CADMIUM IN JEWELRY

by

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Abstract

Most exposures to the toxic heavy metal cadmium come through consumption of trace amounts in food and tobacco smoke. However, cadmium is often used to make jewelry due to its shiny appearance, low cost, and low melting point. This can result in additional exposure to children who mouth or swallow these items. While jewelry may not be marketed directly to children, it may be obtained by children due to low cost (typically around \$1-\$5). The U.S. currently does not regulate the cadmium content of jewelry that is not considered children's jewelry. The objective of this study was to determine the potential for high-cadmium jewelry to release cadmium if mouthed or swallowed by children. Eighty inexpensive jewelry samples were screened for cadmium by X-ray fluorescence. High-cadmium samples were extracted at body temperature with dilute NaCl to simulate mouthing and dilute HCl to simulate digestive action. After initial extractions, jewelry pieces were damaged to determine whether damage to the outer surface increased cadmium release. After extractions were complete, the total cadmium content of the samples was determined. Cadmium concentrations for all solutions were determined by atomic absorption (AA) spectrometry. Thirty-four total replicates of nine jewelry items were extracted as described. The average cadmium release from initial NaCl extractions was 727 µg, and from initial HCl extractions was 66.3 µg. After damage, the average release of cadmium from the NaCl extractions was 3400 µg, and from HCl extractions was 26300 µg. The comparable voluntary standards that have been adopted by the U.S. Consumer Product Safety Commission (CPSC) are a maximum release of 18 µg for NaCl extractions, and 200 µg for HCl extractions (U.S. CPSC 2011). The high levels of extractable cadmium underscore the danger posed by this jewelry.

Introduction

Cadmium is a heavy metal that can have serious health risks after long-term exposure. Cadmium containing compounds are considered carcinogens that can lead to development of several types of tumors, including lung, prostate, renal, pulmonary, and testicular cancers (Waalkes, 2003). Over long-term periods of exposure, cadmium can cause lung cancer in workers who suffer from occupational exposure (Waalkes, 2003). Due to the risk of cancer development in humans, it is important for individuals to avoid exposure to cadmium and cadmium-containing compounds.

Cadmium exposure has also been linked to diabetes, diabetic nephropathy, hypertension, peripheral artery disease, myocardial infarction, diminished lung function, periodontal disease, and age-related macular degeneration (Satarug, 2010). Long-term exposure to low-dose cadmium has also been linked to a loss of re-absorptivity of compounds such as zinc, copper, glucose, amino acids, phosphate, and calcium (Satarug, 2010). Cadmium has a long half-life in the body (Waalkes, 2003), meaning that after ingestion, it will persist and accumulate in the body and it could be years after exposure until side-effects are noticed.

Cadmium is a transition metal, so the body cannot metabolize it into a compound that can be easily used or excreted. This is why it has a long half-life in animal tissues. Cadmium is known to mimic zinc, meaning that the body will attempt to use cadmium in zinc-specific metabolic reactions (Waalkes, 2003). However, because cadmium and zinc are different elements, these metabolic reactions will not proceed correctly, and the necessary reactions will not occur successfully. Metallothioneins, small metal-binding proteins in the body, may also bind with absorbed cadmium. This then forms the structure CdMT, which can be stored in cell cytoplasm to prevent free cadmium from having a toxic effect on the body (Sabolic, 2010). Unfortunately, if these CdMTs are then later taken to the kidneys to be broken down, the cadmium can be released into the kidneys and caused damage to the structure (Sabolic, 2010).

Americans are commonly exposed to cadmium via cadmium-containing foods or tobacco smoke inhalation (Mead, 2010). Cadmium is released into the air from ore smelting and the burning of fossil fuels, leading to its soil deposition, and uptake into food crops and tobacco plants (Mead, 2010). Such uptake leads to eventual cadmium exposure via food or smoke inhalation. Many aquatic filter feeders also accumulate metals such as cadmium, so this could be a source of cadmium intake for humans as well (Satarug, 2010). These routes of exposure are not intentionally created, they simply develop as a by-product of industrial activity. However, cadmium is used intentionally to create jewelry, which can then expose humans to cadmium. Cadmium is often used to produce inexpensive jewelry because it is a by-product of processing other metals, such as copper or zinc (Mead, 2010). This makes it inexpensive to buy, therefore resulting in more profit for companies using it to make jewelry. This jewelry is often marketed towards children, which could lead to exposure in children if the jewelry pieces were to be ingested by the children and the cadmium was extracted by saliva or stomach acid.

While children being exposed to cadmium via mouthing or ingestion of jewelry does not typically cause acute poisoning (Mead, 2010), such unintentional exposure can lead to elevated levels of cadmium. Due to the mode of action of cadmium in the body, chronic exposure is of more concern for individuals, since most Americans are already exposed to cadmium, as discussed above. Because children may absorb ingested cadmium more readily than adults, they are at a higher risk for its accumulation in tissues. This would likely lead to a higher risk of cancer development. Children should not be exposed to high levels of cadmium early in life, as it would likely increase their lifetime accumulation of cadmium (Mead, 2010).

Previous studies have found that some pieces of jewelry contain up to 94.8% total cadmium, although not all of this may be available for extraction from saline or dilute HCl (Weidenhamer, 2011). Based on these findings, the U.S. Consumer Product Safety Commission recalled jewelry pieces due to high levels of contamination and established limits for extractable cadmium levels. Any pieces containing above 300 ppm (0.03%) total cadmium must be tested further using extractions. No more than 200 µg soluble cadmium should be extractable during a 24-hour dilute HCl extraction, and only 18 µg soluble cadmium during a 6-hour saline solution extraction (U.S. CPSC 2011). These previous studies also found that damaging the outer electroplating of these pieces affected the amount of cadmium released (Weidenhamer, 2011). Therefore, damaged extractions were performed during this study as well.

While this study is relevant to the uptake of cadmium through the GI tract (via mouthing or ingestion), it is important to note that only 5% of the amount of ingested cadmium is actually absorbed through the GI tract of adults (Godt, 2006). This figure was determined using absorption data for adults, meaning that it is likely higher for children. Therefore, only a portion of the cadmium that can be extracted from jewelry pieces would actually be taken up by the body. This reduces the amount of cadmium that can build up in the body over time, but, as discussed above, any additional exposure to cadmium besides what naturally occurs over a lifetime increases the potential for negative effects on an individual. The standards for cadmium release adopted by the U.S. CPSC take this inefficiency of cadmium uptake into account.

The objective of this study was to determine the amounts of cadmium that can be released from inexpensive jewelry pieces when mouthed or swallowed. This was done by determining how many currently available pieces contain measurable amounts of cadmium, as well as how much cadmium could potentially be extracted from these contaminated pieces. Simulated saliva extractions used a NaCl solution to estimate exposures from mouthing by children. HCl was employed to simulate stomach acid-induced release upon jewelry ingestion. These jewelry pieces were then completely digested using concentrated acid, allowing for determination of total cadmium present in the jewelry piece as a whole. Knowing both the total amount of cadmium in the jewelry pieces and the amount that could potentially be extracted by saliva or stomach acid is important in determining if the cadmium in these pieces actually poses a risk to humans.

Methods

These methods were developed based on the Consumer Product Safety Commission standard specifications for children's jewelry, which were re-approved in November 2014, after original approval in 2011 (U.S. CPSC 2014).

Materials

Jewelry pieces were purchased from a discount jewelry retailer. Prices ranged from $1 to $5. Additional replicates of high-cadmium items were purchased from the same store after screening of initially purchased items by XRF (x-ray fluorescence spectrometry) analysis.

XRF Analysis

Jewelry items were screened using XRF to determine which pieces had detectable levels of cadmium. This screening was conducted using a Niton XL3t GOLDD XRF spectrometer in Testall mode for 60 seconds. Pieces with detectable levels of cadmium that could be easily be subject to mouthing or swallowing by a child were noted. Nine jewelry items with cadmium levels exceeding 0.03% were selected for further testing.

Simulated Mouthing (NaCl Extraction)

NaCl solution (0.91% w/v) was used to simulate saliva. Pieces were suspended in the solution by nylon thread. The amount of solution (mL) used for cadmium extraction was determined by multiplying the weight of the piece (g) by 50. Pieces were extracted in the dark in the proper volume of solvent while being swirled at 1 revolution per second in a water bath at 37℃ for 6 hours. All pieces of glassware used had been acid washed with 8M ACS grade nitric acid. After extraction, the piece was removed from the solution and rinsed off. Then, 1 mL of concentrated trace metal grade (TMG) nitric acid was added to 49 mL of extractant to ensure that cadmium remained in the solution until AA analysis. Pieces were then used for HCl extraction if applicable. The cadmium-containing solutions were then analyzed using AA flame analysis to determine the cadmium concentration in the solution. If dilutions were necessary, they were done using 5% TMG nitric acid.

Simulated Digestion (HCl Extraction)

Pieces that could fit down a 1.25 in. diameter pipe were considered to be swallowable by a child, as that is the diameter used by the CPSC for a young child's throat (U.S. CPSC, 2020). Additionally, rings or jewelry pendants that were attached to multiple chains were not considered for HCl extraction. Overall, two jewelry pendants were selected for HCl extraction. HCl solution (0.07N) was used to simulate stomach acid. Pieces were suspended in the solution by nylon thread. The amount of solution (mL) used for cadmium extraction was determined by multiplying the weight of the piece (g) by 50. Pieces were extracted in the dark in the proper volume of solvent while being swirled at 1 revolution per second in a water bath at 37℃ for 24 hours. All pieces of glassware used had been acid washed with 8M ACS grade nitric acid. The cadmium-containing solutions were then analyzed using AA flame analysis to determine concentration of the solution. All dilutions used 5% TMG nitric acid.

Extractions of damaged items

Damage to the outer electroplating pieces may change the amount of cadmium released from piece. All pieces went through an undamaged NaCl extraction, and then if applicable, an undamaged HCl extraction. Every piece was then damaged (using metal cutters) and underwent an additional NaCl extraction, and then another HCl extraction, if applicable.

Total Cadmium Digestion

Following the NaCl and HCl extractions, small pieces of jewelry items were cut to approximately 0.1-0.2 g and weighed to determine exact mass. Pieces were then digested with 5 mL of concentrated TMG nitric acid and diluted to 25 mL with 5% TMG nitric acid. After digestion, AA flame analysis was performed to obtain the concentration of cadmium in the sample. This concentration was then used to determine the percentage of cadmium in the original jewelry piece. If dilutions were necessary, they were done using 5% TMG nitric acid.

Atomic Absorption Spectrometry

Cadmium concentrations were measured AA spectrometry (SpectrAA 220 FS; Varian, Walnut Creek, CA) with an air-acetylene flame at 228.8 nm. Stock cadmium solutions were made using a 1,000 ± 4 mg/L certified reference material cadmium standard for AA (no. 51994; Fluka Analytical, St. Louis, MO). Calibration was linear over the range of 0 to 3.0 mg/L. Quality assurance was maintained by analysis of blank and fortified samples. For the total cadmium analysis, reagent grade cadmium granules served as a reference.

Results and Discussion

XRF Analysis and Sample Selection

Of the eighty initial samples analyzed by XRF for cadmium content; twenty-eight of had detectable levels ranging from 0.002% cadmium (±0.001) to 45.9% cadmium (±0.4). Twenty-five of the twenty-eight samples (89%) were over the CPSC screening limit of 300 ppm. The XRF data has been included in Appendix 1. Of the twenty-five pieces containing more than 300 ppm cadmium by XRF, nine high-cadmium items were selected for further analysis, and additional replicates of these items were purchased. Overall, thirty-four samples of these nine high-cadmium jewelry items were used throughout this study for any applicable extractions. The sample ID, picture, and XRF reading of the original piece (replicate A) of these items are included in Table 1.

Table 1: Sample IDs, pictures and XRF readings for high-cadmium jewelry pieces.

Sample ID	Picture	XRF Reading (%)
2.20_6 (5 replicates)		13.4 (±0.1)
2.20_8 (4 replicates)		17.8 (±0.1)
2.20_10		25.5 (±0.2)

Table 1 continued:

2.22_1 (4 replicates)		8.28 (±0.1)
2.22_7 (3 replicates)		45.9 (±0.4)
2.22_8 (4 replicates)		13.6 (±0.1)
2.22_10 (3 replicates)		28.4 (±0.3)
2.22_38 (7 replicates)		10.5 (±0.1)
2.25_14 (3 replicates)		16.1 (±0.2)

These samples were selected for further analysis because of their high cadmium content. XRF readings from Table 1 are compared to additional data from this study below. It is important to note that all of the pieces in Table 1 have a cadmium content well above 300 ppm, or 0.03%, the level considered by the U.S. CPSC to require further testing.

NaCl Extractions (Undamaged and Damaged)

All pieces listed in Table 1 underwent simulated saliva extractions via NaCl solution. Table 2 includes the amount of cadmium extracted during NaCl extractions for undamaged and damaged jewelry pieces.

Table 2: NaCl-extracted cadmium (µg) from undamaged and damaged jewelry.

Sample ID	Cd extracted (µg) during undamaged extraction	Average Cd extracted (µg) from replicates	Cd extracted (µg) during damaged extraction	Average Cd extracted (µg) from replicates
2.20_6A**	_39.5*_	31.0 (±11.5)	*9201*	5760 (±2330)
2.20_6B**	*35.0*		*6540*	
2.20_6C**	*28.7*		*3120*	
2.20_6D**	12.1		*4240*	
2.20_6E**	*39.8*		*5680*	
2.20_8A	*1850*	766 (±867)	*8450*	7540 (±747)
2.20_8B	*1080*		*7410*	
2.20_8C	*24.0*		*6640*	
2.20_8D	*108*		*7670*	
2.20_10	*219*	219***	*2102*	2102***
2.22_1A	7.39	19.0 (±23.3)	2.25	6.33 (±8.19)
2.22_1B	7.05		1.98	
2.22_1C	*54.0*		*18.6*	
2.22_1D	7.51		2.47	
2.22_7A	*4130*	1650 (±2170)	*10800*	10600 (±2780)
2.22_7B	*57.8*		*7750*	
2.22_7C	*776*		*13300*	
2.22_8A	*54.8*	63.0 (±8.15)	*2102*	1170 (±995)
2.22_8B	*68.5*		*441*	
2.22_8C	*71.4*		*189*	
2.22_8D	*57.4*		*1950*	
2.22_10A	*5120*	5310 (±837)	*5970*	6120 (±237)
2.22_10B	*6230*		*6390*	
2.22_10C	*4590*		*5990*	
2.22_38A**	1.78	3.32 (±1.69)	1.55	1.51 (±0.189)
2.22_38B**	1.77		1.25	
2.22_38C**	2.00		1.48	
2.22_38D**	2.49		1.64	
2.22_38E**	5.79		1.36	
2.22_38F**	4.54		1.47	
2.22_38G**	4.86		1.83	
2.25_14A	3.92	6.83 (±3.11)	12.2	10.6 (±1.43)
2.25_14B	6.48		9.47	
2.25_14C	10.1		10.1	

*: Amounts that are italicized signify values higher than the limit set for soluble cadmium in a 6-hour NaCl extraction by the U.S. CPSC.

**: These pieces underwent an HCl extraction between the undamaged and damaged NaCl extractions

Table 2 Footnotes continued:

***: This piece did not have additional replicates, therefore averages and standard deviations were not calculated

Many of the numbers in Table 2 are a cause for concern as they are far above the extraction limits specified by the U.S. CPSC. Out of the sixty-eight values listed, forty-one of them (68%) are above the limit of 18 µg. The maximum amount of NaCl-extractable cadmium for the undamaged items was 6230 µg (sample 2.22_10B), which is over three hundred times the 18 µg limit. Additionally, the maximum amount of NaCl-extractable cadmium for the damaged items was 13300 µg (sample 2.22_7C), which is over seven hundred times the 18 µg limit.

In all, 58% of the undamaged samples were over the limit, and 62% of damaged samples were over the limit. As can be seen above, extractions of damaged pieces released much higher amounts of cadmium overall. The average amount released during the extractions of undamaged items was 727 µg, but 3400 µg for damaged pieces.

HCl Extractions (Undamaged and Damaged)

Two necklaces pendants meeting the CPSC standard for small parts with potential to be swallowed, underwent dilute acid extractions via HCl solution. Table 3 includes the amount of cadmium extracted during HCl extractions for undamaged and damaged jewelry pieces.

Table 3: HCl-extracted cadmium (µg) from undamaged and damaged jewelry.

Sample ID	Cd extracted (µg) during undamaged extraction	Average Cd extracted (µg) from replicates	Cd extracted (µg) during damaged extraction	Average Cd extracted (µg) from replicates
2.20_6A	45.7	133 (±112)	*77400*	63100 (±12700)
2.20_6B	*305**		*67800*	
2.20_6C	182		*45600*	
2.20_6D	34.0		*69800*	
2.20_6E	98.9		*54800*	
2.22_38A	27.0	18.5 (±18.3)	22.3	99.7 (±107)
2.22_38B	57.0		26.2	
2.22_38C	6.67		*303*	
2.22_38D	9.92		47.0	
2.22_38E	11.4		24.6	
2.22_38F	10.5		87.0	
2.22_38G	7.25		188	

*: Amounts that are italicized signify values higher than the limit set for soluble cadmium in a 24-hour HCl extraction by the U.S. CPSC.

Several numbers in Table 3 are also a cause for concern as they are above the limit determined by the U.S. CPSC. In total, one of twelve (8%) of the undamaged samples was over the limit, while six of twelve (50%) damaged samples were over the limit. Out of the 24 values listed above, 7 of them are above this limit, or 29% of the samples extracted with HCl released more than the acceptable amount, although the previous values which distinguished undamaged from damaged likely give a better summary for this extraction, as only one undamaged piece exceeded the CPSC limit. As can be seen above, the damaged extractions generally released much higher amounts of cadmium overall. It is also important to note that every 2.20_6 replicate released more cadmium than the CPSC 200 µg limit. The average amount released during the undamaged extractions was 66.3 µg, but for the damaged extractions it was 26300 µg. However, it is important to note the large difference in averages for the two pieces that underwent HCl extractions. Jewelry item 2.20_6 appears to contain more cadmium, as the average release for the undamaged extraction was 133 µg versus 63100 µg for the damaged extraction. In comparison, item 2.22_38 had average releases of 18.5 and 56.9 µg for undamaged and damaged extractions, respectively.

It is important to note the differences between these numbers and what information they reveal about these two pieces. While both pieces released more cadmium after damaging, only one (2.20_6) released amounts that were much higher than the undamaged extractions. The differences in these values indicates how differently these jewelry pieces can react to the same treatment and extractions. This variation between pieces is cause for concern, as it would make it very difficult to determine which of these pieces could be dangerous to a child that may have mouthed or swallowed the piece, without performing these additional extractions.

The maximum amount of HCl-extractable cadmium for the undamaged items was 305 µg (sample 2.20_6B), which is more than 1.5 times the 200 µg limit. Additionally, the maximum amount of HCl-extractable cadmium for damaged items was 77400 µg (sample 2.20_6A), which is more than three hundred times the 200 µg limit.

Total Cadmium Analysis

Total % cadmium was determined in two ways throughout this experiment, both of which are included in Table 4. Total cadmium content was determined based on XRF readings and by using the values obtained during the total cadmium analyses.

Table 4: XRF- and total cadmium analysis-derived % total cadmium values.

Sample ID	% Cd based on XRF	% Cd based on total cadmium analysis	Average % Cd based on total cadmium analysis
2.20_6A	13.4 (±0.1)	82.4	83.2 (±2.63)
2.20_6B		84.3	
2.20_6C		80.8	
2.20_6D		81.4	
2.20_6E		87.3	
2.20_8A	17.8 (±0.1)	83.3	82.7 (±0.589)
2.20_8B		82.7	
2.20_8C		82.9	
2.20_8D		81.9	
2.20_10	25.5 (±0.2)	83.7	83.7*
2.22_1A	8.28 (±0.1)	33.1	31.8 (±7.85)
2.22_1B		22.4	
2.22_1C		30.1	
2.22_1D		41.4	
2.22_7A	45.9 (±0.4)	90.7	89.2 (±1.62)
2.22_7B		89.5	
2.22_7C		87.5	
2.22_8A	13.6 (±0.1)	44.2	47.3 (±5.13)
2.22_8B		53.6	
2.22_8C		49.2	
2.22_8D		42.2	
2.22_10A	28.4 (±0.3)	80.2	74.8 (±15.4)
2.22_10B		86.8	
2.22_10C		57.4	
2.22_38A	10.5 (±0.1)	24.3	31.1 (±5.42)
2.22_38B		32.7	
2.22_38C		24.5	
2.22_38D		29.0	
2.22_38E		33.1	
2.22_38F		36.4	
2.22_38G		38.0	
2.25_14A	16.1 (±0.2)	42.0	38.3 (±12.4)
2.25_14B		48.5	
2.25_14C		24.5	

*: This piece did not have additional replicates, therefore averages and standard deviations were not calculated

As shown in the table above, values obtained after total cadmium analysis are much higher than those obtained through XRF analysis. This is likely due to XRF being a surface technique, meaning that if pieces are electroplated with metals other than cadmium, the cadmium concentration as determined by XRF may be underestimated in comparison to the actual value. However, the total cadmium analysis technique analyzes an entire piece, meaning that any and all cadmium present in the piece is accounted for with this technique. The higher values resulting from the total cadmium analysis technique indicate that many of the pieces likely contained some form of electroplating as the XRF numbers were lower than the total cadmium analysis numbers.

Conclusions

Based on the data presented above, it can be concluded that the practice of companies using cadmium to produce inexpensive jewelry pieces is still a problem. Based on the sampling done at a one discount jewelry store in Ohio, 31% of pieces contained amounts of cadmium that exceeded the 300 ppm guideline originally published by CPSC in 2011. The average amount of NaCl extractable cadmium for undamaged extractions was 727 µg, which is forty times the limit of 18 µg. The average amount of HCl extractable cadmium for undamaged extractions was 66.3 µg, which is actually under the limit of 200 µg. However, these limits do not take into consideration the effect that damaging a piece could have on its amount of extractable cadmium. Average amounts for the damaged NaCl and HCl extractions were 3400 µg and 26300 µg, respectively. Clearly, damaging the pieces had a large effect of the amount of cadmium that could be pulled off of the piece, meaning that those exposed to these pieces are even more at risk if the pieces has been damaged. As stated above, while these are not technically marketed as children's jewelry, their low cost makes them very accessible to children and increases the chances that a child could end up with one of these pieces. Guidelines set by the CPSC years ago are not being followed and consumers, most notably possible children, are still being put at risk.

These facts call into question the methods put forth by the CPSC for several reasons. First, this method does not account for damage to items, despite the fact that this seems to have a significant impact on the amount of extractable cadmium in an item. Secondly, these methods detail the cadmium level at which a piece should be put through further testing, but they do not put forth any upper limit at which a piece should be considered too contaminated with cadmium to be sold. Out of the thirty-four replicates used in this study, only two had an XRF level above 300 ppm but replicates that had extractable cadmium levels within the acceptable ranges. This indicates the majority of samples that are above the range of 300 ppm are completely outside of extractable cadmium limits set by the CPSC. However, the CPSC methods still fail to describe an upper limit where pieces should be removed from shelves.

Appendix 1

Sample ID	Cd (%, unless otherwise noted)	Cd Error
2.28_12_hairring	0.002	0.001
2.22_23A_teapotcharm	0.003	0.001
2.28_9C_bowfront	0.003	0.001
2.22_23B_heartcharm	0.005	0.003
2.20_7A_charmback	0.006	0.004
2.22_4B_charmclamp	0.007	0.004
2.22_8B_ringband	0.01	0.005
2.22_10B_ringband	0.01	0.005
2.22_6B_charmclamp	0.011	0.006
2.28_7A_ringband	0.011	0.006
2.22_4A_charmback	0.014	0.006
2.25_13A_charmback	0.02	0.009
2.28_15B_hoop	0.02	0.006
2.22_3A_bowcharm	0.022	0.007
2.22_6A_charmback	0.022	0.007
2.28_4C_charmfront	0.023	0.012
2.20_7B_mermaid	0.026	0.007
2.28_15C_hoop	0.026	0.007
2.28_15E_hoop	0.026	0.007
2.28_15A_hoop	0.031	0.007
2.28_15D_hoop	0.033	0.007
2.20_7F_lobsterclasp	0.038	0.008
2.28_8A_earringback	0.064	0.008
2.25_12C_band	0.068	0.01
2.25_4C_charmfront	0.115	0.005
2.28_2A_ringband	0.281	0.019
2.25_5B_charmconnection	0.338	0.026
2.25_13B_charmfront	0.355	0.066
2.20_6B_catclasp	0.439	0.019
2.25_3B_charmconnection	0.964	0.042
2.25_4B_charmconnection	1.083	0.04
2.25_10D_earcuff	1.359	0.041
2.25_10C_frontofflowers	3.176	0.243
2.25_10E_earring	3.493	0.088
2.28_2C_frontgems	3.676	0.713
2.25_1B_ringgems	4.655	0.597
2.25_12A_charmback	5.281	0.123
2.28_13B_heartfront	5.413	0.563
2.28_5C_charmfront	6.774	1.054
2.25_12D_charmfrontnogems	7.463	0.093

2.25_12B_gems	7.917	1.601
2.22_1A_charm	8.276	0.102
2.28_2B_backofflowers	9.114	0.134
2.22_38C_charmfront	9.272	0.122
2.28_8B_earringfront	9.52	0.148
2.25_1_ringband	10.141	0.11
2.22_38A_axecharm	10.456	0.117
2.25_14B_charmfront	11.603	0.133
2.28_7B_charmfront	11.827	0.123
2.22_24A_charmback	11.835	0.132
2.28_5B_charmback	12.105	0.189
2.28_7C_frontgems	12.414	0.138
2.20_6A_backofcat	13.375	0.126
2.22_8A_charmback	13.571	0.148
2.25_5C_charmfront	14.659	1.739
2.25_14A_charmback	16.097	0.155
2.20_9A_backofgems	17.575	0.16
2.20_8A_backofgem	17.801	0.149
2.25_4A_charmback	19.404	0.178
2.25_10F_bowback	22.151	0.216
2.20_10A_backofcat	25.504	0.21
2.25_3A_charmback	25.999	0.225
2.25_10A_bowfront	26.25	0.225
2.25_10B_backofflowers	27.019	0.266
2.25_5A_charmback	27.594	0.222
2.22_10A_charmback	28.355	0.278
2.22_7A_ringband	29.104	0.228
2.28_13A_heartback	30.921	0.268
2.22_7B_skullface	45.899	0.437
2.25_3C_charmfront	32112.13 ppm (3.21%)	1004.49
2.28_8C_post	51803.8 ppm (5.18%)	6280.57
2.20_1_triangleearring	<LOD	0.008
2.20_1A_goldhoops	<LOD	0.005
2.20_1B_goldhoops	<LOD	0.008
2.20_1B_goldhoops	<LOD	0.006
2.20_3A_silvercirclesdangle	<LOD	0.007
2.20_4A_necklacehalfcircle	<LOD	0.009
2.20_4B_necklacerectangle	<LOD	0.005
2.20_4C_lobsterclasp	<LOD	0.009
2.20_5A_ringband	<LOD	0.005
2.20_5B_backofpearl	<LOD	0.005
2.20_5C_backofgem	<LOD	0.006
2.20_5D_mainbracelet	<LOD	0.009
2.20_5E_lobsterclasp	<LOD	0.007
2.20_6C_lobsterclasp	<LOD	0.01

2.20_6D_earringg	<LOD	0.01
2.20_7C_starfish	<LOD	0.004
2.20_7D_dolphin	<LOD	0.003
2.20_7E_heart	<LOD	0.003
2.20_7G_mainchain	<LOD	0.006
2.20_8B_lobsterclasp	<LOD	0.01
2.20_8C_earring	<LOD	0.002
2.20_9B_lobsterclasp	<LOD	0.006
2.20_9C_earring	<LOD	0.017
2.20_10B_lobsterclasp	<LOD	0.012
2.20_10C_earring	<LOD	0.008
2.22_1B_lobsterclasp	<LOD	0.015
2.22_2A_beadclamp	<LOD	0.013
2.22_2B_lobsterclasp	<LOD	0.01
2.22_3B_lobsterclasp	<LOD	0.011
2.22_4C_chain	<LOD	0.005
2.22_4D_earring	<LOD	0.014
2.22_4E_lobsterclasp	<LOD	0.013
2.22_5A_charm	<LOD	0.008
2.22_5B_charmclamp	<LOD	0.003
2.22_5C_clasp	<LOD	0.008
2.22_6C_lobsterclasp	<LOD	0.017
2.22_9A_charmback	<LOD	0.014
2.22_9B_ringband	<LOD	0.008
2.22_11_whitebandclasp	<LOD	0.006
2.22_12_greenbandclasp	<LOD	0.005
2.22_13_pinkbandclasp	<LOD	0.005
2.22_14_bluepawprintback	<LOD	0.008
2.22_15_whitebear	<LOD	0.008
2.22_16_greenheart	<LOD	0.005
2.22_17_elmo	<LOD	0.009
2.22_18_yellowelmo	<LOD	0.005
2.22_19_cat	<LOD	0.006
2.22_20_yellowheart	<LOD	0.006
2.22_21_bird	<LOD	0.01
2.22_22_mouse	<LOD	0.008
2.22_24B_closure	<LOD	0.004
2.22_25_orangeyellowstripelip	<LOD	0.006
2.22_26_goldbluedotlip	<LOD	0.006
2.22_27_redgemlip	<LOD	0.007
2.22_28_fullbluelip	<LOD	0.007
2.22_29_orangesilverlip	<LOD	0.006
2.22_30_yellowwhitelip	<LOD	0.005
2.22_31_flagtongue	<LOD	0.007
2.22_32_moneytongue	<LOD	0.008

2.22_33_facetongue	<LOD	0.007
2.22_34_spiketongue	<LOD	0.009
2.22_35_blueyellowstripetongue	<LOD	0.01
2.22_36_redstartongue	<LOD	0.006
2.22_37_dogphonestand	<LOD	0.01
2.22_38B_lobsterclasp	<LOD	0.006
2.25_2_ringband	<LOD	0.008
2.25_6A_charmback	<LOD	0.006
2.25_6B_charmfront	<LOD	32.67
2.25_6C_charmconnection	<LOD	0.011
2.25_7A_disc	<LOD	0.005
2.25_7B_lobsterclasp	<LOD	0.008
2.25_8A_starcharm	<LOD	34.78
2.25_8B_beadbottom	<LOD	15.38
2.25_8C_lobsterclasp	<LOD	0.006
2.25_9A_thickbraceletoutside	<LOD	0.006
2.25_9B_outsidegems	<LOD	0.002
2.25_9C_thinbraceletoutside	<LOD	0.011
2.25_11A_thick	<LOD	0.006
2.25_11B_twisted	<LOD	0.007
2.25_13C_band	<LOD	0.006
2.25_14C_clasp	<LOD	0.005
2.28_1_ringband	<LOD	0.003
2.28_3A_ringband	<LOD	0.005
2.28_3B_frontofcharm	<LOD	0.003
2.28_4A_ringband	<LOD	0.008
2.28_4B_charmback	<LOD	0.013
2.28_5A_ringband	<LOD	0.012
2.28_6A_ringband	<LOD	0.006
2.28_6B_charmback	<LOD	0.04
2.28_6C_charmfront	<LOD	0.004
2.28_8D_removableback	<LOD	0.008
2.28_9A_backback	<LOD	0.006
2.28_9B_connection	<LOD	0.023
2.28_10A_back	<LOD	0.007
2.28_10B_charmback	<LOD	0.008
2.28_10C_charmfront	<LOD	0.004
2.28_11A_back	<LOD	0.013
2.28_11B_frontgems	<LOD	0.008
2.28_13C_closure	<LOD	0.01
2.28_14A_twistedband	<LOD	0.006
2.28_14B_arrowdashedband	<LOD	0.01
2.28_14C_waffleband	<LOD	0.007
2.28_16_largecharm	<LOD	27.13
2.28_17A_largecharm	<LOD	36.88

2.28_17B_smallbead	<LOD	24.46
2.28_18A_smallbead	<LOD	0.002
2.28_18B_spring	<LOD	0.003

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Maria was born in Kettering, Ohio on April 3rd, 1998. She grew up in Eaton, Ohio and graduated from Eaton High School in 2016. She is a double major in Forensic Biology and Toxicology with a minor in Chemistry. While at Ashland, she has become a member of the tri-Beta Biological Honor Society, Alpha Lamda Delta Honor Society, and the Choose Ohio First Scholarship program, in addition to the Honors Program. She also works tutoring various chemistry and biology courses, and as a Resident Assistant on campus. After graduating, she will be attending Wright State University for their Pharmacology/Toxicology Master's Program.