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# An Evaluation of Lead Contamination in Plastic Toys Collected from Day Care Centers in the Las Vegas Valley, Nevada, USA

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**Abstract** Childhood exposure to environmental lead continues to be a major health concern. This study examined lead content within the plastic of children's toys collected from licensed day care centers in the Las Vegas valley, Nevada. It was hypothesized that the use of lead as a plastics stabilizer would result in elevated lead ($\geq$600 ppm) in polyvinyl chloride plastics (PVC) compared to non-PVC plastics. It was also hypothesized that, due to the use of lead chromate as a coloring agent, yellow toys would contain higher concentrations of lead ($\geq$600 ppm) than toys of other colors. Toy samples were limited to those found in day care centers in Las Vegas, Nevada. 10 day care centers were visited and approximately 50 toy samples were taken from each center. Of the 535 toys tested, 29 contained lead in excess of 600 parts per million (ppm). Of those 29 toys, 20 were PVC and 17 were yellow. Both of the two hypotheses were strongly supported by the data.

**Keywords** Lead · Contamination · Day care center · Plastic toys · PVC

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Lead is a neurotoxin and carcinogen. It can damage the nervous system, reproductive organs, cardiovascular system, liver, immune system and the kidneys (Gidlow 2004). Some of the harmful health effects of lead are cumulative and irreversible (Needleman and Bellinger 1991). Although lead exposure is a health hazard to humans in general (Tong et al. 2000), children are at a much greater risk (Fels et al. 1998; Markowitz and Rosner 2000). A child can absorb up to 50% of lead that enters the body (Bearer 1994) in comparison to an adult's 5–10% (Mahaffey 1977). One emerging source of possible childhood lead exposure has been linked to the inclusion of lead in children's toys.

A void exists in the knowledge base of child safety in day care centers with regard to lead exposure from plastic toys. The objective of this study was to determine lead concentrations in plastic toys from day care centers in the Las Vegas valley, Nevada, and to compare these values to the standards established by the US. Consumer Protection Safety Commission (USCPSC). Two lead sources were of particular interest, lead stabilizers used in PVC plastic products and lead chromate used as a yellow color enhancer in plastics.

## Materials and Methods

Of the 569 licensed day care centers in the Las Vegas valley, approximately 200 were contacted for possible inclusion in the study. Each center received a phone call describing the proposed project, anonymity was assured, and a request for participation was offered. A total of ten centers volunteered to participate in the project.

To determine what comprised a representative sample of toys, prior to sampling, 2 day care centers were visited. A visual assessment was made of the type, quantity, and color of toys present. At both day care centers, almost all plastic toys resided within plastic bins, each contained a single toy type. An authority of the Southern Nevada Health District, who permits these daycare facilities, stated that this was typical of most day care centers. To ensure consistent sampling, toys were grouped into four categories. The first category consisted of simple repetitive shapes. These shapes included link blocks, animal figures, alphabets and numbers, and various geometric shapes such as cubes, rectangles, and pyramids. The majority of these toys were colored yellow, blue, green, and red. The second toy category consisted of realistic animals. The toy animals included cows, horses, lions, and other common animals. Dinosaurs were included within this group. A third category was created for plastic food. Fruits, vegetables, bread, pizza, fried eggs and hamburgers were included in this category. The fourth category was defined as miscellaneous and included plastic cars, planes, dolls, dishes, and educational devices.

A systematic approach to evaluating the toys was designed. A total of 10–15 toys were tested within each of the four groups, at each of the ten centers. Lead concentrations were measured with a portable x-ray fluorescence (XRF) device (Niton Thermo Fisher, Billerica, MA; model XLt 797 2 W). The XRF detection limits of lead, for a 100 s test (CI 99.7%) for this device is 10 ppm for PVC, and 2 ppm for non-PVC plastic. XRF calibrations were conducted at the beginning and end of each testing session, at each facility, and every 4 h as per manufacturer specification. For each calibration, a plastic lead standard (Niton PN 180–554; SN PE 5483-N; Pb concentration [mg/kg] 999; Error ±40; CI 95%) was tested three times for the duration of 60 s. If all three tests were within the bounds suggested by the manufacturer (±10%) testing of toys commenced.

The toys were tested in Bulk Plastic mode for the duration of 10 s. To determine if the 10 s duration was sufficient for this study, the plastic lead standard for XRF calibration was tested for lead concentration ten times, each for the duration of 10 s. An ANOVA was performed on the means of the sample errors. The means did not significantly differ ($p = 0.357$), and were within the bounds suggested by Niton (±10%).

To maintain a visual link between XRF results and the toy, every tested toy was identified and photographed. The identification contains a code number for the day care, the accession number of the XRF test, the toy color, and a brief description of the toy. This information is included in the compiled data. If a toy was found to exceed the USCPSC guidelines for lead (≥600 ppm; USCPSC, 2008), a one square inch portion of the toy was wiped with a Ghostwipe (15 × 15 cm, Environmental Express, Mt. Pleasant, SC) ten times to remove any surface dust. This portion of the toy was then retested with the XRF to determine if the lead was contained in the surface dust or the plastic. If the lead concentration in the toy remained above 600 ppm, the toy was placed into a plastic bag and removed from the premises for future disposal or additional testing.

The additional testing was completed as follows. To determine if lead migrated from the plastic substrate into the surface dust, seven toys with high lead content were thoroughly swabbed of surface dust with a Ghostwipe. Each of the seven wipes was folded and placed into an individual sterile plastic 50 mL centrifuge tube. One method blank was included in the batch to assess contamination. The eight wipes were covered with 10 mL of nitric acid (pH = 0.17). Vessels were hand-sealed and samples were digested in an Anton-Parr Multiwave 3,000 microwave digester (PerkinElmer, Multiwave 3,000; Shelton, CT). The microwave cycle was 5 min warm up, 8 min at peak heat and 90 min cool down. After cool down, 100µL of the resulting effluent was pipetted into a sterile vial. This was diluted with 50 mL of de-ionized water. A 2 mL portion of each of the eight samples was pipetted into sterile vials. The vials were placed into a graphite furnace (PerkinElmer, AAnalyst600; Shelton, CT) and measured for lead concentration by atomic absorption spectroscopy. The detection limit of the furnace was ≥0.3 ppb. All solutions were analyzed three times and the mean concentration was used in calculations.

## Results and Discussion

A total of 535 toys from 10 day care centers were analyzed for lead concentrations. Twenty-nine (5.4%) toys, from seven of the centers contained elevated lead (≥600 ppm). The remaining three centers had zero toys with elevated lead. The lead concentrations in the 29 toys ranged from 621 to 8,081 ppm, with an overall average of 2,019 ± 329 ppm. An additional 31 toys were found with lead concentrations ranging between 10 and 599 ppm (Table 1).

The XRF used for this study has the ability to detect chlorine within a substrate. When used in bulk plastics mode, the XRF can distinguish between polyvinyl chloride (PVC) and other non-chlorine based plastics. Of the 535 samples, 145 (27.1%) were PVC plastic, while the remaining 390 (72.9%) were non-PVC plastic. Twenty of the PVC toys contained elevated lead (≥600 ppm) and an additional 15 had intermediate lead concentrations (10–599 ppm) (Table 2).

The mean lead concentration for PVC toys was 325 ppm (±89); for non-PVC, the mean was 89 ppm (±13). When analysis was limited to only toys with elevated lead concentrations (≥600 ppm), the means were 2,189 ppm (±471) and 1,642 ppm (±162), respectively. A chi-square test for

**Table 1** The frequencies of toys tested, by lead concentration

| Day care code | n | (<10 ppm) | (10–599 ppm) | (≥600 ppm) |
|---|---|---|---|---|
| (01) | 56 | 51 | 5 | 0 |
| (02) | 54 | 52 | 2 | 0 |
| (03) | 51 | 39 | 5 | 7 |
| (04) | 50 | 50 | 0 | 0 |
| (05) | 46 | 35 | 5 | 6 |
| (06) | 50 | 47 | 2 | 1 |
| (07) | 51 | 50 | 0 | 1 |
| (08) | 60 | 59 | 0 | 1 |
| (09) | 58 | 48 | 3 | 7 |
| (10) | 59 | 44 | 9 | 6 |
| Total | 535 | 475 | 31 | 29 |

*ppm* Parts per million

**Table 2** A comparison of observed versus expected frequencies for PVC and non-PVC plastics

| Lead concentration | n | Non-PVC | | PVC | |
|---|---|---|---|---|---|
| | | Observed | Expected | Observed | Expected |
| (<10 ppm) | 475 | 365 | 346 | 110 | 129 |
| (10–599 ppm) | 31 | 16 | 23 | 15 | 8 |
| (≥600 ppm) | 29 | 9 | 21 | 20 | 8 |
| Total | 535 | 390 | 390 | 145 | 145 |

*ppm* Parts per million

independence was performed to determine if there was a relationship between PVC and elevated lead concentrations. The Pearson Chi-square value for PVC toys with elevated lead was 27.2. With the two degrees of freedom, used in this test, and $p < 0.01$, a Pearson Chi-Square value of 9.21 is needed to demonstrate significance. The value calculated for this test is almost three times the value needed, indicating there is a strong relationship between PVC as a substrate and lead concentration in the toys.

Of the toys tested, 115 (21.5%) were yellow, while the remaining 420 (78.5%) were non-yellow. Seventeen of the yellow toys contained elevated lead (≥600 ppm) and an additional one contained intermediate lead (10–599 ppm) (Table 3). The mean lead concentration for yellow toys was 216 ppm (±53); for non-yellow, the mean was 94 ppm (±30). When the analysis was limited to only toys containing ≥600 ppm, the means were 1,440 ppm (±156) and 2,839 ppm (±716), respectively. A chi-square test for independence was performed to determine if there was a relationship between yellow plastic and an elevated lead concentration. The Pearson Chi-square value for yellow toys with elevated lead was 25.0 ($p < 0.01$), almost three times the value needed to show significance, indicating

**Table 3** A comparison of observed versus expected frequencies for yellow and non-yellow plastics

| Lead concentration | n | Non-yellow | | Yellow | |
|---|---|---|---|---|---|
| | | Observed | Expected | Observed | Expected |
| (<10 ppm) | 475 | 378 | 373 | 97 | 102 |
| (10–599 ppm) | 31 | 30 | 24 | 1 | 7 |
| (≥600 ppm) | 29 | 12 | 23 | 17 | 6 |
| Total | 535 | 420 | 420 | 115 | 115 |

*ppm* Parts per million

there is a strong relationship between yellow plastic toys and lead concentration.

After all the XRF data from all ten care centers were gathered, toys with elevated lead (≥600 ppm) were found in seven of the day care centers. One of these toys, from each of the seven centers, was removed for additional testing. These toys were wiped with a Ghostwipe. The wipes were subsequently tested for lead as described in the methods section. Of the wipes tested, three contained a detectable concentration of lead, the highest being 14.25 ppb. This low concentration confirmed that there was no appreciable migration of lead from the plastic substrate to the surface dust.

Of interest, there was no visual or tactile difference between toys constructed of PVC plastics versus non-PVC plastics. It seems unnecessary, for visual appeal, to construct toys with PVC plastics containing lead stabilizers. Also, there was no noticeable visual difference in the color quality or vibrancy of the yellow toys with elevated lead and the yellow toys with non-detectable lead. In light of this, it seems unnecessary to use lead chromate as a color enhancer in yellow toys. It is recommended that toy manufacturers discontinue these practices.

This research was a preliminary step in examining potential lead exposure hazards to children from plastic toys; however, it has its limitations. Due to time constraints, it was not possible to test all the toys within the 10 day care centers visited. Also, one of the experiments checked for lead migration from the plastic substrate to the surface dust. All the toys tested were found indoors. It is unknown if lead migration is affected by toys exposed to UV sunlight or to changes in temperature.

The findings of this study indicate that toys made with PVC plastic and/or yellow colorant, are more likely to contain elevated concentrations of lead (≥600 ppm) than other toys. Additional research is needed to determine if this higher lead concentration increases the hazard of exposure, or poses a real risk to a child's health. It is recommended that future research continue to explore potential lead exposure to children from the use of lead in toys, plastic playground equipment, artificial turf and other products that use similar manufacturing processes for toys. This may be of particular significance in the Southwest US. due to high temperatures and UV rates, similar to those found in Las Vegas.

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