Journal of King Saud University - Science 36 (2024) 103206

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Journal of King Saud University - Science

journal homepage: www.sciencedirect.com

Full Length Article

Presence of hazardous chemical elements in low-cost children's toys: A risk to their development in early childhood

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ARTICLE INFO

Keywords:
Chemical elements
Children's toys
Microwave digestion
ICP/MS
Cancer

ABSTRACT

Objectives: The objectives of the current study was to study the presence of hazardous chemical elements (Ba138, Cd111, Cr52, Pb208, As75, Co59, Cu63, Mn55, Ni60, Se82, Sr88, Zn66 and Hg202) in low-cost children's toys, and the effect of color types on chemical element concentrations.

Methods: Children's toy samples were analyzed using microwave digestion and inductively coupled plasma/mass spectrometry (ICP/MS) method. Samples were prepared into small pieces, and 500 mg of homogenized sample was used for digestion by means of digesting regents HNO_3 (65 %, 5 mL) and H_2O_2 (35 %, 1 mL). During the digestion process, the pressure was held constant at 90 bar and the temperature, hold time, and power were varied 150–170-40° C, 10–30-5 min, 70–90-0 %, respectively. The main operating conditions of ICP/MS were: spray chamber temperature (−20 °C), RF Power (1450 W), nebulizer gas flow (0.9 L/min), auxiliary gas flow (0.8 L/min) and plasma gas flow (14.85 L/min). Samples and blanks were analyzed for 30 s and system was operated in standard mode.

Results: The excellent method performance was achieved in terms of limit of detection (LOD, 0.001–14.89 µg/L); limit of quantification (LOQ, 0.003–45.12 µg/L); correlation coefficient (R^2, 0.975–0.999) with relative standard deviation values (RSD, 0.70–4.98 %). Chemical elements were found in all the toys (0.01–742.72 ng/g) except sample S2 where only Hg202 was found (0.01 ng/g). Outcomes revealed that the Hg202 was present at a very low level (0.01 ng/g) while Zn66 was present at very high level (742.72 ng/g). Furthermore, the toys contamination was also found to be color-specific, with significant amount of chemical elements was found in black type car sample (S5, 946.98 ng/g) whereas other color type samples constitute lower amounts (0.001–210.53 ng/g). Low-cost toys designed for children's use are found to contain chemical elements that should be addressed in the course of action. As a result of exposure to high amounts of chemical elements in toys, children have a high chance of developing cancer.

1. Introduction

Children of young ages are especially at risk from environmental health risks associated with colorants (Zheng et al., 2023). Generally, children's toys are bright and colorful. In addition to their stunning shapes and vibrant colors, consumers are also attracted to children's toys. There are several lethal chemical elements that may be present in children's toys (Abdullahi et al); (Chbihi et al., 2024), and child's mental growth is adversely affected by exposure to such elements (Cui et al., 2015); (Kamara et al., 2023); (Mateus-García and Ramos-Bonilla, 2014); (Zheng et al., 2023). Because of their high deadliness levels, mercury (Hg202), arsenic (As75), lead (Pb208), cadmium (Cd111) and chromium (Cr52) are among the top priority lethal chemical elements that pose a severe health risk particularly in children at early age (Aftab et al., 2023); (Chatterjee et al., 2018); (Dai et al., 2017); (Zheng et al., 2023). There are many factors that determine the metal's fatality, such as type of elements, dose quantity, route of exposure, along with individual's heredity, gender, age, and their dietary habits (Armijos et al., 2021); (Chatterjee et al., 2018); (Emeny et al., 2019); (Khan et al., 2021). Despite the fact that some elements considered as essential elements, and play a significant physiological and biochemical role in the human body (Prashanth et al., 2015); (Zoroddu et al., 2019), when these metals are used in excessive amounts, can damage cells and tissues, which can result in an array of adverse effects and diseases in humans

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https://doi.org/10.1016/j.jksus.2024.103206
Received 28 January 2024; Received in revised form 7 March 2024; Accepted 8 April 2024
Available online 9 April 2024

Fig. 1. Single-color or mixed-color children's toys (cars, building blocks, spoon and plate).

(Bansal, 2023); (Fu and Xi, 2020). Deoxyribonucleic acid (DNA) has been shown to interact with chemical elements, resulting in DNA damage that may modulate cell cycle, cause carcinogenesis (Tchounwou et al., 2012). Ba138 exposure causes various symptoms, for instance nausea, gastric pain, diarrhea, vomiting, hypokalemia, and paralysis (Peana et al., 2021). Cd111 is very lethal to cells, and its exposure can lead to neurotoxic, behavioral, fertility and reproduction effects (Schoeters et al., 2006). Cr52, Cr(III) form is essential for the metabolism of protein, glucose and fat in human body. Nevertheless, Cr(VI) exposure can lead to the risk of lung cancer (Prasad et al., 2021). Pb208 and As75 exposure have been shown to renal, neurological, reproductive, dermal and developmental health effects, and listed as known human carcinogens (Parker et al., 2022). Co59 is an essential chemical element with pervasive alimental exposure. There is adverse health effects associated with its exposure, including impaired vision and cardiomyopathy. Cu63, Mn55, Ni60, Se82, Sr88 and Zn66 are valuable mineral for human health, but chronic exposure can cause cardiovascular threat, cholesterol metabolism alterations, neurotoxicants, and risk of kidney, respiratory, type-2 diabetes, gastrointestinal or urinary tract infections (Araya et al., 2007); (Lucchini et al., 2018); (Peng et al., 2021);

(Rayman, 2012); (Zambelli and Ciurli, 2013). Hg202 has been known to be third deadly elements of universal distress for human health. There are multiple systems of the body that are susceptible to mercury's adverse effects, including central nervous system, cardiovascular system, and immune system (Arrifano et al., 2023); (Basu et al., 2023). A comprehensive assessment of the health threats posed by exposure to chemical in nutriments, toys, water, soil, cosmetics and paints (Achparaki et al., 2012); (Aftab et al., 2023); (Ahmad and Goni, 2010); (Ahmed et al., 2021); (Ali and Al-Qahtani, 2012); (Alqadami et al., 2017); (Ashfaq et al., 2015); (Basu et al., 2023); (Khan et al., 2021). Due to their high levels of toxicity, Cd111, Cr52, Pb208, As75 and Hg202 are considered to be one of the priority chemical elements that have a significant impact on public health (Abu-Ghazaleh et al., 2020); (Mitra et al., 2022). Multiple organ damage can be induced even at low levels of exposure to these universal toxicants (Abu-Ghazaleh et al., 2020). According to the epidemiological and experimental studies, exposure to these chemical elements is associated with a higher incidence of cancer in humans and animals (Abedi et al., 2020); (Kim et al., 2020); (Palma-Lara et al., 2020); (Proctor et al., 2021); (Waalkes and Misra, 2023). Later on, the Environmental Protection Agency (EPA) and International Agency for Research on Cancer (IARC) have classified these chemical elements as "*probable human carcinogens*" (Abedi et al., 2020); (Kim et al., 2020); (Palma-Lara et al., 2020); (Proctor et al., 2021); Waalkes et al., 2023). In 2012, the review of metals in the Toy Safety Standard (ASTM F 963), offers intake limits for some of the chemical elements (Pb208, As75, Ba138, Cr52, Cd111, Se82 and Hg202) that may present in toys ranged from 0.1 to 25 μg/day (https://www.cpsc.gov/s3fs-public/pdfs/blk_pdf_F963status03142012.pdf). The monitoring of these toxicants in children's toys is essential for reducing adverse health effects. To ensure the health safety of individuals, effective actions must be taken to prevent these toxicants from being introduced into toys intended for the use of children, and this would result in a substantial reduction in diseases and death numbers caused by harmful chemicals present in toys, food, air, cosmetics, water and soil.

In this study, a microwave digestion and ICP/MS technique were applied to the analysis of chemical elements (Ba138, Cd111, Cr52, Pb208, As75, Co59, Cu63, Mn55, Ni60, Se82, Sr88, Zn66 and Hg202) in children's toys. From the findings, individuals and manufacturers may gain some awareness of the existence of these toxicants in such types of samples, and health authorities will be able to decrease chemical element contaminations in toys precisely designed for children to use early in their lives.

2. Materials and methods

2.1. Materials

Sequential dilutions of certified reference materials (10 μg/mL, Ultra scientific, Rhode Island, USA) of the investigated chemical elements (Ba138, Cd111, Cr52, Pb208, As75, Co59, Cu63, Mn55, Ni60, Se82, Sr88, Zn66 and Hg202) were used to prepare standard solutions. Sample digestion was carried out using nitric acid (HNO_3, 65 %, 5 mL) and hydrogen peroxide (H_2O_2, 35 %, 1 mL), achieved from Loba Chemie (Mumbai, India). Deionized water was purified in the laboratory using an ultrapure water purification system from Millipore® (Bedford, MA, USA). A 50 mL conical centrifuge tube was achieved from Thermo Scientific, (Rochester, NY, USA). Before sampling, glassware was immersed in 10 % HNO_3, for 24 h and washed several times with deionized water. To analyze chemical elements, individual calibration curve solutions in the range of 0.5 to 100 μg/L were prepared.

2.2. Toy sample

Children's toys (cars, building blocks, spoon and plate) of single or mixed colors (Fig. 1) were obtained from the local toys market for a low price (Riyadh, Saudi Arabia). Toys were of plastic and precisely designed for use by children under three years of age. The choice of low-cost toys was made due to their possible high element concentration caused by recycling contaminated materials. Measurements were taken on parts of toys contacted by children by disassembling them into small pieces. A cutter was used to cut toys into small pieces, and 500 mg of sample was used to measure the chemical elements concentration.

Table 1
Operational conditions of the microwave digestion system.

Phase	Temperature, °C	Pressure, bar	Ramp, min	Hold, min	Power (%)
1	150	90	5.0	10.0	70
2	170	90	5.0	30.0	90
3	40	90	1.0	5.0	0

2.3. Sample analysis

Hand-homogenization process was used to homogenize samples of toys of varying colors. Homogenized sample (500 mg) was directly weighed into modified polytetrafluorethylene weighing cups (TFM-PTFE). An aluminum rupture disc and a TFM-PTFE coupling cap were used to secure the sample inside the pressure vessels of the microwave digestion (model, TOPwave, PM 60) system. (Analytik Jena AG, Munich, Germany). A 60 mL pressure vessel was used, with a maximum pressure of 60 bars, a temperature of 210 °C with continuous operation, a sample weight of 500 mg, and a minimum volume of 7 mL (acid). Approximately 5 mL of HNO_3 and 1 mL of H_2O_2 were added to the pressure vessel containing the toys samples for digestion. Samples were left at room temperature for 15 min, and then transferred to the microwave system for pressure digestion. Table 1 presents the optimized conditions for the system that have been selected for the optimization process.

Upon completion of the digestion process, the sample was allowed to stabilize for a while and then transferred to a conical centrifuge tube. The sample was then diluted with deionized water (25 mL), and the sample was left for 10 min to settle down the matrices before being analyzed. A multi-elemental determination technique (ICP/MS) was applied to investigate the samples, which is known to be an effective system for investigating highly complex samples. Adding/recovery calculations were used to measure system accuracy as plastic toys certified reference materials were inaccessible. In order to conduct these valuations, known amounts of chemical elements were fortified to each sample before digestion and analysis. This was done by comparing the obtained concentrations with the fortified and found concentrations.

2.4. Control and assurance quality

The quantification of chemical elements was performed by means of individual calibration curves from a mixture of standard solutions comprising Ba138, Cd111, Cr52, Pb208, As75, Co59, Cu63, Mn55, Ni60, Se82, Sr88, Zn66 and Hg202. LOD and LOQ of the studied chemical elements were calculated using 3.3σ/S and 10σ/S, respectively. σ represents the standard deviation of the response and S represents the slope of calibration curve. In order to achieve the recovery values estimation, toy samples were fortified with known amounts of chemical elements, and it was estimated by comparing the variance of determined element amounts between the fortified and non-fortified toy samples to the concentration of fortified elements. In order to analyze the data statistically, ANOVA was used to conduct a two-way analysis of variance.

2.5. Determination method (ICP/MS)

ICP/MS (Thermo Scientific™, Bremen, Germany) was used to identify the Ba138, Cd111, Cr52, Pb208, As75, Co59, Cu63, Mn55, Ni60, Se82, Sr88, Zn66 and Hg202 in children's toys. The system includes a secondary electron multiplier detector, a peltier cooled spray chamber, a

Table 2
ICP/MS conditions applied for the analysis of chemical elements in children's toys.

Parameters	Value
RF frequency	40 MHz
RF Power	1450 W
Pirani Pressure	1E + 2 mbar
Penning Pressure	9.549E-8 mbar
Detector Counting Voltage	1750 V
Detector Analog Voltage	−1825 V
Plasma gas flow[Ar, 99.997]	14.85 L/min
Auxiliary gas flow[Ar, 99.997]	0.80 L/min
Nebulizer gas flow [Ar, 99.997]	0.90 L/min
Sampler and Skimmer cone	Nickel
Mode of operation	Standard mode (STD)
Sample Uptake	30 s
Peristaltic Pump Rate	40 rpm
Nebulizer	Glass concentric type
Spray Chamber	Quartz, Cychronic type
Spray Chamber Temperature	−20 °C
Injector	Quartz, 2.5 mm I.D.
Torch	Two concentric quartz tubes
Sample tubing	Standard 0.508 mm I.D.
Drain tubing:	Standard 1.290 mm I.D.
Dwell Time	0.01 s
Number of Replicates	3
Rinse Time	30 s
Resolution m / z	238 amu
Short-term stability	< 3 % RSD

amu, atomic mass unit; RSD, relative standard deviation

Table 3
Quality parameters of the ICP/MS method.

Chemical elements	LOD, μg/L	LOQ, μg/L	R^2	RSD, %
Ba138	14.89	45.12	0.997	1.880
Cd111	0.005	0.015	0.999	1.560
Cr52	0.005	0.016	0.999	1.710
Pb208	0.001	0.004	0.998	0.700
As75	0.005	0.015	0.999	1.250
Co59	0.004	0.013	0.999	1.390
Cu63	0.001	0.003	0.991	5.110
Mn55	0.003	0.010	0.999	0.750
Ni60	0.002	0.006	0.999	2.130
Se82	0.057	0.173	0.975	0.760
Sr88	0.003	0.010	0.997	1.140
Zn66	0.005	0.015	0.992	0.910
Hg202	0.001	0.003	0.999	4.980

Limit of detection (LOD = 3.3σ/S); Limit of quantification (LOQ = 10σ/S); R^2, correlation coefficient; RSD, relative standard deviation

mass analyzer, a peristaltic pump, a nebulizer, a torch and an interface. Foremost operating conditions of the ICP/MS were as follows: spray chamber temperature (−20 °C), RF Power (1450 W), nebulizer gas flow (0.9 L/min), auxiliary gas flow (0.8 L/min) and plasma gas flow (14.85 L/min). A detailed description of the operating conditions of ICP/MS has been provided in Table 2. Qtegra™ Intelligent Scientific data solution software (Thermo Scientific™, Bremen, Germany) was used to monitor and maintain the system. Samples and blanks were analyzed for 30 s while the system was operating in standard mode.

3. Results and discussion

ICP/MS is a highly sensitive and robust technology, that allowing simultaneous estimation of a variety of compounds in complex samples proficiently, without interference, and quickly (Sader and Ryan, 2020). Besides, in highly matrixed samples, the ICP/MS can reliably determine minor and major element levels following a very simple digestion step. In order to digest the toy samples, primarily digesting regents HNO_3 (65 %, 5 mL) and H_2O_2 (35 %, 1 mL) was chosen owing to their high matrix nature. During the digestion, the pressure was held constant at 90 bar and temperature, hold time, and power were varied 150–170-40 °C, 10–30-5 min, 70–90-0 %, respectively (Table 1). Various parameters were considered to assess the system performance, such parameters included LOD (signal-to-noise ratio 3:1), LOQ (signal-to-noise ratio 10:1), precision, linearity (R^2) and accuracy. According to the individual calibration equations, LOD and LOQ values were determined by using the 3xstandard deviation of the response/slope and 10xstandard deviation of the response/slope, respectively. A range between 0.003 to14.89 μg/L and 0.003–45.12 μg/L was found for LOD and LOQ, respectively. It was determined that LOD and LOQ values were applicable to determining these type of element in highly matrixed samples. A summary of the results has been provided in Table 3.

In order to assess the run-to-run and day-to-day precision of the technique, a mixture solution containing 1 ng/mL of chemical elements was analyzed. The run-to-run precision was determined by performing six analyses of the same standard solution on three occasions within a 24 h period. On each of the three consecutive days, six analyses of the standard solutions were performed to determine the day-to-day precision. Using relative standard deviation (RSD%) as a measure of precision, run-to-run precision was calculated to be lower than 1 % and day-to-day precision to be smaller than 5 %. To determine the linearity (R^2) of the experiments, individual calibration curves of the chemical elements (Ba138, Cd111, Cr52, Pb208, As75, Co59, Cu63, Mn55, Ni60, Se82, Sr88, Zn66 and Hg202) were achieved from the system. R^2 values of the system were usually found higher than 0.999 in most cases (Table 3). Fig. 2 illustrates calibration curves for some chemical elements (Cd111, Pb208, As75, Co59, Sr88 and Hg202) obtained using ICP/MS method.

According to the results of the method, chemical elements levels from lower to higher were linear. To test the method's accuracy, toy samples were spiked with known amount of chemical elements, and the recovery rates were obtained higher than 99 %. All the values were found similar to those identified in earlier work (Khan et al., 2021). The quality parameters of the system were found to be suitable for the analysis of chemical elements in ten toy samples (cars, building blocks, spoon and plate) of sole or mixed colors. Toys were of plastic and precisely designed for use by children under three years of age. The low-cost toy selection was made due to their conceivable high elemental level caused by recycling of contaminated materials. In Table 4 the concentrations of Ba138, Cd111, Cr52, Pb208, As75, Co59, Cu63, Mn55, Ni60, Se82, Sr88, Zn66 and Hg202 in toy samples have been presented, were found in all of the toys range from 0.01 to 742.72 ng/g except sample S2 where only Hg202 was identified at 0.01 ng/g. Among samples, S5 was found to contain the highest concentration of chemical elements, totaling 946.98 ng/g followed by S10 (210.53 ng/g), S1 (195.32 ng/g), S8 (70.47 ng/g), S4 (69.38), S9 (61.77 ng/g), S7 (46.83 ng/g), S3 (36.44 ng/g), S6 (33.24 ng/g). The total concentration variation of the chemical elements in toy samples have been presented in Fig. 3.

Samples S10 and S1, S8 and S4 and S9, S3 and S6 constitute identical concentration in most of the cases. Cd111, Pb208, As75, Co59 and Hg202 constitute the leading list of hazardous substances and caused to neurodegenerative disease and oxidative stress (Dong and Li, 2024); (Hutton, 1987); (Jose and Ray, 2018).

From the outcomes, Ba138 constitutes concentration from 1.04 to 92.52 ng/g in all the samples except S2 where found not detected. As75 and Cd111are also grouped with Ba138, which is used in children's products. Potentially toxic and previously undetected threat Ba138 contaminated seven of the children's products pulled from shelves in 2008 in Canada (https://209.217.71.106/PR/home-accueil-e.jsp). In earlier work, researchers have studied the Ba138 in toys and children's jewry, Crayon set toys constitute high amounts (3205 ng/g) (Guney et al., 2014). As a result, higher values were found than those achieved in the current study. Cd111 has been more heavily regulated in recent decades due to its toxic properties, and should be less than 23000 ng/g in plastic toys (Turner, 2019). According to our results, the plastic toys

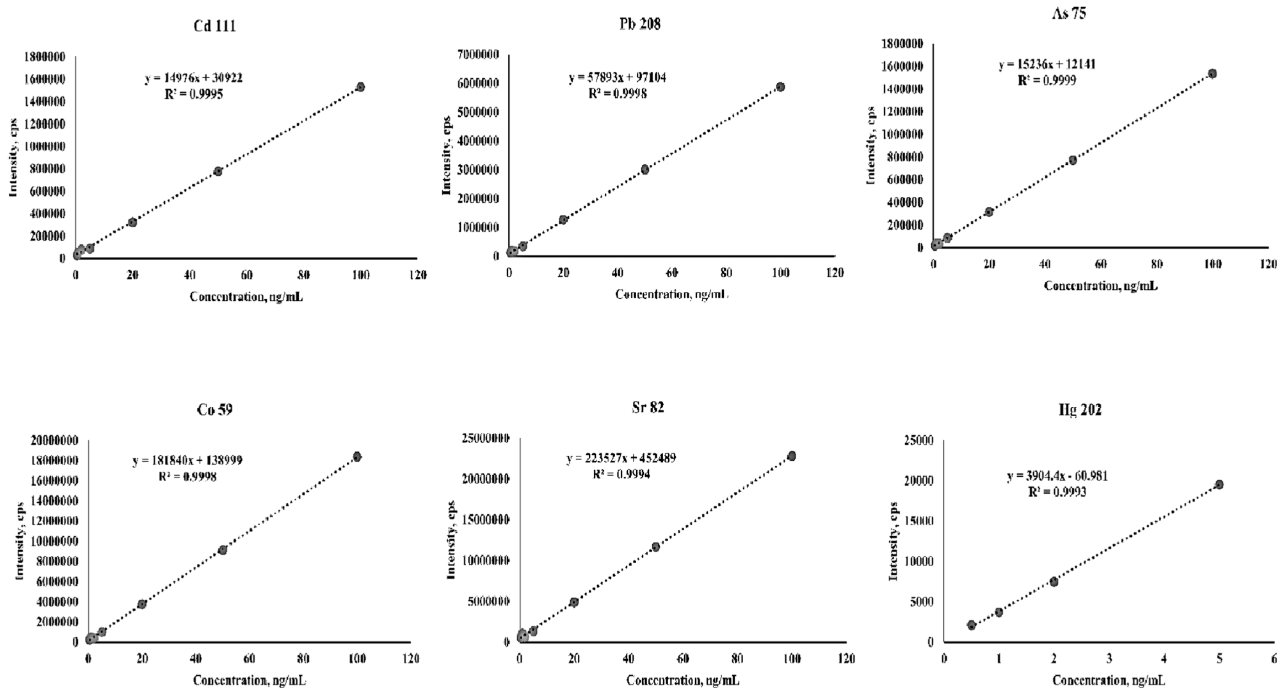

Fig. 2. Calibration curves of certain chemical elements (Cd111, Pb208, As75, Co59, Sr88 and Hg202) obtained by ICP/MS.

Table 4
Amounts of chemical elements in children's toys identified by microwave digestion and ICP/MS method.

Sample	Ba138 (ng/g ± sd)	Cd111 (ng/g ± sd)	Cr52 (ng/g ± sd)	Pb208 (ng/g ± sd)	As75 (ng/g ± sd)	Co59 (ng/g ± sd)	Cu63 (ng/g ± sd)	Mn55 (ng/g ± sd)	Ni60 (ng/g ± sd)	Se82 (ng/g ± sd)	Sr88(ng/g ± sd)	Zn66(ng/g ± sd)	Hg202 (ng/g ± sd)
S1	2.98 ± 0.06	0.04 ± 0.05	5.95 ± 0.05	9.38 ± 0.02	0.01 ± 0.10	0.17 ± 0.4	nd	4.64 ± 0.04	3.92 ± 0.05	0.08 ± 0.20	13.46 ± 0.05	154.50 ± 0.03	0.21 ± 0.30
S2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.01 ± 0.01
S3	2.03 ± 0.07	0.01 ± 0.05	2.06 ± 0.04	4.59 ± 0.01	nd	0.06 ± 0.05	nd	2.59 ± 0.05	0.67 ± 0.09	nd	2.00 ± 0.01	22.36 ± 0.05	0.07 ± 0.02
S4	22.28 ± 0.01	0.01 ± 0.04	3.34 ± 0.06	3.59 ± 0.05	0.01 ± 0.01	0.06 ± 0.04	9.19 ± 0.6	2.32 ± 0.03	1.73 ± 0.04	nd	0.57 ± 0.01	26.30 ± 0.02	nd
S5	92.52 ± 0.01	0.08 ± 0.02	5.17 ± 0.04	11.15 ± 0.01	0.27 ± 0.06	5.85 ± 0.02	21.20 ± 0.02	34.05 ± 0.02	6.10 ± 0.01	0.39 ± 0.09	27.48 ± 0.02	742.72 ± 0.01	nd
S6	8.83 ± 0.02	nd	2.80 ± 0.02	1.03 ± 0.01	nd	0.07 ± 0.01	nd	2.56 ± 0.03	0.99 ± 0.08	nd	0.45 ± 0.01	16.54 ± 0.03	nd
S7	5.93 ± 0.01	0.01 ± 0.01	2.54 ± 0.02	3.92 ± 0.01	nd	0.07 ± 0.02	nd	2.44 ± 0.02	1.13 ± 0.02	nd	0.82 ± 0.05	29.99 ± 0.02	nd
S8	33.99 ± 0.02	nd	2.91 ± 0.03	0.82 ± 0.03	nd	0.06 ± 0.02	nd	2.31 ± 0.02	0.94 ± 0.04	nd	1.60 ± 0.04	27.86 ± 0.01	nd
S9	1.04 ± 0.01	nd	2.80 ± 0.01	0.31 ± 0.02	nd	0.05 ± 0.02	nd	1.96 ± 0.01	1.07 ± 0.01	nd	2.27 ± 0.01	52.26 ± 0.01	nd
S10	47.54 ± 0.04	0.22 ± 0.03	4.34 ± 0.04	114.67 ± 0.04	0.70 ± 0.03	0.16 ± 0.04	10.87 ± 0.07	4.72 ± 0.04	1.39 ± 0.05	0.52 ± 0.07	2.43 ± 0.08	22.97 ± 0.04	nd

sd, standard deviation (n = 3); nd, not detected.

analyzed in this study are Cd111 safe. Cr52 has also been known to be a toxic element and has been studied in various kind of samples. In earlier studies, researchers have studied the Cr52 in cheap children toys, found higher amounts (8025 ng/g) of Cr52 (Karaś and Frankowski, 2018). Nevertheless, in our case the Cr52 was identified at low concentration up to 5.9 ng/g, plastic toys could be assumed as safe. Toys containing Pb208, are a major health risk and have received a lot of attention from international organizations, such as EPA and WHO. Recently, Shen et al. (2018) have studied the children's toys painted with lead-based paint, found very high amounts 32000 ng/g (Shen et al., 2018). Recently, Peng el al. (2023) have also reported the lead content in toys and in the blood of young children in Shanghai, obtained highest average Pb208 amounts 39130 ng/g (Peng et al., 2023). These values are so high as compared to the current study's results (114.67 ng/g). Relating to As75, many earlier studies illustrate that its consumption increases the threat of various cancers for instance liver, skin and bladder (Kumar & Ghosh, 2019; Tchounwou et al., 2023). As75 has been determined to be a known human carcinogen by the USEPA and Department of Health and Human Services (DHHS) (Health and Services, 1999). IARC has also listed that As75 is carcinogenic to human beings (https://www.epa.gov/sites/default/files/2014–03/documents/arsenic_toxfaqs_3v.pdf). We have identified As75 in five toys samples with maximum concentration of 0.70 ng/g. Yazdanfer et al., (2022) have reported that the Iranian children's toys marketed for sale contain potentially toxic metals, found As75 900 ng/g (Yazdanfar et al., 2022). Based on a standard dose lower confidence limit for a 1% increased risk of bladder, skin and lung cancer,

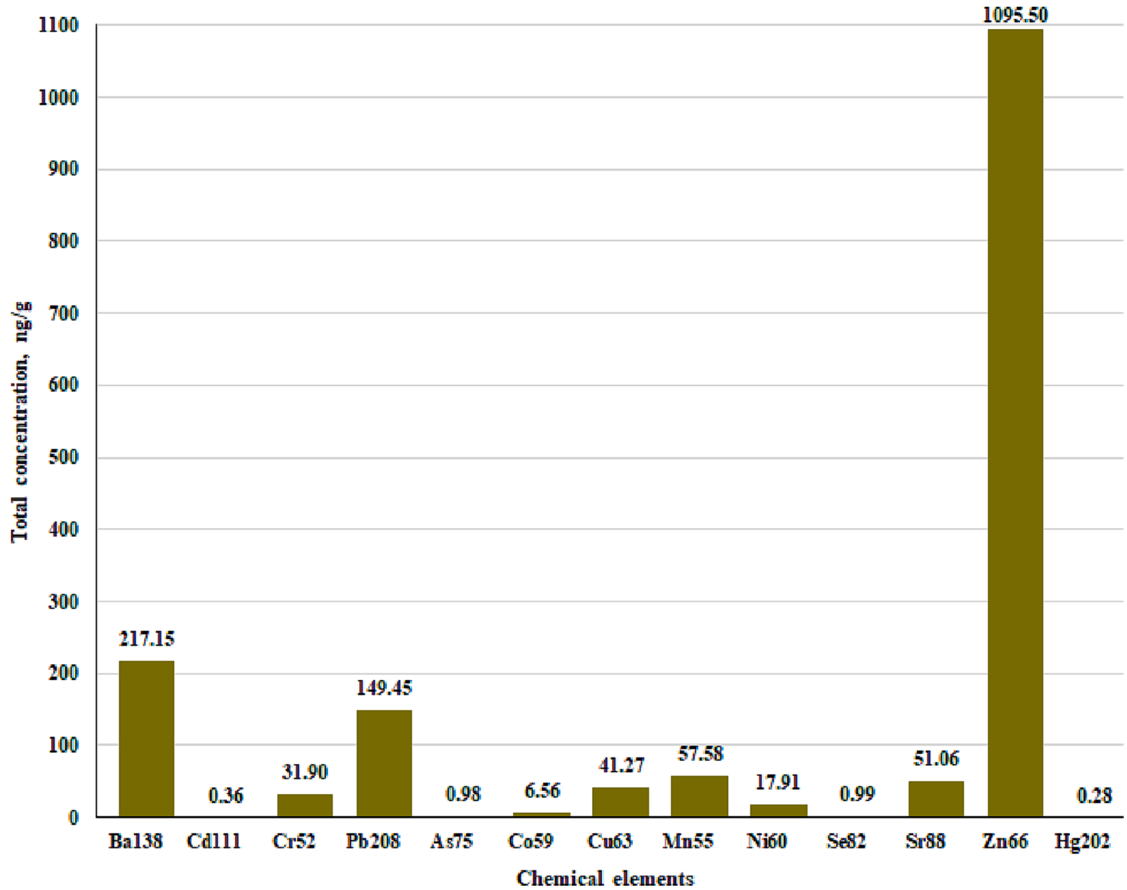

Fig. 3. Variation in the total concentration of chemical elements in analyzed toy samples.

the European Food Safety Authority (EFSA) established a reference point at 0.3 to 8 μg/kg bw/day (EFSA, Arcella et al., 2021). In accordance with the International Agency for Research on Cancer (IARC) classification, arsenic has also been classified as 'carcinogenic to humans' (Group 1) (IARC, 2012). Typically, a parametric value of 10 ng/mL is established without separating types of As75 (EFSA, Arcella et al., 2021). Comparing our results to the parametric values, results were satisfactory for health safety. Co59 is an essential oligo-element that contributes to the composition of the vitamin B12 molecule. There may be an increased risk of lung cancer when the individuals are frequently exposed to it (Lauwerys and Lison, 1994). Co59 has been identified in all the samples with a concentration of 5.85 ng/g except sample S2. (Omolaoye et al., 2010) have assessed the heavy metals in several Chinese soft plastic toys imported into Nigeria, and higher amounts of Co59 (6170 ng/g) were identified (Omolaoye et al., 2010). Comparing our results to these values, outcomes are not acceptable for health security. The Co59 levels are 7–10 g/L or greater, adverse effects can occur (Venkatraman et al., 2020). In terms of health safety, our results were acceptable. Cu63 can be toxic to human beings at high concentrations, even though it is an essential micronutrient for healthy immune function. Cu63 has been identified in S4, S5 and S5 at amounts 9.19, 21.20, and 10.87 ng/g, respectively. According to the results of this study, these values are in good agreement with those obtained in earlier studies (Bost et al., 2016). Mn55, in addition to being an essential trace element, Mn55 can also be neurotoxic in high doses. Mn55 has been obtained at higher amounts (1.96–34.05 ng/g) in all of the studied samples except S2. Earlier study had found Mn55 concentrations in children's toys ranging from 30 to 4220 ng/g, which are far greater than the current results except S5 (Mohammed et al., 2020). As far as health safety is concerned, our results were acceptable in terms of health safety. Human health is at risk from Ni60 exposure at high levels. A recent study by Al Kindi and Ali (2020) found that Ni60 levels in children's toys varied from 16,400 to 20600 mg/g (Al Kindi and Ali, 2020). Based on our results at concentrations between 0.67 and 6.10 ng/g, these values are extremely high (Al Kindi and Ali, 2020). Se82 is essential micronutrients, and addition to it, there are other antioxidant micronutrients that inhibit its anticarcinogenic effects. Se82 has been found in S1, S5 and S10 at concentrations 0.08, 0.39 and 0.52 ng/g, respectively. According to (Yazdanfar et al., 2022), toxic metals in children's toys ranged from 30 to 1100 ng/g. These values were greater than those obtained in current studies (Yazdanfar et al., 2022). As compared to current studies, these values were higher (Yazdanfar et al., 2022). Sr88, there is no evidence to suggest that Sr88 is essential for human health (Chowdhury and Blust, 2011). Its radionuclides produce radiological hazards that make Sr88 hazardous to organisms (Chowdhury et al., 2011). A concentration of 0.45 to 27.48 ng/g of Sr88 was found in all samples except S2. This is the first report on the presence of Sr88 in children's toys to our knowledge. Zn66 is an essential nutrient plays a significant role in public health (Chasapis et al., 2020). The highest amount of Zn66 has been identified in all the samples except S2, amounts ranged from 22.36 to 742.72 ng/g. S5 (black car) constitutes the highest percentage, which is similar to results obtained in previous studies (Al Kindi and Ali, 2020). Hg202, a naturally occurring chemical elements in the earth's crust and is one of the most toxic and hazardous substance (Tchounwou et al., 2003). The toxic effects can be produced by all forms of Hg202 at high concentrations, and adversely affects children and adults' neurological development (Henriques et al., 2019); (Tchounwou et al., 2003). According to current findings, Hg202 was detected at lower concentrations in samples S1, S2 and S3 in the range of 0.21, 0.07, and 0.7 ng/g, respectively. As a result, these values fall below the migratable limit (60 mg/kg) (Guney and Zagury, 2012). Regulatory agencies should monitor the levels of these lethal contaminants in these

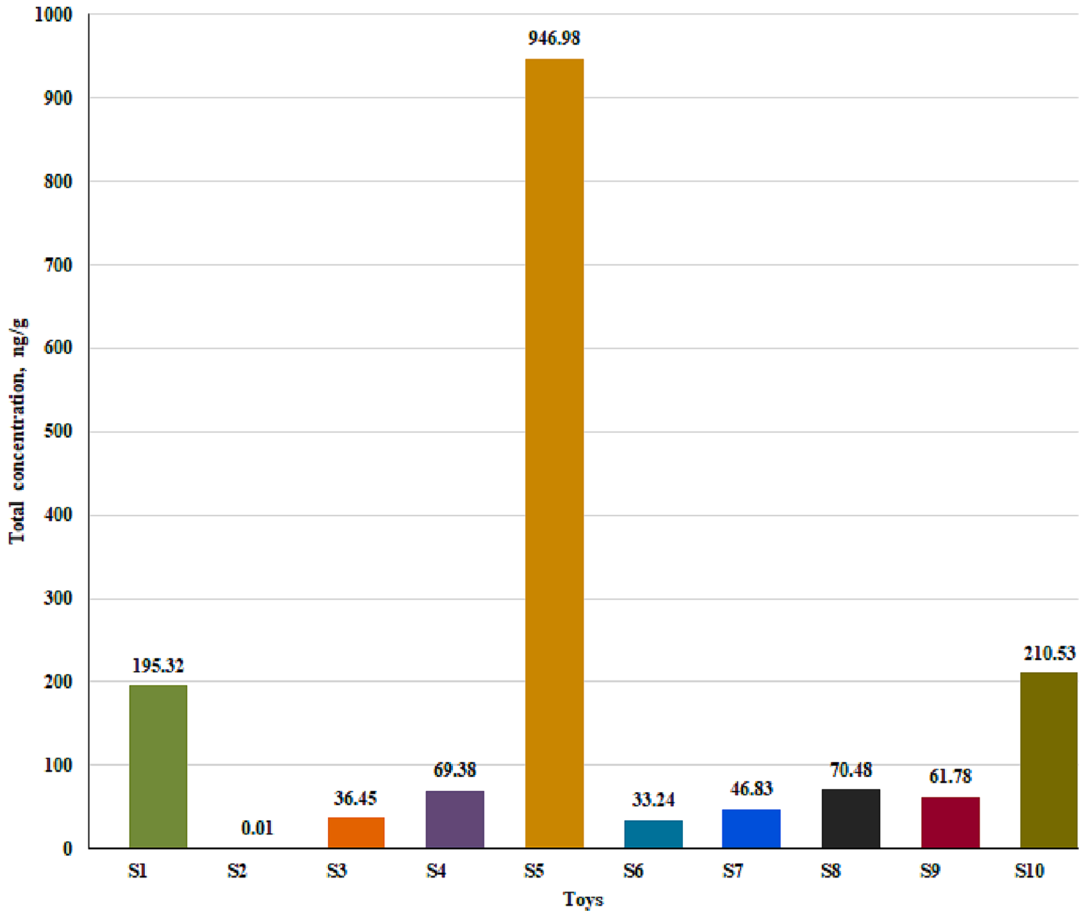

Fig. 4. Color types versus chemical elements in analyzed samples.

products, and regulate their maximum control limits since these chemicals are present in all types of children's toys. It has also been identified that the amounts of chemical elements are also depend on the color types (Fig. 4).

The black color car (S5) has high amount of chemical elements (Al Kindi and Ali, 2020) followed by S10 (4 mixed color), S1 (red color), S8 (black and red), and other were found at lower concentration (<70 ng/g). As a result of the observations made in the research, it has been shown that the chemical elements in the different color toys were highly unstable. In light of the results obtained in this study, it appears that children's toys may inadvertently expose children to higher amounts of these hazardous chemicals, thus increasing the possibility of cancer developing in the future.

4. Conclusions

On the basis of our findings, it is evident that low-cost toys that are commonly used by children are highly contaminated with chemical elements particularly Ba138, Cd111, Cr52, Pb208, As75, Co59, Cu63, Mn55, Ni60, Se82, Sr88, Zn66 and Hg202. The chemical elements were identified (0.01–742.72 ng/g) in all the studied samples except sample S2 where only Hg202 was found at a concentration of 0.01 ng/g. Outcomes revealed that Hg202 contributes lower amount (0.01 ng/g) while Zn66 contributes higher amount (742.72 ng/g). Some of samples have been found to be in excess of the limits suggested by the regulatory agencies. Toys contamination were also found to be color-specific, the black type car (S5) constitutes total amounts (946.98 ng/g) of chemical elements than other color types. Low-cost toys designed for children's use are found to contain chemical elements that should be addressed in the course of action. As a result of this study, valuable information has been obtained regarding the presence of certain chemical elements in children's low-cost toys, as well as the potential risks associated with exposure to these hazardous elements that may lead to cancer and other illnesses.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors would like to thank the Researchers Supporting Project number (RSPD2024R938), King Saud University, Riyadh, Saudi Arabia.

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