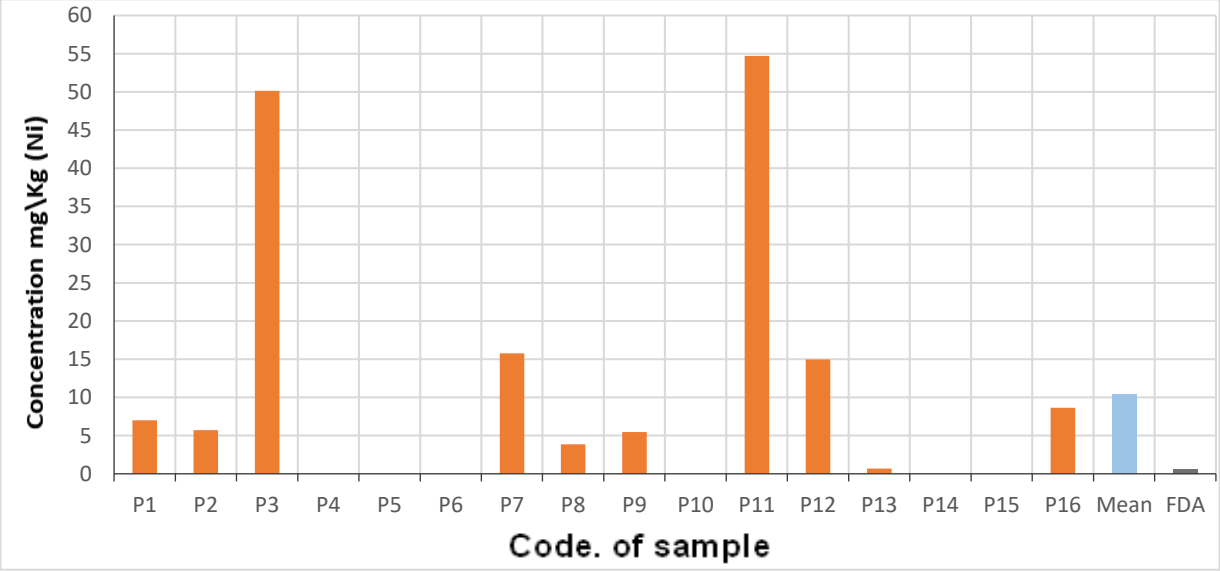


Figure 6. Nickel concentrations (mg/Kg) in Baby Powder samples.

2.2 Health Risk Assessment of use Baby Powder

The average concentration (mg\Kg) of the six metals, namely aluminum, cadmium, chromium, copper, lead, and nickel were used to calculate the chronic daily intake (CDI).

The four age groups for babies were comparable the daily exposure to baby powder. Figures 7 and 8 shows the distribution of data for the CDI. The baby powder samples exhibit decreasing mean CDI values in the order Al>Cd>Cr>Cu>Ni>Pb.

In spite of inconclusive findings from prior studies, previous studies not finding any correlation between sex differences. This study revealed that exposure daily per body weight

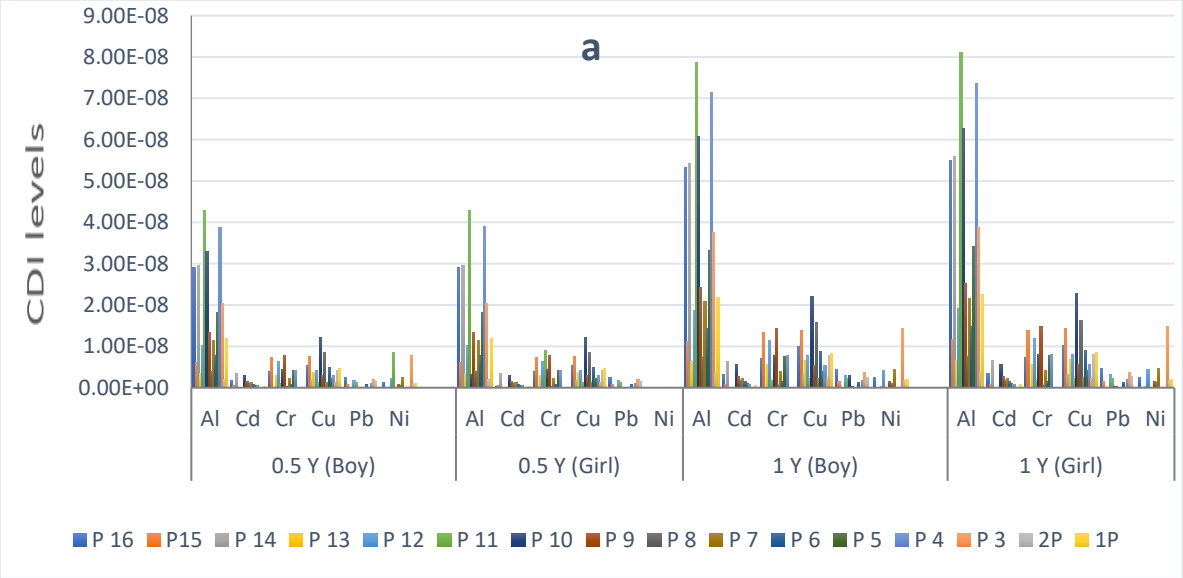


Figure 7: The chronic daily intake (CDI) values of heavy metals (mg/day) for 0.5 and 1 Years old.

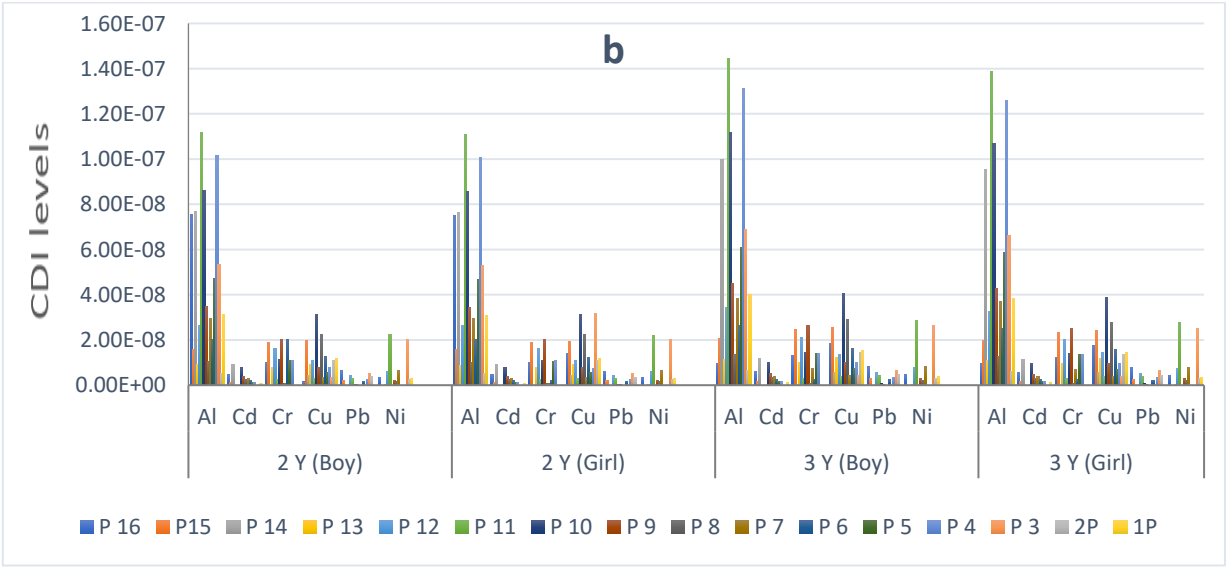


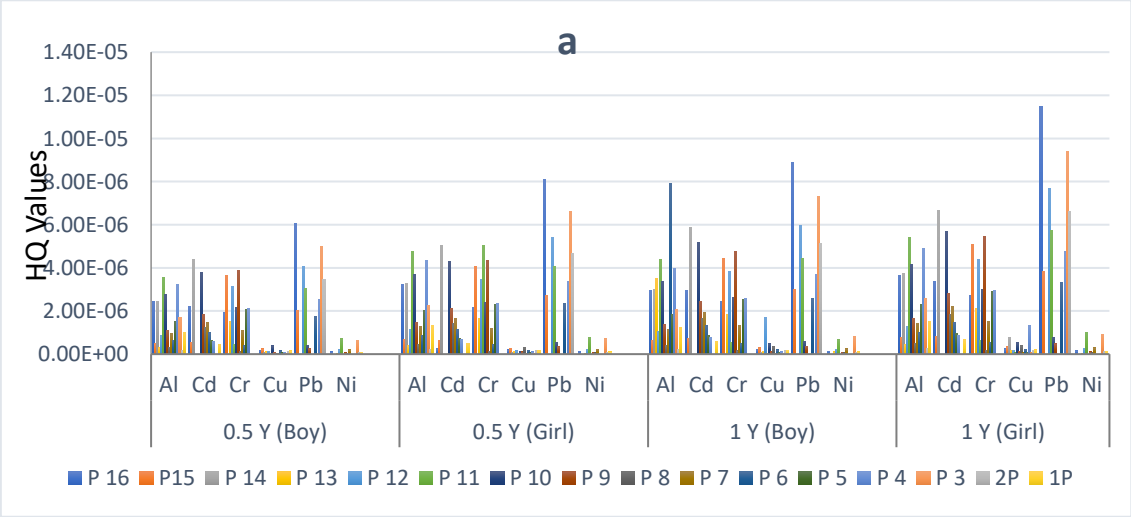
Figure 8: The chronic daily intake (CDI) values of heavy metals (mg/day) for 2 and 3 Years old

unit for girls aged 0.5 and 1 year was slightly higher than that compared to exposure to boy babies of the same ages, and vice versa for ages 2 and 3 years, where the chronic daily intake for boys is higher than for girls. For each heavy metal, the daily exposure per each body weight unit increases with an increase in the baby's age. The results obtained in figures 9 and 10

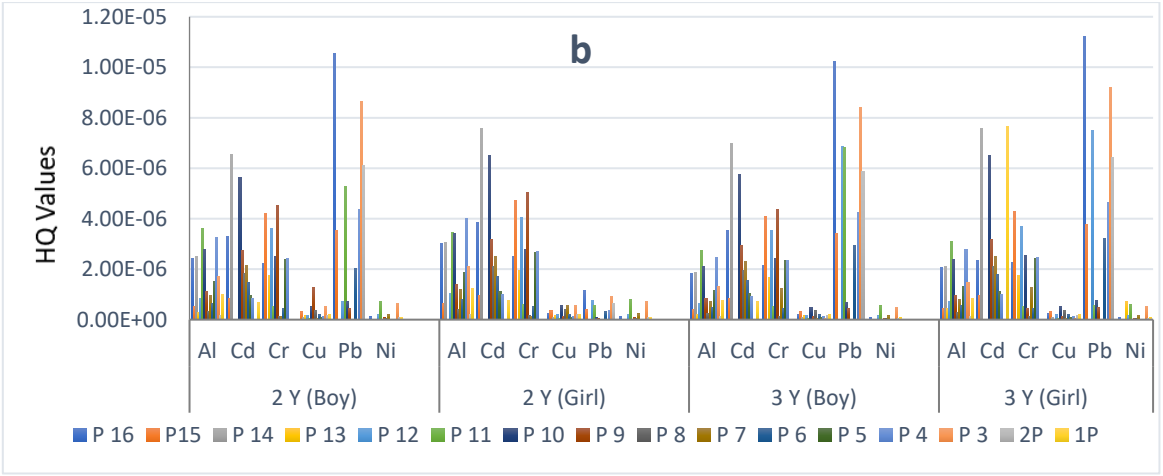
showed the range HQ values for boys had 0.5, 1, 2 and 3 y of age, were: 1.672×10^{-6}-1.292×10^{-5}, 2.097×10^{-6}-1.761×10^{-5}, 1.944×10^{-6}-1.866×10^{-5}, 1.715×10^{-6}-1.807×10^{-5}, and girls had the range of HQ values were: 2.091×10^{-6}-1.403×10^{-5}, 2.506×10^{-6}-2.160×10^{-5}, 2.306×10^{-6} - 1.084×10^{-5} and 1.889×10^{-6}- 1.820×10^{-5}.

The target hazard quotient (HQ) for the six metals studied for each sample was calculated and then has been plotted graphically as shown in the figures 9 (0.5y & 1y) and figures 10 (2y & 3y). These figures revealed that the HQ for all the metals was lower than 1 obtained for all the baby powder samples, indicating that dermal adsorption of the studied baby powder by infants' babies (0.5 to 3 y of age) of Libya would not pose babies to a high risk of health issue.

The mean HI values were 6.041×10^{-6}, 8.187×10^{-6}, 7.743×10^{-6}, 7.874×10^{-6} for 0.5, 1, 2 and 3y of boys, and for girls were 7.192×10^{-6}, 9.869×10^{-6}, 9.429×10^{-6}, and 8.347×10^{-6}, respectively. This study revealed that girls' HI value was higher than that of boys, with a lower HI value compared to boys, as a result of their lighter body mass. The HI values were less than the established criteria 1, and the inverse relationship with age was observable as the HI values were inversely related to those of the assumed age. HI value expresses the combined non-carcinogenic effects of multiple elements. For the utilization of selected baby powder, HI was <1 as shown in Table (6) indicating that consumers are found to be safer.



Figurer 9. The hazard quotient (HQ) values of heavy metals (mg/Kg/day) for 0.5 and 1 Years old.



Figurer 10. The hazard quotient (HQ) values of heavy metals (mg/Kg/day) for 2 and 3 Years old.

Table (6): The hazard index (HI) values of heavy metals (mg/day) for 0.5, 1, 2 and 3 Years old.

Code No. samples	Age of Boy				Age of Girl			
	0.5	**1**	**2**	**3**	**0.5**	**1**	**2**	**3**
P1	1.672 $\times10^{-6}$	2.097 $\times10^{-6}$	1.944 $\times10^{-6}$	1.715 $\times10^{-6}$	2.091 $\times10^{-6}$	2.506 $\times10^{-6}$	2.306 $\times10^{-6}$	1.889 $\times10^{-6}$
P2	3.851 $\times10^{-6}$	5.570 $\times10^{-6}$	6.503 $\times10^{-6}$	6.229 $\times10^{-6}$	5.093 $\times10^{-6}$	7.132 $\times10^{-6}$	1.132 $\times10^{-6}$	6.816 $\times10^{-6}$
P3	7.359 $\times10^{-6}$	1.023 $\times10^{-5}$	1.107 $\times10^{-5}$	1.024 $\times10^{-5}$	3.690 $\times10^{-6}$	1.296 $\times10^{-5}$	4.341 $\times10^{-6}$	1.469 $\times10^{-5}$
P4	8.522 $\times10^{-6}$	1.112 $\times10^{-5}$	1.106 $\times10^{-5}$	1.012 $\times10^{-5}$	1.079 $\times10^{-5}$	1.297 $\times10^{-5}$	8.241 $\times10^{-6}$	1.122 $\times10^{-5}$
P5	4.289 $\times10^{-6}$	5.325 $\times10^{-6}$	4.975 $\times10^{-6}$	4.565 $\times10^{-6}$	5.129 $\times10^{-6}$	6.259 $\times10^{-6}$	5.764 $\times10^{-5}$	4.938 $\times10^{-6}$
P6	3.923 $\times10^{-6}$	5.346 $\times10^{-6}$	4.802 $\times10^{-6}$	5.645 $\times10^{-6}$	3.986 $\times10^{-6}$	6.470 $\times10^{-6}$	3.555 $\times10^{-6}$	6.227 $\times10^{-6}$
P7	3.715 $\times10^{-6}$	4.710 $\times10^{-6}$	3.495 $\times10^{-6}$	4.442 $\times10^{-6}$	4.388 $\times10^{-6}$	5.486 $\times10^{-6}$	4.609 $\times10^{-6}$	4.800 $\times10^{-6}$
P8	1.753 $\times10^{-6}$	2.591 $\times10^{-6}$	2.711 $\times10^{-6}$	2.722 $\times10^{-6}$	2.338 $\times10^{-6}$	2.982 $\times10^{-6}$	3.1323 $\times10^{-6}$	2.951 $\times10^{-6}$
P9	7.251 $\times10^{-6}$	9.151 $\times10^{-6}$	1.014 $\times10^{-5}$	8.753 $\times10^{-6}$	8.433 $\times10^{-6}$	1.064 $\times10^{-5}$	9.847 $\times10^{-6}$	5.244 $\times10^{-6}$
P10	9.469 $\times10^{-6}$	1.228 $\times10^{-5}$	1.211 $\times10^{-5}$	1.145 $\times10^{-5}$	1.105 $\times10^{-5}$	1.421 $\times10^{-5}$	1.334 $\times10^{-5}$	1.268 $\times10^{-5}$
P11	7.801 $\times10^{-6}$	1.010 $\times10^{-5}$	1.017 $\times10^{-5}$	1.066 $\times10^{-5}$	1.468 $\times10^{-5}$	1.285 $\times10^{-5}$	5.435 $\times10^{-6}$	9.856 $\times10^{-6}$
P12	8.360 $\times10^{-6}$	1.124 $\times10^{-5}$	5.556 $\times10^{-6}$	1.134 $\times10^{-5}$	1.040 $\times10^{-5}$	1.380 $\times10^{-5}$	6.253 $\times10^{-6}$	1.226 $\times10^{-5}$
P13	1.907 $\times10^{-6}$	5.583 $\times10^{-6}$	2.184 $\times10^{-6}$	2.056 $\times10^{-6}$	2.271 $\times10^{-6}$	6.001 $\times10^{-6}$	2.468 $\times10^{-6}$	2.230 $\times10^{-6}$
P14	6.907 $\times10^{-6}$	8.950 $\times10^{-6}$	9.109 $\times10^{-6}$	8.931 $\times10^{-6}$	8.375 $\times10^{-6}$	1.115 $\times10^{-5}$	1.072 $\times10^{-5}$	9.776 $\times10^{-6}$
P15	6.962 $\times10^{-6}$	9.089 $\times10^{-6}$	9.394 $\times10^{-6}$	9.052 $\times10^{-6}$	8.332 $\times10^{-6}$	1.088 $\times10^{-5}$	7.012 $\times10^{-6}$	9.739 $\times10^{-6}$
P16	1.292 $\times10^{-5}$	1.761 $\times10^{-5}$	1.866 $\times10^{-5}$	1.807 $\times10^{-5}$	1.403 $\times10^{-5}$	2.160 $\times10^{-5}$	1.084 $\times10^{-5}$	1.823 $\times10^{-5}$
Mean of HI	6.041 $\times10^{-6}$	8.187 $\times10^{-6}$	7.743 $\times10^{-6}$	7.874 $\times10^{-6}$	7.192 $\times10^{-6}$	9.869 $\times10^{-6}$	9.429 $\times10^{-6}$	8.347 $\times10^{-6}$

The carcinogenic risk (CR) was calculated for each metal and then plotted graphically as shown in the figures 11 (0.5y & 1y) and 12 (2y & 3y). Carcinogenic risk between 1×10^{-6} to 1×10^{-4} is regarded as acceptable [38]. From the result, that the cancer risk of each metal was found to be lower than the acceptable range, is indicating no CR from consumption from dermal exposure of baby bower by infants.

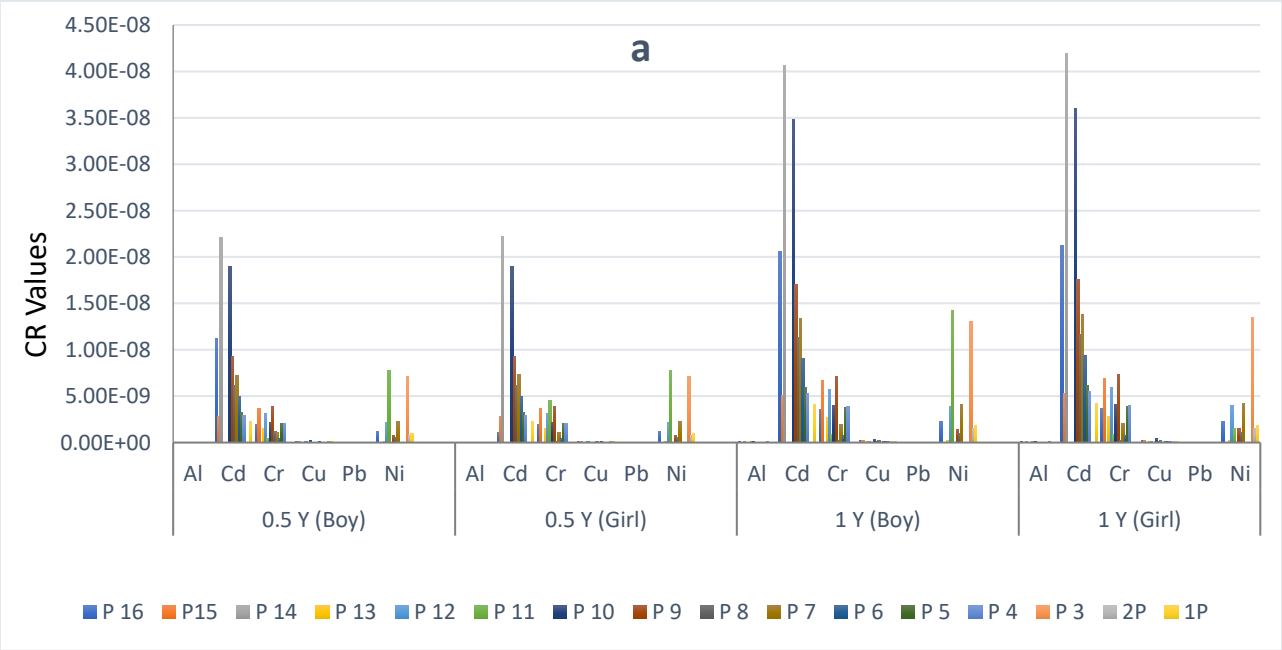


Figure 11. The carcinogenic risk (CR) of heavy metals (mg/day) for 0.5 and 1 Years old.

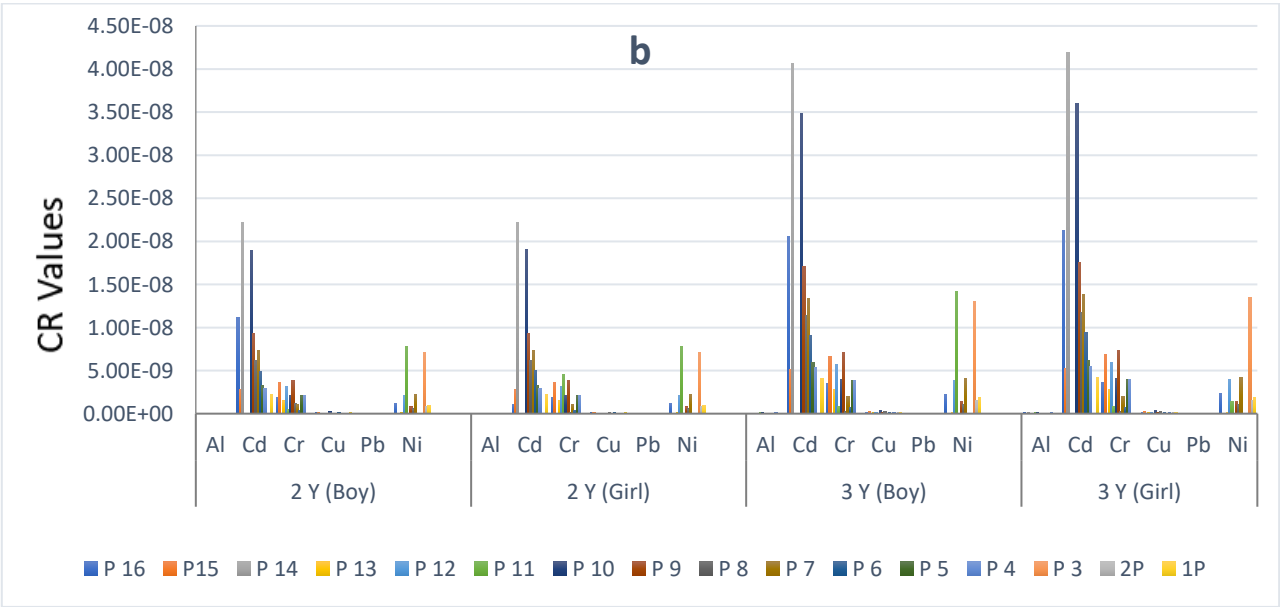


Figure 12. The carcinogenic risk (CR) of heavy metals (mg/day) for 2 and 3 Years old.

4. Conclusion

The results of this study indicate that Cr, Cd, Ni, Pb, Al and Cu concentration levels in most of baby powders sold in Benghazi are not compliance with FDA safety standards for heavy metal content.
The results indicate that the levels of heavy metals in the baby powder samples do not pose a significant health risk to infants according to established safety standards. The carcinogenic risk (CR) values for all metals were below the acceptable threshold, demonstrating a low probability of cancer development through indirect ingestion or dermal exposure. Furthermore, the non-carcinogenic risk indices (HQ and HI) were less than 1 in all samples, suggesting that dermal absorption of heavy metals by infants aged 0.5–3 years is unlikely to result in adverse health effects.

5. Limitations of the Study

Several limitations should be acknowledged in this study. Notably, the sample size was limited to sixteen baby powder products obtained from selected pharmacies within Benghazi City. Expanding the number of samples and including a broader geographic distribution would enable a more robust and representative evaluation of heavy metal contamination in baby powders across the region. The study exclusively evaluated four heavy metals (aluminum, cadmium, chromium, copper, and lead). While the other potentially harmful metals, such as mercury (Hg) and arsenic (As), were not included in the assessment.

Recommendations

Regulations on heavy metals in baby powders should be tightened, and strict quality control should be implemented during production. It is necessary to conduct regular monitoring of heavy metal levels and educate parents about the associated health risks. Research on the effects of heavy metal exposure should be supported, and the use of safe, non-toxic alternatives should be encouraged. In addition, transparency among manufacturers should be improved, cooperation with them should be strengthened, and awareness campaigns should be launched to raise awareness of the risks of heavy metals in products intended for children.

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Conflicts of interest

The authors of this study have declared no conflicts of interest and received no external funding..

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