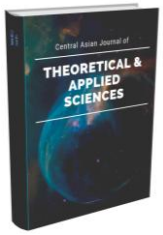

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Article

Toxicological Evaluation of Selected Heavy Metals in Toothpastes : Quantitative Findings and Public Health Perspectives

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Abstract: Toothpastes is important nowadays for frequent daily personal use to clean and whiten. Due to the increasing number of diseases in recent years related to the accumulation of heavy metals in the body , and due to the daily use of toothpaste , it has become important to check its safety from the heavy metals it contains . The importance lies in Knowing the safety of objects that enter or come into contact with human body , especially in the oral area , as they come into contact with the gums and salivary glands , and some children swallow them .This study has shown that there are high levels of some heavy elements examined in this work , namely lead (Pb) and arsenic (As) , among four heavy elements .The highest levels of lead (0.57 mg/kg) and arsenic (0.27mg/kg) were found in the analyzed toothpastes samples .These concentrations have been found to be very high and exceed the limits permitted by global health standards , especially in children`s toothpastes.

Keywords: Toothpastes , Heavy metals , Public health perspective.

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Introduction

The presence of heavy metals and foreign matter is not considered a major concern in cosmetics. While cosmetics have limited use among certain population groups, the daily use of toothpaste for oral hygiene is widespread globally. Consequently, the continuous daily ingestion of heavy metals and foreign matter present in toothpaste formulations raises significant safety concerns [1]. This is because many countries do not regulate the levels and concentrations of heavy metals and foreign matter in cosmetic products. The presence of these metals in toothpaste is often unintentional, resulting from impurities in other ingredients or from the manufacturing process [2]. Toothpaste is subject to different regulations, with some classified as cosmetics or personal care products and others as medications, depending on the country of manufacture. For example, in the United States, toothpaste containing fluoride is available without a prescription under the supervision of the Food and Drug Administration (FDA) [3]. In the European Union, toothpaste is regulated as a cosmetic product, while in India, it is used as both a medicine and a cosmetic. Although toothpaste may be used as a cosmetic or medicinal product, its regular use as a chemical product that comes into contact

with the oral mucosa multiple times a day may raise concerns due to its ingredients [4].

It has been shown that lead (Pb), cadmium (Cd), mercury (Hg), and arsenic (As) can cause a number of adverse health effects in humans under certain conditions [5]. According to a review by the Agency for Toxic Substances and Disease Registry (ATSDR), the serious health effects resulting from human exposure to high levels of lead include kidney, reproductive, immune, and neurological diseases, among others [6]. It has also been noted that "no safe level of lead in children's blood has been established," and that, according to the US Centers for Disease Control and Prevention (CDC), a blood lead level of 3.5 μg/dL is considered the reference level for high exposure in adults [6]. Furthermore, serious symptoms and diseases affecting multiple body systems, such as osteoporosis and kidney damage, have been observed as a result of high levels of cadmium ingested orally [7]. Mercury also has harmful effects on human health due to elevated blood levels resulting from oral ingestion, causing various pathological conditions such as neurological and renal inflammation in all forms of mercury in epidemiological and animal studies. Numerous additional effects (such as cardiovascular, hematological, immunological, and reproductive effects) have also been observed in animal studies [8]. Finally, arsenic ingestion in adults and children has been reported to cause similar effects, including gastrointestinal irritation, decreased red and white blood cell production, vascular damage, and cutaneous effects (darkening of the skin and the appearance of corns or warts on the palms, soles, and trunk). However, some evidence has also been found of reduced IQ scores in children as a result of chronic exposure to inorganic arsenic [9]. The roles of heavy metals as contaminants in toothpaste products have not been clearly defined. However, three main sources have been proposed to explain toothpaste contamination with heavy metals. One of these is believed to be the absorption of heavy metals by plant leaves or raw materials, which increases the contamination of toothpaste with these metals [10]. This is because heavy metals are known to have a strong affinity for plant leaves, and are therefore easily absorbed from fertilizers, herbicides, and pesticides [11]. Another possible reason is the addition of some heavy metals as therapeutic agents or to enhance the effectiveness of treatments based on toothpaste [12, 13] .

Methodology

Five grams were taken from each sample of toothpaste used for each specific type , which are ten different types .Each of these toothpastes underwent a wet digestion process using nitric and sulfuric acids for two hours . All samples were purchased either from the Iraqi market or from the most popular online marketplaces .All samples were sent for analysis using flame atomic absorption spectroscopy (AAS) to determine the proportions of heavy metals in these samples , namely lead ,cadmium , mercury arsenic .**Table 1** shows the types of toothpastes used and the company that supplied them in this research paper .

Table 1. Types of toothpastes used with supplying company .

Type	Brand company
Fluoride	*Colgate*
Fluoride free	*Tom`s of Maine*
Whitening	*Crest 3D white*
Sensitive	*Sensodyne*

Herbal	*Himalya Herbals*
Organic	*Desert Essence*
Kids	*Colgate kids*
Tartar control	*Colgate total*
Antibacterial	*Parodontax*
Multi purpose	*Oral- B complete*

Wet digestion process

In the sample preparation process for digestion , a mixture of concentrated nitric 70% and sulfuric 98% acids in 1:1 ratio was used . To measure each sample , a weight of 5 gm was taken in each wet digestion , then the required volume was completed to the mark with deionized water D2O. After the digestion process was completed for each of the samples individually the solutions were filtered through filter paper and stored in opaque volumetric bottles [19].

Results

Based on the values obtained from atomic absorption spectroscopy (AAS) of ten types of toothpastes , the results are shown in table .2 . The concentrations of heavy elements were determined in milligrams per kilogram of the materials used in accordance with internationally . In ordrer to accurately detect the four required elements , the device was calibrated with standard materials to detect the boundaries with extreme precision .

Table 2. Heavy metals concentrations in toothpastes samples in mg/kg.

Type of toothpaste	Brand	Sample No.	Arsenic (As) (mg/kg)	Cadmium (Cd) (mg/kg)	Lead (Pb) (mg/kg)	Mercury (Hg) (mg/kg)	Regulatory Compliance
Fluoride	*Colgate*	S1	0.046	0.009	0.57	<0.001	Exceeds limits for lead
Fluoride free	*Tom`s of Maine*	S2	0.088	<0.005	0.57	<0.001	Compliant
Whitening	*Crest 3D white*	S3	0.27	<0.001	0.51	<0.001	Exceeds limits for arsenic and lead
Sensitive	*Sensodyne*	S4	0.011	<0.005	0.009	<0.005	Compliant
Herbal	*Himalya Herbals*	S5	0.070	<0.005	0.015	<0.001	Compliant
Organic	*Desert Essence*	S6	<0.005	<0.005	<0.005	<0.001	Compliant
Kids	*Colgate kids*	S7	<0.001	<0.00196	0.52	<0.005	Exceeds limits for lead
Tartar control	*Colgate total*	S8	0.010	<0.001	0.011	<0.005	Compliant

Antibacterial	*Parodontax*	S9	0.128	<0.001	0.009	<0.005	Exceeds limits for arsenic
Multi purpose	*Oral- B complete*	S10	0.021	<0.005	<0.005	<0.005	Compliant

The results obtained from the atomic absorption technique are documented in table 2 .To determine the internationally permissible values of heavy elements , they are listed separately in table 3 .

Table 3. Permissible values in international standards for heavy elements.

Regulatory body/ State	Arsenic *(As)*	Lead *(Pb)*	Cadmium*(Cd)*	Mercury*(Hg)*	Scientific source
EU (European Union)	0.5 mg/kg	0.5 mg/kg	0.1 mg/kg	0.1 mg/kg	[14]
BVL Germany	0.5 mg/kg	2 mg/kg	0.1 mg/kg	0.1 mg/kg	[15]
WHO(Global Health Organization)	3 µg/g	10 µg/g	0.3 µg/g	0.1 µg/g	[16]
FDA (United States of America)	3 – 5 µg/g	5 µg/g	----------	----------	[17]
Health Canada	3 µg/g	10 µg/g	0.3 µg/g	0.1 µg/g	[18]

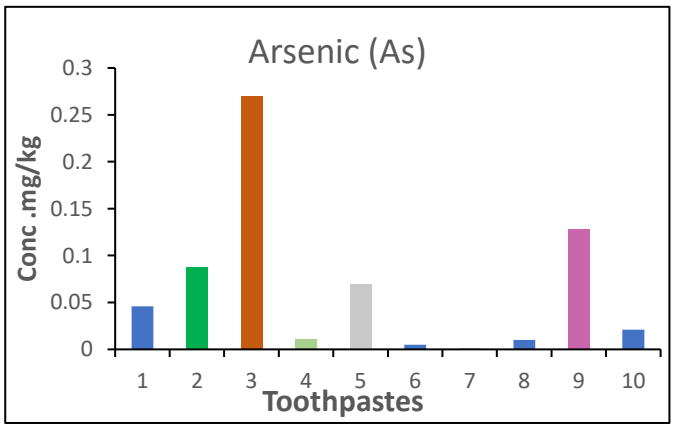

Fig .1 Level of As in toothpastes

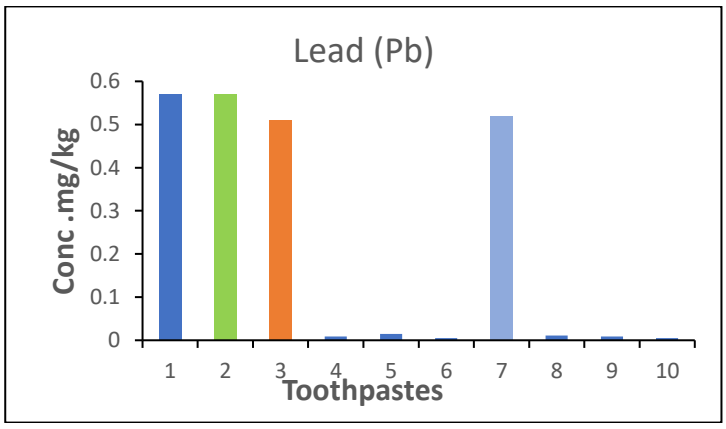

Figure 2. Levels of Pb in toothpastes

1=S1 , 2= S2 , 3=S3 , 4=S4 , 5=S5 , 6=S6 , 7= S7 , 8=S8 , 9=S9 , 10= S10

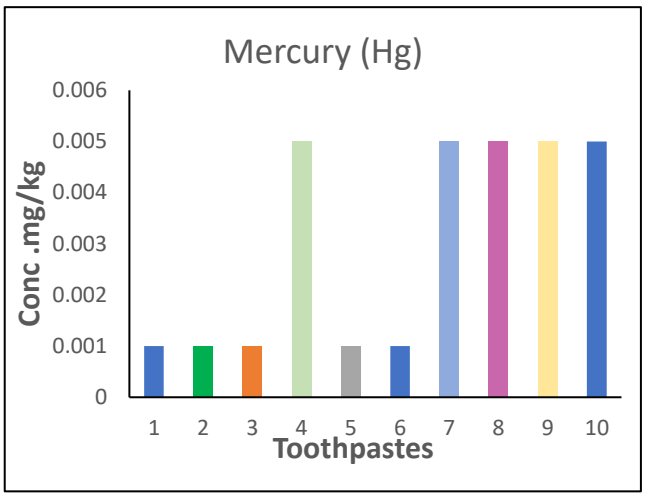

Figure 3. Level of Hg in toothpastes.

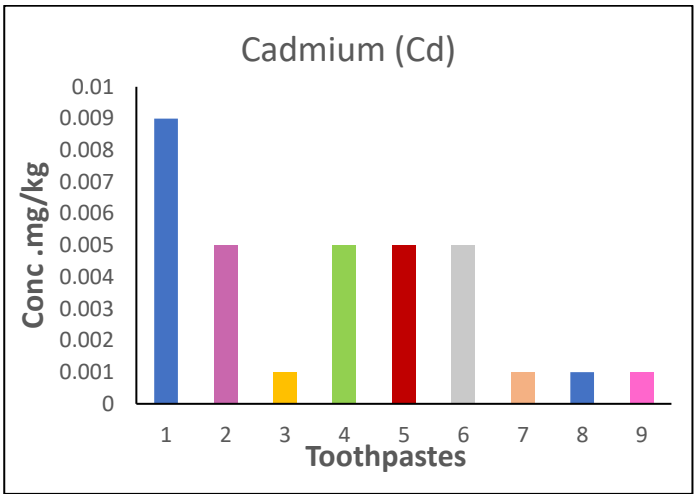

Figure 4. Levels of Cd in toothpastes.

Table 4. Statistical values of heavy metals in the toothpastes used.

Element	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	Standard Deviation (mg/kg)
Cadmium(Cd)	<0.001	0.009	0.003	0.003
Arsenic(As)	<0.001	0.27	007	0.09
Mercury (Hg)	<0.001	<0.005	0.002	0.001
Lead (Pb)	<0.005	0.57	0.23	0.25

Analysis of the results obtained from the results

This work measured several different types of pastes and examined the percentage of heavy metals present in them . Four harmful heavy metals were found in ten types of toothpastes available in the Iraqi market and online . High levels of certain elements were found , particularly arsenic and lead . Table 2 shows that the concentrations of elements exceeding internationally permitted limits are also found in toothpastes containing fluoride , Whitening , and antibacterial agents . Lead levels were found to exceed 0.5mg/kg in some samples , surpassing the limits permitted in the European Union (EU) . Lead is considered the most dangerous ingredient in children`s toothpaste, especially .The results also show that the arsenic content in some samples exceeded 0.1 mg/kg , which is a very high level exceeding in the recommended limits in all standards , especially the European Union and German standards, as shown in table 3. Cadmium and mercury remained within very low limits , with no exceedances .The organic toothpaste showed perfect results , with all values below the detection limit . All the results obtained from the device are shown in graphs as in figures 1,2,3 and 4. The results are numbered from 1 to 10 and assigned symbols from S1 to S10 for ease of measurements . The statistical ranges for all values found , and the standard deviation was found by repeating the resulting values , as shown in table 4.

Discussion

For many years, scientists have been determining the general characteristics of heavy metals, such as their toxicity, and how their amounts and concentrations affect human health. Cadmium, for instance, is a heavy metal that is used to color cosmetics. As with lead and arsenic, it has also been discovered to pollute the environment [20]. While mercury is uncommon in other cosmetic products, it has been found in significant amounts in skin-lightening creams [20]. The use of cosmetics and other personal care products on the skin can gradually accelerate the accumulation of heavy metals to dangerous levels, even though heavy metals,

whether added purposefully or accidentally, have an effective role in cosmetics, medicines, and toothpastes, such as silver diamine fluoride against tooth decay [21]. As a result, regulatory agencies impose restrictions on the amount of certain metals that may be found in toothpaste and cosmetics. The US Food and Drug Administration (FDA) has set upper limits for appropriate levels of certain heavy metals. For instance, the top limit is 1 ppm for mercury, 20 ppm for lead, and 3 ppm for arsenic [22]. Lead, cadmium, and mercury have upper limits defined by the World Health Organization (WHO) of 10 ppm, 0.3 ppm, and 1 ppm, respectively [23]. The European Union (EU) has established upper limits of 0.5 ppm for lead and mercury, 0.1 ppm for arsenic, and 1.0 ppm for chromium [24]. Lead, arsenic, cadmium, and mercury levels in cosmetics are limited to 20, 5, and 1 parts per million (ppm), respectively. Canadian sources state that the maximum allowable levels of lead, arsenic, cadmium, and mercury in toothpaste are 1 ppm, 0.5 ppm, 0.1 ppm, and 0.2 ppm, respectively [25]. The maximum amount of heavy metals in toothpaste in India is 20 parts per million, according to the Bureau of Indian Standards (BIS) [26]. The environment is full with toxic metals, such as lead (Pb), cadmium (Cd), mercury (Hg), and arsenic (As). They are known to have a detrimental effect on male reproductive health and may contribute to the development of numerous human diseases, such as kidney disease, neurological disorders, developmental delays, cardiovascular disease, and cancer, when humans are exposed to them through food, water, toothpaste, and occupational sources [27]. The effects of ambient arsenic levels on male reproductive results have been the subject of well-documented investigations.

After controlling for smoking and age, a cross-sectional investigation of males visiting reproductive clinics in Michigan, USA, discovered a substantial increase in the likelihood of impaired sperm motility and decreased semen volume with lower arsenic levels [28]. Throughout the world, mercury (Hg) and its compounds have killed many people in a variety of circumstances. The majority of methylmercury (MeHg) poisonings impact the central nervous system, particularly the regions in charge of motor coordination, vision, hearing, and sensory perception. Gingivitis, tremors, and increased excitability and irritability are common symptoms of this impact. Ataxia (unsteady gait) and blurred or double vision may develop in more severe cases of these symptoms, which first appear as tingling in the mouth, lips, and extremities [29,30]. Lead has detrimental impacts on human biochemistry, critical systems, and behavior. The cardiovascular system, the central nervous system, and the renal system are the three main areas where these significant health impacts appear. Children under six and fetuses are the most vulnerable. Currently, blood lead levels between 50 and 100 parts per billion are advised. It's unclear, though, if these impacts have a lower bound. Lead has a 20-year biological half-life and builds up in teeth and bones. People who are exposed to lead do not totally get rid of it, just like with cadmium [31]. When locals near a mine that was releasing untreated wastewater tainted with cadmium into the Jintsu River basin (Fuchu, Japan) complained of joint, bone, and muscular discomfort as well as renal failure, the public became aware of the harmful effects of cadmium on people. Later, this collection of health issues was dubbed Itai-Itai (ouch-ouch) illness, and several locals perished as a result. For up to 30 years, the locals had been exposed to rice cultivated in these locations that was tainted with cadmium. It takes 50% of cadmium to be removed from a person's body between the ages of 20 and 30, 75% between the ages of 40 and 60, and 87.5% between the ages of 60 and 90 [32]. Heavy metals are regarded as hazardous or undesirable in healthcare settings. The majority of heavy metals are hazardous, and continuous exposure to them can cause major ailments when they build up in the body [33]. Although cadmium's harmful effects on cells are well established, the exact mechanism underlying its

toxicity remains unclear. When cadmium binds to the cysteine-rich protein methalothionine, its concentration increases three thousand times. The cysteine-methalothionine combination in the liver causes hepatotoxicity. It then moves to the kidneys and builds up in their tissues, resulting in nephrotoxicity. Iron shortage may result from cadmium's capacity to bind to cysteine, glutamate, histidine, and aspartate [34]. Lead poisoning in living cells is caused by oxidative stress and ionic stress. Numerous studies have demonstrated that an imbalance between the formation of antioxidants required to detoxify reactive intermediates or repair damage and the creation of free radicals causes oxidative stress in live cells. The cell's antioxidants, including glutathione, guard against free radicals like $H2O_2$. However, when lead is present, antioxidant levels fall and reactive oxygen species (ROS) levels rise. Due to the fact that glutathione may be either reduced (GSH) or oxidized (GSSG), its reduced form stabilizes reactive oxygen species by providing their reduced equivalents (H^++-e) of thiol groups in cysteine [35].

Conclusion

This research investigated several types of harmful heavy metals found in toothpastes .The importance of highlighting the toxicity of heavy metals such us lead ,arsenic ,mercury and cadmium in ten different types and effects of toothpaste was discussed . The study indicates that heavy metals leak into toothpaste manufacturing in some way through processing or transportation equipment and are subsequently transferred to the human body via the mouth and gums , or unintentionally ingested by children . Statistical data from the work clearly indicated elevated levels of arsenic and lead in some types of toothpaste, including children's toothpaste. Through careful examination of the selected elements using flame atomic absorption spectroscopy, it was found that the standard deviation values obtained for the work ranged between 0.001 and 0.25 . The scientific importance of this research lies in the fact that repeated use of pastes containing leaking elements leads to numerous diseases, including diseases of the nervous system.

Recommendations

Through this work, I recommend conducting periodic tests on all types of toothpastes available on the market and measuring their safety from heavy metals using various analytical methods . I also recommend periodic testing for heavy metals deposited in the human body to ensure safety from their various harmful effects.

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