



Quality Assurance Project Plan Metals in Cookware Preparation Method Development Study

By
Karna Holquist and Michael Zahn

For the
Environmental Assessment Program,
Washington State Department of Ecology
Olympia, Washington

September 2026, Publication 26-03-112

Publication Information

Each study conducted by the Washington State Department of Ecology must have an approved Quality Assurance Project Plan (QAPP). The plan describes the objectives of the study and the procedures to be followed to achieve those objectives. After completing the study, Ecology will post the study's final report to the Internet.

This QAPP was approved to begin work in November 2025. It was finalized and approved for publication in September 2026.

The final QAPP is available on Ecology's website at

<https://apps.ecology.wa.gov/publications/SummaryPages/2603112.html>.

Suggested Citation

Holquist, K. and M. Zahn. 2026. Quality Assurance Project Plan: Metals in Cookware Preparation Method Development Study. Publication 26-03-112. Washington State Department of Ecology, Olympia. <https://apps.ecology.wa.gov/publications/SummaryPages/2603112.html>.

The Activity Tracker Code for this study is 26-013.

Federal Clean Water Act 1996 303(d) Listings Addressed in this Study. See Section 3.3.

Any use of product or firm names in this publication is for descriptive purposes only and does not imply endorsement by the author or the Department of Ecology.

Contact Information

Publications Coordinator
Environmental Assessment Program
Washington State Department of Ecology
P.O. Box 47600, Olympia,
WA 98504-7600
Phone: 564-669-3028

Washington State Department of Ecology – <https://ecology.wa.gov>

The Department of Ecology is committed to providing people with disabilities access to information and services by meeting or exceeding the requirements of the Americans with Disabilities Act (ADA), Section 504 and 508 of the Rehabilitation Act, and Washington State Policy #188.

To request an ADA accommodation, contact the Environmental Assessment Program's Publications Coordinator by phone at 564-669-3028 or email at EAPpubs@ecy.wa.gov. For Washington Relay Service or TTY call 711 or 877-833-6341. Visit Ecology's website at <https://ecology.wa.gov/accessibility> for more information.

Department of Ecology's Region Offices

Map of Counties Served



Southwest Region
360-407-6300

Northwest Region
206-594-0000

Central Region
509-575-2490

Eastern Region
509-329-3400

Region	Counties Served	Mailing Address	Phone
Southwest	Clallam, Clark, Cowlitz, Grays Harbor, Jefferson, Mason, Lewis, Pacific, Pierce, Skamania, Thurston, Wahkiakum	PO Box 47775 Olympia, WA 98504	360-407-6300
Northwest	Island, King, Kitsap, San Juan, Skagit, Snohomish, Whatcom	PO Box 330316 Shoreline, WA 98133	206-594-0000
Central	Benton, Chelan, Douglas, Kittitas, Klickitat, Okanogan, Yakima	1250 W Alder St Union Gap, WA 98903	509-575-2490
Eastern	Adams, Asotin, Columbia, Ferry, Franklin, Garfield, Grant, Lincoln, Pend Oreille, Spokane, Stevens, Walla Walla, Whitman	4601 N Monroe Spokane, WA 99205	509-329-3400
Headquarters	Across Washington	PO Box 47600 Olympia, WA 98504	360-407-6000

Quality Assurance Project Plan

Metals in Cookware

Preparation Method Development Study

By Karna Holquist and Michael Zahn

September 2026

QAPP Approval Signatures

Signature:	Date:
------------	-------

Jessica Archer, Client, Author's Section Manager, EAP

Signature:	Date:
------------	-------

Sara Sekerak, Client, Author's Unit Supervisor, EAP

Signature:	Date:
------------	-------

Michael Zahn, Author / Project Manager, EAP

Signature:	Date:
------------	-------

Karna Holquist, Author / Principal Investigator, EAP

Signature:	Date:
------------	-------

Rob Waldrop, Director, Manchester Environmental Lab, EAP

Signature:	Date:
------------	-------

Christina Frans, Ecology Quality Assurance Officer, EAP

EAP: Environmental Assessment Program

QAPP: Quality Assurance Project Plan

Signatures are not available on the Internet version.

1.0 Table of Contents

	Page
1.0 Table of Contents	4
List of Figures	7
List of Tables	7
2.0 Abstract	8
3.0 Background	8
3.1 Introduction and problem statement	8
3.2 Study area and surroundings.....	9
3.3 Water quality impairment studies	13
3.4 Effectiveness monitoring studies	13
4.0 Project Description	14
4.1 Project goals	14
4.2 Project objectives	14
4.3 Information needed and sources	15
4.4 Tasks required.....	15
4.5 Systematic planning process	16
5.0 Organization and Schedule	17
5.1 Key individuals and their responsibilities	17
5.2 Special training and certifications	18
5.3 Organization chart	18
5.4 Proposed project schedule.....	18
5.5 Budget and funding	19
6.0 Quality Objectives	20
6.1 Data quality objectives	20
6.2 Measurement quality objectives.....	20
6.3 Acceptance criteria for quality of existing data	22
6.4 Model quality objectives	22
7.0 Study Design	23
7.1 Study boundaries.....	23
7.2 Field data collection	23

7.3	Modeling and analysis design.....	24
7.4	Assumptions underlying design.....	24
7.5	Possible challenges and contingencies.....	24
8.0	Field Procedures.....	25
8.1	Invasive species evaluation	25
8.2	Measurement and sampling procedures	25
8.3	Containers, preservation methods, holding times.....	25
8.4	Equipment decontamination.....	26
8.5	Sample ID.....	26
8.6	Chain of custody	26
8.7	Field log requirements.....	26
8.8	Other activities	26
9.0	Laboratory Procedures	27
9.1	Lab procedures table	27
9.2	Sample preparation method(s)	27
9.3	Special method requirements	27
9.4	Laboratories accredited for methods.....	27
10.0	Quality Control Procedures	28
10.1	Table of field and laboratory quality control	28
10.2	Corrective action processes	28
11.0	Data Management Procedures	29
11.1	Data recording and reporting requirements.....	29
11.2	Laboratory data package requirements.....	29
11.3	Electronic transfer requirements	29
11.4	Data upload procedures.....	29
11.5	Model information management.....	29
12.0	Audits and Reports.....	30
12.1	Field, laboratory, and other audits.....	30
12.2	Responsible personnel	30
12.3	Frequency and distribution of reports	30
12.4	Responsibility for reports	30

13.0	Data Verification	31
13.1	Field data verification, requirements, and responsibilities	31
13.2	Laboratory data verification	31
13.3	Validation requirements, if necessary.....	31
13.4	Model quality assessment.....	31
14.0	Data Quality (Usability) Assessment	32
14.1	Process for determining project objectives were met.....	32
14.2	Treatment of non-detects	32
14.3	Data analysis and presentation methods.....	33
14.4	Sampling design evaluation.....	33
14.5	Documentation of assessment.....	33
15.0	References	34
16.0	Appendix A.....	38
	Acronyms and Abbreviation, Units of Measurements, and QA Glossary and References.	38

List of Figures

Figure 1. Example of pan design from manufacturer’s website.....	11
--	----

List of Tables

Table 1: Laboratory analytes to be assessed	12
Table 2. Organization of project staff and responsibilities.....	17
Table 3. Schedule for completing field and laboratory work.	18
Table 4. Schedule for final report.	18
Table 5. Project budget and funding.	19
Table 6. Laboratory budget details.	19
Table 7. Drilling method quality objectives	20
Table 8. Measurement quality objectives	20
Table 9. Anticipated purchasing categories of cookware.....	23
Table 10. Sample containers, preservation, and holding times.	25
Table 11. Measurement methods (laboratory).	27
Table 12. Quality control samples, types, and frequency.	28
Table 13. Analytical data qualifiers.....	33

2.0 Abstract

Recent studies have found that some metal cookware can contain high levels of lead. Two studies in Washington primarily focused on assessing imported cookware using rapid screening and leaching test methods (Fellows 2022, 2025). To further understand optimal methods for processing cookware samples for regulatory testing, this study focuses on metal skillets and frying pans used for heating food on a stove top or other heat source and offered for sale in Washington. We will use well-established EPA-validated determinative test methods instead of screening or leaching methods to develop processing methods to determine the presence of heavy metals in the products.

3.0 Background

3.1 Introduction and problem statement

Cookware is a vital part of daily life because cooking improves physical and chemical properties of food, making many foods more palatable for consumption (Alabi and Afolabi 2024). Most households regularly eat food that has been heated in some form of cookware. Cooking can cause metals present in cookware to leach out and transfer into the food (Mohamed 1996). By eating cooked food, people may ingest metals that leach out of cookware (Weidenhammer 2017). This is particularly concerning if those leached metals are toxic, such as lead, cadmium, or arsenic. Additionally, all cookware has an end of life and once disposed of, those toxic metals can be released into the environment.

Lead is a known human toxicant (ASTDR 2020), leading to lower cognitive ability and a variety of developmental delays. Lead exposure in children can lead to brain and nervous system damage resulting in slowed growth and development, learning and behavior problems, as well as hearing and speech problems (CDC 2020a). For children less than six years old, the health effects of lead exposure can be more harmful because they are still developing and growing rapidly (CDC 2020b).

Cadmium and cadmium compounds are known carcinogens. Long-term exposure to even low levels of cadmium can lead to kidney damage, lung damage, and fragile bones (ATSDR 2012). Cadmium exposure has been linked to several harmful health outcomes, including damage to the kidneys, brain, and other organs (Chwalba et al. 2023). This can lead to oxidative stress, which makes it harder for cells to process energy and disrupts their internal electron balance (Yong-Xin et al. 2022).

Long-term exposure to high arsenic in drinking water has been associated with skin disorders and increased risks for diabetes, high blood pressure, and several types of cancer. Inorganic arsenic and arsenic compounds are linked to cancer (EPA 2021) (ASTDR 2007).

Disposing of household products can lead to heavy metal contamination in the environment. For example, lead in landfills can leach out to wastewater treatment plants and be released in wastewater or sewage sludge (EPA 1999). Many sites across Washington state have some form of heavy metal pollution. Ecology's cleanup website¹ shows 1,997 sites with lead contamination, 1,222 sites with arsenic contamination, and 2,191 with priority pollutant contamination, which includes cadmium and other metals. As contaminants in the environment, heavy metals can have devastating effects on human, animal, and plant health.

Lead contamination in the environment can cause problems in animals and plants. Lead in the soil can be taken up by plants resulting in decreased plant and root growth (EPA 2025a, Collins 2022). Lead can also bioaccumulate in vertebrates, causing potential impact to reproduction as well as neurological effects. (Collins 2022, Kshyanaprava 2023, EPA 2025a). Animals that do not die directly from acute lead exposure face sub-lethal effects of chronic lead exposure, which can contribute to their inability to survive in the wild (Ecology 2009).

Cadmium reduces the ability of plants to take in and transport nutrients and water, disrupting plant metabolism, and restricting growth, shape and overall health (Haider et al. 2021). Cadmium and other metals have also been shown to weaken plant cell walls (Hocaoğlu-özyiğit and Genç 2020).

Arsenic causes a wide range of adverse effects in plants, including yellowing leaves, stunted growth, and reduced photosynthesis. Arsenic can disrupt the plant's water uptake and nutrient absorption, leading to nutrient deficiencies and plant death. Additionally, arsenic can accumulate in the plant tissue, making it toxic to herbivores that feed on the plant (De 2023).

Exposure to heavy metals can have wide-ranging negative effects on humans, animals, and plants (ASTR 2005, 2012, 2025). A few studies in Washington have found some cookware contains high levels of lead (Fellows 2022, 2025). These studies focused on imported cookware, were not representative of general cookware, and used human health-based testing approaches to test for lead. Previous studies may not have considered impacts from an environmental perspective, where toxic metals from product sources add to the overall burden on our environment.

A wider scope of cookware and larger selection of toxic metals will be included in this method development study. This research will generate additional data to inform consumers and guide stronger chemical policies.

3.2 Study area and surroundings

This study will focus on a variety of cookware offered for sale in Washington state that is used to heat food on a stovetop or in an oven and is made of metal, with or without a coating.

¹ <https://apps.ecology.wa.gov/neighborhood/>

Multiple price points and purchase locations, such as retail stores and online purchases, will be included. This study will focus on cookware that is used to heat food on a stovetop or in an oven and is made of metal, with or without a coating.

Ten-to-twelve-inch pots and pans will be assessed in this study, including cookware made of stainless steel, aluminum, brass, and mixed metals. Color can be used as a means of distinguishing components with different metals, even if they are not labeled as distinct on the packaging. While glazed ceramic cookware is known to be a possible source of lead (Mohamed 1995, Valles-Madenia 2014), analysis of pure ceramic cookware, such as clay bowls and plates, will require method development beyond the scope of this study.

3.2.1 History of study area

Cookware of various materials have been in use since the prehistoric period to heat food in a controlled manner. This allows more of the nutrients from food to be absorbed. (Carmodi 2009) As more cookware materials and techniques to make food become available, the number of possible options available to the consumer are large and shifting.

According to a report released by The National Kitchen & Bath Association in 2021, rising homeowner expenditure on kitchen refurbishing projects would increase the demand for kitchenware and cookware products. High standards of living, supported by rising disposable income levels, influence the demand for high-end cookware products across the globe. The size of the world market for cookware was estimated at \$30.60 billion in 2023, and it is projected to increase at a compound annual growth rate of 6.2% between 2024 and 2030 (Alabi and Afolabi 2024).

New cookware products are introduced to the market frequently. Industry and non-governmental organizations suggest replacing coated or non-stick pans every 1 to 2 years. New product availability and recommendations to switch out pans likely mean that many consumers have cookware of varying ages in their kitchen. One study in India found households replaced cookware every 5-10 years or over 10 years for kitchen durables (Anilkumar 2013). Informal internet polls on Reddit and Quora indicate that many people do not throw away and replace cookware every 1-2 years, although the answers are not precise and not representative enough to make detailed assessments of how often cookware is replaced. Another study found replies were often informal and imprecise such as “10-15 years,” “haven’t replaced it yet,” or “when I notice chipping” (Nugun 2022).

Consumers want products that perform well (Carmody 2009). As more pans are optimized for quick and even heat transfer, non-stick surfaces or other desired attributes at the lowest cost economically viable, the complexity of the cookware increases. To provide all these properties in a single product, cookware pieces are frequently made of more than one material or alloy, either in different parts of the cookware or in different layers. Brass is sometimes used in handles or lid decorations. Cooking surfaces may be disclosed as an advertising or selling point, but the metal composition in items like handles or rivets are frequently not labeled. Many cookware packages do not give details about what is used in all parts of the cookware. Consumers trust that the cookware on store shelves is generally safe. The US Food and Drug

Administration (FDA) has some regulations for food contact materials, but not all parts of the cookware market are regulated.



Figure 1. Example of pan design from manufacturer's website

3.2.2 Summary of previous studies and existing data

Previous studies by King County (Fellows 2022, 2025) and Pure Earth (Binkhorst 2025) studied cookware available in King County and several middle-income countries. Middle-income countries were defined in the Pure Earth protocol (Sargsyan 2024, Binkhorst 2025). These studies used X-ray fluorescence spectroscopy (XRF) to screen for lead. Other studies looked at lead in cookware in Pakistan using XRF (Ali Sultan 2014), and Cameroon (Weidenhamer 2014). XRF is a rapid screening tool and must be confirmed with laboratory testing.

The studies in King County found high levels of lead in traditional Afghan cookware, but not all the cookware was purchased in Washington. There are few other background studies specifically for products purchased in the state of Washington. Cookware is a broad category that includes many products and a shifting market.

Both Pure Earth and King County followed their XRF screening with a leachate test. Other leachate studies have found that heavy metals can leach, or dissolve in small amounts, out of metal cookware and into food (Zhou 2017). In addition to lead, cadmium has been observed to leach out of stainless-steel cookware (Alabi and Afolabi 2024). A 2017 study conducted by Weidenhamer was the most robust look at leaching of arsenic. The study found lower levels of arsenic than either lead or cadmium generally, though some levels were above World Health Organization recommendations (Weidenhamer 2017). These studies used different leaching methods, but they all involve some amount of heat, acid, and time.

Leaching is heavily influenced by coatings and pan conditions. Over time, scratches and wear on the cookware can lead to changes to leachability. In some studies, used cookware was tested as well as new (Fellows 2024), but results were not segregated based on use history or reported separately for new and used samples.

One study (Weidenhamer 2022) looked at total metal content in artisanal cookware in western Africa. Their study found multiple pieces with lead levels over 200 parts per million (ppm).

End of life disposal in landfills and recycling issues are determined by an EPA defined environmental-based leaching test, such as EPA 1311. Municipal Solid Waste landfills have detected some heavy metals in leachate (EPA 1999), but it is not usually possible to determine what items in the landfill contributed to the metal concentrations found in the leachate. From 1970 to 2000, EPA data reported a trend of increasing waste disposal, including lead and cadmium containing objects (EPA 1999).

3.2.3 Parameters of interest and potential sources

Table 1: Laboratory analytes to be assessed

Metals	Abbreviation	Chemical Abstracts Service (CAS) #
Lead	Pb	7439-92-1
Cadmium	Cd	7440-43-9
Arsenic	As	7440-38-2

Heavy metals such as lead, cadmium and arsenic can come from a variety of sources. Lead is a known part of brass to increase malleability, while other sources of lead are not so obvious. For example, heavy metals are frequently used as colorants. Not all colorant formulas are easily verifiable.

Cookware may use recycled metals which can include heavy metals from sources such as batteries, electronics or other contamination sources. Historical bronze can also be made with arsenic (Charles 1967). Aluminum ores can have heavy metal contamination (Sun 2019). Since the beginning of the aluminum industry in 1920, the use of scrap metal debris as a source for artisanal cookware manufacturing has increased globally by more than 40% (Alabi & Adeoluwa, 2020). By the year 2000, 43 nations around the world were using scrap metal as their principal supply of aluminum. Of the primary aluminum recovered from scrap metal waste, around 35% came from the United States (Patricia 2000).

Cadmium is used in pigments for plastics, ceramic, glass, and enamels. It is also used as a stabilizer for polyvinyl chloride (PVC) and in alloys and coatings on steel and other metals. Most cadmium used in the United States is extracted during the production of other metals like zinc, lead, and copper (ASTDR 2012). Batteries are a common household source of cadmium.

Arsenic is a naturally occurring element widely distributed in the earth's crust (ASDR 2007). Arsenic is known to exist in some ceramic glazes and colorants (Norita 1995) and can co-occur with aluminum deposits. Historical examples include arsenic green dye for home goods. Arsenic can be used in alloys of lead for hardening (EPA 2025) and can be used in pesticides.

3.2.4 Regulatory criteria or standards

This study is not designed to assess compliance with Washington's laws.

Several laws in Washington regulate heavy metals in consumer products at different levels for different reasons. In December of 2000, Ecology released its Proposed Strategy to Continually Reduce Persistent, Bioaccumulative Toxins (PBTs) in Washington State. The PBT Strategy guides the continual reduction of risks to human health and Washington's environment from exposures to PBTs, including lead and cadmium. In 2006, the PBT rule (Chapter 173-333 WAC) went into effect, laying the groundwork for subsequent, more targeted chemical restriction laws. Arsenic, lead, and cadmium are all considered PBTs. They persist in the environment, have the potential to cause harm and bioaccumulate up the food chain.

In 2024, the Washington State Legislature passed chapter 70A.565 RCW to reduce the amount of lead in cookware. In 2025, this law was changed to focus on types of cookware that are the most likely to expose people to lead. The first of the restrictions went into effect on January 1, 2026.

Federally, the FDA regulates food contact substances, which are substances that come into contact with food, and are not intended to have a technical effect such as acting as an antioxidant, a humectant, or a stabilizer in such food (21 C.F.R. Part 172). This includes food packaging and its components, processing equipment, food preparation surfaces, or cookware (FDA 2025). The FDA identifies what level of lead is found using a leaching method and does not define what level of lead in the product could potentially be considered actionable. However, there are no mandated testing schedules for manufacturers of general consumer cookware. Much of the FDA's testing efforts are focused on imported cookware or in performing reactive testing when there is a suspected health concern associated with a food contact substance.

The Resource Conservation and Recovery Act (42 U.S.C. §6901 et seq) contains the established standards for lead, cadmium, and arsenic in solid waste. In recent years, the EPA has largely focused on building hazardous and municipal solid waste programs and fostering a strong societal commitment to recycling and pollution prevention (EPA 2025). Washington has a companion policy (chapter 173-303 WAC) for regulating lead, cadmium, and arsenic in dangerous waste from products and industries.

Other enacted laws that regulate one or more of the compounds included in the study are the Chapter 70A.430 RCW and chapter 70A.340 RCW. Both contain varying limit restrictions for lead and cadmium in children's products and brake materials, respectively. In 2019, chapter 70A.350 RCW passed, which allowed for the implementation of the Safer Products for Washington program. This law gives Ecology the authority to restrict certain priority chemicals, such as lead, in a wider selection of consumer products. More recently, the Toxic Free Cosmetic Act (TFCA) (chapter 70A.560 RCW) further extended restrictions on lead in cosmetics.

3.3 Water quality impairment studies

N/A

3.4 Effectiveness monitoring studies

N/A

4.0 Project Description

The project will involve method development for sample preparation of metal cookware samples before they are submitted to Ecology's Manchester Environmental Laboratory (MEL). Successful sample preparation best practices from this project will be documented as a Product Studies Unit (PSU) standard operating procedure (SOP). SOPs will be prepared for laboratory and field activities to describe the process, safety, and include quality assurance and quality control for the procedure. SOPs allow Ecology to generate reproducible data.

In addition, this study will assess levels of lead, arsenic, and cadmium in metal cookware sold in Washington. For this study, metal cookware is defined as pots and pans that are used to heat food on a stovetop or in an oven and is made of metal with or without a coating. Popular websites²³ list 10 inch – 12 inch frying pans as the most sold cookware products. Products are limited to those available to Washington state residents in retail stores or online.

Samples will be submitted to MEL for metals analysis by EPA Method 6020B by inductively coupled plasma mass spectrometry (ICP-MS). Laboratory data will be reviewed for quality assurance and published online in the [Consumer Products Database \(CPD\)](#).⁴ A report documenting study findings, and a data narrative will be made available.

This study will visually assess the cooking surface of a small subset of samples by scanning electron microscopy-electron dispersive x-ray spectroscopy (SEM-EDX) imaging and elemental screening. After testing for lead, arsenic, and cadmium, samples with high levels of target metals may be chosen for SEM-EDX. SEM-EDX images will be used to assess product construction and inspect homogeneity/heterogeneity of the metal materials.

4.1 Project goals

This study is designed to meet the following goals:

- Provide data to Ecology's team to identify any preparation method induced contamination and verify sufficiency of a reference method for metal cookware.
- Assess the levels of heavy metals in a variety of metal cookware available for sale in Washington State.
- Identify if any methodological or technical issues exist to measuring heavy metals in metal cookware.

4.2 Project objectives

Study goals will be met through the following objectives:

² www.amazon.com

³ www.Madeincookware.com

⁴ <https://apps.ecology.wa.gov/consumerproducts/>

- Purchase up to 58 pieces of cookware available for sale in Washington.
- Prepare samples of documented purity aluminum and steel standards, known to have low to undetectable concentrations of lead, arsenic, and cadmium. Samples are to be used as a laboratory blind blank and quality control (QC) check.
- Send up to 68 samples (including laboratory blind blanks and standards) for laboratory analysis of total lead, arsenic, and cadmium.
- Develop an SOP with best practices for cookware preparation for submission to MEL.

4.3 Information needed and sources

A literature review of previous studies on heavy metals in cookware will be conducted. Literature exclusively about ceramics will be reviewed for colors in glaze, but ceramics will not be included in this study due to lab digestion difficulties. Literature will be reviewed for measurement and sample preparation techniques as well as result values if applicable. Information such as product Universal Product Codes (UPC), product brands, and design patterns will also be reviewed to identify similar products available in the current market.

4.4 Tasks required

The following tasks will be performed for this study:

- Review previous Ecology studies, research literature and available data of cookware.
- Conduct in-store and online search for availability of and prioritize products for purchase.
- Purchase up to 58 cookware products.
- Purchase documented purity aluminum and steel standards.
- Document purchasing information, product details, and product component descriptions in the consumer product database.
- Prepare the cookware for lab analysis by collecting shavings from a drill press.
- Prepare aluminum and steel standards for lab analysis by collecting shavings from drill press.
- Document the sample identification, item description, condition before deconstruction, deconstruction/drilling process, issues encountered, condition after deconstruction/drilling, and any additional comments from processing.
- Submit up to 68 component samples for analysis of lead, arsenic, and cadmium at MEL.
- Perform appropriate data verification and review data report(s).
- Review as needed reports of problems in the lab with digestion or analysis on any samples.
- Document validated and qualified lab analysis data in the database.
- Perform a QA review of product and lab analysis data.

- Send up to 5 samples for additional scanning electron microscopy-Electron Dispersive X-ray Spectroscopy (SEM-EDX) imaging and elemental screening, if warranted (e.g., inspect products with high levels of target metals, assess product construction, and inspect homogeneity/heterogeneity).
- Review SEM-EDX images for physical characteristics and elemental composition.
- Analyze study data and write a report for publication by Ecology.
- Develop a standard operating procedure (SOP) detailing the steps for cookware sample deconstruction, including sample preparation, tool use, safety, and documentation.
- Publish laboratory data and product information through Ecology's Consumer Products Database.

4.5 Systematic planning process

This QAPP addresses comprehensive systematic planning for this study.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 2 shows the responsibilities of those who will be involved in this project.

Table 2. Organization of project staff and responsibilities

Staff ¹	Title	Responsibilities
Michael Zahn Product Studies Unit Statewide Coordination Section Phone: 564-669-4394	Project Manager	Contributes to the QAPP. Oversees product collection, sample processing, and transportation of samples to the laboratory. Assists with drill method development and sample processing. Conducts QA review of data, analyzes and interprets data, and enters data into the consumer products database and QA reviews data entry. Writes the draft report and final report.
Karna Holquist Product Studies Unit Statewide Coordination Section Phone: (564) 669-4189	Principal Investigator	Writes the QAPP. Leads product collection, sample processing and transportation of samples to the laboratory. Leads drill method development. Conducts QA review of data, analyzes and interprets data, and enters data into the consumer products database and QA reviews data entry. Writes the draft report and final report, writes SOP
Jenna Rushing Product Studies Unit Statewide Coordination Section Phone: (360) 819-3670	Sample Prep Lead	Reviews draft QAPP and approves final QAPP. Enters purchasing and product data into CPD upon sample receipt. Assists with drill method development and sample processing. Assists in QA review of project data in the database. Enters data into the database. Reviews draft report.
Sara Sekerak Product Studies Unit Statewide Coordination Section Phone: 360-480-9501	Client, PSU Unit Supervisor	Provides internal review of the QAPP, approves the project scope and budget, and approves the final QAPP. Oversees project progress, reviews draft report and approves final report.
Jessica Archer Statewide Coordination Section Phone: 360-890-2721	Client; Statewide Coordination Section Manager	Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP and report.
Rob Waldrop Manchester Environmental Laboratory Phone: 360-519-2083	Laboratory Director	Reviews and approves the final QAPP.
Christina Frans Phone: 360-407-6964	Ecology Quality Assurance Officer	Reviews and approves the draft QAPP and the final QAPP.

¹ All staff are from EAP.

EAP= Environmental Assessment Program; PSU= Product Studies Unit; QAPP= Quality Assurance Project Plan.

5.2 Special training and certifications

Staff making purchases with an Ecology credit card must attend the online training programs and have a signed credit card authorization on file.

All staff will follow appropriate SOPs detailed in Chapters 8 and 9.

5.3 Organization chart

Not Applicable

5.4 Proposed project schedule

Tables 3 – 4 list key activities, due dates, and lead staff for this project.

Table 3. Schedule for completing field and laboratory work.

Task	Due Date	Lead Staff
Product purchasing	December 31, 2025	Karna Holquist Jenna Rushing Michael Zahn
Product data entry	Jan 07, 2026	Jenna Rushing
Product data entry QA	Jan 15, 2026	Karna Holquist Michael Zahn
Drill processing	Feb 27, 2026	Karna Holquist Jenna Rushing Michael Zahn
Samples sent to lab	March 02, 2026	Karna Holquist Michael Zahn
Laboratory analyses	May 15, 2026	MEL staff

Table 4. Schedule for final report.

Task	Due Date	Lead Staff
Draft to supervisor	September 31, 2026	Karna Holquist Michael Zahn
Draft to client/ peer reviewer	October 21, 2026	Karna Holquist Michael Zahn
Final draft to publications team	November 20, 2026	Karna Holquist Michael Zahn
Final report due on web	February 15, 2027	EAP Publications
SOP draft to publications team	September 31, 2027	Karna Holquist

5.5 Budget and funding

Tables 5 and 6 show the budget for laboratory and other expenses for the project.

Table 5. Project budget and funding.

Item	Cost (\$)
Products and blank reference materials	4600
MEL analysis (See Table 6 for details)	8432
SEM-EDX (See Table 6 for details)	1500
Project Total	14260

Table 6. Laboratory budget details.

Parameter	Number of Samples	Number of QC Samples	Total Number of Samples	Cost Per Sample (\$)	Lab Subtotal (\$)
Metals (Lead, cadmium, arsenic)	58	12	70	136	7072
Drill process blanks and standards	10	0	10	136	1360
SEM-EDX images and elemental (contract lab)	5	0	5	300	1500
Laboratory Total					9932

6.0 Quality Objectives

6.1 Data quality objectives

The overall data quality objective (DQO) is to provide analytical data that meets all documented precision and bias standards. Ecology's product studies follow established Guidelines for Data Verification and Validation of Chemical Data from Ecology's QA Coordinator (Ecology 2004).

Analytical laboratory testing will follow standard methods that meet measurement quality objectives (MQO) outlined below. Qualitative testing may not have specific MQOs but will be reviewed for suitability and accuracy by the project manager and principal investigator.

DQOs and MQOs will be evaluated by the project manager and principal investigator to document the performance of the procedure and write an SOP for future studies.

The drilling method will be evaluated based on the following criteria:

- 1) **Detection** — Rate of detection of analytes (presence/absence) compared to known standards.
- 2) **Precision** — Reproducibility measured by repeat purchase of one skillet and drilling duplicate samples of 10 percent. Relative percent difference when there are two replicates.
- 3) **Recovery** — Steel and aluminum will be prepped as a sample and recovery recorded.

Table 7. Drilling method quality objectives

Criteria	Threshold
Detection/sensitivity	< LOQ for non-present samples
Precision	70%–130% recovery
Recovery	80

6.2 Measurement quality objectives

6.2.1 Targets for precision, bias, and sensitivity

The MQOs expressed as precision, bias, and sensitivity of metals data are presented in Table 7. SEM-EDX wavelengths are calibrated annually and verified every 6 months.

Table 8. Measurement quality objectives

Parameter	Lab Duplicate (RPD)	Matrix Spike Duplicate (RPD)	Lab Control Standard (%Recovery)	Matrix Spike (% Recovery)	Method Blank	Lowest Concentrations of Interest
Lead	≤ 20%	≤ 20%	85–115	75–125	< LLOQ	1 ppm
Cadmium	≤ 20%	≤ 20%	85–115	75–125	< LLOQ	1 ppm
Arsenic	≤ 20%	≤ 20%	85–115	75–125	< LLOQ	1 ppm

RPD=relative percent difference

6.2.1.1 Precision

Precision is a measure of variability among replicate measurements due to random error. Laboratory precision will be assessed through analysis of one sample duplicate, matrix spike duplicate (MSD) and laboratory control spike duplicate (LCSD) per analytical batch. Precision for duplicate samples will be measured as the relative percent difference between the two results.

Precision assessments through collection of duplicate product replicates may be conducted if manufacturing lot/batch information is available. Duplicate drill samples of one product will be sent as a check on the precision of the preparation.

The MQOs are presented in Table 8.

6.2.1.2 Bias

Bias is the difference between the sample mean and the true value. Lab analysis bias will be assessed through lab control samples (LCS) and matrix spike (MS) samples. MQOs for LCS and MS are shown in Table 7.

A sample of the drill bit and four blind standards with known concentration will be submitted to assess contamination and or bias added by the processing/drilling method. Bias will be documented and included in the final SOP.

6.2.1.3 Sensitivity

Sensitivity is a measure of the capability of a method to detect a substance. It is commonly described as a detection or reporting limit. The lowest concentrations of interest for all the analytes are shown in Table 7.

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

Comparability will be ensured by implementing standardized procedures for sampling and analysis. Data from this study can be compared to publicly available data of similar product types and analyzed using substantially similar analytical methods, if available.

Energy Dispersive Xray spectroscopy (EDX) elemental results will be used to roughly visualize composition of tested pans, no formal comparison to ICPMS measurements will be conducted.

6.2.2.2 Representativeness

Products purchased through retail stores or online for this study are intended to represent a range of metal cookware available to residents of Washington.

6.2.2.3 Completeness

The project manager will consider purchasing for this study to be complete if 90% of the identified products are collected within the study collection timeframe. The project manager will consider the study to be complete if 95% of the lab samples meet the MQOs in Table 7.

6.3 Acceptance criteria for quality of existing data

Not Applicable

6.4 Model quality objectives

Not Applicable

7.0 Study Design

7.1 Study boundaries

To discover any necessary techniques for sample preparation, the study will focus on purchasing pots and pans for heating food on a stove or in an oven. and made of:

- Aluminum, both silver/grey and brass colored
- Stainless steel, both silver/grey and brass colored.
- Cast iron of any color
- Ceramic or other nonstick coated cookware, either aluminum or steel base.

A sample of the cooking surface will be collected and submitted for lab testing. If two different colors of metal are observed in the product, one sample will be taken from each. Coatings will not be removed.

Table 9 illustrates the targeted procurement plan:

Table 9. Anticipated purchasing categories of cookware.

Material	Minimum Number of Samples
Aluminum	10
Stainless steel	10
Mix or coated	24
Cast iron	10

An effort will be made to purchase the number of items within each material category listed in Table 9. Lack of availability may change the number of products purchased from each category.

7.2 Field data collection

Products will be purchased online and from retail stores in the Puget Sound area of Washington.

Stores will be prioritized for purchasing if they have multiple locations across Washington state, to ensure representation of products available to residents of Washington.

At least one specialty store and at least two big box physical stores will be sampled. Products from third party sellers available online will be excluded from the study.

7.2.1 Sampling locations and frequency

Products will be purchased online and from retail stores in the Puget Sound area of Washington.

This study will focus on stores that carry pots and pans.

7.2.2 Field parameters and laboratory analytes to be measured

There are no field parameters to be measured in this study. Table 1 lists laboratory analytes to be studied.

7.3 Modeling and analysis design

N/A

7.4 Assumptions underlying design

Products purchased for this study are assumed to reflect those currently available and on the market for sale to residents of Washington. It is assumed that that large retail stores or cookware specific store chains sell similar products at locations throughout Washington.

7.5 Possible challenges and contingencies

The possible logistical challenges, constraints, and schedule limitations for this study are described in the subsections below.

7.5.1 Logistical problems

The purpose of this study is to record technical issues that are found during sample processing. Different cookware types may cause problems with processing and may require alternate processing methods or be excluded from future studies.

7.5.2 Practical constraints

Researching purchase options and establishing a purchasing schedule will help guide sampling. However, since product availability and shortages are unpredictable, the plan must remain flexible and will include alternatives. For purchasing products online, it may be that marketing leads to purchasing products not in the “correct” category if the marketing or labeling is incorrect.

7.5.3 Schedule limitations

Complex matrices may require an extended period of time for laboratory analysis. Additional cleaning or other tasks can be needed when analyzing consumer product samples. Complex data sets may require extended data QA procedures or data validation. Immediate communication about MEL staff or resource shortages and instrument issues will help inform management of schedule and deadline changes.

8.0 Field Procedures

8.1 Invasive species evaluation

NA. Invasive species are not expected to be encountered during the work of this project.

8.2 Measurement and sampling procedures

Product purchasing and processing will follow SOP PTP001 v.2.2 (Ecology 2021). Data entry and data quality assurance will follow SOP PTP002 v.3.0 (Ecology 2022).

Products collected for this study will be brought to Ecology's Product Studies Preparation Room, where they will be stored and processed under secure holding conditions.

Samples of metal cookware will be collected by drilling to create small sized shavings using a heavy-duty drill press. Shavings from the bottom of pans and along the length of handles will be collected and sent to MEL in glass jars. Multiple drill sites will be included to generate at least 2.5 grams of material to be tested. After drilling, leftover material will be cut into samples with a hole press with diameter 1 3/8" for shipment for SEM-EDX.

8.3 Containers, preservation methods, holding times

Table 10 presents sample containers, minimum quantity, storage and preservation, and holding times for sample matrices are shown in Table 9.

Table 10. Sample containers, preservation, and holding times.

Parameter	Matrix	Minimum Quantity Required	Container	Preservative	Holding Time
Lead	Metal with or without coatings	2.5 g	4 to 8 oz. glass jars	Ambient temperature	1 year
Cadmium	Metal with or without coatings	2.5 g	4 to 8 oz. glass jars	Ambient temperature	1 year
Arsenic	Metal with or without coatings	2.5 g	4 to 8 oz. glass jars	Ambient temperature	1 year
SEM	Metal with or without coating	Approximately 2" square	Plastic bags	Ambient temperature	1 year

8.4 Equipment decontamination

Decontamination procedures will follow protocols in SOP PTP001. Product testing staff will clean the drill press, drill bit and drill press guard with 1% Liquinox solution followed by a 24% ethanol wipe prior to use, and between processing each product. Staff will change into new gloves between processing products. Drill bits will be screened for detectable contamination and drill bit shavings will be submitted to the lab to verify lack of contamination. A clean drill bit will be used in deconstruction and componentization of each new product.

8.5 Sample ID

Upon entry into the database, individual product component identification codes are automatically assigned as outlined in SOP PTP002. Product IDs convey information about the store of purchase, the purchase event, product number, and component number. For example, “WM-1-3-1” means Walmart store, purchase event 1, product number 3, component number 1 of the product tested.

A Pre-Sampling Notification form will be submitted to MEL prior to the planned submission of samples. MEL will generate a work order number for each sample set for a study.

8.6 Chain of custody

Appropriate chain of custody procedures will be followed according to SOP PTP001. Products gathered for this study will be kept in locked cabinets in Ecology’s Product Studies Preparation Room for the duration of the study. Product component samples will be stored in glass sample jars in locked cabinets prior to shipment to MEL for laboratory analysis (Sekerak 2016). A detailed chain of custody form will accompany all samples during shipment to the lab.

8.7 Field log requirements

Product advertisements, photos of in-store or online marketing, and receipts for purchases will be collected during purchasing events and scanned and saved in the database. Purchasing event information will be entered into the database as outlined in SOP PTP002.

At a minimum, the store name, street address, website address, purchase date, purchase price, brand name, manufacturer name, manufacture date, and distributor name will be recorded in the database for all products in this study.

8.8 Other activities

N/A

9.0 Laboratory Procedures

9.1 Lab procedures table

Table 11 presents the methods for the assessment of metals that will be performed at MEL.

Table 11. Measurement methods (laboratory).

Analyte	Sample Matrix	Sample Number	Arrival Date	Expected Range of Results	Detection or Reporting Limit	Sample Prep Method	Analytical Method
Lead	Metals-coated and uncoated	68	February 2026	Unknown	1 ppm	EPA 3052*	EPA 6020B
Cadmium	Metals-coated and uncoated	68	February 2026	Unknown	1 ppm	EPA 3052*	EPA 6020B
Arsenic	Metals-coated and uncoated	68	February 2026	Unknown	1 ppm	EPA 3052*	EPA 6020B
SEM-EDX	Metals-coated and uncoated	5	July 2026	Unknown	N/A	N/A	Lab SOP

ppm = parts per million

N/A=Not applicable

*Preparation method modified to omit use of hydrofluoric acid

9.2 Sample preparation method(s)

Product component sample preparation will follow SOP PTP001 for purchase and storage. Laboratory sample preparation and digestion will follow EPA Method 3052, less the use of hydrofluoric acid. The omission of hydrofluoric acid is due to the lack of need for silica glass solubilization and to comply with MEL safety policies.

9.3 Special method requirements

Pictures of any samples not completely digested will be sent with the report to allow tracking of the digestion process.

9.4 Laboratories accredited for methods

Samples will be analyzed at Manchester Environmental Laboratory. The laboratory is accredited for the analysis of all target analytes by EPA Method 6020B by WA department of Ecology.

Ecology does not offer accreditation for SEM-EDX imaging. An accreditation waiver will be obtained before any imaging.

10.0 Quality Control Procedures

10.1 Table of field and laboratory quality control

Table 12 presents the lab QC samples for this study. Lab QC tests will consist of lab control samples, lab control sample duplicates, sample duplicates, method blanks, matrix spikes, and matrix spike duplicates.

Table 12. Quality control samples, types, and frequency.

Parameter	LCS/LCSD	Laboratory Method Blanks	Analytical Duplicates	Laboratory Matrix Spikes/MSD
Lead	1/batch	1/batch	1/batch	1/batch
Cadmium	1/batch	1/batch	1/batch	1/batch
Arsenic	1/batch	1/batch	1/batch	1/batch

LCS = lab control sample

LCSD = lab control sample duplicate

MS = matrix spike

MSD = matrix spike duplicate

Batch = 20 samples or fewer

10.2 Corrective action processes

Ecology staff will adhere to the appropriate SOPs and study-specific processing and preparation protocols in this QAPP. MEL staff will document whether project data meet method QC criteria. The lab will notify the project manager if substantial departures of method techniques will be required. Any departures from stated analytical methods will be documented by the laboratory and described in the case narrative. When MQO or QC criteria are not met, or if the integrity of the processing and preparation processes are in question, the project manager will determine if samples should be re-collected, re-analyzed, rejected, or used with appropriate qualification.

11.0 Data Management Procedures

11.1 Data recording and reporting requirements

Product data logging will follow SOP PTP002 (Ecology 2022). Study data will be stored in Ecology's CPD. Study data records will include purchase receipts, product descriptions, product component descriptions, product photos, and laboratory testing data. Purchase and product metadata of store name, street address, website address, purchase date, purchase price, brand name, manufacturer name, and distributor name will be recorded in the database.

Laboratory data will be received as an analytical report in PDF format and an electronic data deliverable (EDD) or comparable package. The project manager will perform a final QA review of all data before they are uploaded into the CPD. All raw data, lab case narratives, and validation reports are managed under appropriate retention criteria.

11.2 Laboratory data package requirements

MEL will provide a data package sufficient for a stage 4 validation. The lab data will contain all required specific content, along with sample and QC data. The data package must include all sample raw data, QC sample raw data, and chain of custody forms needed to perform independent verification of the results and sample handling procedures.

Case narratives will be included to discuss any problems encountered with the analyses, corrective action taken, changes to the requested analytical method, and a glossary for data flags.

SEM data will include a report noting any nonconformances, images of the samples and an EDX spectrum as a PDF.

11.3 Electronic transfer requirements

Laboratory analytical reports with case narratives will be in PDF format and EDDs will be in a .CSV spreadsheet format that meets Ecology's product testing formatting requirements unless an alternative format is approved in advance by the project manager.

11.4 Data upload procedures

The data for this project will be stored in Ecology's Consumer Products Database according to SOP PTP002 Data Entry and Data Entry Quality Assurance (Ecology 2022).

11.5 Model information management

NA

12.0 Audits and Reports

12.1 Field, laboratory, and other audits

Analytical labs must participate in performance and system audits of their routine procedures. The product testing process conducted at Ecology will be audited at a minimum of one audit a year.

12.2 Responsible personnel

Ecology's QA Officer or their designee will conduct the product studies process audit. The processes can include product acquisition, product documentation and data entry in the database, sample screening, sample processing, chain of custody, and adherence to product testing QAPPs and SOPs.

12.3 Frequency and distribution of reports

A final published report summarizing the data and findings will be written when the study is completed. The final report will include at a minimum:

- An overview of the study.
- Goals and objectives of the study.
- Discussion of the results.
- Discussion of methods, any corrective actions, and the significance of any problems encountered.
- Summary statistics of the laboratory results from products purchased.
- Summary tables and graphs of laboratory data.
- Notes and an SOP regarding the processing procedure for metal cookware.

The final report will be [available online](#).⁵

12.4 Responsibility for reports

The principal investigator and project manager will be responsible for reports. In addition to the general report for this project, the principal investigator will be responsible for writing an SOP compliant with EAP procedure 01-08 (Ecology 2019) that describes the methods Ecology will use to prepare cookware samples based on criteria listed in table 7.

⁵

<https://apps.ecology.wa.gov/publications/UIPages/PublicationList.aspx?IndexTypeName=Topic&NameValue=Product+Testing&DocumentTypeName=Publication>

13.0 Data Verification

13.1 Field data verification, requirements, and responsibilities

The principal investigator, project manager, or assigned designee, will conduct a final review of product purchases, product components, component screening, and additional product metadata entered into the database. All data will be reviewed by the project manager at several stages during the study according to SOP PTP002.

13.2 Laboratory data verification

Lab data verification is examination of a data set for errors or omissions, and assessment of the Data Quality Indicators related to that data set for compliance with acceptance criteria (MQOs). Verification is a detailed quality review of a data set (Ecology 2004). Lab data used to evaluate compliance will undergo verification by the project manager according to SOP PTP002. The project manager will review data packages and conduct a QA review of the data to assess suitability. The project manager is responsible for the final acceptance of lab data and will document all decisions in a case narrative. Based on these verification assessments, the data will be either accepted, accepted with qualifications, rejected with re-analysis considered, or rejected without re-analysis considered.

13.3 Validation requirements, if necessary

Data validation will not be performed for this project, but the full Level 4 data package will be available in case future projects require validation.

13.4 Model quality assessment

NA

14.0 Data Quality (Usability) Assessment

14.1 Process for determining project objectives were met

Laboratory data will be reported down to the reporting limit, with an associated “U” or “UJ” qualifier for samples below the reporting limit. All samples will be evaluated against the associated method blank for each analytical batch. Sample results less than or equal to 3x of the method blank concentration will be qualified as non-detect due to lab background.

14.2 Treatment of non-detects

The project manager will examine data from all sample preparation and lab procedures to ensure that the data were collected using proper procedures, fall into the expected range of results, and meet quality objectives as described in Sections 6, 8, and 9. The project manager will assess the quality of the data based on case narratives, data packages, and the lab report. Laboratory QC tests will be examined to determine if the lab met MQOs for method blanks, LCSs, duplicates, matrix spike samples, and surrogates when applicable. Reporting limits will be examined to ensure that the contract-defined reporting limit was met (Sekerak 2016).

If all MQOs and QC criteria are met, the quality of the data will be considered suitable for meeting study objectives. The study will be considered complete and objectives met if 95% of the samples meet MQOs and QC criteria. If a sample does not meet MQOs or any QC criteria, the project manager may apply a “REJ” qualification to the data. The final report for this study will discuss the data quality findings and whether the project objectives were met. If limitations in the data are identified, they will be noted. Analytical data qualifiers that will be used in the CPD are described in Table 13.

Table 13. Analytical data qualifiers.

Qualifier Symbol in Consumer Product Database	Qualifier Description
U	Analyte was not detected above the reporting limit.
UJ	Analyte was not detected above the reporting limit. However, the reporting limit is an estimated value.
J	Analyte was positively identified. The reported result is an estimate.
NJ	The analyte was tentatively identified in the sample, but the result value reported is an estimate.
REJ	The sample result was rejected due to serious deficiencies in the ability to analyze the sample, meet quality control criteria or other technical reason. The presence or absence of the analyte cannot be verified.

14.3 Data analysis and presentation methods

The final report will include a summary of the results of this study. Simple summary statistics and data will be presented in tables and graphs. Example summary statistics may include minimum, maximum, median, and frequencies of detection.

The report will include a link to the study data available on the Consumer Products Database.

14.4 Sampling design evaluation

The samples collected and tested were designed to determine method needs and product availability. This study design does not necessarily support estimating prevalence in a population, identifying wider areas of contamination, making wider comparisons, or estimating a market parameter. The results of this study may be used to plan future study events with a larger sample size, a wider variety of consumer products, or for establishing a follow-up on products tested within this study. The results of this study are not designed to determine regulatory compliance with any law or regulation.

Further use of these data to draw conclusions beyond those reported requires consultation with the principal investigator for this study and QA personnel to assess the need for a QAPP for existing data.

14.5 Documentation of assessment

Final documentation of data usability assessment will be in the final report.

15.0 References

- Alabi, O., and A. Afolabi. 2024. Cookware as source of toxic metals: An overview: Heavy metal leaching from cookware. *Kashmir Journal of Science*. 3(2): 57-80.
<https://kjs.org.pk/index.php/kjs/article/view/46>
- Alabi, O., and Y. Adeoluwa. 2020. Production, Usage, and Potential Public Health Effects of Aluminum Cookware: A Review. *Annals of Science and Technology*. 5. Doi:10.2478/ast-2020-0003.
- Ali Sultan, S.A., F.A. Khan, A. Wahab, B. Fatima, H. Khalid, A. Bahader, et al. 2023. Assessing Leaching of Potentially Hazardous Elements from Cookware during Cooking: A Serious Public Health Concern. *Toxics*, 11(7): 640.
<https://www.mdpi.com/2305-6304/11/7/640>.
- Anilkumar, N., and J. Jelsey. 2013. Consumer Behavior: Kitchen Durables. *Journal of Indian Management*, VolX no.4 p24-38.
<https://doi.org/10.31305/rrijm.2024.v09.n01.026>
- ATSDR (Agency for Toxic Substances and Disease Registry). 2007. Toxicological profile for Arsenic. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.
<https://www.atsdr.cdc.gov/ToxProfiles/tp2.pdf>.
- ATSDR [Agency for Toxic Substances and Disease Registry]. 2012. Toxicological profile for Cadmium. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.
<https://www.atsdr.cdc.gov/ToxProfiles/tp5.pdf>.
- ATSDR (Agency for Toxic Substances and Disease Registry). 2020. Toxicological profile for Lead. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.
<https://www.atsdr.cdc.gov/ToxProfiles/tp13.pdf>.
- Binkhorst, G., Jones, B. Sargsyan, A. van Geen, A. and K. Wagner. 2025. Potential lead exposure from aluminum cooking pots in lower and middle-income countries, *Journal of Hazardous Materials*. Volume 492, 138134.
<https://doi.org/10.1016/j.jhazmat.2025.138134>.
- Carmody, R.N. and R.W. Wrangham. 2009. Cooking and the human commitment to a high-quality diet. *Cold Spring Harb Symp Quant Biol.*;74: 427-34.
- Charles, J.A. 1967. Early Arsenical Bronzes—A Metallurgical View. *American Journal of Archaeology*, Volume 71.
- Chwalba, A., J. Orłowska, M. Słota, M. Jeziorska, K. Filipecka, F. Kinga, F. Bellanti, and M. Dobrakowski, et al. 2023. Effect of Cadmium on Oxidative Stress Indices and Vitamin D Concentrations in Children. *Journal of Clinical Medicine*. 12. 1572. Doi: 10.3390/jcm12041572.
- CDC (U.S. Centers for Disease Control and Prevention). 2020a. Overview of Lead Poisoning Prevention. Retrieved Aug 2023 from
<https://www.cdc.gov/nceh/lead/overview.html>.

- CDC (U.S. Centers for Disease Control and Prevention). 2020b. Childhood Lead Poisoning Prevention: Health Effects of Lead Exposure. Retrieved Aug 2023 from <https://www.cdc.gov/nceh/lead/prevention/health-effects.htm>.
- Collin, S., A. Baskar, D.M. Geevarghese, M. Niyaz Syed Ali, P. Bauhubali, R. Choudhary, et al. 2022. Bioaccumulation of lead (Pb) and its effects in plants: A review, Journal of Materials Letters, Volume 3, 100064. <https://doi.org/10.1016/j.hazl.2022.100064>.
- De, Amartya. R. Nilanjanav Huq, and S.M. Imamul. 2023. Consequences of Arsenic in the Environment chapter in Arsenic in the Environment — Sources, Impacts and Remedies. DOI: 10.5772/intechopen.1001476.
- Ecology [Washington State Department of Ecology]. 2004. Guidance for the Preparation of Quality Assurance Project Plans for Environmental Studies. Ecology, Olympia, WA. <https://apps.ecology.wa.gov/publications/SummaryPages/0403030.html>.
- Ecology [Washington State Department of Ecology]. 2009. Lead Chemical Action Plan. <https://apps.ecology.wa.gov/publications/SummaryPages/0907008.html>.
- Ecology [Washington State Department of Ecology]. 2016 [2022]. PTP002, Version 1.6, Product Testing Database for Data Entry and Data Entry Quality Assurance. <https://apps.ecology.wa.gov/publications/SummaryPages/2203208.html>
- Ecology [Washington State Department of Ecology]. 2019. Development, Adoption, Use, and Revision of Technical Standard Operating Procedures. Olympia, WA. For a copy of this document, please [submit a request online](#) or visit ecology.wa.gov/publicrecords.
- Ecology [Washington State Department of Ecology]. 2021. PTP001, Version 2.2, Product Collection and Sample Processing. Olympia, WA. <https://apps.ecology.wa.gov/publications/SummaryPages/2103201.html>
- EPA. 2025a. <https://www.epa.gov/lead-air-pollution/basic-information-about-lead-air-pollution> viewed July 23, 2026.
- EPA. 1999. Characterization of Products Containing Lead and Cadmium in Municipal Solid Waste in the United States, 1970-2000.
- EPA. 2025b. IRIS Toxicological Review of Inorganic Arsenic, <https://iris.epa.gov/document/&deid%3D363892>.
- EPA 2021. Arsenic Summary Fact Sheet US Food and Drug Administration, FDA https://www.fda.gov/food/food-ingredients-packaging/food-packaging-other-substances-come-contact-food-information-consumers?trk=public_post_comment-text.
- FDA. 2025. Inventory of Food Contact Substances listed in 21 CFR <https://hfpappexternal.fda.gov/scripts/fdcc/index.cfm?set=IndirectAdditives>.
- Fellows, K.M., S. Samy, and S.G. Whittaker. 2025. Evaluating metal cookware as a source of lead exposure. J Expo Sci Environ Epidemiol 35, 342–350 doi: 10.1038/s41370-024-00686-7.

- Fellows, K.M., S. Samy, and Y. Rodriguez. 2022. Investigating aluminum cookpots as a source of lead exposure in Afghan refugee children resettled in the United States. *J Expo Sci Environ Epidemiol* 32, 451–460. doi: 10.1038/s41370-022-00431-y.
- Haider, Fasih U., C. Liqun, J. A. Coulter, S.A. Cheema, J. Wu; R. Zhang. 2021. Cadmium toxicity in plants: Impacts and remediation strategies. *Ecotoxicology and Environmental Safety*, Vol 211. 111887.
<https://doi.org/10.1016/j.ecoenv.2020.111887>.
- Hocaoglu-özyiğit, A., and B.N. Genç. 2020. Cadmium in Plants, Humans and the Environment. *Frontiers in Life Sciences and Related Technologies*, (1), 12-21.
<https://dergipark.org.tr/en/pub/flsrt/article/781913>
- Kshyanapra, R. and Alok Prasad Das. 2023. Lead pollution: Impact on environment and human health and approach for a sustainable solution, *Environmental Chemistry and Ecotoxicology*, Volume 5. Pages 79-85.
<https://doi.org/10.1016/j.enceco.2023.02.001>.
- Lombard, S., and C. Kirchmer. 2004. Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies. Washington State Department of Ecology, Olympia, WA. Publication 04-03-030.
<https://apps.ecology.wa.gov/publications/SummaryPages/0403030.html>.
- Mohamed, N., Y.M Chin, F.W. Pok. 1995. Leaching of lead from local ceramic tableware, *Food Chemistry*. 54(3)245-249.
[https://doi.org/10.1016/0308-8146\(95\)00035-H](https://doi.org/10.1016/0308-8146(95)00035-H).
- Nguyen, T. 2022. Minimalistic Consumption: Study On Finnish Consumers With the Context of Kitchenware Consumption, master's thesis, University of Olulu.
- Norita Mohamed, Y.M. Chin, F.W. Pok, Leaching of lead from local ceramic tableware, *Food Chemistry*, Volume 54, Issue 3, 1995, Pages 245-249
- Patricia, A. P. 2000. Metals and Minerals. In: U.S. Geological Survey Minerals Yearbook, Vol. 1, USGS Publications, Washington DC.
- RCW Chapter: 70A.340. Better Brakes Law. Revised Code of Washington.
<https://app.leg.wa.gov/rcw/default.aspx?cite=70A.340>.
- RCW Chapter: 70A.350. Revised Code of Washington. Toxic Pollution Law.
<https://app.leg.wa.gov/RCW/default.aspx?cite=70A.350>.
- RCW Chapter: 70A.430. RCW (Children's Safe Product Act. Revised Code of Washington.
<https://app.leg.wa.gov/rcw/default.aspx?cite=70A.430>.
- RCW Chapter: 70A.560. Toxic Free Cosmetics Act. Revised Code of Washington.
<https://app.leg.wa.gov/RCW/default.aspx?cite=70A.560>.
- RCW Chapter: 70A.565. Cookware Containing Lead Law. Revised Code of Washington.
<https://app.leg.wa.gov/RCW/default.aspx?cite=70A.565>.

- Sargsyan, A., E. Nash, G. Binkhorst, J.E. Forsyth, et al. 2024. Rapid Market Screening to assess lead concentrations in consumer products across 25 low- and middle-income countries. *Sci Reports* 14, 9713
<https://doi.org/10.1038/s41598-024-59519-0>.
- Sekerak, S. 2016. Quality Assurance Project Plan: Product Testing Program, Version 1.0. Publication 16-03-113. Washington State Department of Ecology, Olympia, WA.
<https://apps.ecology.wa.gov/publications/SummaryPages/1603113.html>
- Sun, C., J. Chen, K. Tian, D. Peng, X. Liao, and X. Wu. 2019. Geochemical Characteristics and Toxic Elements in Alumina Refining Wastes and Leachates from Management Facilities. *Int J Environ Res Public Health*. 16(7):1297. doi: 10.3390/ijerph16071297.
- Valles-Medina, A., A. Osuna-Leal, A. Martinez-Cervantes, M. Castillo-Fregoso, M. Vazquez-Erlbeck, and A. Rodriguez-Lainz. 2014. Do Glazed Ceramic Pots in a Mexico-US Border City Still Contain Lead? *International Scholarly Research Notices*. Oct 29; 2014:474176. doi: 10.1155/2014/474176.
- WAC 173-333 Washington Administrative Code (WAC). Persistent Bioaccumulative Toxin.
<https://app.leg.wa.gov/wac/default.aspx?cite=173-333>.
- Weidenhamer, J. D., M. Chasant, P. Gottesfeld. 2022. Metal exposures from source materials for artisanal aluminum cookware. *International Journal of Environmental Health Research*, 1-33(4):374-385. doi: 10.1080/09603123.2022.2030677.
- Weidenhamer, J., A. P. Fitzpatrick, A. M. Biro, A.M. Kobunski, P.A. Hudson, M.R. Corbin, R.W. and P. Gottesfeld. 2017. Metal exposures from aluminum cookware: An unrecognized public health risk in developing countries, *Science of The Total Environment*, Volume 579,
- Weidenhamer, J.D., P.A. Kobunski, R.W. Gilbert Kuepouo, and P.G. Corbin. 2014. Lead exposure from aluminum cookware in Cameroon, *Science of The Total Environment*, (496) 339-347. doi: 10.1016/j.scitotenv.2014.07.016.
- Yong-Xin, M., S. Qunchao, Y. Chengguang, Z. Hui, Z. Jiaqiao, Z. Hongyan, S. Ruilong, and L. Zongping. 2022. The Effect of Oxidative Stress-Induced Autophagy by Cadmium Exposure in Kidney, Liver, and Bone Damage, and Neurotoxicity. *International Journal of Molecular Sciences*, 23(21), 13491. doi: 10.3390/ijms232113491
- Zhou, L., H. Rui, Z. Wang, F. Wu, J. Fang, K. Li, and X. Liu. 2017. Migration law of lead and cadmium from Chinese pots during the cooking process. *International Journal of Food Properties*, 20(sup3), S3301–S3310.
<https://doi.org/10.1080/10942912.2017.1404472>.

16.0 Appendix A

Acronyms and Abbreviation, Units of Measurements, and QA Glossary and References.

Acronyms and Abbreviations

CAS	Chemical Abstracts Service
DQO	Data Quality Objective
e.g.	For example
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
EDD	Electronic Data Deliverable
et al.	And others
FDA	U.S. Food and Drug Administration
i.e.	In other words
MEL	Manchester Environmental Laboratory
MQO	Measurement quality objective
MS	Matrix Spike
MSD	Matrix Spike Duplicate
N/A	Not applicable
QA	Quality assurance
QC	Quality control
RPD	Relative percent difference
SOP	Standard operating procedures
SRM	Standard reference materials
UPC	Universal Price Code
WAC	Washington Administrative Code
XRF	X-ray Fluorescence Spectrometry

Units of Measurement

°C	degrees centigrade
Kg	kilograms, a unit of mass equal to 1,000 grams
m	meter
mm	millimeter
mg	milligram
mg/kg	milligrams per kilogram (parts per million)
mg/L	milligrams per liter (parts per million)
mL	milliliter
µg/g	micrograms per gram (parts per million)
ww	wet weight

Quality Assurance Glossary

Accreditation: A certification process for laboratories, designed to evaluate and document a lab's ability to perform analytical methods and produce acceptable data. For Ecology, it is "Formal recognition by (Ecology)...that an environmental laboratory is capable of producing accurate analytical data." [WAC 173-50-040] (Kammin 2010)

Accuracy: The degree to which a measured value agrees with the true value of the measured property. USEPA recommends that this term not be used, and that the terms *precision* and *bias* be used to convey the information associated with the term *accuracy* (USGS 1998).

Analyte: An element, ion, compound, or chemical moiety (pH, alkalinity) which is to be determined. The definition can be expanded to include organisms, e.g., fecal coliform, *Klebsiella* (Kammin 2010).

Bias: The difference between the sample mean and the true value. Bias usually describes a systematic difference reproducible over time and is characteristic of both the measurement system and the analyte(s) being measured. Bias is a commonly used data quality indicator (DQI) (Kammin 2010; Ecology 2004).

Blank: A synthetic sample, free of the analyte(s) of interest. For example, in water analysis, pure water is used for the blank. In chemical analysis, a blank is used to estimate the analytical response to all factors other than the analyte in the sample. In general, blanks are used to assess possible contamination or inadvertent introduction of analyte during various stages of the sampling and analytical process (USGS 1998).

Calibration: The process of establishing the relationship between the response of a measurement system and the concentration of the parameter being measured (Ecology 2004).

Check standard: A substance or reference material obtained from a source independent from the source of the calibration standard; used to assess bias for an analytical method. This is an obsolete term, and its use is highly discouraged. See Calibration Verification Standards, Lab Control Samples (LCS), Certified Reference Materials (CRM), and/or spiked blanks. These are all check standards but should be referred to by their actual designator, e.g., CRM, LCS (Kammin 2010; Ecology 2004).

Comparability: The degree to which different methods, data sets and/or decisions agree or can be represented as similar; a data quality indicator (USEPA 1997).

Completeness: The amount of valid data obtained from a project compared to the planned amount. Usually expressed as a percentage. A data quality indicator (USEPA 1997).

Continuing Calibration Verification Standard (CCV): A quality control (QC) sample analyzed with samples to check for acceptable bias in the measurement system. The CCV is usually a midpoint calibration standard that is re-run at an established frequency during the course of an analytical run (Kammin 2010).

Control chart: A graphical representation of quality control results demonstrating the performance of an aspect of a measurement system (Kammin 2010; Ecology 2004).

Control limits: Statistical warning and action limits calculated based on control charts. Warning limits are generally set at ± 2 standard deviations from the mean, action limits at ± 3 standard deviations from the mean (Kammin 2010).

Data integrity: A qualitative DQI that evaluates the extent to which a data set contains data that is misrepresented, falsified, or deliberately misleading (Kammin 2010).

Data quality indicators (DQI): Commonly used measures of acceptability for environmental data. The principal DQIs are precision, bias, representativeness, comparability, completeness, sensitivity, and integrity (USEPA 2006).

Data quality objectives (DQO): Qualitative and quantitative statements derived from systematic planning processes that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions (USEPA 2006).

Data set: A grouping of samples organized by date, time, analyte, etc. (Kammin 2010).

Data validation: An analyte-specific and sample-specific process that extends the evaluation of data beyond data verification to determine the usability of a specific data set. It involves a detailed examination of the data package, using both professional judgment and objective criteria, to determine whether the MQOs for precision, bias, and sensitivity have been met. It may also include an assessment of completeness, representativeness, comparability, and integrity, as these criteria relate to the usability of the data set. Ecology considers four key criteria to determine if data validation has actually occurred. These are:

Use of raw or instrument data for evaluation.

Use of third-party assessors.

Data set is complex.

Use of EPA Functional Guidelines or equivalent for review.

Examples of data types commonly validated would be:

Gas Chromatography (GC).

Gas Chromatography-Mass Spectrometry (GC-MS).

Inductively Coupled Plasma (ICP).

The end result of a formal validation process is a determination of usability that assigns qualifiers to indicate usability status for every measurement result. These qualifiers include:

No qualifier – data are usable for intended purposes.

J (or a J variant) – data are estimated, may be usable, may be biased high or low.

REJ – data are rejected, cannot be used for intended purposes.

(Kammin 2010; Ecology 2004).

Data verification: Examination of a data set for errors or omissions, and assessment of the Data Quality Indicators related to that data set for compliance with acceptance criteria (MQOs). Verification is a detailed quality review of a data set (Ecology 2004).

Detection limit (limit of detection): The concentration or amount of an analyte which can be determined to a specified level of certainty to be greater than zero (Ecology 2004).

Duplicate samples: Two samples taken from and representative of the same population, and carried through all steps of the sampling and analytical procedures in an identical manner. Duplicate samples are used to assess variability of all method activities including sampling and analysis (USEPA 1997).

Field blank: A blank used to obtain information on contamination introduced during sample collection, storage, and transport (Ecology 2004).

Initial Calibration Verification Standard (ICV): A QC sample prepared independently of calibration standards and analyzed along with the samples to check for acceptable bias in the measurement system. The ICV is analyzed prior to the analysis of any samples (Kammin 2010).

Laboratory Control Sample (LCS): A sample of known composition prepared using contaminant-free water or an inert solid that is spiked with analytes of interest at the midpoint of the calibration curve or at the level of concern. It is prepared and analyzed in the same batch of regular samples using the same sample preparation method, reagents, and analytical methods employed for regular samples (USEPA 1997).

Matrix spike: A QC sample prepared by adding a known amount of the target analyte(s) to an aliquot of a sample to check for bias due to interference or matrix effects (Ecology 2004).

Measurement Quality Objectives (MQOs): Performance or acceptance criteria for individual data quality indicators, usually including precision, bias, sensitivity, completeness, comparability, and representativeness (USEPA 2006).

Measurement result: A value obtained by performing the procedure described in a method (Ecology 2004).

Method: A formalized group of procedures and techniques for performing an activity (e.g., sampling, chemical analysis, data analysis), systematically presented in the order in which they are to be executed (EPA 1997).

Method blank: A blank prepared to represent the sample matrix, prepared and analyzed with a batch of samples. A method blank will contain all reagents used in the preparation of a sample, and the same preparation process is used for the method blank and samples (Ecology 2004; Kammin 2010).

Method Detection Limit (MDL): This definition for detection was first formally advanced in 40CFR 136, October 26, 1984 edition. MDL is defined there as the minimum concentration of an analyte that, in a given matrix and with a specific method, has a 99% probability of being identified, and reported to be greater than zero (Federal Register 2025).

Percent Relative Standard Deviation (%RSD): A statistic used to evaluate precision in environmental analysis. It is determined in the following manner: $\%RSD = (100 * s)/x$ where s is the sample standard deviation and x is the mean of results from more than two replicate samples (Kammin 2010).

Parameter: A specified characteristic of a population or sample. Also, an analyte or grouping of analytes. Benzene and nitrate + nitrite are all parameters (Kammin 2010; Ecology 2004).

Population: The hypothetical set of all possible observations of the type being investigated (Ecology 2004).

Precision: The extent of random variability among replicate measurements of the same property; a data quality indicator (USGS 1998).

Quality assurance (QA): A set of activities designed to establish and document the reliability and usability of measurement data (Kammin 2010).

Quality Assurance Project Plan (QAPP): A document that describes the objectives of a project, and the processes and activities necessary to develop data that will support those objectives (Kammin 2010; Ecology 2004).

Quality control (QC): The routine application of measurement and statistical procedures to assess the accuracy of measurement data (Ecology 2004).

Relative Percent Difference (RPD): RPD is commonly used to evaluate precision. The following formula is used: $[\text{Abs}(a-b)/((a + b)/2)] * 100$ where “Abs()” is absolute value and a and b are results for the two replicate samples. RPD can be used only with 2 values. Percent Relative Standard Deviation is (%RSD) is used if there are results for more than 2 replicate samples (Ecology 2004).

Replicate samples: Two or more samples taken from the environment at the same time and place, using the same protocols. Replicates are used to estimate the random variability of the material sampled (USGS 1998).

Representativeness: The degree to which a sample reflects the population from which it is taken; a data quality indicator (USGS 1998).

Sample (field): A portion of a population (environmental entity) that is measured and assumed to represent the entire population (USGS 1998).

Sample (statistical): A finite part or subset of a statistical population (USEPA 1997).

Sensitivity: In general, denotes the rate at which the analytical response (e.g., absorbance, volume, meter reading) varies with the concentration of the parameter being determined. In a specialized sense, it has the same meaning as the detection limit (Ecology 2004).

Spiked blank: A specified amount of reagent blank fortified with a known mass of the target analyte(s); usually used to assess the recovery efficiency of the method (USEPA 1997).

Spiked sample: A sample prepared by adding a known mass of target analyte(s) to a specified amount of matrix sample for which an independent estimate of target analyte(s) concentration is available. Spiked samples can be used to determine the effect of the matrix on a method’s recovery efficiency (USEPA 1997).

Split sample: A discrete sample subdivided into portions, usually duplicates (Kammin 2010).

Standard Operating Procedure (SOP): A document which describes in detail a reproducible and repeatable organized activity (Kammin 2010).

Surrogate: For environmental chemistry, a surrogate is a substance with properties similar to those of the target analyte(s). Surrogates are unlikely to be native to environmental samples. They are added to environmental samples for quality control purposes, to track extraction efficiency and/or measure analyte recovery. Deuterated organic compounds are examples of surrogates commonly used in organic compound analysis (Kammin 2010).

Systematic planning: A step-wise process which develops a clear description of the goals and objectives of a project, and produces decisions on the type, quantity, and quality of data that will be needed to meet those goals and objectives. The DQO process is a specialized type of systematic planning (USEPA 2006).

References for QA Glossary

- Ecology [Washington State Department of Ecology], 2004. Guidance for the Preparation of Quality Assurance Project Plans for Environmental Studies. Ecology, Olympia, WA.
<https://apps.ecology.wa.gov/publications/SummaryPages/0403030.html>.
- Federal Register. 2025. Appendix B to Part 136, Title 40—Definition and Procedure for the Determination of the Method Detection Limit—Revision 2 [1/5/2025]. Code of Federal Regulations, Federal Register. Washington DC.
<https://www.ecfr.gov/current/title-40/part-136/appendix-Appendix%20B%20to%20Part%20136>.
- Kammin, B. 2010. Definition developed or extensively edited by William Kammin, 2010. Washington State Department of Ecology, Olympia, WA.
- USEPA [U.S. Environmental Protection Agency]. 1997. Environmental Monitoring and Assessment Program — QA Glossary [Last updated on 2/21/2016].
https://archive.epa.gov/emap/archive-emap/web/html/qa_terms.html.
- USEPA [U.S. Environmental Protection Agency]. 2006. Guidance on Systematic Planning Using the Data Quality Objectives Process EPA QA/G-4.
<https://www.epa.gov/sites/default/files/2015-06/documents/g4-final.pdf>.
- USGS [U.S. Geological Survey]. 1998. Principles and Practices for Quality Assurance and Quality Control. Open-File Report 98-636.
<https://pubs.usgs.gov/of/1998/ofr98-636/pdf/ofr98636.pdf>.