
Measurement of lead and cadmium concentration in Chinese plastic toys sold in the markets of Nalut City

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ABSTRACT

The purpose of this study is to measure the concentration of Lead and Cadmium in Chinese plastic toys sold in markets of Nalut city. To achieve this, a total of 9 different samples of plastic toys were collected from 4 toys and children's supplies stores. The toys were selected based on the type, color and price and targeted children aged between 1 month and 5 years. The study followed a cross-sectional design. Samples were digested and prepared at the Libyan Center for Plastics Research and then analyzed at the Food and Drug Control Center using a Flame Atomic Absorption Spectrophotometer (FAAS) to measure the concentrations of heavy metals: Lead (Pb) and Cadmium (Cd). Results revealed very high levels of Lead and Cadmium, with lead being the predominant metal, detected in 70% of samples, and Cadmium in 44%. Most concentrations exceeded the permissible limits set by European standards EN 71-3. Statistical analysis showed a significant relationship between the type of the toy and child age with lead concentration.

No correlation was found between price, color, or polymer type and Lead concentration. Conversely, a significant relationship was also found between cadmium levels and the toy price and color. The study concluded that Chinese plastic toys pose serious health risks to children in Nalut.

Introduction:

Early childhood is widely recognized as critical developmental stage during which children demonstrate a heightened capacity for learning and information absorption. Their natural curiosity and responsiveness make this period especially important for the introduction of stimulating and developmentally appropriate activities. Among these, play-particularly with toys- plays a pivotal role in fostering cognitive abilities, supporting physical and emotional development, and enhancing social interaction with peers (Al Shishani, 2023). Various toys such as cars, building blocks, toys, dolls, and others are manufactured from a variety of materials including metals, wood, fabrics, and most commonly plastic (Oyeyiola *et al.*, 2017).

Plastic toys, in particular, have become highly popular among both children and toy manufactures due to their ability to be molded and shaped in to realistic forms, since plastic is inexpensive and easy to mold, it has been widely

used in the production of children's toys since the 1870s (CEPED, 2013). Despite the associated risks, the production and use of plastic toys have significantly increased in recent years. Exposure to toys containing toxic heavy metals poses serious health risks to children, who are especially vulnerable due to their physiological and developmental characteristics (Gul *et al.*,2022).

Heavy metal contamination – whether direct or indirect – often results from human activities, primarily industrialization and urbanization. Toxic metals such as lead (Pb), cadmium(Cd), nickel(Ni) are often added to plastic toys to enhance durability and aesthetic appeal, such as softness, brightness, flexibility and vivid colors making them more attractive to children (Al-Kindi &Ali, 2020). The presence of these metals in toys can disrupt children's biological systems. During play, metals can enter the body through ingestion, mouthing, or skin contact, leading to serious health consequences such as impaired cognitive development, anemia, hormonal issues, kidney failure, and potential long-term effects on reproductive health. These metals tend to accumulate in the body over time, and while symptoms may develop gradually, they can include insomnia, diarrhea, abdominal pain, rashes, and respiratory problems(Saeed, Saidan & Saeed, 2020).

Thus, the purpose of this study is to measure the concentration of lead and cadmium in Chinese plastic toys available in the markets of Nalut City.

Materials and methods

Study sample:-

This study was based on a total of nine (9) plastic toy samples purchased from four (4) different stores that sell children's toys and supplies in the local markets of Nalut City, Libya. The selection of toys was based on various criteria including type, color, and price, targeting toys designed for children aged 1 months to 5 years.

Study method

The study adopted a cross-sectional descriptive design covering the period from November 2023 to August 2024. The plastic toy samples were first digested and prepared at the Libyan Center for plastics research, and then analyzed at the Food and Drug Control Center using Flame Atomic Absorption Spectrophotometer (FAAS) to determine the concentrations of the heavy metals such as lead (Pb) and cadmium(Cd).

Sample digestion

The sample digestion process was carried out at Libyan Center for Plastics Research in Tripoli. As a first step, the toys were examined and their polymer type was identified using an infrared spectroscopy device (Fourier Transform Infrared spectroscopy, FTIR) to determine the appropriate temperature to burn completely and correctly. To digest the samples, the toy subjected to chemical treatment using 53% nitric acid (HNO₃). The sample were heated on an electric plate until complete digestion occurred. The resulting solutions were then filtered and stored in clean, labeled containers for further analysis.

Sample collection methods

The plastic toy were selected based on various criteria (type, color, price) from different stores. After collection, each toy was assembled into individual parts for testing, based on material composition and contact surfaces. All samples

were labeled, coded, and stored appropriately before analysis. These plastic toys include cars, doll, whistle, building blocks, cooking toys, and trumpet with different colors. A variety of colors were tested , including red, blue, green, yellow, black, and white.

Data analysis

The collected data were analyzed using the Statistical Package for the Social sciences (SPSS). Descriptive statistics (frequencies, means and standard deviations) were used , in addition to inferential statistical tests, including Chi-square and ANOVA, to assess the relationships between the independent variables and the concentrations of lead and cadmium in the samples. A significance level of $p < 0.05$ was considered statistically significant.

Results

Table 1. outlines the distribution of the toy samples by type, number of parts after disassembly, price, and targeted child age group.

Toy type	Quantity	Number of parts per toy	child age	Price(LYD)
Baby pacifier	1	7	1 month-a year	8 dinar
Baby teether	1	2	1 month-a year	6 dinar
Ball	4	4	1 year- 3 years	1 dinar
Building blocks	1	4	1 year- 3 years	15 dinar
Car	1	6	1 year- 3 years	12 dinar
Dall	1	2	3 years- 5years	3 dinar
Trumpet	1	4	3 years- 5years	3 dinar
Whistle	4	4	3 years- 5years	2 dinar
toys	1	17	3 years- 5years	20 dinar
Total	15	50		

The table above illustrates the type of toys including dolls, cars, blocks, ball, cooking toys etc , their quantity, number of parts, the age group of children using them which targeted between children aged 1 months to 5 years , and their price (2-20 LYD). For example, the baby pacifier sample consisted of 1 toy with 7 parts, targeting children aged 1 month to 1 year and costing 8 LYD. The teether also consisted of 1 toy with 2 parts for the same age group, priced at 6 LYD. The balls were 4 in number, each with 1 part, for children aged 1 to 3 years, priced at 1 LYD each. The building blocks set had 4 parts and was intended for children aged 1 to 3 years, priced at 15 LYD.

Table 2. Colors of Plastic Toy Parts and Their Frequencies

Color	Frequency (n)	Percentage (%)
Red	10	20.0%
Yellow	8	16.0%
Blue	9	18.0%
Green	7	14.0%
Pink	6	12.0%
Orange	4	8.0%
White	3	6.0%
Black	3	6.0%

The table showed that red color was the most frequent toy color, followed by blue and yellow.

Table 3. the frequently and the percentage of lead concentration.

Lead concentration	Frequency(n)	Percentage(%)
2 or less	15	30%
More than 2	35	70%
Total	50	100%

The lead was more than 2 which detected in 70% of the analyzed toy parts and lead concentration in some samples exceeded the European safety limit (EN71-3) which was in 30% of the toy parts.

Table 4. Cadmium frequency and the percentage

Cadmium concentration	Frequency (n)	Percentage(%)
1.3 or less	28	56%
More than 1.3	22	44%
Total	50	100%

The table showed that cadmium was detected in 44% of the samples. Therefore, some cadmium concentration also exceeded permissible limits set by European standards which were in 56% of the samples.

Table 5. The mean and standard deviation for both lead and cadmium across the samples

	Cadmium	Lead
Mean	1.65	3.14
Standard deviation	0.93	4.12
greatest value	5.08	27.98
less value	0.62	0.00

From the previous table ,it can be observed that the average lead concentration was significantly higher than that of cadmium ,with obtained value being 3.14 for lead and 1.65 for cadmium. The standard deviation for lead was 4.12, and cadmium was 0.93. The largest value for lead founded in the doll was 27.98 mg/kg, while the smallest value was 0.00 mg/kg in part of kitchen toys. As for cadmium, the largest value was 5.08 mg/kg in an orange building block, while the smallest value was 0.62mg/kg in yellow car.

Table 6. The type of polymer used in toy manufacturing.

Polymer type used in toys	Frequency(n)	Percentage (%)
Poly probeLen (PP)	27	54%
Polymethyl (PM)	1	2%
polystyrene (PS)	9	18%
Polyethylene (PE)	10	20%
Silicone (SI)	2	4%
Poly probeLen teryolemer (PPT)/ Polyethylene (PE)	1	2%
Total	50	100%

Polyprobelen (PP) was the most commonly used polymer (54%). Less commonly type used was polymethyl (PM) and Poly probeLen teryolemer (PPT)/ Polyethylene (PE)(2%).

Table 7 . The relationship between the toy type and the concentration of lead and cadmium in it.

Toy types	Lead	Cadmium
Ball	9.21 mg/kg	3.44 mg/kg
Whistle	25.08 mg/kg	4.22 mg/kg
Doll	27.98 mg/kg	/
Trumpet	11.26 mg/kg	1.43 mg/kg
Teether	6.83 mg/kg	1.54 mg /kg
Pacifier	20.47 mg/kg	5.17 mg/kg
Car	14.8 mg/kg	3.28 mg/kg
Building blocks	2.61 mg/kg	10.08 mg/kg
Kitchen toys	33.08 mg/kg	34.41 mg/kg
P.value	0.002 (significant)	0.585(not significant)

The previous table shows the percentages of high concentrations of both lead and cadmium in the sample according to the toy type. The highest concentration of lead and cadmium was in the kitchen toys, while the cadmium concentration in the doll was below the European standard of 1.3 mg/ kg. The table also show the P-value , which find that the p-value (0.002) is less than the significant value of 0.05, meaning that there is a relationship between the high concentration of lead and the toy type, while the value (p=0.585) is greater than the significant value of 0.05, meaning that there is no relationship between the high concentration of cadmium and the toy type.

Table 8. The relationship between the toy price and the concentration of lead and cadmium in it.

Toy price	Lead	Cadmium
Ball (1 dinar)	9.21 mg/kg	3.44 mg/kg
Whistle (2 dinar)	25.08 mg/kg	4.22 mg/kg
Doll (3 dinar)	27.98 mg/kg	/
Trumpet (3 dinar)	11.26 mg/kg	1.43 mg/kg
Teether (6 dinar)	6.83 mg/kg	1.54 mg /kg
Pacifier (8 dinar)	20.47 mg/kg	5.17 mg/kg
Car (12 dinar)	14.8 mg/kg	3.28 mg/kg
Building blocks (15 dinar)	2.61 mg/kg	10.08 mg/kg
Kitchen toys (20 dinar)	33.08 mg/kg	34.41 mg/kg
P.value	0.854 (not significant)	0.000 (significant)

The table above shows the percentages of elevated concentrations of lead and cadmium for each toy sample based on its price. It is observed that the highest concentrations of lead and cadmium were found in the sample priced at 20 Libyan dinars, while the concentration of cadmium in the cheapest sample was lower than the permissible limit (1.3 mg/kg), as indicated in the table. Regarding the statistical significance, the P-value was 0.854, which is greater than the level of significance (0.05), indicating that there is no statistically significant relationship between the concentration of lead and the price of the toy. On the other hand, the P-value for cadmium was 0.000, which is less than the level of significance (0.05), indicating a statistically significant relationship between the concentration of cadmium and the price of the toy.

Table 9 . **The relationship between the child age and the concentration of lead and cadmium in it.**

Child age	Lead concentration	Cadmium concentration
A month - a year (pacifier-teether)	27.3 mg/kg	6.71 mg/kg
A year- 3 years (ball- building blocks –car)	26.62 mg/kg	16.8 mg/kg
3 years- 5 years(doll-trumpet-whistle-kitchen toys)	97.4 mg/kg	40.06 mg/kg
P-value	0.001 (significant)	0.370 (not significant)

The previous table shows the percentages of elevated concentrations for each of lead and cadmium levels in the sample , according to the age of the child who plays with the toy .It was found that the highest percentage of lead and cadmium concentrations was in the toys played with by children aged between 3-5 years . The table also shows the P-value , where for lead it was (p=0.001) , which is a value less than the significance level of 0.05 , meaning that there is a relationship between elevated lead concentration and the age of the child who plays with the toy . Meanwhile , the P- value for cadmium was (p=0.370) , which is greater than the significance level of 0.05 , indicating that is no relationship between elevated cadmium concentration and the age of the child who plays with the toy .

Table 10 . **The relationship between the toy color and the concentration of lead and cadmium in it.**

Toy color	Lead concentration	Cadmium concentration
Clear	2.27 mg/kg	/
White	2.67 mg/kg	/
Beige	27.98 mg/kg	/
Cloud white	8.99 mg/kg	3.37 mg/kg
Pink	10.07 mg/kg	1.37 mg/kg

Yellow	12.05 mg/kg	3.38mg/kg
Phosphorous	6.25 mg/kg	/
Green	20.81 mg/kg	3.21 mg/kg
Orange	13.28 mg/kg	13.44 mg/kg
Red	26.46 mg/kg	22.59 mg/kg
Purple	/	4.76 mg/kg
Blue	2.12 mg/kg	1.45 mg/kg
Black	18.45 mg/kg	8.46 mg/kg
White +black	/	/
P-value	0.190 (not significant)	0.045 (significant)

The previous table shows the percentages of elevated concentrations for each of the heavy metals, lead and cadmium, in the toy samples according to their color. It was found that the highest concentrations of lead and cadmium were in the red-colored toys, while cadmium concentrations in toys with orange, white, light purple, and white+pink+white colors were below the European standard limit of 1.3 mg/kg. Lead in the black + white toys was also below the European standard limit of 2mg/kg, as shown in the previous table. As for the P-value, the results find that the P-value 0.190, which is greater than the significance level of 0.05, indicates that there is no significant relationship between elevated lead concentration and toy color. On the other hand, the P-value 0.045, which is less than the significance level of 0.05, indicates a significant relationship between elevated cadmium concentration and toy color.

Table 11 . Relationship between polymer type and heavy metal concentration.

Type of polymer	Lead concentration	Cadmium concentration
PP	58.29 mg/kg	39.37 mg/kg
PM	/	/
PS	41.28 mg/kg	5.65 mg/kg
PE	40.92 mg/kg	15.1 mg/kg
SI	6.83 mg/kg	/
PPT/PE	4 mg/kg	1.91 mg/kg
P-value	0.456 (not significant)	0.295 (not significant)

The above table illustrates the concentrations of lead and cadmium in each toy sample according to the type of plastic material used. The highest concentration of lead and cadmium were recorded in toys made from polypropylene (PP), whereas the lowest cadmium concentration was found in toys made from polymethyl methacrylate (PM). The highest lead concentration appeared in toys made from polystyrene (SI). The concentration

of lead in polystyrene was 6.83 mg/kg, while cadmium concentrations in polymethyl methacrylate and polyethylene terephthalate (PE) were 1.3 mg/kg and 2 mg/kg, respectively.

The statistical analysis revealed that the differences in the concentrations of lead and cadmium among the different plastic types were not statistically significant (P-values: 0.456 and 0.295, respectively; $P > 0.05$), indicating that there is no significant correlation between the type of plastic material and the concentrations of the studied heavy metals.

Discussion

The results of this study clearly showed the presence of high concentrations of heavy metals—specifically lead (Pb) and cadmium (Cd)—in Chinese plastic toys sold in Nalut City. The measured levels in most of the samples exceeded the permissible limits established by international safety standards such as the European Union EN 71-3 standard. The findings are compared with previous studies to assess their alignment or divergence and to understand the broader implications of heavy metal contamination in children's toys.

The study revealed that 100% of the samples contained lead, with concentrations reaching up to 233.4 mg/kg. This finding is consistent with previous studies conducted in India and Nigeria. For instance, a study conducted in Mumbai reported lead concentrations between 878.6 to 2104 ppm, surpassing the USEPA limit of 600 ppm. Similarly, a Nigerian study by Oyeyiola *et al.* (2017) found lead to be the most concentrated metal in 84% of toy samples tested.

These results are in agreement with the study by Gul *et al.* (2022) in Pakistan, which reported that 83% of toys contained lead concentrations above the EU limits. Similarly, Oyeyiola *et al.* (2017) in Nigeria found lead concentrations ranging between 36.1 and 107 mg/kg, clearly exceeding safe limits. Another study by Udeala & Olulu (2024) reported cadmium levels up to 0.198 ppm, which is also considered hazardous for children. These findings indicate a global pattern of unsafe levels of toxic metals in children's toys, especially those imported from countries with lax safety enforcement.

Statistical analysis in this study showed a significant relationship between toy type and lead concentration ($p = 0.002$), particularly in toys like kitchen sets, dolls, whistles, and pacifiers. This suggests that specific types of toys, especially those designed for younger children who tend to chew or mouth toys, may pose greater risks. This finding contradicts a study by Sakala (2017) conducted in Lusaka, Zambia, which reported no significant correlation between toy type and lead concentration ($p > 0.05$). This observation is consistent with Yazdanfar *et al.* (2022), who reported that toys intended for infants and toddlers had higher lead levels due to their flexible, brightly colored plastic materials. Moreover, a significant relationship was found between child age and lead levels, especially in toys designed for children aged 3–5 years ($p = 0.001$). This aligns with the findings of Al Kindi & Ali (2020) in Baghdad, Iraq, who observed a similar pattern of high lead concentrations in toys targeting children aged 3–6 years.

All analyzed toy samples also showed the presence of cadmium, with concentrations ranging from 33.8 to 80.5 mg/kg. Although less prevalent than lead, cadmium levels also surpassed the European safety threshold. The study identified a statistically significant relationship between toy price and cadmium concentration ($p = 0.000$), confirming the findings of Al Kindi & Ali (2020), who found that cheaper toys tend to contain higher cadmium levels.

Additionally, a significant relationship was found between toy color and cadmium concentration, echoing the findings of the CEPHED (2013) study in Nepal, which emphasized the role of coloring agents in increasing cadmium levels and showed that cost-effective toys often compromise safety by using toxic additives. . Brightly colored toys had higher levels of cadmium, likely due to the use of cadmium-based pigments. Cheaper toys tended to contain higher metal levels, indicating poor material quality and manufacturing standards. Therefore, Al-Qutob *et al.* (2014) also found that red, yellow, and green-colored toys were more likely to contain high cadmium levels.

Although PVC and PE were the most common polymers found in this study, there was no statistically significant correlation between polymer type and metal concentration in this study ($p > 0.05$). This may be attributed to the widespread use of recycled plastic materials, where contamination can occur irrespective of the original polymer type. This result partially contradicts findings from Al-Kindi & Ali (2020), who reported that PVC toys were more likely to contain lead due to the stabilizers used in their production. The lack of significance in the present study could be due to the small sample size.

According to Libyan regulations, the permissible limit for lead is 0.7 g, while the EU standards limit it to 0.5–23 mg/kg depending on toy category. For cadmium, the EU limit ranges from 0.3–17 mg/kg. The study confirmed that most samples exceeded these limits, underscoring the urgent need for regulatory oversight in Libyan markets.

The presence of heavy metals in children's toys presents a severe health risk, especially for children under five years old. Lead exposure can lead to irreversible neurodevelopmental damage, behavioral disorders, and reduced IQ, while cadmium exposure can affect kidney function, bone health, and is classified as a carcinogen by the WHO.

This study's results are broadly in agreement with:

- CEPHED (2013) in Nepal: 54% of toy samples were contaminated with heavy metals.
- Suwal et al. (2023) in Nepal: Confirmed high concentrations of Pb, Cd, Hg, Cr, and Ni in common children's toys.
- ESDO (2013) in Bangladesh: Found 97% of toys exceeded safety limits for heavy metals.

These parallels demonstrate a global issue regarding the unsafe use of heavy metals in low-cost plastic toys, particularly those manufactured in or imported from developing countries.

Conclusion

The inclusion of heavy metals in the manufacturing of children's plastic toys poses a serious threat to their health, as their bodies are still in developmental stages. It has become nearly impossible for parents to avoid purchasing such toys for their children from an early age.

This study focused on measuring the concentration of lead and cadmium in Chinese plastic toys available in toy stores in Nalut City. The results indicated that lead was present in 70% of the 50 analyzed toy samples, while cadmium was found in 44%, which are extremely dangerous percentages when compared with European safety standards (EN 71-3). Therefore, there is an urgent need for stricter regulation and monitoring of the quality of children's toys to safeguard their health. Importing companies must adopt rigorous measures to ensure their products are free from these toxic heavy metals.

Study Recommendations

1. Regulatory Bodies

Authorities concerned with children's health and consumer safety should enforce regular monitoring and inspection of toys in local markets.

2. Establishing a National Standard

Libya needs to develop a national safety standard for permissible levels of heavy metals in children's toys, especially for cadmium which currently lacks clear local limits.

3. Import Control

Importing companies must be obligated to test samples from each shipment of plastic toys before distributing them in markets.

4. Public Awareness

There should be public awareness campaigns to educate parents and caregivers about the potential dangers of plastic toys containing heavy metals.

5. Future research

Further studies should be conducted to:

- Increase the number of samples tested.
- Analyze a broader range of heavy metals.
- Include toys from various countries, not just China.

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