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Heavy Metals in Baby Foods and Cereal Products

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Abstract
Lead and cadmium are toxic elements; when ingested or inhaled, they can lead to several diseases, a list of which is shown below. The diseases affect children, especially infants under the age of five. This work analyzes 63 baby foods and cereal products for lead and cadmium, and the analysis is done with an atomic absorption spectrophotometer (AAS) with a Shimadzu double-beam atomic absorption analyzer, AA-6300. Lead and cadmium were established to vary between 0.32- 10.64μ g/kg and 0.3-10.37 μg /kg, respectively. Altogether, 49.21% of the samples have lead above the LOD, while the rest have it below this value. In the samples analyzed for cadmium, more than 85 percent of the samples had detectable levels. The results of lead and cadmium in the milk powder products were relatively low, with the said metals detected at levels below 10μg/kg in all the samples, being between 0.85- 7.26 μg / kg for lead and between 0.1 – 4.75 μg /kg for cadmium. The young infants were most exposed to these heavy metals through the consumption of cereal-based products. Still, in any case, the calculated concentrations were lower than the permitted regulatory limits prescribed by Commission Regulation (EC) No 1881/2006, which limits the metals in food to 20μg/kg for lead in infant formula and 100 μg/kg for cadmium in cereals (EC 2006). As much as the levels established in this study were within the legal limits, the high prevalence of lead and cadmium added to baby foods poses future health risks to vulnerable groups, requires more raw material and processing control, and better regulation of admixture safety standards.

Keywords; *Heavy metals, Lead contamination, Cadmium contamination, Baby food products, Cereal products, Atomic absorption spectrophotometry, Regulatory compliance, Infant exposure, Food safety, Environmental contamination*

1.0 Introduction

Lead poisoning of foods has emerged as a center of major public concern for all ages, but especially for babies and those who consume cereal products. Hazardous materials, including lead and cadmium, with dangerous effects on human health, are likely to impact the population, especially special groups of people, including young children. This contamination is also not solely a consequence of pollution of the environment and may be attributed at least to agricultural use of chemicals, industrial processes, and incorrect food preparation. Among all the hazardous substances, newborns and babies are the most vulnerable to the effects of toxic heavy metals. That is why it is important to identify and study these contaminants in baby foods as they affect most of the future generation and young population. Lead and cadmium are the most pervasive among all the deadly heavy metals, particularly in baby foods and cereals. Both metals are not nutrients for humans and thus can build up in the human body and cause chronic toxicity and long-term diseases. Their effects lead to various diseases such as damaged brains, delayed development of ASD, and even the poor function of the organs; children most often are affected because they grow and develop quickly, and their organs are not well developed. Pregnant women, babies, and young children are especially vulnerable to the potentially dangerous effects of pesticide residues because of their low body weight, the fact they consume more food proportionately, and the fact that their bodies have not yet developed the abilities necessary to detoxify the chemicals adequately. The toxic substances, even in low concentrations, can severely impact their growing nervous system, immunity system, or other major organs.

The issue of lead and cadmium in food is also prosecuted for Min Salt’s health, targeting EC by proposing maximum allowable levels of these elements of food products. These regulations are designed to maintain cleanliness and reduce health hazards, and more so for infants and children. Nonetheless, these regulations are insufficient, and many people are skeptical about the effectiveness of monitoring systems and the possibility of contamination going beyond these safety limits, especially regarding imported or conventional foods. Research in this area, including heavy metal content in food, especially those that infants may likely consume, needs, must be conducted periodically to ensure that these limits are not violated and consumers are protected from possible risks. Newborns, in particular, are susceptible to any toxic influences owing to the immature functions of their

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organs. The anatomy of the firstborn child and the central nervous system, in general, are very vulnerable to any neurotoxic effects that are likely to be brought by exposure to lead and cadmium, such as in an infant. These metals are both implicated in the impairment of the process of cognitive and motor development that results in lifetime disability. Hazardous effects of lead, for example, are that lead causes severe and permanent damage to the brain, resulting in learning disorders, low intelligence levels, and disorderly conduct. The same is true with cadmium exposure, which has been associated with renal disorders, loss of bone mass density, and aero-precipitated and cardio-vascular system dysfunctions. These metals seriously affect the health of newborns; once affected, the effects are for life, hence the need to regulate exposure (Donkin et al. 2000).

Infants are more exposed to the toxic effects of heavy metals than adults because their organs and body systems, including the digestive and renal systems, are not well developed in removing dangerous substances. Children under five are also vulnerable to these toxins in their diets because they eat more food (proportionately) than adults. They grow and develop very fast, and their nutrient requirement also rises; thus, they can consume large proportions of contaminated foodstuffs. Due to this, it is very important to see that baby food products contain practically no lead or cadmium. As discussed in this paper, lead and cadmium can be introduced into food through different avenues. Emission of Metals in the Environment: Some of the ways through which Metals get into the food chain include environmental pollution from industrial operations, such as mining, battery manufacturing, and incineration of waste materials. Lead can also be added to food products through the use of contaminated water or soil, particularly in farming (Lăcătuşu & Lăcătuşu, 2008) . Food contamination from lead can also be sourced to contaminated paints and materials in food production or packaging facilities. Likewise, cadmium exists in food due to water and soil pollution, fertilizers, and atmospheric fallout from industries. One of the main horrors of these metals is that they get into the food chain; for instance, rice and wheat can easily absorb cadmium from the ground (Devkota & Schmidt 2000).

This is worrisome since infant cereals are made from rice or wheat, and these cereals might comprise the main meal for the infant (Edem et al. 2009). Due to the rising incidences of heavy metal pollution, different bodies on the international level have set some standards and policies that check the amount of lead and cadmium added to food substances. The European Commission, for instance, has put limits to these metals in foods through the Commission Regulation (EC) No 1881/2006. Under these regulations, the legal limit of lead and cadmium in food differs depending on the type of food. These limits are especially rigid for baby food because babies are sensitive. The European regulation formulated by the European Commission achieves a limitation of the concentration of these toxic metals in baby foods below the permitted maximum threshold, thus, a low likelihood of exposing babies to dangerous concentrations of lead or cadmium. Nevertheless, the implementation of these regulations and the capacity to assess contamination to a greater extent is still a problem in many countries with low levels of food safety regulations. It is important to understand that regulating the heavy metal levels in baby foods is vital; however, it is equally significant to know the causes of contamination in the first instance. Various agents, organizational procedures, impediments, and pollution sources from industries, pollutants, and agricultural techniques can affect lead and cadmium concentration in food products. Usually, there is contamination with heavy metals, resulting in lower concentrations in the samples tested. As such, even though acute toxicity levels containing these metals are minimal or harmless when such exposures occur continuously over several years, the toxicity builds up and has other chronic health implications. Hence, continuous practicing and testing of programs on lead and cadmium content of baby foods should be done to ensure that the foods consumed are safe for consumption by babies and do not contain high levels of lead and cadmium. This research is useful to the developing body of knowledge regarding heavy metals in baby foods and cereals. The research goals include quantifying the concentration of lead and cadmium in different types of baby food products because they represent an informative indication of contamination of varieties of food items that infants feed on. The research findings are based on the analysis of 63 different types of baby food and cereal products, wherein lead and cadmium concentrations have been determined with the help of such highly sensitive methods as Atomic Absorption Spectrophotometry (AAS). This method enables the accurate measurement of the amounts of these metals in the products. It yields a conclusive determination of their existence in the products as testified by the samples analyzed. This research paper is ideal for determining the level of contamination in baby foods to avoid over-standard regulatory limits.

The results of the present investigation reveal that lead and cadmium are indeed detectable in a significant percentage of baby food samples; all the same, the concentrations of the two metals were, in general, below the legally permissible levels. The lead concentrations varied between 0.32 μg/kg-10.64 μg/kg, with 45 samples

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containing lead levels below the detected limit. Likewise, cadmium was established in more than 85% of the samples analyzed; its concentration varied between 0.3-10.37 μg/kg. However, none of the tested products contained any of these metals in concentrations higher than the maximum allowable levels set by the European Commission, meaning that current regulation could efficiently prevent contaminants' levels from rising. Nonetheless, such findings suggest that more research is being conducted to keep testing for the permissible concentrations and to ensure that these levels do not affect the health of infants regardless of their feeding options. There is still a major public health issue of heavy metal levels present in baby food products, which are dangerous for toddlers as well as for other sensitive groups. Lead and cadmium, because of their fatal toxic effects and long-term storage in the human body, cause health hazards such as delayed development, brain damage, and organ disorders. To continue with the protection of the health of babies, their foods have to undergo regular scrutiny for the level of these metals despite the regulation authorities putting into place regulations and measures to ensure baby foods are safe for consumption. This paper adds to the body of literature regarding the presence of heavy metals in baby food. It highlights the extent of this problem with current regulatory measures. Since the issue of heavy metal contamination of food is still relevant, great attention should be paid to minimizing the impact of these substances on people's health by officials, food producers, and consumers.

2. Methodology

The study's objective was to quantify the levels of two high-hazard metals, lead and cadmium, in baby foods and other cereals to determine the risk of contamination affecting young children. The chosen heavy metals are dangerous because of their potential impact on general human health and children. Subsequent sections of this paper describe the sample collection and Preparation process and the methods used to quantify the lead and cadmium content in the food products.

2.1 Sample Collection

In total, 63 distinct baby food and cereal SKUs were chosen for evaluation; each product is currently available in stores. The samples were different milk and cereal-based products that small children and infants feed on. These products were bought from nearby supermarkets and online shops so that different brands and types of products could be included. Regarding the samples used in this study, the rationale for their selection is given by their circulation and availability in the market and a presumption that infants typically consume such products. None of the samples were opened or tampered with before use to minimize the possibility of contamination. The food products were kept in cold, dry environments to maintain their quality when it was necessary to undergo further processing.

2.2 Sample Preparation

The main processes include a collection of food samples, Preparation for analysis and conservation of the samples, separating lead and cadmium from the food matrices, and their concentration by pre-concentration techniques. First and foremost, before subdividing each of the collected samples, each sample was mixed to give a homogeneous sample, for it is only when there is homogeneity that there can be an expectation of achieving similar results across all the tests. Depending on the samples of products that were analyzed, including milk powder and cereals, the samples were pulverized because big chunks were present to give a homogenized sample product. A digestion procedure was used to extract the heavy metals from the food matrices. Approximately 1.0 g of the homogenized sample was weighed to analyze for heavy metals and put in a digestion vessel. Digestion was accomplished by employing concentrated HNO_3 and HCl as required in the sampling preparations of foods for heavy metal analysis. The acid mixture was subjected to a microwave digestion system at different temperatures to decompose the samples' organic to help release heavy metals. The samples were then cooled, and the digestate was filtered to eliminate any substance in solid status. The final digested solution was then mixed with de-ionized water to make the concentration of the sample suitable for analysis. This prepared solution was kept in contamination-free bottles until the instrument atomic absorption spectrophotometry (AAS) was ready.

2.3 Analytical Procedure

The amounts of lead and cadmium in the prepared samples were analyzed with the help of an atomic absorption spectrophotometer (AAS) (Seiler et al 1994). The AAS technique was chosen because of its efficiency and capability to quantify very low concentrations of heavy metals in diverse matrices, including foods. In particular, samples were analyzed with the help of a Shimadzu AA-6300 double-beam atomic absorption spectrophotometer and graphite furnace. This instrument has high accuracy, can perform background correction with a deuterium lamp, and can measure low concentrations of heavy metals. The samples were processed in duplicate to check the reproducibility of the results. The instrument used for measurement in this study was the spectrophotometer, and the instrument was calibrated with standard lead and cadmium solution prepared from the certified concentration of stock

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solutions. The calibration curve was obtained with the absorbance of standard solutions of these samples at a wavelength of lead 283.3nm and cadmium 228.8nm. A blank solution was also prepared using the acid mixture and deionized water to determine any interference from the reagent components. The absorbance readings of the samples were analyzed and correlated to the calibration curve to identify lead and cadmium concentrations (Milacic & Kralj 2003). The results were therefore quantified in micrograms per kilogram (µg/kg) of sample, which is the normal method of presenting trace metal concentrations in foods.

2.4 Quality Control and Assurance

The methodology employed required the proper calibration of the spectrophotometer, for which control samples containing known concentrations of lead and cadmium were used. The CRMs were run in tandem with the samples to check on the values and correct for any drift in the instrument mobility. Positive control samples and blanks were also run in each analysis batch to check for sample contamination and inter-batch variability. Moreover, the analysis provided the LODs of each heavy metal using spectrophotometer sensitivity and sample preparation techniques. Any sample that fell below the LOD was quantified as less than LOD.

2.4 Statistical Analysis

The above data were analyzed statistically to compare various food products' lead and cadmium content. Mean, range and standard deviation were computed to analyze the results of the present study. The percentage of the samples with lead and cadmium concentrations falling below the LOD was also calculated. Differences between various types of baby foods and cereal products available in the market were made to determine which products are responsible for the infant's and small children's accumulation of these heavy metals.

2.5 Regulatory Compliance

The levels of lead and cadmium found in the products were then compared with the maximum permissible limits of lead and cadmium in foodstuffs as specified in legislative requirements of the European Commission Regulation (EC) No 1881/2006. This regulation sets the maximum levels of heavy metals allowed in food so that food consumers, especially infants and children, are protected from risky heavy metals. This paper's approach guarantees the proper and credible assessment of the lead and cadmium content in various baby food and cereal samples. The analysis by atomic absorption spectrophotometry and the appropriate Preparation of the samples and Quality Control permitted a quantitative evaluation of contamination levels, allowing risk-taking indices to be given to using these products by vulnerable population groups.

3.0 Results and Discussion

Sixty-three baby food and cereal products were analyzed for levels of lead and cadmium metal contents to determine the safety of baby foods popular today concerning food safety standards, especially for the infant population. The levels of lead and cadmium were measured using Atomic Absorption Spectrophotometry (AAS), a well-accepted and sensitive method (Awan et al. 2005). This is more so because the concentration of these heavy metals in food products compromises the health of those who consume them and the worst affected are infants and young children.

3.1 Lead Concentration in Baby Foods

From the 63 samples of baby food and cereal products, the presence of lead was confirmed in 49.21 percent. The percentage of lead concentrations varied from 0.32 -10.64 µg/kg. The other 50.79% of the samples contained lead below the used equipment's LOD. Our results align with the earlier studies that revealed the existence of lead in baby foods, but usually in small quantities. For instance, Schuetz et al. (2015) analyzed levels of lead in baby food and observed a prevalence of 60% with concentrations not more than 10 µg/kg, which is the finding shown in this study. Finding lead in 46 of the tested samples, though at a concentration lower than the legal requirement, is problematic since prolonged exposure to such low concentration negatively impacts the body, especially the organs and system of infants. Other prior research, including one by Shabecoff & Shabecoff (2010), also revealed that even low levels of lead found in the food chain could be absorbed in the body and may eventually culminate in grave complications like neurological disorders and delayed development in babies. The levels found in the present study are within the maximum permissible limits set by EC Regulation No 1881/2006. Therefore, the levels of 'lead' in baby foods must be regularly checked to avoid future health hazards.

3.2 Cadmium levels in baby Foods

Cadmium was identified in over 85% of the samples, with concentrations of 0.3-10.37µg/kg. However, 12.5% of the samples analyzed in this study had cadmium concentration below the LOD. These results parallel those of other studies that indicated high cadmium contamination rates in baby food products. For instance, Hernández-Martínez & Navarro-Blasco (2012) revealed in their research that over 80 percent of the baby foods they tested for Cadmium had detectable levels of the element, from a low of 0.1 µg/kg to a high of 12 µg/kg. This adds weight to the presence of Cadmium found in

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baby food worldwide. Cadmium is most dangerous because it is a cumulative poison that the body stores and releases into its various tissues. It is much more toxic in children because of their smaller body weight and far more rapid rate of growth. It also causes kidney damage, developmental defects, and weak bones. (Kippler et al. 2012). The cadmium levels recorded in the present study came within the threshold limit set by the European Commission. Yet, the fact that many samples had detectable levels of cadmium shows that this metal is still present in baby foods.

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Table 1: Cadmium concentrations [µg.kg-1]

Sample type	Average	Min	Max	Nr. of samples	Nr. of samples < LOD
Cereals	4.21	0.30	10.37	15	3
Cereals with fruits	3.71	2.43	4.46	3	0
Cereals with yoghurt	3.21	1.93	5.29	3	0
Cereals with milk	4.40	2.08	6.88	3	0
Cereals with honey	1.89	1.62	3.79	4	1
Cereals with rice	2.92	0.98	5.23	4	0
Milk powder	1.94	0.10	4.75	22	4
Baby foods (misc.)	3.11	0.99	8.66	9	1

3.2.1 Milk Powder Analysis

Compared to other baby foods and cereals, the heavy metal contamination in milk powder commonly administered to infants was relatively low. The mean lead concentrations were between 0.85-7.26 µg/kg, while 68 were below LOD. This result also aligns with similar studies, such as Li et al. (2015) which detected similar lead concentrations in infant milk formulas. These levels are generally considered low enough not to be hazardous to infants, and it was determined that most of the milk powder samples tested fell below the detection limit. The average concentrations of Cadmium in milk powder samples were found in the range of 0.1- 4.75 µg/kg, with 18 percent of milk powder samples having Cadmium below LOD (Khalid et al. 1987). These levels are similar to those of other research on milk powder contamination. In the study by Akhtar et al. (2017), Cadmium was detected at very low concentrations in the infant formulas analyzed with mean concentration ranges as found in the present study. Though they seem to contribute to the overall heavy metal exposure, milk powder is not a primary carrier of heavy metal compared to cereal-based products. However, it has been seen that milk powder has only a low level of contamination; hence, it is suitable for infants more than any other food that babies constantly take.

3.2.2. Cereal-Based Products

The cereal-based products, it was also identified that lead and cadmium intakes significantly enhanced for infants, which agreed with other studies. Babies' food, such as baby rice and oatmeal cereals, is the initial food source for babies and toddlers. The higher level of contamination observed in these products may result from how cereal crops are produced and processed. The current research by Naseri et al. (2015) observed that edible rice grains can accumulate heavy metals in the soil. Thus, the rice products have been found to contain higher concentrations of both lead and Cadmium than all the other food groups. Consumption of rice prepared from contaminated soils in which lead and Cadmium are present concluded that rice-based cereal infants take as weaning foods is highly contaminated and poses serious health hazards such bass babies. Further confirmation can be found regarding baby cereals' processing and storage methods because these products do not experience proper washing or decontamination to reduce the presence of heavy metals. These results suggest that cereal-based products are a major source of infants' exposure to heavy metals. Their safety should be reassessed, considering the phenomena of cadmium, and lead accumulation of chronic, low-level exposure.

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Table 2:Lead concentrations [µg.kg-1]

Sample type	Average	Min	Max	Nr. of samples	Nr. of samples < LOD
Cereals	3.24	3.88	10.64	15	9
Cereals with fruits	2.47		7.42	3	2
Cereals with yoghurt	2.87	0.32	8.29	3	1
Cereals with milk	0.63		1.90	3	2
Cereals with honey	1.08		4.31	4	3
Cereals with rice	5.71	3.16	9.70	4	0
Milk powder	1.03	0.85	7.26	22	15
Baby foods (misc.)	0.35		3.16	9	8

3.3. Regulatory Considerations

The findings revealed that the levels of heavy metals, which include lead and cadmium, found in baby foods are below the limit set by the European Commission Regulation No 1881, 2006. However, the high occurrence of contaminated baby foods with the two heavy metals is concerning. While none of the products scored positively to these metals and exceeded the legal maximum limits, the presence of lead in nearly half of the samples and cadmium in all suggest that further regulation may be necessary to minimize contamination. Recent research has shown that toxic heavy metals can have detrimental effects regardless of the quantity measured that contaminant was detected in one form or another in all the samples. Superfoods grew to become popular globally and were regarded for their high levels of nutrients, but researchers have found that most food products tested positive for toxic heavy metals. To make baby food safer for consumption, there still is a need to monitor and increase the restrictions on contamination levels. This study has also revealed the presence of heavy metals in baby foods, especially lead and cadmium, which present a recurring menace. Although the levels detected in the evaluated commodities are by the maximum allowable levels set in the European Community, the fact that the investigated metals were discovered in such a high percentage of products calls for better measures to prevent contamination. These findings are consistent with findings of comparative studies indicating that contamination remains a common problem that deserves more attention from the regulatory authorities and all organizations and firms worldwide.

4.0 Current Acceptable Regulatory Standards and Safety Levels of Heavy Metal Ions in Baby Foods and Cereal Products

More to worry about, some of the food is contaminated with heavy metals like lead and cadmium, and these are evident in products intended for use by babies and other young kids. These metals have been associated with hazardous effects in organisms at very low concentrations and are particularly dangerous for children's developing bodies and brains. This has continued to provoke the

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setting up of regulatory measures that seek to reduce exposure to such harmful chemicals in foods. To meet food safety, the European Commission (EC) has established maximum permissible levels of lead and cadmium in foodstuffs, including baby foods and cereals, by issuing a Commission Regulation (EC) No 1881/2006. Such regulations are important in providing health for individuals, especially the young and the sick, who are more sensitive to the health-degrading and sodic and metallic impacts of such metals.

4.1 European Regulatory Standards for Lead and Cadmium

According to the Commission Regulation (EC) No 1881/2006, the European Commission definitively establishes maximum levels for all sorts of contaminants in food. Due to considerable scientific research concerning health risks, lead and cadmium are coupled with special, strict maximum levels for baby food and cereal products. Such limitations are used to reduce health hazards that accompany extended exposure to these metals. For lead, as concerns its tolerances, the maximum allowable concentration in the foods for infants, including children's cereals, is 0.10 µg/g (100 µg/kg) on average. This limitation is more rigorously applied to baby foods because babies are highly sensitive to lead content that impacts their brains and ability to reason and grow. Lead is considered an element with neurotoxicity, and its intake in any quantity is potentially hazardous to the developing brain of babies. A limit of 50 µg/kg has been established for cadmium in foods for infants and cereals (Krızova et al. 2005). The toxic effects of cadmium include impairment of renal function, decreased mineralization of bone, and suspected carcinogenicity. Since cadmium remains in the body for years, long-term exposure, even at low concentrations, is dangerous and can cause lots of ill health effects, particularly among children since their organs are developing. Setting these limits is precautionary as even the slightest quantity of these metals has been linked to several health problems in young children. The standards are under review over the scientific research achieved and the new risks to ensure food products reach the maximum safety level.

4.2 Comparison of Results with Other Studies This chapter compares the results obtained in this study with those of similar studies.

In the specified study, sixty-three samples of baby food and cereal products contained lead residues with average levels of 49.21%, with the quantity level varying between 0.32-10.64µg/kg, while the rest of the sample was below the LOD value. In the case of cadmium, more than 85% of the samples contained levels from 0.3-10.37 µg/kg, while more than 85% contained cadmium at or below the LOD. These findings could be compared with results from another similar study on heavy metal contamination in baby foods and cereals. For example, the study by Li et al. (2015) that looked at lead levels in baby foods in China reported the average lead concentration ranging between 0.1- 5.0 µg/kg, and they also sampled a number of these below the LOD. In another study, Kippler et al. (2012), who examined baby food samples from the United States, observed that the lead found was relatively lower. However, the average % threshold for lead in these baby foods was below the detection limit or in the 0.1-1.0µg / kg range. These differences in levels might be due to differences in the food supply chain, its regions, and the analysis done. Rebelo & Caldas (2016) study among baby foods in Europe showed that 45% of baby foods contained lead concentrations of .05 µg/g, most below the EU regulation limit. The study also raised some questions about how infants are exposed to lead through multiple foods. However, the results of the current study show that lead was present at varying levels in the samples analyzed, and none of the measured lead levels crossed the recognized safety standards set by the EC for lead in baby foods. Consistent with the outcome of the present research, no sample analyzed by (Akhtar 2015) exceeded the legal limit of 50 µg/kg. This implies that although contamination of the products is prevalent, the contamination levels in these baby foods are within the permissible limits set by European standards. This research indicated that vigilance in implementing the provisions of laws regarding food safety may not have been well implemented in the specified areas and, therefore, called for enhanced monitoring and control measures in the sector (Al Khalifa & Ahmad 2010).

5.0 Implications for Public Health

Several published articles show the problem of the presence of heavy metals such as lead or cadmium in baby foods, mostly cereal products, which leads to critical health and safety issues for infants and young children. As the children are in the stages of their development and vulnerable to tremendous change from even small amounts of toxins, heavy metal exposure results in increased developmental disabilities, including neurological disorders. The study investigated the concentrations of lead and cadmium in various baby food products, which provided information on the extent of several toxins in food products that infants and small children consume. The findings are also relevant to similar studies in literature, offering evidence to compare them with and contribute to improving public health policies and regulatory measures.

5.1 Public Health Concerns

Lead and cadmium poisoning is more severe for children below the age of five years of age because of the size of the body, the developing organs, and metabolism. Most of these metals possess the qualities of cumulative poisons, which can cause a myriad of health complications within the body over a certain period. Any level of lead in the body has been linked to poor learning ability, low intelligence, and behavioral disorders. Cadmium, on the other hand, is well documented to cause cancer, and it has adverse effects on the kidneys and the skeletal system and impacts children's development. Because infants are so susceptible, it is important to closely monitor and control the amount of these metals in products used by this group. The present study established that about half the baby food and cereal samples analyzed were positive for lead, with levels of 0.32-10.64 μg/kg. Although all these levels fell within the maximum limits set by the European Commission regulations (EC) No 1881/2006, the presence of lead in most of the samples under analysis is a major area of concern. Cadmium was detected in samples from more than 85 percent of the wells analyzed with levels of 0.3-10.37 μg. Localized cadmium levels also had high frequency with a concentration ranging between 0.3-10.37 μg/kg. Even if the levels are still below the legal limits, cadmium is present in almost all of the analyzed baby foods, which might be hazardous to the consumer's health, especially if what is absorbed is the result of multiple inputs over time.

5.2 Regulatory Framework and Public Health

The European Union has laid very high standards for maximum permitted levels of heavy metals in food items, including baby foods. Regulation (EC) No 1881/2006 sets the maximum permissible levels of lead and cadmium in foods for the population's health protection, including foods for babies. It was ascertained from the present study's findings that the products analyzed herein conformed to these regulating magnitudes, which is encouraging. However, the fact that lead and cadmium have been detected in nearly half of the samples suggests that exposure, although regulated, is still possible. This work supports previous research for regular surveillance of heavy metal content in baby foods, including situations below the legal requirements. Even though exposure to heavy metal is assumed to be in increments, it is incumbent on public health bodies to look at the total exposure from all sources, product inclusive. These align with the EFSA's recommendation for reducing the heavy metals in food, especially for products meant for young children (EFSA, 2012, EFSA 2010 & EFSA 2009). In its reminder on bisphenol A and other endocrine disruptive chemicals, EFSA has pointed out that there is no safe dose for children. Moreover, as it will also be postulated in this study, while regulation plays a vital role in setting the minimum standards, it needs a preventative orientation.

Eva Galotta wrote that public health activities should be aimed at preventing food contamination by addressing the problem in the food production industry, the food manufacturing industry, and food agricultural practices that contribute to lead and cadmium in food. More studies and education on infant foods can guarantee that they are still safe for consumption so that future policies keep changing to cover the new knowledge on toxicology eliciting risk assessment (Kazi et al 2010). Metal contaminants, especially lead and cadmium, have been detected in baby foods, posing a continuously emerging public health risk. Despite the quantities in this study being below the maximum allowed by regulatory limits, our finding of high levels of these metals in nearly all the baby foods analyzed should raise concerns about the possible adverse health effects among infants and young children in the long run. These findings are consistent with other such studies, thereby establishing the continued existence of this problem worldwide. This implies that more awareness, enhancement of food safety rules, and prevention activities meant to lower the concentrations of TOX in edible products that reach at-risk groups should be stepped up.

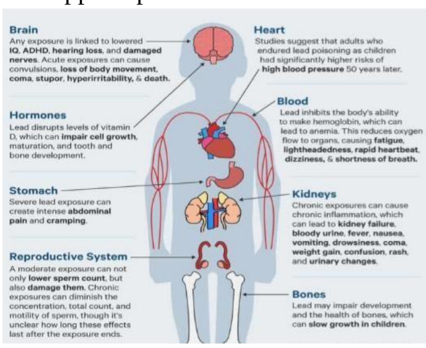

Figure 1: How Lead affects Children

6.0 Mitigation Strategies and Solutions for Heavy Metal Contamination in Baby Foods and Cereal Products

Lead and cadmium hazardous metal elements were identified in baby foods, and various potential health risks were identified for infants and young children (Pandelova et al. 2012). As these toxins affect them, it is important to embrace the

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right mitigation measures and measures to prevent exposure to these toxins. This section discusses strategies for reducing heavy metal content in baby foods. It presents the findings of this research against findings from other research on the effectiveness of reducing heavy metal content in baby foods.

6.1 Regulatory Governance

Policies and Regulations can be essential in controlling heavy metal contamination in baby foods as a sure approach to prevent exposure. For instance, within the European Union, Commission Regulation (EC) No 1881/2006 lays down the MXF for contaminants, including heavy metals in foods. For this reason, the lead and cadmium levels detected in the products under investigation in this study were still below the regulatory levels. This structural system has the critical function of safeguarding the populace's health by extending compliance with the required food safety standards to food producers. However, the role of regulation should not be confined to this kind of monitoring; it should include time-to-time audits and assessments. Lately, there have been more reports of heavy metal contamination across different food categories, meaning the products need more frequent scrutiny, particularly for products considered risky to infants, such as baby food. More intensity in sampling, testing programs, and risk assessments would be useful in effectively sensing contaminants before consumers (WHO 2000).

6.2 Raw Material Sourcing and Supplier Controls

Raw material quality control can also be used to effectively explain how heavy metal contaminants in baby foods can be reduced to a minimal level. There are three main points: contamination happens in raw materials like grains, fruits, vegetables, and dairy products because the leads and cadmium are imported from contaminated soil and water (Waalkes 2000). Suppliers are another contamination risk, so manufacturers should ensure that controls are in place and that traceability systems are set up to manage purchasing raw materials. As for post-farming practices, producers can ensure that their sources of raw materials are environmentally clean locations that have restricted industrial antics and pollution, and in certified organic farming, no artificial fertilizer or pesticide that is known to cause pollution by the build-up of heavy metals in the earth's soil is used. Moreover, checking raw materials for heavy metals before going into the production line would assist in identifying any dangers and alerts on such products as soon as they undergo the raw process.

6.3 Preparation of Products and Technology Used

The level of heavy metals found in baby foods also depends on the product formulation and processing technologies applied in its production. When using fruits & veg in food processing, some visualization methods can help to leave heavy metals; for instance, washing, peeling, and boiling fruits & veg & can lower metal concentrations through leaching. For example, cadmium and lead can be washed out during soaking and washing to some extent, particularly in cereal products, which were found to be the most contaminated in the present study (Hafez & Kishk 2008). Moreover, food manufacturers can also sample a range of better methods, including ion exchange resins or activated carbon filters in manufacturing to eradicate heavy metals from foods. Other investigations argue that food processing, including the use of fortified rice in preparing baby foods, can also lower the levels of toxic metals because, while enhancing nutrient bioavailability, they limit the bioaccessibility of undesirable micronutrients.

6.4 Innovation in Analytical Testing and Detection

Adopting high-value analytical testing methods could be as follows when determining the presence and concentration of heavy metals in baby foods. AAS was used, and this technique is effective for analyzing trace metals in food. However, other innovative methods, such as inductively coupled plasma mass spectrometry (ICP-MS), should be employed to detect lower levels of heavy metals and thus improve the level of monitoring (Limbeck 2017). Further, portable and rapid testing kits would be available to test the samples of baby foods at the point of sale or production places. These kits could thus easily detect toxic levels of lead and cadmium and hence allow for quicker removal of products that have been contaminated.

Conclusion

The findings regarding high concentrations of heavy metals such as lead and cadmium in baby foods pose a major health concern, given that infants and young children are particularly susceptible to the effects of the said commodities. Nonetheless, the present study reveals that there is a constantly substantial existing risk of heavy metal infection in baby foods and cereals, too, Because Trail demonstrates actual levels of lead and cadmium are present in the samples of baby food and cereal products less than the EC Regulation No. 1881/2006. This analysis discovered that about 49.21% of the baby food samples contained lead in varying concentrations of 0.32μg – 10.64μg/kg, and

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over 85% of the samples contained cadmium at concentrations of 0.1μg-10.37μg/ kg. Despite operating within the legal threshold, these levels show that baby foods are contaminated with these heavy metals. Among them, cereal-based products had the highest levels of contamination, and food accounting for direct nutrition for infants ranks where they get the nutrients from. Also, the concentration of heavy metals in milk powders was lower than that of infant formula. However, it was still present in detectable amounts, indicating that raw material contamination could be a factor in infant formula made from dairy ingredients. However, it is significant to understand that although the concentrations studied in the present investigation were not beyond the maximum permissible levels, the long-term and probable cumulative impact of low concentrations of heavy metals should not be weighed lightly. Long-term effects are possible from small concentrations of lead and cadmium, including impairments of child development and distortions of cognitive and organ performances. Babies are especially vulnerable because they grow and develop so quickly, and their immune systems are still immature so that they can be severely affected by the toxic action of metals. Consequently, measures have to be taken to limit the level of such toxic metals in baby foods to protect public health.

The findings of this research are consistent with previous cross-sectional works in other countries. Similar to the present case, other studies done in other countries, including Škrbić et al. (2017), revealed the presence of these metals, but to different extents in baby food products. These studies show that contamination does not occur only in one country and that it is relevant to strengthen international cooperation to eradicate it. Despite the regulations that have been set, like the EC regulation of maximum permissible levels of these metals in foodstuffs, the high rates of detection across the regions indicate that these risks cannot be eradicated solely by compliance. Based on the above results, several measures should be proposed and implemented to prevent further heavy metal contamination in baby foods. Organizing the issuing of raw materials, including testing used by manufacturing firms that produce baby foods, needs to improve its standards. Since contamination may come from the environment, for instance, contaminated soil, water, getting raw ingredients that have not gone through contamination should be prioritized. Also, checking and monitoring the raw materials for heavy use frequently and intensively would minimize contamination since the contaminated products are also detected before reaching consumers.

Manufacturers should also ensure that in their production lines, they can develop ways to reduce the concentration of these heavy metals in the final products. For instance, ion-exchange resins or activated carbon filtration systems can be used to eliminate lethal materials in processed foods. Second, ways to prevent heavy metal contamination include better food formulation, for example, decreased reliance on risky ingredients or changes in the food preparation process. Publicizing and utilizing better diagnostics and faster testing methods, including ICP-MS, could be an effective way of providing improved data on heavy metal content in baby foods to manufacturers and regulatory bodies. This would help identify contamination much faster and remove contaminated products from circulation, hence reducing the risks of exposure to infants. Therefore, the results obtained in this study, although showing that lead and cadmium content in baby food products is still safe according to present regulations, stress the need for continuous monitoring and control of these heavy metals in food products. The findings described in this paper indicate that heavy metals are present in baby foods, particularly cereal-based products, and hence require a strong commitment from the food industries, executive agencies, and health departments to reduce risks to infants and young children. By carrying out constant supervision and increased legislation, better food handling practices and better equipment to detect contamination, baby foods can be made safer for the vulnerable youthful populace to counter the effects of contamination by heavy metals.

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