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Thomas O. Carmichael
Alabama School of Mathematics and Science, tcarmichael1396@gmail.com

Ruth H. Carmichael
Dauphin Island Sea Lab, rcarmichael@disl.org

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BRAVING THE ELEMENTS: LOSS OF METALS FROM MARDI GRAS BEADS DUE TO HANDLING AND WEATHERING

Thomas O. Carmichael[1] and Ruth H. Carmichael[2,3*]
*[1]Alabama School of Mathematics and Science, 1255 Dauphin St., Mobile, AL 36604; [2]Dauphin Island Sea Lab, 101 Bienville Blvd., Dauphin Island, AL 36528; [3]University of South Alabama, Mobile, AL 36688; *Corresponding author, email: rcarmichael@disl.org*

Abstract: The largest Mardi Gras celebrations in the U.S. are found along the Gulf of Mexico coast. With increasing awareness of and concern for environmental and human health risks due to pollution from Mardi Gras celebrations, there is a need for studies to quantify potential harms. We conducted a 2–part study to determine whether use–related handling and weathering of common Mardi Gras beaded necklaces results in loss of potentially harmful metals to the environment at levels of ecological or human health concern. Our data indicate that weathering and use–related handling can cause metals to be shed from the metallic coating of beads to the environment. The quantity of metals released depended on the color of beads and type or intensity of handling. Even light handling, however, resulted in measurable release of metallic coating and comprising metals. In addition to indicating the need for personal caution, our data suggest metal forms that are most soluble in water may pose the greatest potential environmental and human health risks. Metals contamination from Mardi Gras beads and other accessories is worthy of additional study and consideration in monitoring efforts.

Key words: trace elements, ICP–MS, necklace, dissolution, pollution

Introduction

Mardi Gras, also known as 'Fat Tuesday' or 'Carnival' outside the U.S., has roots in seasonal celebrations that date back to 12th century Europe (Roberts 2015). Today, some version of Mardi Gras or Carnival is celebrated in more than 50 countries across several continents, with hundreds of millions of participants every year and lasting up to 8 weeks (Roberts 2015). The largest Mardi Gras celebrations in the U.S. are found along the Gulf of Mexico coast in New Orleans, LA, and Mobile, AL, the latter of which was the first U.S. city to host a Mardi Gras–style celebration in the early 18th century. The event began to resemble modern Mardi Gras celebrations in 1866, when Joseph 'Joe' Stillwell Cain, Jr., an American Civil War veteran, led a procession in Mobile and threw items to crowds, a tradition of Mardi Gras 'throws' that continues today (Roberts 2015). Among the most common and popular 'throws' are necklaces of shiny round, faceted, or custom designed beads. An estimated 50 million beaded necklaces were imported to New Orleans alone in 2020, with the vast majority distributed to and thrown during Mardi Gras celebrations in New Orleans and Mobile (MacCash 2022).

In recent years concern has been raised about the environmental and human health impacts of Mardi Gras throws, particularly beaded necklaces (e.g., Boudreaux 2021, Redmon[1], Shepherd[2]). Throws contribute large quantities of debris to the environment, cluttering water ways and constricting storm drains, exacerbating flooding and potentially harming aesthetics and wildlife, and ultimately requiring costly clean–up efforts (Gearhart and Peña 2013, Boudreaux 2021). In the City of New Orleans alone, 10 days of Mardi Gras celebrations during 2014 created at least 3.5 million pounds of trash (Heneghan[3]), and in 2018, the city reported recovery of 46 tons of Mardi Gras beads from storm drains within a 5–block area (Evans[4]). These individual efforts cost the city nearly $8 million and reflect a minimal level of clean–up effort considering the city hosts ~80 parades during Mardi Gras each year, along a roughly 5 mile parade route (Norah[5]). Of greater concern is recent recognition that many Mardi Gras throws, including beads, contain potentially harmful chemicals, including metals (Gearhart and Peña 2013, Boudreaux 2021, MacCash 2022). While toxicity and potential for environmental harm and human health risks are speculated, surprisingly few studies have quantified metals composition of Mardi Gras beads, and to our knowledge, none have directly quantified nor tested mechanisms of loss of metals from beads to the environment.

Here, we conducted a 2–part study to determine if use–related handling or weathering of common Mardi Gras beaded necklaces may result in loss of potentially harmful metals to the environment. First, we determined if metals could be released from beads due to handling by directly measuring the metal concentrations in the coating of beads before and after light handling and in beaded necklaces collected from parades,

[1]Redmon, D. 2017. The toxic truth behind Mardi Gras beads. The Conversation. https://theconversation.com/the–destructive–life–of–a–mardi–gras–bead–71657?xid=PS_smithsonian (viewed on 10/12/2023).

[2] Shepherd, B. 2020. Plastic Mardi Gras Beads Are Cheap, Fun To Throw – And Toxic For The Environment. WWNO. www.wwno.org/post/plastic–mardi–gras–beads–are–cheap–fun–throw–and–toxic–environment (viewed on 10/12/2023).

[3] Heneghan, C. 2015. Can Mardi Gras go green? Earth Island Journal, Earth Island Institute. www.earthisland.org/journal/index.php/articles/entry/can_mardi_gras_go_green/ (viewed on 10/12/2023).

[4] Evans, B. 2018. 46 tons of Mardi Gras beads found in clogged catch basins. NOLA.com. https://www.nola.com/news/politics/46–tons–of–mardi–gras–beads–found–in–clogged–catch–basins/article_37e0ff53–894c–5aed–b4c3–129852582269.html (viewed on 10/12/2023).

[5] Norah, L. 2023. Mardi Gras 2024 in New Orleans–A full guide. https://www.findingtheuniverse.com/visiting–new–orleans–during–mardi–gras/ (viewed on 10/12/2023).

using laser ablation inductively coupled plasma mass spectrometry (ICP–MS). Second, we determined the quantity of metals released from beads under simulated weathering and different levels of intensity of handling by agitating beaded necklaces in water or in a mechanical shaker, representing treatment that may occur at a parade or when dropped in the street or discarded. To estimate potential environmental impacts, we compared our data to EPA standards for metals in water and soils, and we applied our data to scale–up an estimate for the quantity of metals that may have been lost to the environment from the 46 tons of beaded necklaces recovered from storm drains in New Orleans during 2018 (Evans[4]). The data demonstrate that it is possible for metals to be released to the environment through dissolution or loss of particles from the metallic coating on common Mardi Gras beads.

Materials and Methods

Part I: Metals on new, lightly handled, and parade beads

Bead preparation and handling. Metallic green and silver faceted Mardi Gras beads (84 cm long, 7 mm diameter) were purchased new (Toomey's Mardi Gras, Mobile, AL) and manually handled or collected from Mardi Gras parades in Mobile, AL during 2018. We identified 3 treatments: New, Handled and Parade. For the purposes of this study, 'New' beads are defined as those handled exclusively for the purpose of preparation for analysis, without additional handling. 'Handled' beads from the same lot as New were rubbed between nitrile gloved hands for 5 min, ensuring that every bead was touched to represent light handling. 'Parade' beads of the same type (7 mm diameter faceted metallic green or silver) were acquired during Mardi Gras parades and were of unknown but expected moderate to intense handling (beads may be used new or reused for multiple parades and may be from a different supplier and lot; MacCash 2022, authors pers. obs.). For all 3 treatments, a randomly selected individual metallic green or silver faceted bead was removed from each of 12 necklaces using ceramic scissors (n = 12 individual beads per color, per treatment; n = 72 beads analyzed in total). Beads were mounted onto a sample tray using adhesive dots (Glue Dots® International Adhesives, 5 mm) and plastic forceps.

Metals determination (LA–ICPMS). All beads (New, Handled, Parade) were analyzed by laser ablation inductively coupled plasma mass spectrometry (LA–ICP–MS; ESI NWR213 laser ablation system coupled to an Agilent 7700 Series ICP–MS). National Institute of Standards and Technology reference material (NIST 612) was used as the tuning and reference standard. Samples were analyzed for elements of environmental and human health concern (^{52}Cr, ^{63}Cu, ^{75}As, ^{114}Cd, ^{208}Pb, ^{238}U) and elements that may reflect weathering as exposure to river or rainwater (^{137}Ba) by ablating a 25 µm spot (5 sec dwell time, 10 Hz, 20% laser energy, 5 µm depth). Laser warmup time was 15 s and washout delay 10 s. A shallow ablation depth was used to sample the metallic coating without penetrating the core of the beads, which has a different composition. We opted to limit analyses to metallic coating on beads because this is the component that may be most readily mobilized during handling and weathering.

Data analysis. ICP–MS data were exported as counts per second for sample and reference materials. Background counts (10 s of gas blank), collected before the ablation of standards or samples, were averaged and subtracted from mean counts for each element in each sample. After background subtraction, negative values were equated to a value of zero, and counts were manually converted to concentrations using a 2–point calibration to the reference standard (variation ≤ 2%; K. McLauchlin, Elemental Scientific Lasers, LLC, pers. comm.). Concentrations of each metal were compared between beads of different color and among treatments using a 2–way Analysis of Variance (ANOVA), followed by a Tukey's HSD post–hoc test, with $\alpha = 0.05$. All statistical analyses were performed in StatPlus:mac Pro 8.0.4.0. Error is reported as standard error.

Part II: Metals released from beads due to weathering, moderate and intense handling

Bead preparation and handling. To determine the quantity of metals released from beads under simulated expected weathering and handling, we tested necklaces of metallic green and silver faceted Mardi Gras beads from the same lot used in Part I. For simulated weathering, we placed green necklaces (n = 12) and silver necklaces (n = 12) into separate unused ziplock bags each containing 750 ml of natural rainwater. One additional bag held 750 ml of rainwater alone (control). Rainwater (3L total) was collected from an open, shallow cistern on Dauphin Island, AL. Each bag was nested into a second ziplock bag to prevent damage to the sample bag and placed on the top level (20.3 cm diameter tray) of an oscillating mechanical sieve shaker (W.S. Tyler's RO–TAP®, RX–29) for 5 min (~278 ± 10 oscillations/min, 2.86 x 1.11 cm displacement). After shaking, water was decanted from sample bags and filtered through combusted 0.7 mm Whatman glass microfiber filters (Merck Millipore Ltd. Burlington, MA) and then 0.45 µm Whatman Polyethersulfone syringe filters (GE Healthcare, Buckinghamshire, UK), fixed with 0.9 µl of concentrated nitric acid (HNO_3), and stored at 4°C until analysis (Mohan and Walther 2015).

To simulate moderate and intense handling, necklaces (n = 12 of each color per treatment) were individually weighed (to 0.01 g) and placed into the top level of the mechanical shaker and agitated for 10 min (Moderate handling). For 'Intense' handling, this initial agitation was followed by addition of 50 g of gravel (0.5–10.0 mm diameter) that was pre–washed with ultrapure water to remove any particulates and agitated for an additional 5 min. After shaking, beads were reweighed to determine the quantity of metallic coating lost for the 'Moderate' handling and 'Intense' handling treatments. To control for handling prior to and following shaking, replicate bead samples were weighed, placed in the shaker for 10 min without agitation, and reweighed; these samples were expected to be similar to 'Handled' samples in Part 1 ('Light' handling).

Metals determination (ICP–MS and calculations). Water samples (n = 2 each for green, silver, and control water) were analyzed on an Agilent 7500ce quadrupole ICP–MS in solution mode in a 500 ppm TDS dilution in 2% HNO_3 at the University of Texas Jackson School of Geosciences to determine trace metal concentrations (Mohan and Walther 2015). Replicates and matrix spikes were analyzed every 12 samples to assess mean spike recoveries and monitor instrument drift. Quality control replicate and spike recoveries were 93—109% for all elements analyzed.

Data analyses. The quantity of metals lost from beads due to simulated weathering was determined by subtracting the mean concentration of each metal in the control water from the mean concentrations in the water agitated with beads (because the 2 samples were analyzed from the same bag, no error is reported). The resulting values were divided by the number of necklaces in each bag (n = 12) to determine the concentration difference per necklace. To estimate the quantity of metals lost from beads due to different types of dry handling, we used the difference in necklace weight before and after shaking (or resting for the control) as the estimate of metallic coating lost due to each type of handling and multiplied that weight by the concentration of each element in New beads determined in Part I. Weight loss was compared between beads of different color and among handling treatments using a 2—way Analysis of Variance (ANOVA), followed by a Tukey's HSD post—hoc test, with $\alpha = 0.05$. All statistical analyses were performed in StatPlus:mac Pro 8.0.4.0. Error is reported as standard error.

Estimating environmental impacts. To estimate potential harm to the environment and animals, including humans, we compared our metal concentration values to a) EPA Maximum Contaminant Levels for metals in water (MCL), representing the highest level of a contaminant that is allowed in drinking water (EPA 2023a), and b) EPA Soil Screening Levels (Eco—SSL), representing the concentrations of contaminants in soil that are protective of biota that live in or on soil for plants, invertebrates, birds, and mammals (EPA 2023b). For simplicity, Eco—SSL values for this study are considered relative to the range (minimum—maximum values) for all biota. We additionally applied our data to scale—up an estimate for the quantity of metals that may have been lost to the environment from the 46 tons of beads recovered from a 5 block area of New Orleans, LA during Mardi Gras celebrations in 2018. To do this, we first converted the weight of beads recovered (46 tons) to number of necklaces, assuming all recovered beads had similar composition to the common faceted green or silver beads tested for this study (17.12 ± 0.62 g total weight per necklace). We then multiplied the quantity of each element lost per necklace due to weathering, Light (control) or Intense handling determined in Part II by the estimated number of necklaces in 46 tons of beads to estimate minimum and maximum values of possible loss for each metal. To put these data into context and facilitate comparisons to EPA MCL, we additionally multiplied the number of recovered necklaces by 750 ml to relate the concentrations potentially lost due to water—associated weathering to the volume of water that would yield those concentrations, equivalent to conditions in this study.

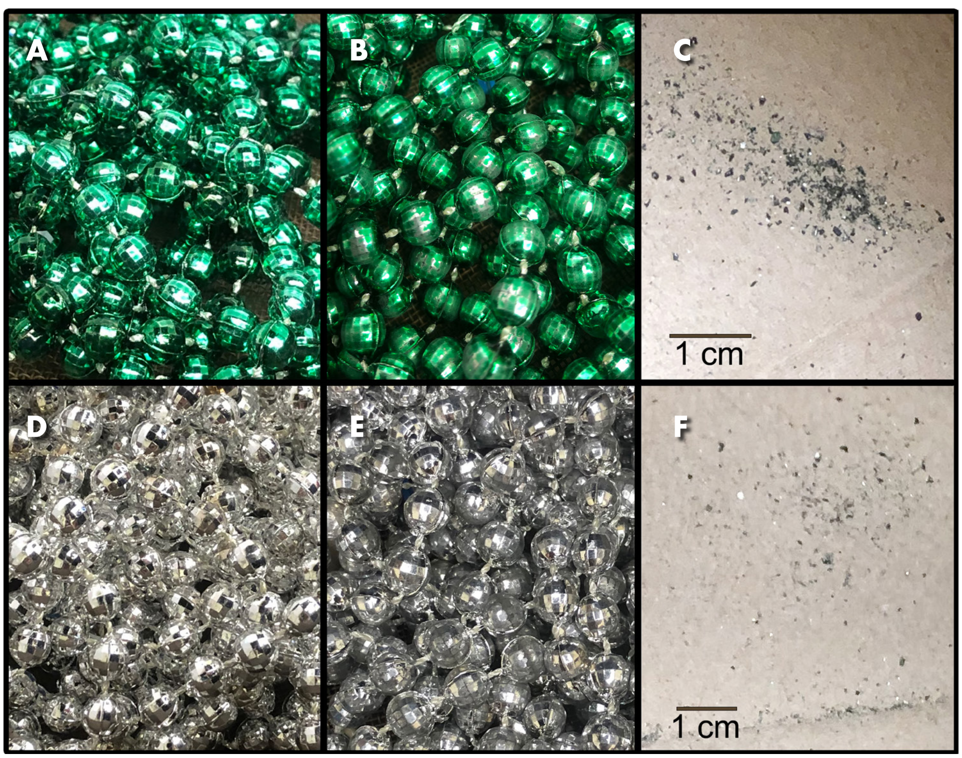

Figure 1. *Green and silver Mardi Gras beads used in the experiment. A. New green faceted beads before handling. B. Green faceted beads after intense handling (shaking with gravel). C. Examples of the green chips, flakes, and powders lost from beads during handling treatments. D. New silver faceted Mardi Gras beads before handling. E. Silver faceted beads after intense handling (shaking with gravel). F. Examples of silver chips, flakes, and powders lost from beads during handling treatments.*

Results

Part I: Metals on new, lightly handled and parade beads

During handling for metals analysis and the 'Handled' treatment, chips, flakes, and powders of metallic particles were visibly shed from the outer surface of beads onto adjacent surfaces (Figure 1). Concentrations of metals in the metallic coating on beads differed with bead color (green, silver) and type (New, Handled, Parade), depending on the metal analyzed (Table 1A). Green Mardi Gras beads had higher concentrations of Cr and Cu (Cr_{color}: $F_{1,71} = 13.46$, $p < 0.01$; Cu_{color}: $F_{1,71} = 15.31$, $p < 0.01$) but lower As compared to silver (As_{color}: $F_{1,71} = 10.40$, $p < 0.01$). The Cu concentrations were highest on green Parade beads (Cu_{type}: $F_{2,71} = 3.54$, $p = 0.03$; $p < 0.01$ for all significant comparisons, Tukey's HSD). The Ba and Pd concentrations varied with bead type, with higher concentrations on Parade beads compared to others (Ba_{type}: $F_{2,71} = 6.19$, $p < 0.01$; Pb-

TABLE 1. *Concentration and weight loss of 7 selected metals in metallic coating for 2 colors (green and silver) of common Mardi Gras beads. A. Mean (± se) concentration from 12 necklaces. B. Mean (± se) weight loss per necklace due to handling. New—beads from newly purchased necklaces handled exclusively for metals analysis; Handled—beads from the same lot as New, but lightly handled prior to analysis; Parade—Beads of the same type acquired during a Mardi Gras parade and of unknown but expected moderate to intense handling. Light (control)—New beads handled for determining weight (light handling). Moderate and Intense—beads subjected to different levels of mechanical agitation (shaken without or with gravel, respectively). — indicates data not available.*

A. Bead Color		**Concentration (ppm)**						
	Bead Type	**^{52}Cr**	**^{63}Cu**	**^{75}As**	**^{114}Cd**	**^{137}Ba**	**^{208}Pb**	**^{238}U**
Green	New	1305.86 ± 514.43	1815.8 ± 710.67	13.06 ± 2.19	58.86 ± 49.99	314.28 ± 56.08	58.64 ± 30.27	0.07 ± 0.04
	Handled	1098.78 ± 421.29	1582.29 ± 566.26	18.06 ± 4.52	9.20 ± 1.99	449.00 ± 156.24	31.39 ± 7.81	0.10 ± 0.04
	Parade	178.76 ± 6.03	6219.46 ± 2244.14	22.95 ± 288	11.85 ± 1.45	1091.47 ± 252.84	132.26 ± 23.92	0.13 ± 0.04
	Literature[1]	177.43 ± 49.64	–	26.86 ± 5.53	37.00 ± 17.56	–	4742.00 ± 1997.57	–
	Literature[2]	76	–	14	26	–	149	–
Silver	New	37.47 ± 5.90	45.88 ± 5.10	26.12 ± 2.38	21.87 ± 5.81	623.97 ± 85.79	43.04 ± 4.17	0.12 ± 0.05
	Handled	52.44 ± 8.54	29.80 ± 2.21	24.40 ± 2.65	15.96 ± 2.76	605.37 ± 117.07	41.66 ± 5.78	0.05 ± 0.03
	Parade	47.63 ± 7.78	69.24 ± 12.88	31.81 ± 5.53	14.66 ± 1.56	1660.71 ± 622.30	211.50 ± 119.12	0.09 ± 0.06
	Literature[3]	70.75 ± 6.56	–	27.38 ± 5.01	33.88 ± 7.79	–	220.50 ± 24.00	–

B. Bead Color		**Weight loss**	
	Handling treatment	**mg**	**%**
Green	Light	1.27 ± 0.42	0.007 ± 0.002
	Moderate	4.87 ± 0.24	0.029 ± 0.005
	Intense	9.08 ± 1.41	0.06 ± 0.01
Silver	Light	0.49 ± 0.40	0.002 ± 0.002
	Moderate	0.91 ± 2.66	0.005 ± 0.016
	Intense	12.02 ± 2.42	0.07 ± 0.01

[1]Green bead necklace; [2]Green round bead or multishaped necklaces; [3]Silver round bead or multishaped necklaces (Gearhart and Peña 2013)

$_{type}$: $F_{2,71}$ = 4.20, p = 0.02; p ≤ 0.05 for all comparisons, Tukey's HSD). Other elements did not differ by bead color or type.

Part II: Metals released from beads due to weathering, moderate and intense handling

Simulated weathering. All metals tested in water shaken with beads showed detectable release to water (Figure 2A), with Ba and Cu having the highest concentrations released per necklace compared to other elements. Most metals were lost at higher concentrations from silver beads compared to green (except As and U). The concentration of As released to water from green beads (0.012 mg/L) and Pb lost from silver beads (0.023 mg/L) from as little as one necklace in 750 ml of water (Figure 2A, arrows) were above EPA MCLs (the highest levels allowed in drinking water; Table 2).

Handling. There was loss of metallic coating, detectable as weight loss due to all types of handling of green and silver beads. This loss was visible as a loss of vibrancy and color of beads and as chips, flakes, and powders on surfaces and at the bottom of the shaker trays (Figure 1). After handling, there was more weight loss from beads shaken with gravel (Intense handling) than control (Light handling) or shaken alone (Moderate handling) (Table 1B; 2—way ANOVA: Handling: $F_{2,71}$ = 20.52 p < 0.001; p < 0.001 for all significant comparisons, Tukey HSD). There were no weight differences between bead colors.

Using concentrations of metals on New beads measured in Part I, we equated the weight loss of metallic coating to the quantity of individual metals released during handing (Figure 2B, C, D). Green beads released more elements than silver during Light (control) and Moderate (shaken) handling (Figure 2B, C). During Intense handling (gravel shaken), however, silver beads released more As, Ba, and U than green beads (Figure 2D). The highest quantities of Cu and Ba per necklace were lost from green and silver beads, respectively, while U had the lowest loss from both colors of beads. All quantities of metals released due to handling for a single necklace were below the minimum EPA Eco—SSL for 1 kg of soil (Table 2), estimates to be protective of all biota.

Potential environmental impacts. Forty—six tons of Mardi Gras beads were recovered from storm drains in a 5 block area of New Orleans, LA during the same year as Part I of this study. Assuming all recovered beads were the same size and weight (17.12 ± 0.62 g total weight per necklace) and had the same composition of metallic coating as the beads used in this experiment, an estimated 2,437,244 beads were recovered, with

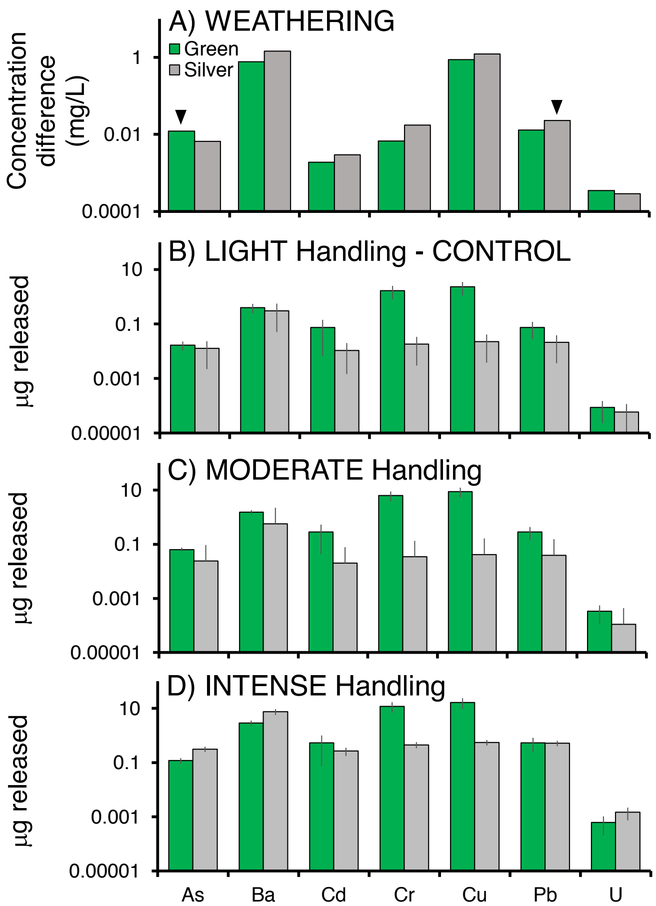

Figure 2. *The quantity of selected elements released from common green and silver Mardi Gras beads due to simulated weathering and handling. A. The concentration of metals released by agitation in 750 ml of natural rainwater per necklace. Black arrows indicate values above the EPA Maximum Contaminant Levels for drinking water. B. Weight loss per necklace after light handling. C. Weight loss per necklace after moderate handling. D. Weight loss per necklace after intense handling. As–^{75}As; Ba–^{137}Ba; Cd–^{114}Cd; CR–^{52}Cr; Cu–^{63}Cu; Pb–^{208}Pb; U–^{238}U.*

the potential to release metals to the environment (Table 2). We estimated that all metals had potential to be released at high concentrations from beads in New Orleans storm drains via water–associated weathering (Table 2). If natural weathering conditions were similar to the simulated weathering in this study, concentrations comparable those reported in Figure 2A would be possible with 5 min of agitation in 1.83 million L of rainwater (~482,889 ga). Assuming the recovered beads were most similar to green beads, quantities of As, Ba, and Pb could be released at levels exceeding the EPA Eco–SSL protective range for some biota under Light handling and for all biota under Intense handling, if concentrated in 1 kg of soil (Table 2), and other metals (Cd, Cr, Cu) could exceed the EPA Eco–SSL protective range if concentrated in 1 kg of soil for all biota, even under Light handling (Table 2). When quantities of metals from silver beads were scaled–up, all values exceeded the EPA Eco–SSL protective range for some biota if concentrated in 1 kg of soil (Table 2).

Discussion

Our data indicate that weathering and use–related handling can cause metals to be shed from the metallic coating of common Mardi Gras beads to the environment. The quantity of metals released depended on the color of beads and type or intensity of handling. Even light handling, however, resulted in measurable release of metallic coating comprising metals. In general, release of metals due to simulated weathering or handling was highest for metals that were of highest concentration on New beads, including Cu and Cr on green beads and Ba on silver beads tested for this study. Higher concentrations of metals such as Cu, Cr, and Ba on beads is consistent with variation in metal content needed to produce color (Müller et al. 2006). Specifically, Cr and Cu produce green colors and Ba is typically silvery–white, consistent with our findings of higher

TABLE 2. *Estimates of amounts of metals that may have been released from 46 tons of Mardi Gras beads (n = ~2,437,244) recovered from a 5 block area of New Orleans, LA, assuming all beads had similar composition to the common green or silver beads tested for this study and were similarly weathered or handled. Data show the possible concentrations due to water–associated weathering (mg/L) and range weight (range mg) with propagated mean % error due to handling. Minimum and maximum values in each range are based on estimates of light and intense handling, respectively. EPA Maximum Contaminant Levels for metals in drinking water (MCL) and EPA Soil Screening Levels (Eco–SSL) for the species with the lowest and highest Eco–SSL for each element are shown for reference. – indicates data not available.*

	mg/L		Green		Silver			
Element	**Green**	**Silver**	**Range (mg)**	**% error**	**Range (mg)**	**% error**	**EPA MCL (mg/L)**	**EPA Eco–SSL (mg/kg)**
As	29653	16045	40–289	30 ± 10	31–765	52 ± 43	0.01	18[1]–46[4]
Ba	1869570	3507601	973–6955	31± 10	748–18287	54 ± 42	2.0	330[2]–2000[4]
Cd	4638	7196	182–1303	89 ± 3	26–641	60 ± 38	0.005	0.36[4]–140[2]
Cr	16543	42774	4045–28883	47 ± 7	45–1098	55 ± 41	0.1	26[3]–130[4]
Cu	2109130	2973337	5624–40185	47 ± 7	55–1345	53 ± 42	1.3	28[3]–80[2]
Pb	31603	55803	182–1298	58 ± 5	52–1262	53 ± 43	0.015	11[3]–1700[2]
U	849	705	0.21–1.50	70 ± 4	0.15–3.55	72 ± 31	–	–

[1]*plants,* [2]*invertebrates,* [3]*birds,* [4]*mammals*

concentrations of the former metals on green beads and the latter on silver.

The concentrations of metals on the Mardi Gras beads in this study were similar to or lower than concentrations on previously tested beads (Gearhart and Peña 2013). A variety of Mardi Gras related accessories (toys, cups, beads) have been shown to contain a range of metals (Gearhart and Peña 2013). Our findings of higher concentrations of some metals, particularly Pb, on Mardi Gras beads collected at parades compared to New beads, highlights the potential for variation in metals content on beads despite similarity of size, shape, and color. Of note, beads collected from parades, which presumably had some prior moderate to intense level of handling, had concentrations of Pb > 100 ppm; 90 ppm is the U.S. Consumer Product Safety Commission limit for Pb in paint in children's products and 100 ppm is the limit for total Pb in accessible parts (CPSC 2018). Our findings are unique in demonstrating that these metals are not only present on beads at concentrations of concern, but that they can be mobilized at concentrations of concern. For example, during simulated weathering As and Pb were released from individual necklaces into 750 ml of water at concentrations higher than EPA MCLs in drinking water. In contrast, dry handling alone in most cases did not release metal quantities of concern, suggesting there may be greater potential for environmental and human health concern due to weathering than handling.

There are several lines of evidence that indicate weathering of beads may be of greater concern than loss from direct, even intense handling alone. Weathering and other water—associated release of metals likely combine dissolution and mechanical loss. For example, beads are commonly dropped on sidewalks, streets, and other impervious surfaces where they may be walked on, runover by vehicles, and washed by rain and street cleaners before being swept into drains following parades (Boudroux 2021, MacCash 2022, authors' pers. obs.), with many opportunities for metals to be lost. For this study, we had the benefit of the New Orleans clean—up effort to provide some estimate of beads discarded or lost to the environment, which supports estimating potential metals released from beads on a relevant scale. While simulated weathering showed potential for mobilization of metals at concerning concentrations from a single necklace and certainly from 46 tons of discarded necklaces, no dry handling treatments resulted in release of metals from a single necklace at potentially concerning levels. Even scaled—up to account for 46 tons of beads, light handling resulted in some metals remaining within the EPA protective range for 1 kg of soil for some biota. Cd, which was released from a single necklace at quantities nearest the EPA protective range for mammals, would require >673 necklaces to be intensely handled over 1 kg of soil to release sufficient Cd to exceed the lowest EPA Eco—SSL.

Because we cannot account for the final volume of water or area of soil or sediments over which metals lost from Mardi Gras beads were or will be distributed (even for the 5 block area of New Orleans), it is difficult to fully predict the potential environmental risk. It is logical that risk may be highest where quantities of discarded beads are highest such as drains or lawns and parks along parade routes; streams, rivers and other adjacent receiving waters, and in or adjacent to landfills. This notion may be borne out in higher Pb levels previously detected in residential soils near parade routes (H. Mielke, referenced in Redmon[1]). Furthermore, it is likely that beads caught in storm drains or other outdoor areas will be exposed to weathering forces for weeks, months or years, allowing ongoing weathering and associated abrasion and dissolution of metals to the environment. While the metals tested in this study have potential for toxicity to humans, domestic animals and wildlife, these effects necessarily depend on exposure that is sufficiently high via a compromising route (Goyer and Clarkson 1996, EPA 2023a, b). The metals we tested are common in paints (Mielke et al. 2001) and may require ingestion or aspiration for toxicity, further limiting risks from handling alone. If dissolution in water is the major route of mobilization of metals from beads at concentrations of concern, then the toxicity of metal forms that are most soluble in water are likely to pose the greatest potential health risks and are worthy of consideration in future studies and monitoring efforts.

Of additional concern is that Mardi Gras beads and comprising metals represent a fraction of the 'throws' and associated contaminants handled and discarded during Mardi Gras celebrations (Gearhart and Peña 2013, Boudreaux 2021), and the cumulative environmental and public health impacts are unknown. Additional study is needed, particularly under natural conditions, to determine the spatial and temporal scale of potential pollution due to use of Mardi Gras beads. Future studies could include analysis of beads and other 'throws' for release of a broader range of chemical contaminants and could consider release of contaminants from the internal composition of beads in addition to the metallic coating. Prior studies have made recommendations for responsible handling and use of Mardi Gras beads, including washing hands after handling, checking consumer information when it is available, not putting beads in the mouth, and not giving beads to children without supervision (Gearhart and Peña 2013). Our findings support this level of personal caution, and we additionally recommend that distributors and consumers demand greater oversight of product composition as well as environmental precautions of limiting use of beads, using natural alternatives (e.g., Kato 2019), collecting and properly disposing of beads to minimize transport to storm drains, and supporting bead re—use programs to limit the addition of new beads to the environment (MacCash 2022).

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