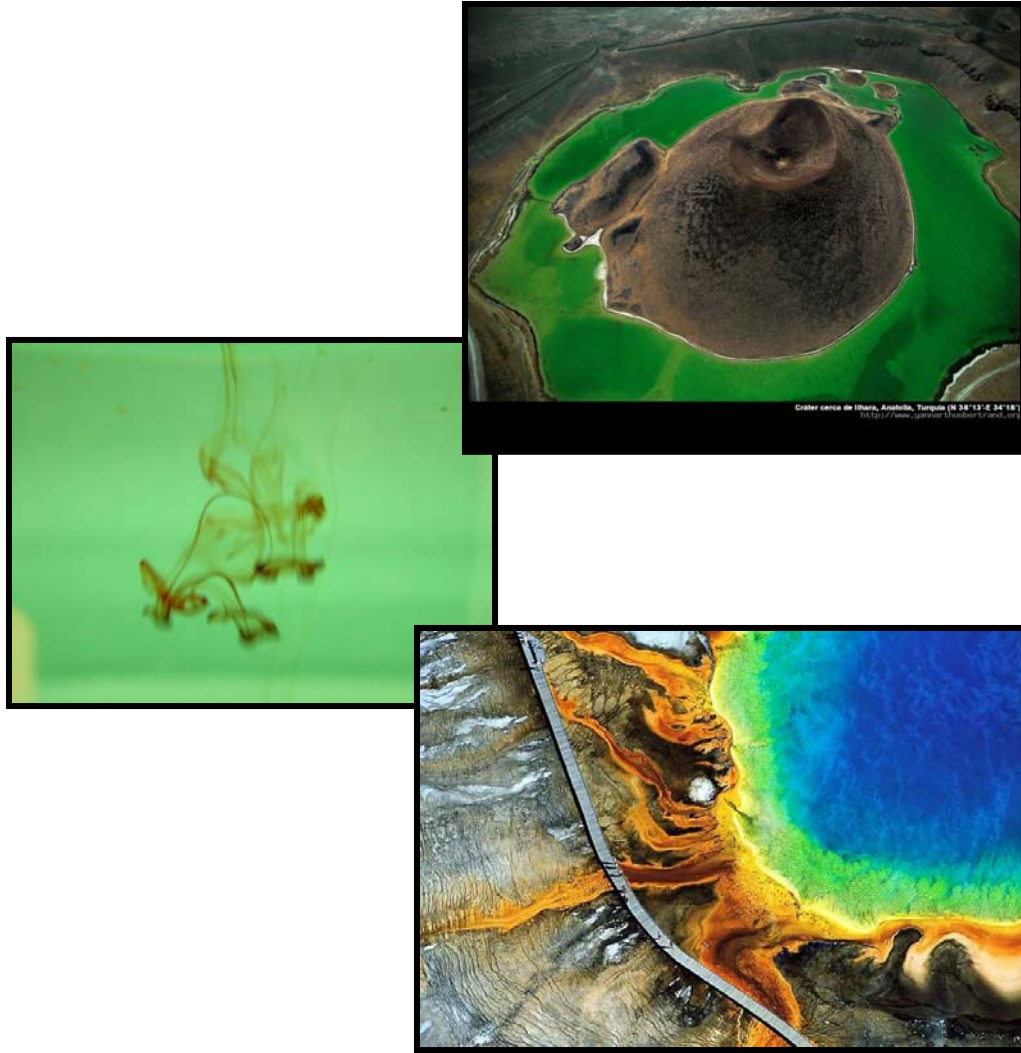


Statement of Qualifications

www.appliedspeciation.com



Applied Speciation and Consulting, LLC

Analysis

Research

Consulting

Applied Speciation and Consulting, LLC

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Company Profile

Applied Speciation and Consulting, LLC is a superior analytical testing and consulting laboratory providing trace metals speciation and ultra trace metals analysis for the environmental, pharmaceutical, agricultural, textile, and research community. ASC merges sound business practices with leading edge science to provide economically viable solutions when absolute certainty is needed. Laboratory services provided at ASC support all aspects of a project. Initial investigations for most projects apply trace metals analysis to identify the existence and scope of the contamination. Once the scope of contamination is identified useful tools such as speciation, sequential extractions, and organic/inorganic trace metals analyses clarify risk assessment and mobility to identify if remediation is necessary and what measures would be most efficient. Information generated from speciation and other investigative analyses assist in the optimization of bench scale studies prior to implementation of remedial actions and can also identify issues involved with pilot plant efficiencies. ASC empowers our clients with knowledge to make science-based decisions to save time and money.

Applied Speciation and Consulting, LLC was formed in 2004 as a Washington based limited liability company to meet the current and future scientific needs of the commercial, industrial and academic world. Currently, no known laboratories exist in North America specializing in metal(loid) speciation analyses and consulting, resulting in haphazard method application and a lack of focus for science. By concentrating our experience, education, and efforts on metals speciation and consulting, Applied Speciation and Consulting, LLC has the capability to offer services unavailable by any other commercially available laboratory.

The success of Applied Speciation and Consulting, LLC is defined by our low overhead and extensive knowledge and experience in the field. Currently, management is driven by three individuals, Russell Gerads (Vice President), Dr. Hakan Gürleyük (Senior Scientist) and Jacob Meyer (Laboratory Manager). Mr. Gerads, Dr. Gürleyük, and Mr. Meyer have over 25 years of combined experience in the industry.

“Currently, no known laboratories exist in North America specializing in metal(loid) speciation analyses and consulting, resulting in haphazard method application and a lack of focus for science.”

Professional Experience

The widespread applicability of the services offered by Applied Speciation and Consulting has generated a diverse client base and extensive experience. The experience attained from each client and sample type continually expands the knowledge base of ASC scientists which equates to more robust methodologies and a better understanding of chemical interactions. The application of this expanded knowledge base and experience to our clients has been documented to decrease the overall project costs while maximizing the confidence in the rendered services.

The following pages reflect general outlines of the experience Applied Speciation and Consulting has with each of our markets. More detailed summaries and professional references can be supplied upon request.

Wastewater treatment failures are often a result of changes in influent chemistry during treatment. These failures can be avoided by better understanding and monitoring the individual chemistry changes at different stages of treatment.

Pharmaceuticals
Clinical Studies
Catalyst Removal
Purity Assessment
Metabolite Identification

Environmental Consulting
Fate and Transport
Natural Attenuation
Phase I, II, and III Studies
Superfund
Treatment Optimization
Monitoring
Modeling
Bench Scale Treatment studies

Academia
Method Development
Research
Grant Proposals

Nutraceuticals
Treatment Efficacy
Purity Assessment
Characterization
Carcinogen Assessment

Textiles and Chemicals
Purity Assessment
Waste Characterization
Treatment Optimization
Production Optimization
Carcinogen Assessment

Regulatory Compliance
Monitoring Studies
NPDES Compliance Monitoring
Groundwater Monitoring
River monitoring
Translator Studies

Market: Environmental Consulting

Applied Speciation and Consulting, LLC premise for environmental investigations identifies that marginal data quality and “accepted” methodologies can only provide a rudimentary representation of projected contaminant impacts on flora and fauna. True risk assessment and site interpretation necessitates qualitative and quantitative identification of the specific contaminants of interest accompanied by characterization of the contaminants’ environment.

Analytical and professional services offered by Applied Speciation and Consulting can support all phases of contaminant investigations associated with trace metals. From regulatory compliant monitoring to bench scale treatability studies, ASC scientists can support all analytical needs.

Professional experience for the environmental consulting market includes, but not limited to:

Sample Matrices

River Water
Seawater
Wastewater
Soil
Sediment
Fish Tissue
Invertebrates
Air Particulate
Non-point Source Runoff

Services

Trace Metals Analysis
Arsenic Speciation Analysis
Selenium Speciation Analysis
Chromium Speciation Analysis
Manganese Speciation Analysis
Leachability Tests (TCLP, SPLP, etc)
Whole body and muscle homogenization
Sample compositing (all matrices)
Bench scale treatability studies
Sampling Plan Formulation
RFP Narration
Proposal formulation

Specific project references can be provided upon request.

Market: Wastewater Treatment Industrial/Municipal

Exceedance of discharge permit limits due to poor treatment efficiencies often result in costly fines. Unfortunately, inherent interferences associated with most analytical methods applied to the regulatory monitoring can result in biased data artificially representing systematic problems.

A significant interest regarding selenium removal has developed in the Flue Gas Desulphurization (FGD) and oil refinery industries. This interest has been induced by increasingly demanding regulatory constraints compounded by variable coal sources and a total lack of engineering unity between facilities. The supportive consulting and treatment technology industries are finding that the treatment of selenium and other metals is considerably more complicated than initially projected and is necessitating a more detailed investigation than standard trace metal analyses provides (due to the array of species that can be formed during the combustion and treatment processes).

The methods applied and developed at Applied Speciation and Consulting were designed to support FGD and refinery waste, not just treated effluent or drinking water. Robust methodology, direct industrial experience, and accumulated scientific knowledge ensure that the project managers and scientists at Applied Speciation and Consulting can support nearly any facet of the wastewater treatment industry.

Professional experience for the wastewater treatment plant market includes, but not limited to:

Sample Matrices Services

FGD Influent Trace Metals Analysis

FGD Process Water Arsenic Speciation Analysis

FGD Effluent Selenium Speciation Analysis

Oil Refinery Influent

Oil Refinery Process Water

Oil Refinery Effluent

Municipal Effluent

Municipal Influent

Specific project references can be provided upon request.

Market: Pharmaceuticals

The pharmaceutical industry demands absolute results and extensive supportive documentation as the decisions based on the analytical results can have significant repercussions on public health and the client's financial status. Services provided by Applied Speciation and Consulting have supported clinical trials, clean up efficiencies of catalysis, impurity identification, and lot monitoring.

Intermediates and final pharmaceutical compounds can be quite complex requiring extensive knowledge regarding the target analyte and the applicable methodologies for dissolution and analysis of the materials. Scientists at Applied Speciation and Consulting have the knowledge and experience to identify the most appropriate techniques for analysis of the most complex pharmaceutical molecules.

Applied Speciation and Consulting is a BSL-2 laboratory which can support all phases of clinical studies which are not associated with communicable diseases. By applying trace metals speciation analyses to clinical studies the drug efficacy can be optimized, lowering research cost and funding demand, and the final drug patent can be expanded to recognize the specific interactions which result in treatment. Historically, the types of services offered by Applied Speciation and Consulting have been limited to in-house resources which can increase overhead and risk for investors.

Professional experience for the pharmaceutical market includes, but not limited to:

Sample Matrices

Mouse Blood
Mouse Organs
Human Blood (and blood components)
Human Urine
Pharmaceutical Intermediates
Final Pharmaceutical Products
Source Materials

Services

Trace Metals Analysis
Arsenic Speciation Analysis
Selenium Speciation Analysis
Chromium Speciation Analysis
Trace Pd, Ru and Rh Analysis
Trace Pb, B and S Analysis
Iodine Speciation Analysis
Bromine Speciation Analysis
Impurity Research and Development

Specific project references can be provided upon request.



Market: Nutraceuticals

Although the efficacy for many of the compounds facilitated in the nutraceutical industry is well documented the impurities and molecular confirmation of the target material can be elusive.

Since most facets of the nutraceutical industry are not regulated by the FDA very few analytical methods have been promulgated to support the industry. This is a major concern to the industry since some states (e.g. California Prop 65) have ratified regulations which necessitate that the products must be tested and be documented to be free of listed carcinogens. Since there are limited or no promulgated methods to directly support the nutraceutical industry, EPA environmental methods or *Standard Methods* are often facilitated resulting in inconclusive results.

Hexavalent chromium quantitation has been consistently problematic for nutraceutical products as the extraction procedures (EPA Method 3060 and 3060A) are not designed for the complex organic matrices. Significant analytical interferences associated with colorimetric detection have also been documented due to the highly soluble aromatic compounds.

Due to the complex nature of nutraceutical products Applied Speciation and Consulting offers an array of different scientifically based analytical and preparatory methods. If current methodology is found to produce inconclusive results (based on rigorous quality control) our scientists have the experience and knowledge to direct method development and research to ensure the product can be safely consumed.

Professional experience for the nutraceutical market includes, but not limited to:

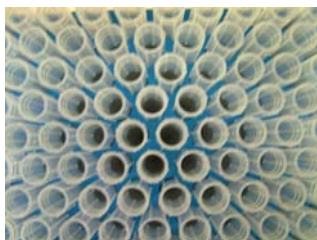
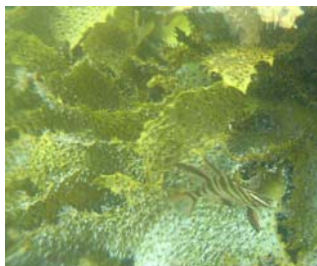
Sample Matrices

Chromium supplements
Selenium supplements
Selenium enriched yeast
Kelp extracts
Vitamin powders
Vitamin supplements
Source Materials

Services

Trace Metals Analysis
Arsenic Speciation Analysis
Selenium Speciation Analysis
Chromium Speciation Analysis
Analytical Method Development

Specific project references can be provided upon request.



Market: Research (Academia)

Applied Speciation and Consulting currently collaborates with a number of different universities and academic institutions around the world to further the scientific understanding of trace metals. Collaborations associated with trace metals have ranged from complete fate and transport investigations in ecosystems to focused metabolic pathway identification in animals and humans. Scientists at Applied Speciation and Consulting are well versed in scientific research with the advantage of understanding the importance of proper quality control (rooted from regulatory compliance analyses) to provide completely defensible data.

Applied Speciation and Consulting can also assist in the generation of grant proposals which reduces the workload of the Academic Principle Investigator and, due to the experience of the scientists, can increase the probability of funding.

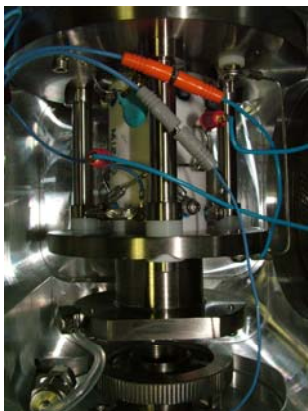
Professional experience for the academic market includes, but not limited to:

Sample Matrices

River Water
Seawater
Wastewater
Soil
Sediment
Fish Tissue
Invertebrates
Air Particulate
Animal organs
Animal fluids
Human fluids

Services

Trace Metals Analysis
Arsenic Speciation Analysis
Selenium Speciation Analysis
Chromium Speciation Analysis
Whole body and muscle homogenization
Sample compositing (all matrices)
Bench scale treatability studies
Sampling Plan Formulation
Grant Proposal formulation



Specific project references can be provided upon request.

Market: Textile and Chemical Industries

Increasing trade and sales regulations within the United States and around the world has induced an increased demand for trace metals and trace metals speciation analyses. Further demand for specialty analysis has increased to maximize fabrication efficiency and hazardous waste minimization.



Applied Speciation and Consulting has collaborated with a number of product manufacturers and development companies to identify the safety of their products and how to minimize and treat the hazardous waste generated during the fabrication process. Due to the complex nature of some fabrication processes non-target metalloids compounds can be created which can require method development for identification and monitoring. The application of our scientists' knowledge and experience can often significantly reduce the necessity and scope of investigative analyses which can ultimately save precious time and money.



The ratification of ROHS on January 1, 2006 has dramatic implications on the electronics industry throughout the world. The ROHS directive stands for "the restriction of the use of certain hazardous substances in electrical and electronic equipment". This directive requires that all electronic components sold and traded in the EU meet regulatory limits for cadmium, mercury, lead, and hexavalent chromium (not including other organic compounds). Non-compliance to the ROHS directive can have significant financial implications for any electronic manufacturer and distributor in the United States.

Professional experience for the textile industry includes, but not limited to:

Sample Matrices

Various Chemicals
Stainless Steel
Filtration Systems
Watches

Services

Trace Metals Analysis
Chromium Speciation Analysis
Arsenic Speciation Analysis
Selenium Speciation Analysis



Specific project references can be provided upon request.

Market: Regulatory Compliance

Applied Speciation and Consulting is currently certified in a number of states to meet the trace metals regulatory compliance demands of wastewater treatment plants and industrial compliance monitoring. The inclusion of trace metals speciation analysis for regulatory purposes has already expanded beyond hexavalent chromium in Wisconsin and is projected to increase across the United States. Applied Speciation and Consulting has been proactive in implementing trace metals speciation analyses for regulatory purposes and is currently certified for a number of analytical methods for trace metals speciation across the country.

Although trace metals analysis may seem straightforward, interferences inherent with nearly all analytical platforms can result in significantly biased results. Application of an inductively coupled plasma mass spectrometer (ICP-MS) equipped with a dynamic reaction cell (DRC) for trace metals analyses minimizes, often totally eliminating, isobaric interferences associated with ICP-MS. The DRC facilitates different reactive gases to preferentially react with different interferences (Cl, S, Ar, C, etc.). Pending confirmation of elevated trace metals concentrations in treatment plant discharge, a more detailed examination of the target trace metals, in the form of speciation, can be performed to identify operational modifications to achieve the desired treatment efficiencies.

Trace metals speciation analysis is a powerful tool to identify the exact molecular form of the target analyte and the chemical equilibrium within the system. Upon identification of the exact chemical species, chemists can apply this information to identify appropriate treatment methods and efficiencies with a focused experimental plan using bench scale and process studies. In addition, monitoring trace metals species in the influent and effluent can identify issues associated with variable waste streams for modifying operations prior to regulatory compliance sampling. Depending on the complexity of the influent waste stream chemical modeling may be necessary to generate a more robust treatment process to accommodate variability.

Professional experience for regulatory compliance includes, but not limited to:

Sample Matrices

Municipal Wastewater (influent and effluent)
FGD Wastewater (influent and effluent)
Soil/ Sediment
Groundwater
Refinery Wastewater (influent and effluent)
Refuse Truck Wash

Services

Trace Metals Analysis
Chromium Speciation Analysis
Arsenic Speciation Analysis
Selenium Speciation Analysis

Specific project references can be provided upon request.



Analytical and Professional Services List

Trace Metals Analysis
Standard ICP-MS

Groundwater and Wastewater

| Name | Symbol | MDL (µg/L) |
|------------|--------|--------------------|
| Aluminum | Al | 2 |
| Antimony | Sb | 0.05 |
| Arsenic | As | 0.2 |
| Barium | Ba | 0.02 |
| Beryllium | Be | 0.05 |
| Bismuth | Bi | 0.5 |
| Boron | B | 0.5 |
| Cadmium | Cd | 0.010 |
| Calcium | Ca | 10 |
| Cesium | Cs | 0.005 |
| Chromium | Cr | 0.05 |
| Cobalt | Co | 0.05 |
| Copper | Cu | 0.05 |
| Gallium | Ga | 0.005 |
| Germanium | Ge | 0.005 |
| Gold | Au | 0.005 |
| Iron | Fe | 1.5 |
| Lead | Pb | 0.005 |
| Lithium | Li | 10 |
| Magnesium | Mg | 10 |
| Manganese | Mn | 0.05 |
| Mercury | Hg | 0.05 |
| Molybdenum | Mo | 0.05 |
| Nickel | Ni | 0.02 |
| Potassium | K | 10 |
| Selenium | Se | 0.5 |
| Silicon | Si | 1.5 |
| Silver | Ag | 0.005 |
| Sodium | Na | 10 |
| Thallium | Tl | 0.005 |
| Tin | Sn | 0.10 |
| Titanium | Ti | Call for Quotation |

RCRA

Arsenic (As)
Barium (Ba)
Cadmium (Cd)
Chromium (Cr)
Lead (Pb)
Mercury (Hg)
Selenium (Se)
Silver (Ag)

IOC

Antimony (Sb)
Arsenic (As)
Barium (Ba)
Beryllium (Be)
Cadmium (Cd)
Chromium (Cr)
Mercury (Hg)
Nickel (Ni)
Selenium (Se)
Thallium (Tl)

Analytical and Professional Services List

Trace Metals Analysis Groundwater and Wastewater Standard ICP-MS

| Name | Symbol | MDL ($\mu\text{g/L}$) |
|----------|--------|-------------------------|
| Uranium | U | 0.005 |
| Vanadium | V | 0.10 |
| Zinc | Zn | 0.10 |

Trace Metals Analysis Groundwater/Wastewater/Saline Water ICP-DRC-MS

| Name | Symbol | MDL ($\mu\text{g/L}$) |
|------------|--------|-------------------------|
| Arsenic | As | 0.010 |
| Chromium | Cr | 0.010 |
| Iron | Fe | 0.050 |
| Vanadium | V | 0.050 |
| Phosphorus | P | 10 |
| Sulfur | S | 10 |
| Selenium | Se | 0.010 |

Trace Metals Analysis Groundwater/Wastewater/Saline Water CV-ICP-MS

| Name | Symbol | MDL ($\mu\text{g/L}$) |
|---------|--------|-------------------------|
| Mercury | Hg | 0.0002 |

Highlights

Trace Level Detection
Limits (ng/L and ug/kg)
Matrix Specific Methods
Competitive Pricing
Standard 14 day TAT
Experienced Staff

Various Anthropogenic Sources of Arsenic

Pesticides
Herbicides
Wood treatments
Smelters
Mining operations
Electronics manufacturing
Cattle dips
Poultry food additives
Vitamin supplements
Pharmaceuticals
Nutraceuticals
Coal combustion
FGD plants
Cigarettes
Paint
Dye
Cosmetics

Applied Speciation
and Consulting, LLC
is a BSL-2 laboratory
which can support all
phases of clinical
studies...

Analytical and Professional Services List

Trace Metals Speciation Analysis (IC-ICP-DRC-MS) Groundwater/Wastewater /Saline Water

| Name | MDL (ug/L) |
|---|------------|
| Arsenic | |
| Arsenite | 0.05 |
| Arsenate | 0.05 |
| Monomethyl Arsonic Acid | 0.05 |
| Dimethyl Arsenous Acid | 0.05 |
| Trimethyl Arsonic Acid | 0.05 |
| Arsenobetaine | 0.05 |
| Arsenocholine | 0.05 |
| Arsenopropionate | 0.05 |
| 4-Hydroxy phenlarsonic acid | 0.05 |
| p-Arsanilic acid | 0.05 |
| Roxarsone | 0.05 |
| 3-Amino-4-hydroxyphenylarsonic acid | 0.05 |
| 4-Aminophenylarsonic acid | 0.05 |
| Nitarsone | 0.05 |
| Phenylarsonic acid | 0.05 |
| Various Arseno-thiols | 0.50 |
| Various Arsenosugars (S and P) | 0.50 |
| Hexafluoroarsenate | 0.05 |
| Other Arsenic Species Available Upon Request | |
| Selenium | |
| Selenite | 0.05 |
| Selenate | 0.05 |
| Selenocyanate | 0.05 |
| Methyl Seleninic Acid | 0.05 |
| Selenomethionine | 0.05 |
| Se-Methyl-L-Selenocystiene | 0.05 |
| Other Selenium Species Available Upon Request | 0.05 |

| | |
|---------------------------|--|
| Arsenosugar-glycerol | (CH ₃) ₂ AsO[(C ₅ H ₄ O)(OH) ₂]OCH ₂ CHOHCH ₂ OH |
| Thio-arsenosugar-glycerol | (CH ₃) ₂ Ass[(C ₅ H ₄ O)(OH) ₂]OCH ₂ CHOHCH ₂ OH |
| Arsenosugar-phosphate | (CH ₃) ₂ AsO[(C ₅ H ₄ O)(OH) ₂]OCH ₂ CHOHCH ₂ HPO ₄ CH ₂ CHOHCH ₂ OH |
| Thioarsenosugar-phosphate | (CH ₃) ₂ Ass[(C ₅ H ₄ O)(OH) ₂]OCH ₂ CHOHCH ₂ HPO ₄ CH ₂ CHOHCH ₂ OH |
| Arsenosugar-sulfonate | (CH ₃) ₂ AsO[(C ₅ H ₄ O)(OH) ₂]OCH ₂ CHOHCH ₂ SO ₃ |
| Thioarsenosugar sulfonate | (CH ₃) ₂ Ass[(C ₅ H ₄ O)(OH) ₂]OCH ₂ CHOHCH ₂ SO ₃ |
| Arsenosugar-sulfate | (CH ₃) ₂ AsO[(C ₅ H ₄ O)(OH) ₂]OCH ₂ CHOHCH ₂ OSO ₃ H |

Analytical and Professional Services List

| Trace Metals Speciation Analysis (IC-ICP-DRC-MS) | Groundwater/Wastewater /Saline Water |
|---|---|
| Name | MDL (ug/L) |
| <i>Mercury</i> | |
| Inorganic Hg | 0.02 |
| Monomethyl mercury | 0.02 |
| Phenyl Hg | 0.02 |
| <i>Chromium</i> | |
| Trivalent Chromium | 0.05 |
| Hexavalent Chromium | 0.05 |
| <i>Metal Cyanide Species</i> | |
| AgCN | 5 |
| CuCN | 5 |
| SeCN | 0.1 |
| CoCN | 0.1 |
| FeCN | 0.1 |
| NiCN | 0.1 |
| AuCN | 0.1 |



| | |
|---|--|
| $H_2N-CH(COO^-)-CH_2-SeH$ | Selenocysteine |
| $H_2N-CH(COO^-)-CH_2-Se-Se-CH_2-(COO^-)CH-NH_2$ | Selenocystine |
| $H_2N-CH(COO^-)-CH_2-CH_2-Se-Me$ | Selenomethionine |
| $H_2N-CH(COO^-)-CH_2-Se-Me$ | Se-Methylselenocysteine |
| $H_2N-CH(COO^-)-CH_2-CH_2-CO-NH-CH(COO^-)-CH_2-Se-Me$ | γ -Glutamyl-Se-methylselenocysteine |
| $H_2N-CH(COO^-)-CH_2-CH_2-Se-CH_2-CH(COO^-)-NH_2$ | Selenocystathionine |
| $H_2N-CH(COO^-)-CH_2-CH_2-SeH$ | Selenohomocysteine |

Analytical and Professional Services List

Other Specialty Analytical Services

| Name | Scope |
|--|--|
| Isotopic Ratio Testing | Analyte and Concentration Specific |
| EPA Method 6800 (SIDMS) | Analyte and Concentration Specific |
| Organic/Inorganic Metals Fractionation | Analyte Specific |
| Sequential Extraction (BLM Method) | Cationic Metals |
| Sequential Extraction | Anionic Metal Complexes (As, Sb, etc.) |

All listed analyses are available for other matrices including: tissue, process water, saline water, supersaline water, soil, sediment, air, pharmaceuticals, and other anthropogenic and naturally occurring materials. Please contact an Applied Speciation and Consulting project manager for more detailed information. Method detection limits are not listed for other matrices other than drinking water and wastewater due to the complexity of the chemistry. Dilutions and method modifications may be necessary to accomplish project goals associated with complex matrices; therefore, without a basic understanding of certain project parameters, listing detection limits would be a disservice to our clients.

Professional Services

| Name |
|--|
| Method Development |
| Method Validation |
| Data Verification and Validation (G8 Protocol) |
| Project Consultation |
| Sampling Training |
| On-Site Analytical Training |
| On-site Professional Project Management Training |

All professional services are rendered on an individual basis. Please contact an Applied Speciation and Consulting project manager for more details.



Standard Operating Procedures

| | |
|-----------|---|
| ASC-001.1 | Generation of Standard Operating Procedures |
| ASC-002.1 | Document Control and Storage |
| ASC-003.1 | Corrective Action |
| ASC-004.1 | Data Correction |
| ASC-005.1 | Data Validation |
| ASC-006.1 | Generation of Level I Report |
| ASC-007.1 | Generation of Level II Report |
| ASC-008.1 | Internal Audit |
| ASC-009.1 | Documentation of Training |
| ASC-010.1 | Contract Review |
| ASC-011.1 | Procedure for Customer Complaint |
| ASC-012.1 | Computer System Quality Assurance |
| ASC-013.1 | Identification and Generation of Method Variability |
| ASC-014.1 | Acceptable Deviation from Documented Protocols |
| ASC-015.1 | Method Development |
| ASC-016.1 | Human Resources - Hiring Process |
| ASC-020.1 | Sample Receipt, Chain of Custody, Internal Sample Tracking |
| ASC-021.1 | Cleaning of Sampling and Laboratory Equipment for Trace Metals Analysis |
| ASC-022.1 | Clean Sampling for Trace Metals Collection (EPA Method 1669) |
| ASC-023.1 | Sample Storage |
| ASC-024.1 | Clean Oxidic Sampling for Speciation |
| ASC-025.1 | Clean Anoxic Sampling for Speciation |
| ASC-026.1 | Hazardous Sample Handling and Disposal |
| ASC-027.1 | Quality Assurance for Water System |
| ASC-028.1 | Sub-Sampling |
| ASC-029.1 | Homogenization of Animal and Plant Tissue Samples |
| ASC-030.1 | Homogenization of Soil and Sediment Samples |
| ASC-031.1 | Ultra-Clean Sample Filtration |
| ASC-032.1 | Clean Sampling for Trace Metals Speciation in Blood and Blood Components |
| ASC-035.1 | Total Recoverable Metals Digestion in Aqueous Matrices |
| ASC-036.1 | Total Metals Digestion |
| ASC-037.1 | Total Metals Digestion for Lanthanides, Actinides, and Al |
| ASC-038.1 | Porewater Extraction from Soil and Sediment by Centrifugation |
| ASC-039.1 | Total Solids (Percent Moisture) Determination |
| ASC-040.1 | Total Suspended Solids Determination |
| ASC-041.1 | Balance Calibration |
| ASC-042.1 | Pipette Calibration |
| ASC-043.1 | Laboratory Cleanliness Quality Control Measures |
| ASC-044.1 | Conductivity Meter |
| ASC-045.1 | pH Meter |
| ASC-046.1 | Determination of Redox Potential |
| ASC-047.1 | Stock and Working Standards for Trace Metals |
| ASC-048.1 | Stock and Working Standards for Speciation Analysis |
| ASC-050.1 | Total Metals Digestion for Plant and Animal Tissue using HNO ₃ |
| ASC-051.1 | Acidic Extraction of Arsenic Species from Tissue |
| ASC-052.1 | Neutral pH Extraction of Arsenic Species from Tissue |
| ASC-053.1 | Extraction of Selenium Species from Tissue |

Standard Operating Procedures (continued)

| | |
|-----------|---|
| ASC-054.1 | Extraction of Hexavalent Chromium from Tissue |
| ASC-055.1 | TCLP Extraction for Soils, Sediments, and Sludges |
| ASC-056.1 | Citrate-Bicarbonate-Ditionite (CBD) Extraction for Soils, Sediment and Sludges |
| ASC-060.1 | Digestion of Sediment and Simple Soil Samples by Aqua Regia Oven Bomb Digest for Total Metals |
| ASC-061.1 | Digestion of Rock and Complex Soil Samples by Ovened HF-HNO ₃ -HCl for Total Metals |
| ASC-062.1 | Digestion of Coal Samples by Ovened Aqua Regia for Total Metals |
| ASC-063.1 | Digestion for Metal Filings and Other Metal Debris by Aqua Regia-HF for Total Metals |
| ASC-064.1 | Digestion of Sediment, Rock, and Other Silica Based Matrices Using Lithium Metaborate |
| ASC-065.1 | Extraction for Arsenate Speciation in Sediment (Na ₃ PO ₄) |
| ASC-066.1 | Extraction for Arsenite Speciation in Sediment (H ₃ PO ₄) |
| ASC-067.1 | Extraction for Selenium Speciation in Sediment |
| ASC-068.1 | Sequential Extraction for Arsenic in Soil and Sediments |
| ASC-069.1 | Sequential Extraction for Cd, Zn, Pb, and Cu in Soil and Sediments (BCR Method) |
| ASC-070.1 | Extraction of Hexavalent Chromium from Soils and Sediments (EPA Method 3060A) |
| ASC-080.1 | Trace Element Analysis by Inductively Coupled Plasma Mass Spectrometry (EPA Method 200.8) |
| ASC-081.1 | Trace Element Analysis for Complex Matrices by Inductively Coupled Plasma Dynamic Reaction Cell Mass Spectrometry (ICP-DRC-MS) |
| ASC-083.1 | Determination of Hexavalent Chromium by IC-ICP-MS |
| ASC-084.1 | Selenium Speciation Analysis by Ion-Chromatography Inductively Coupled Plasma Mass Spectrometry (IC-ICP-MS) |
| ASC-085.1 | Arsenic Speciation Analysis by Ion-Chromatography Inductively Coupled Plasma Mass Spectrometry |
| ASC-086.1 | Determination of Metal-Cyanide Complexes by Ion-Chromatography Inductively Coupled Plasma Mass Spectrometry (IC-ICP-MS) |
| ASC-087.1 | Determination of Inorganic-organic Metals in Aqueous Matrices |
| ASC-088.1 | Determination of Lead Isotope Ratios by Inductively Coupled Plasma Dynamic Reaction Cell Mass Spectrometry (ICP-DRC-MS) |
| ASC-089.1 | Procedure for Generating Speciation Datasets |
| ASC-090.1 | Determination of Hexavalent Chromium by Colorimetry (Diphenylcarbazide) |
| ASC-091.1 | Determination of Hexavalent Chromium by Speciated Isotope Dilution Mass Spectrometry (Modified EPA Method 6800) |
| ASC-092.1 | Determination of Divalent Transition Metals by Ion-Pairing Chromatography Inductively Coupled Plasma Mass Spectrometry (IPC-ICP-MS) |
| ASC-093.1 | Determination of Fe(II) and Fe(III) by Colorimetry |
| ASC-094.1 | Arsenic Speciation Analysis Including Hexafluoroarsenate by Ion-Chromatography Inductively Coupled Plasma Mass Spectrometry (IC-ICP-MS) |
| ASC-095.1 | Determination of Organic and Inorganic Arsenic Species Including Roxarsone by Ion-Chromatography Inductively Coupled Plasma Mass Spectrometry (IC-ICP-MS) |
| ASC-096.1 | Selenium Speciation Analysis Including Selenomethionine by Ion-Pairing Chromatography Inductively Coupled Plasma Mass Spectrometry (IP-ICP-MS) |
| ASC-097.1 | Determination of Mercury Species by Ion-Pairing chromatography Inductively Coupled Plasma Mass Spectrometry (IPC-ICP-MS) |
| ASC-098.1 | Arsenic Speciation Analysis for Samples Containing Elevated Fe and Mn Concentrations by Ion-Chromatography Inductively Coupled Plasma Mass Spectrometry (IC-ICP-MS) |
| ASC-099.1 | Determination of Lead Speciation by Ion-Pairing Chromatography Inductively Coupled Plasma Mass Spectrometry (IPC-ICP-MS) |
| ASC-100.1 | Determination of Mercury Species by Speciated Isotope Dilution Mass Spectrometry (Modified EPA Method 6800) |
| ASC-101.1 | Sample Extrusion from Soil and Sediment Cores |

Facility

The facility for Applied Speciation and Consulting, LLC is approximately 5500 sqft with strategically segregated departmental sections. The facility is located within 1 mile of FedEx, UPS, and USPS shipping locations. To facilitate time sensitive shipments, ASC's facility is also located 4 miles from Washington's largest international airport, SeaTac International Airport.

All office space, sample preparation, and sample analysis is performed in enclosed sections to ensure maximum cleanliness throughout the processes. The entire laboratory space is under positive pressure to minimize external atmospheric contamination. Adhesive flooring supplements are also positioned at all physical entrances to the laboratory to remove active particulate contamination from laboratory personnel.

Capital Equipment

| Item | Manufacturer | Product Description | Model Number |
|------|-------------------|----------------------------------|----------------|
| 1) | Revco | Cryo Freezer | ULT 2186-3-A39 |
| 2) | Fisher Scientific | Analytical Balance (3) | 2020e |
| 3) | Thermo Electron | Spectrophotometer | 400114 |
| 4) | Lab-Line | Flammable Refrigerator/freezer | cat#3551-10 |
| 5) | Dell | Laptop (8) | |
| 6) | Dell | Desktop (7) | I1560 |
| 7) | Sheldon | Laboratory Oven (5) | I320 |
| 8) | Thermolyne | Muffle Furnace | 62700 |
| 9) | Cetac | Sonicated Nebulizer | U-5000AT |
| 10) | Dionex | Liquid Chromatography System | GPM-2 |
| 11) | Dionex | Liquid Chromatography System (5) | GPM-2 |
| 12) | ESI | Peltier cooled spray chamber | PC3 |
| 13) | Brother | Printer/FAX/Copier (5) | MFC-8840D |
| 14) | Perkin Elmer | ICP DRC MS (4) | 026910 |
| 15) | Cuisenart | Industrial Homogenizer | DLC-X-Plus |
| 16) | Polyscience | Chiller (5) | N0772026 |
| 17) | Barnstead | Nanopure UV Water system (2) | D11911 |
| 18) | CETAC | Auosampler (4) | ASX-500 |
| 19) | ESCO | Fume hood | SDC-4A2 |
| 20) | ESCO | Clean Hood (6) | AHC-4A2 |
| 21) | ESCO | Clean Hood | AHC-4A3 |
| 22) | Perkin Elmer | HPLC | |

The above is a sample presentation and does not reflect the entire capital equipment at Applied Speciation and Consulting, LLC

Introduction to Speciation Analysis

Speciation analysis is defined as the separation and quantification of different oxidation states or chemical forms of a particular element. In the past, the determination of total element concentrations was considered to be sufficient for clinical and environmental considerations. Although the total concentration of an element is still useful to know and essential in many areas the determination of each species is an important task. The concentration of a toxic species is more relevant in the setting of environmental and ecological standards than is the total elemental concentration. The collection, treatment and preservation of samples for quantitative analysis of species require careful consideration and planning. This separates speciation studies from procedures for "total" element determinations, and analytical chemists are faced with very difficult problems in the acquisition of accurate data. Speciation analysis is essential for predicting and modeling fate, risk, and effects while it's a must have for designing custom - tailored treatment strategies. Wastewater treatment failures are often a result of not understanding the individual chemistry at different stages of treatment. The speciation of an element can directly affect the efficiency of the treatment process.

Unfortunately, speciation analysis is not as common as traditional total elemental analysis because while speciation data is accepted by some regulators, there are no set laws or regulations on this matter. We believe that the lack of species-specific regulations is due to the absence of methods that can reliably measure the analytes of interest at the regulatory levels. For instance, the analytical methods currently available for elements such as arsenic and chromium are either not selective enough or do not provide sufficiently low detection limits. Another important issue for speciation analysis is its cost. Even though it has been shown time after time that speciation analysis can save time and money with respect to remediation and risk assessment, it is usually more expensive than routine elemental analyses.

One of the most important aspects of speciation analysis is the issue of preservation. In the ideal world, we would be able to perform speciation analysis in the field. Unfortunately, this is still not possible for most analytes of interest so even the most sophisticated analytical methods for the determination of an element's speciation are "useless" if it cannot be assured that the species distribution in the sample remains unchanged between sample collection and analysis. Therefore, choosing the right preservation techniques for the right matrix is obligatory to ensure that the speciation information in the sample remains intact during shipping and storage until the analysis is performed.

Analytical speciation procedures require experienced personnel who understand proper sampling and analytical protocols. As a result, most commercial full-service environmental laboratories do not provide this service. Applied Speciation and Consulting, LLC has been instituted to fill this gap providing routine and non-routine analytical speciation services and consulting to the scientific community. Our experience with a variety of matrices allow us to choose the right sampling protocols and right analytical methods depending on the target species and the sample environment.

Analytical Methods for Speciation Analysis



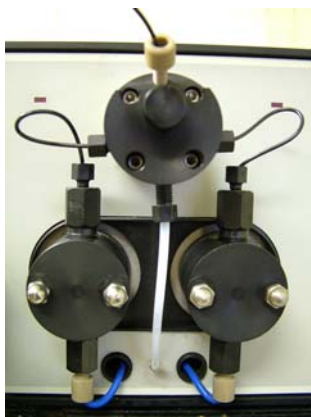
Ion chromatography (IC) is based on the differences in the attraction of the solute ions to the charged sites on the chromatographic column (stationary phase). It provides tremendous separation power and by changing the pH and ionic strength of the eluant (mobile phase), a variety of ionic species can be separated in a single analytical run. The most common detectors for ion chromatography are conductivity and UV spectrophotometry due to their relative low cost. Even though these detectors are useful for some species, they can not provide enough sensitivity and selectivity especially for metal(loid)s.

Inductively coupled plasma - mass spectrometry (ICP-MS) has been the choice for the determination of total metals and metal(loid)s because it's a mature technique with incredible sensitivity and selectivity. As with every analytical technique, it is prone to interferences but most of these interferences have been well documented. In fact, with the introduction of second generation ICP-MS instruments that are equipped with dynamic reaction cells, almost interference-free analysis at trace levels is becoming reality.

Coupling the separation power of ion chromatography to the detection power of ICP-MS is extremely beneficial for the determination of metals and metalloids. Although, it has been an "old" analytical technique with hundreds of scientific articles in the literature, it has not been utilized in regulatory methods. To our knowledge, the only accepted method that acknowledges and utilizes IC-ICP-MS is ASTM Method D6994-04 for cyanide speciation analysis. This specific method was developed by our senior scientist, Dr. Hakan Gürleyük as part of a joint ASTM and EPA Inter-Laboratory Collaborative for the validation of a Cyanide Speciation Analysis method.

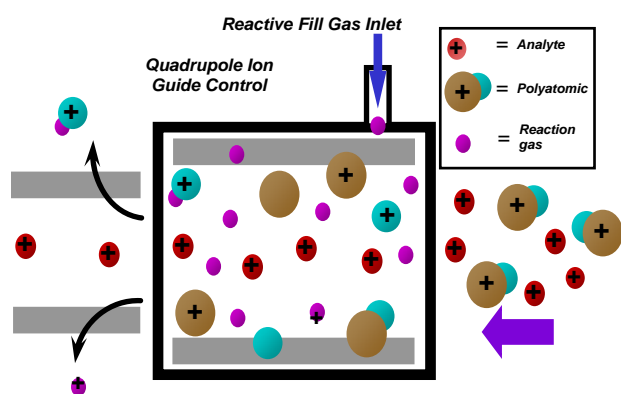
IC-ICP-MS can not only provide detection limits in the range of 1-10 ppt (ng/L) for various analytes, it can also eliminate false positives since most analytes are identified according to their isotopic ratios in addition to retention time matching. Determination of a variety of analytes simultaneously is also possible in some circumstances since many mass-to-charge ratios can be monitored in a single run. In fact, in our laboratory, this feature has been routinely used to monitor interfering species to provide the most accurate results.

In our laboratory, we utilize Perkin Elmer and Dionex chromatography systems and couple them to a Perkin Elmer ICP-MS system equipped with a Dynamic Reaction Cell. We have developed various methods for the speciation analysis of a variety of analytes including arsenic, selenium, chromium, mercury, metal-cyanide complexes and transition metals. Each of these methods are described in following sections.



Utilizing Dynamic Reaction Cell Technology for Trace Metals and Trace Metals Speciation Analysis

Applied Speciation and Consulting, LLC facilitates state of the art, inductively coupled plasma mass spectrometry with dynamic reaction cell (DRC) technology, to accurately determine arsenic, selenium, iron, chromium and various other elements with previously unattainable detection limits. With Dynamic Reaction Cell technology, most polyatomic interferences are reduced to near background levels resulting in dramatic improvements in detection limits and a reduction in biased results.



Chemical Resolution in the Dynamic Reaction Cell

The DRC is a quadrupole enclosed within a reaction chamber (or cell) that is between the ion lens system and the analyzing quadrupole. A reactive gas such as NH_3 is introduced into the cell. The gas reacts with the ion beam through a number of ion-molecule reaction mechanisms, converting the interfering ions into species that will not interfere with the analyte. The analyte of interest, under the same conditions, remains stable and is able to proceed to the detector. This cleansing process is known as “chemical resolution” (1, 2).

Conventional ICP-MS are prone to interferences from the matrix components that form polyatomic species in the plasma (Table 1). Dynamic reaction cell is designed to reduce interferences and overcome many of these limitations. The end result is the elimination of false-positives and lowest detection limits for the toughest matrices

Table 1. Various analytes and common interferences that affect them

| Analyte | Interference | Source |
|-------------------------------|---|--|
| Chromium (^{52}Cr) | $^{40}\text{Ar}^{12}\text{C}^+$ | Carbon |
| Chromium (^{53}Cr) | $^{37}\text{Cl}^{16}\text{O}^+$ | Chlorine |
| Arsenic (^{75}As) | $^{40}\text{Ar}^{35}\text{Cl}^+$, $^{40}\text{Ca}^{35}\text{Cl}^+$ | Chlorine, Calcium |
| Selenium (^{78}Se) | $^{40}\text{Ar}^{38}\text{Ar}^+$, $^{38}\text{Ar}^{40}\text{Ca}^+$ | Argon (plasma gas), Calcium |
| Selenium (^{80}Se) | $^{40}\text{Ar}^{40}\text{Ar}^+$, $^{32}\text{S}^{16}\text{O}_3^+$, $^{40}\text{Ar}^{40}\text{Ca}^+$ | Argon (plasma gas), Sulfur, Calcium |
| Selenium (^{82}Se) | $^{81}\text{Br}^1\text{H}^+$, $^{34}\text{S}^{16}\text{O}_3^+$ | Bromine, Sulfur |
| Iron (^{54}Fe) | $^{40}\text{Ar}^{14}\text{N}^+$, $^{37}\text{Cl}^{16}\text{O}^1\text{H}^+$, $^{38}\text{Ar}^{16}\text{O}^+$ | Nitrogen, Chlorine, Argon (plasma gas) |
| Iron (^{56}Fe) | $^{40}\text{Ar}^{16}\text{O}^+$, $^{40}\text{Ca}^{16}\text{O}^+$ | Argon (plasma gas), Calcium |

1. S. D. Tanner, V. I. Baranov, *Atomic Spectroscopy*, 20, 2, 45-52, (1999)
2. K. Kawabata Y. Kishi, and R. Thomas, *Analytical Chemistry*, Vol. 75, No. 9, 423A, (2003)

Arsenic Speciation Analysis

Arsenic is the 20th most abundant element in the earth's crust. The weathering of the 200+ arsenic-containing minerals and human activities (arsenical pesticides, leaching of wood preservatives, application of fertilizers, irrigation, dust from the burning of fossil fuels, and disposal of industrial and animal wastes) are responsible for the current levels of arsenic in the environment. With more stringent regulations on arsenic levels in drinking waters and industrial discharges, accurate determination of arsenic species at sub-ppb levels is a necessity. In order to meet or exceed our client's data quality objectives, Applied Speciation and Consulting employs the separation power of ion chromatography (IC) and couples it with the detection power of ICP-DRC-MS (IC-ICP-DRC-MS).

The experience of Applied Speciation and Consulting, LLC comes into play when arsenic speciation in difficult matrices is to be determined. We have developed a variety of different methods that utilize different chromatographic separation modes. These methods allow us to identify the most appropriate separation technique which allows for the lowest detection limits possible. For instance, arsenic speciation in a 40,000 ppm Fe, Ca, Al and high sulfate matrix or highly saline samples (up to 2%) can be determined with sub-ppb detection limits.

The most important variable associated with arsenic speciation analysis is to maintain sample integrity prior to analysis. Immediately after any sample is removed from its ambient environment the equilibrium may change inducing species conversion.

Identification of proper sampling protocols cannot be identified without first understanding the environment the sample is being extracted from. Many variables can assist in identifying sample protocols including, but not limited to: other metals concentrations, redox, pH, concentration of organics, structure of environment (air, water, soil, tissue, etc.). Generic application of any sample preservation protocol for speciation analysis will ultimately result in highly biased results that will eventually cost the client time and money.

Our experience with a variety of matrices allows us to choose sampling protocols depending on the target species and the sample environment. For arsenic speciation analysis, possible sampling methods may cryo-freezing in the field, hydrochloric acid, EDTA, and acetic acid.

Brief List of Quantified Arsenic Species

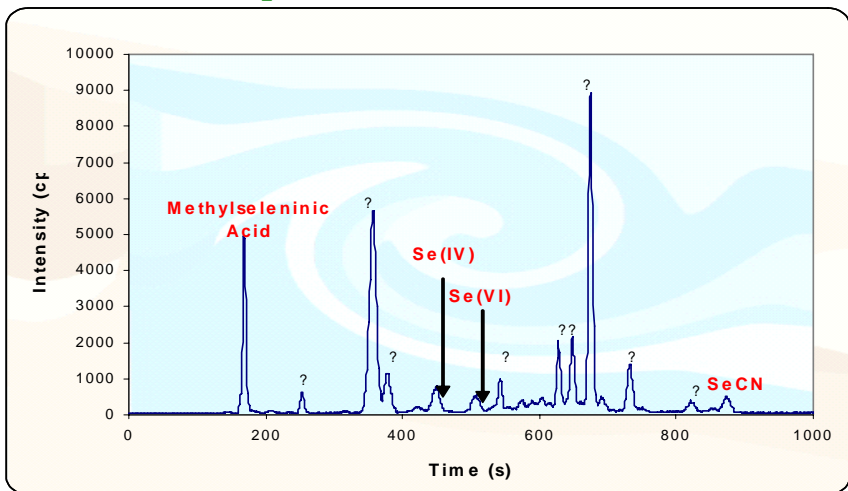
| | |
|------------------------------|-------------------------------------|
| Arsenite | p-Arsanilic acid |
| Arsenate | Roxarsone |
| Monomethyl Arsonic Acid | 3-Amino-4-hydroxyphenylarsonic acid |
| Dimethyl Arsenous Acid | 4-Aminophenylarsonic acid |
| Trimethyl Arsonic Acid | Nitarsonic acid |
| Arsenobetaine | Phenylarsonic acid |
| Arsenocholine | Arseno-thiols |
| Arsenopropionate | Arseno-sugars (S and P) |
| 4-Hydroxy phenylarsonic acid | hexafluoroarsenate |

Selenium Speciation Analysis

Selenium is becoming a priority pollutant in many parts of North America (and elsewhere), because of its high toxicity to aquatic wildlife. Many flue gas desulphurization plants and mining operations face (or will face) extensive regulation with respect to their selenium discharges, which results from poor treatment efficiencies and accidental mobilization during the respective mining process. In all environmental and industrial processes, individual selenium species differ greatly in their behavior and treatability; therefore, the determination of these individual species and their relative distribution is of critical importance. In lower concentrations, selenium is a necessary nutrient for the existence of life; however, at concentrations ten times the recommended dosage, selenium becomes a carcinogen with deleterious health impacts.

Applied Speciation and Consulting employs anion chromatography coupled with the detection power of our ICP-DRC-MS. The Dynamic Reaction cell is used to eliminate the background signal from the plasma gas components allowing us to achieve detection limits around 10 ppt (ng/L). The species of interest are usually Se(IV) and Se(VI).

Selenium Speciation in FGD Process Water



FGD water can be especially complex compared to most other matrices as the selenium present in the coal is combusted and driven out of the stack emissions with lime and other chemicals facilitated in the desulphurization process. The source and type of coal, firing temperature, stack engineering, and a multitude of other variables directly impacts the diversity of selenium species present in the waste stream. Due to the number of variables associated with FGD waste,

quantification of only selenite and selenate can oversimplify the situation resulting in generation of an inapplicable waste treatment system.

Elemental selenium is usually mobilized by cyanide in mine runoff; therefore, the main species after mobilization is selenocyanate (SeCN) and Se(VI). Since this species can be present in many mining wastewaters, FGD wastewater, and oil refining wastewaters we have a number of methods that includes SeCN in the separation scheme. Just like arsenic, depending on the matrix, different analytical separation modes can be utilized for selenium speciation analysis to improve detection and/or eliminate certain interferences.

Special Note: If you intend on facilitating hydride generation analytical techniques for selenium speciation it is highly recommended that you contact an ASC project manager before inception of the project. This could save considerable time, money, and alleviate unneeded frustration.

Chromium Speciation Analysis

Chromium is a naturally occurring metal found in small quantities associated with other metals, particularly iron. It is commonly used for making steel and other alloys, bricks in furnaces, dyes and pigments, chrome plating, leather tanning, and wood preserving. Due to its extensive use in industrial processes, large quantities of chromium compounds are discharged into the environment. Although chromium can exist in all oxidation states from 0 to VI, Cr(III) and Cr(VI) are the most prevalent. Even though Cr(III) is an essential nutrient, Cr(VI) is a known mutagen and carcinogen and is more soluble and therefore, more mobile than Cr(III).

There is a need for lower detection limits because public awareness of hexavalent chromium has increased recently and the US National Water Quality Criteria for Cr(VI) in freshwaters is set at 11 ppb ($\mu\text{g/L}$). More regulations on Cr(VI) are expected in the future. In addition, for better risk assessment, treatment, and remediation studies, an accurate trace value can be more valuable than a nondetect from a method that only has a detection limit in the sub-ppm range (EPA Method 7196A). Accurate determination of Cr(VI) at ng/L levels is a major challenge because the existing methods are neither not selective or not sensitive enough. For instance, the colorimetric determination of Cr(VI) is prone to interferences from molybdenum and vanadium. Anion chromatography is used in EPA Method 7199 (1636) to separate Cr(VI) from the matrix. In that method, Cr(VI) is determined spectrophotometrically after a post column reaction with diphenylcarbazide. Even though most of the problems mentioned above are avoided with this technique, there are still problems when permanganate is present in the samples.

Determination of chromium by conventional inductively coupled plasma mass spectrometry alone has various limitations due to the formation of $^{40}\text{Ar}^{12}\text{C}^+$ and $^{37}\text{C}^{16}\text{O}^+$ in the plasma in the presence of carbon and chlorine. Therefore, samples high in chloride, carbonate, or organic matter usually produce results with positive bias, making accurate quantitation extremely difficult. By employing the DRC technology, most of these interferences are completely eliminated allowing us to achieve sub-ppt detection limits for hexavalent chromium. Spectrophotometric methods described above only use retention times for identification and anything absorbing at the same wavelength can produce a peak. In IC-ICP-DRC-MS technique, on the other hand, chromium is identified using its unique isotopic abundance ratio ($^{52}\text{Cr}/^{53}\text{Cr}$) in addition to retention times. Therefore, false positives or negatives are completely eliminated in this technique.



EPA Method 6800

Speciated Isotope Dilution Mass Spectrometry (SIDMS)

The application of trace metals speciation analyses has increased exponentially in the past decade due to information dissemination regarding the direct applicability of the data for risk assessment and focused treatment identification. Quantification of trace metals species has evolved over the past thirty years with the advent of new technology which, when operated in the hands of an experienced analysts, can provide more absolute results. The evolution of trace metals speciation analyses has evolved from reactionary based chemistry to chromatographic separation finally resulting with speciated isotope dilution mass spectrometry (SIDMS).

Speciated isotope dilution mass spectrometry diverges from the traditional analytical methods in the sense that calibration curves, matrix duplicates, and matrix spikes become unnecessary. Each sample is spike with isotopically enriched speciation standards (e.g. $^{50}\text{Cr(III)}$ and $^{53}\text{Cr(VI)}$) at known concentrations and is analyzed in triplicate or quadruplicate (for statistical purposes). The trace metals species of interest in the sample are assumed to conform to the relative natural abundances documented and accepted by the scientific community (e.g. 4.345% ^{50}Cr , 83.789% ^{52}Cr , 9.501% ^{53}Cr , and 2.365% ^{54}Cr). The different isotopes are then monitored during the speciation analysis (ion chromatography inductively coupled plasma mass

spectrometry) and isotope ratios are generated for each trace metals species (e.g. $^{50}\text{Cr}/^{52}\text{Cr}$ and $^{53}\text{Cr}/^{52}\text{Cr}$ for each chromium species). Monitoring the isotope ratios for each target species allows for identification of species conversion during sample preparation and analysis.

A Representation of the Deconvolution Mathematics

$$R_{50/52}^{\text{III}} = \frac{(A_x^{50}\text{C}_x^{\text{III}}\text{W}_x + A_s^{50}\text{C}_s^{\text{III}}\text{W}_s^{\text{III}})(1-\alpha) + (A_x^{50}\text{C}_x^{\text{VI}}\text{W}_x + A_s^{50}\text{C}_s^{\text{VI}}\text{W}_s^{\text{VI}})\beta}{(A_x^{52}\text{C}_x^{\text{III}}\text{W}_x + A_s^{52}\text{C}_s^{\text{III}}\text{W}_s^{\text{III}})(1-\alpha) + (A_x^{52}\text{C}_x^{\text{VI}}\text{W}_x + A_s^{52}\text{C}_s^{\text{VI}}\text{W}_s^{\text{VI}})\beta}$$
$$R_{53/52}^{\text{III}} = \frac{(A_x^{53}\text{C}_x^{\text{III}}\text{W}_x + A_s^{53}\text{C}_s^{\text{III}}\text{W}_s^{\text{III}})(1-\alpha) + (A_x^{53}\text{C}_x^{\text{VI}}\text{W}_x + A_s^{53}\text{C}_s^{\text{VI}}\text{W}_s^{\text{VI}})\beta}{(A_x^{52}\text{C}_x^{\text{III}}\text{W}_x + A_s^{52}\text{C}_s^{\text{III}}\text{W}_s^{\text{III}})(1-\alpha) + (A_x^{52}\text{C}_x^{\text{VI}}\text{W}_x + A_s^{52}\text{C}_s^{\text{VI}}\text{W}_s^{\text{VI}})\beta}$$
$$R_{50/52}^{\text{VI}} = \frac{(A_x^{50}\text{C}_x^{\text{III}}\text{W}_x + A_s^{50}\text{C}_s^{\text{III}}\text{W}_s^{\text{III}})\alpha + (A_x^{50}\text{C}_x^{\text{VI}}\text{W}_x + A_s^{50}\text{C}_s^{\text{VI}}\text{W}_s^{\text{VI}})(1-\beta)}{(A_x^{52}\text{C}_x^{\text{III}}\text{W}_x + A_s^{52}\text{C}_s^{\text{III}}\text{W}_s^{\text{III}})\alpha + (A_x^{52}\text{C}_x^{\text{VI}}\text{W}_x + A_s^{52}\text{C}_s^{\text{VI}}\text{W}_s^{\text{VI}})(1-\beta)}$$
$$R_{53/52}^{\text{VI}} = \frac{(A_x^{53}\text{C}_x^{\text{III}}\text{W}_x + A_s^{53}\text{C}_s^{\text{III}}\text{W}_s^{\text{III}})\alpha + (A_x^{53}\text{C}_x^{\text{VI}}\text{W}_x + A_s^{53}\text{C}_s^{\text{VI}}\text{W}_s^{\text{VI}})(1-\beta)}{(A_x^{52}\text{C}_x^{\text{III}}\text{W}_x + A_s^{52}\text{C}_s^{\text{III}}\text{W}_s^{\text{III}})\alpha + (A_x^{52}\text{C}_x^{\text{VI}}\text{W}_x + A_s^{52}\text{C}_s^{\text{VI}}\text{W}_s^{\text{VI}})(1-\beta)}$$

If a sample was spiked with $^{50}\text{Cr(III)}$ and the sample matrix was oxidative in nature, the ratio of $^{50}\text{Cr}/^{52}\text{Cr}$ for Cr(VI) would be elevated. The same can occur if the sample is reductive in nature (monitoring $^{53}\text{Cr}/^{52}\text{Cr}$ for Cr(III)). By monitoring all isotopes for the target analyte during speciation analysis and applying statistics from replicate analyses quality control is essentially being performed on each sample.

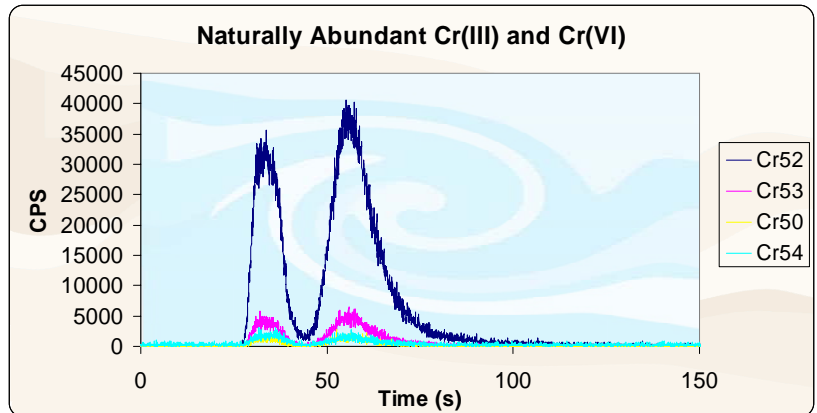
While application of SIDMS is very straightforward for aqueous matrices, solid and sludge samples require one or more extractions which are not always 100% efficient at extracting and stabilizing the target species. The isotopically enriched speciation standards must be applied prior to the extraction procedures to monitor conversion during the extraction process. If species conversion did occur during the extraction procedure, the isotopic ratios will identify the issue and can mathematically correct for it.

Although SIDMS can quantitate, and account for species conversion, for the different species of interest with considerable precision it provides limited information regarding the extraction efficiency for insoluble species. To identify the extraction efficiency total trace metals analysis must be performed on the

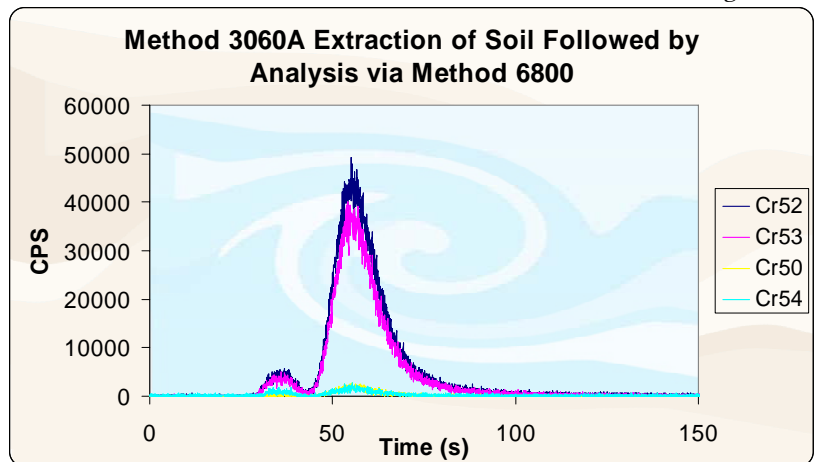
native material for any sample analyzed by SIDMS. If the extraction procedure does not account for 100% of the total trace element in the sample the end user of the data must consider the following: (1) more than two species can exist in almost any sample matrix, (2) certain matrix components may have high adsorption capacities for the target trace metals species, or (3) not all trace metals species have been documented. Before a more rigorous extraction procedure is applied to increase the extraction efficiency (as dictated by the end user of the data) the propensity of species conversion must be identified; otherwise, science is merely being manipulated to fit the inflexible requirements of project data quality objectives.

It should be noted the trace metals of interest must qualify before SIDMS can be applied. The trace metal analyte of interest (regardless of species) must meet the following requirements: (1) the element must have at least three different isotopes, (2) the target isotopes must be stable (not radioactive), and (3) the target isotopes cannot be a product of radioactive decay. Many trace metals fit the requirements including: Cr, Se, Hg, Sn, and Fe.

As with any mass spectrometry based analytical method the quantitation of each isotope must be free from isobaric interferences (same m/z). Interfering compounds can be monitored with a standard ICP-MS and the final isotope measurements can be adjusted accordingly but this can significantly increase the variability of the method. Reduction of these interferences can be accomplished via application of an



Notice how the ratios of ^{52}Cr and ^{53}Cr are different between chromatograms?



ICP-MS with dynamic reaction cell (DRC) technology. The benefit of a DRC versus a collision cell based instrument is the flexibility of using the specific reactionary gases and ability to optimize the reactionary gas parameters to provide an almost interference free signal to the mass spectrometer. It is highly recommended that any client requesting SIDMS analysis inquire about the laboratory's methods for mitigating isotopic interferences.

As with any analytical method one of the most important variables associated with the analysis is the experience of the analyst. The theory of SIDMS couples three different chemical concepts: ion chromatography, ICP-MS analysis, and nuclear chemistry. Although a basic understanding of each of the concepts alone would suffice for pursuit of that given field, very few laboratories and chemists have the experience of coupling all three together. It is highly recommended that prior to submitting samples to any laboratory touting to provide SIDMS (EPA Method 6800) analyses the experience and technical background of the supporting project managers and chemists must be investigated.

In Method 6800, quality control is essentially being performed on each sample.

Determination of Metal-Cyanide Complexes

Metal-cyanide complexes exist as a natural function of geology and chemistry. Often times, most individuals are concerned with total cyanide or weak acid dissociable cyanide to identify risk assessment. Unfortunately, the basic analytical methods to perform these measurements do not provide ample information to make educated decisions. Metal-cyanide complexes are an inherent function of mining operations, especially for gold extraction. The released cyanide will react with naturally occurring compounds containing metals. The availability of these metals and other parameters can dictate the mobility, risk assessment, and identification if remediation efforts are necessary.

Cyanide itself can not be determined using ICP-MS but when it is complexed with a metal, ICP-MS becomes an excellent detector considering its sensitivity for metals. Determination of cyanide complexes of Ag, Au, Cu, Co, Ni, Fe, and Se at sub-ppb levels are possible when these species are chromatographically separated and detected by ICP-DRC-MS. It should be noted that identification of AgCN and CuCN complexes are typically qualitative due to the weak dissociable bonds.

Supported Cyanide Species

CuCN
AgCN
AuCN
SeCN
NiCN
CoCN
FeCN



Stable Isotope Ratios

Each element has a unique isotopic pattern and small differences in the ratios of these isotopes can help in identification of the source, transport and biogeochemical fate of elements in atmospheric bulk deposition, soils, freshwater, and seawater matrices.

Typically, accurate stable metal isotope measurement is achieved by thermal ionization mass spectrometry which can only be found in academic research environments. Applied Speciation and Consulting utilizes its Inductively Coupled Plasma Mass Spectrometer equipped with a Dynamic Reaction Cell to achieve similar results with appropriate QA/QC. This specific instrument not only removes interferences for low level analysis of various matrices, but also allows extremely accurate and precise determination of isotopic ratios limited with counting statistics (<0.1% most ratios). The confidence in isotopic ratio testing is typically limited to sample concentration and matrix interferences. By identification of these interferences and implementation of preconcentration techniques and appropriate sample preparation, the applicability of isotopic ratio testing for most matrices is now a reality. As with every analytical technique, institution of proper sampling plans is a necessity to ensure all localized variables are identified to include all possible sources.

Use of stable isotope ratio testing can often decrease the scope of work for investigative projects ultimately reducing the cost of the investigation and increasing the confidence in results due to the absolute nature of the testing procedure.

Please contact us to discuss analytes that can be analyzed with this technique.



Certifications

Applied Speciation and Consulting currently retains laboratory certifications for the states of Washington, New Jersey, and California for non-potable water and solids. The following list outlines the state certifications, applicable analytes, and reciprocity agreements:

| <u>State</u> | <u>Sample Matrix</u> | <u>Analyte</u> |
|--------------|----------------------|------------------------|
| Washington | Non-potable water | Trace Metals |
| | Non-potable water | As Speciation Analysis |
| | Non-potable water | Se Speciation Analysis |
| | Non-potable water | Cr Speciation Analysis |
| | Non-potable water | EPA Method 6800 |
| | Solids | Trace Metals |
| New Jersey | Solids | EPA Method 6800 |
| | Non-potable water | Trace Metals |
| | Non-potable water | As Speciation Analysis |
| | Non-potable water | Se Speciation Analysis |
| | Non-potable water | Cr Speciation Analysis |
| | Non-potable water | EPA Method 6800 |
| | Solids | Trace Metals |
| Solids | EPA Method 6800 | |

Reciprocity Agreements:

Florida
Maine
Minnesota
Nevada
North Carolina
South Carolina
Wisconsin

Applied Speciation and Consulting is currently pursuing other certifications for compliance with other state, federal, and international regulatory requirements. Please contact an Applied Speciation and Consulting project manager for more details.

Copies of state certifications are available upon request

Curriculum Vitae of Principal Owners

Russell Gerads, *Vice President*

Mr. Gerads has over 10 years of experience in the industry with a majority of that time specializing in project management and consultation associated with complex metalloid speciation projects. Mr. Gerads is the primary liaison for all internal and external scientific investigations assisting in their formulation, management, and execution. Mr. Gerads has managed hundreds of research and monitoring projects associated with trace metals and trace metals speciation analyses pertaining to environmental, pharmaceutical, nutraceutical, government, and chemical manufacturing markets.

In 2003, Mr. Gerads provided consultation and technical advice to a prominent San Francisco Bay oil Refinery to mediate regulatory compliance associated with a waste water treatment plant. By educating the WWTP operator and associated regulatory agency on mercury speciation, mobility, and risk assessment, a more scientific approach was applied to the issue resulting in significant savings to the industrial client while reducing unnecessary regulatory compliance measures. The project is becoming a model for the API in the San Francisco Bay area.

Mr. Gerads experience in managing speciation and ultra trace metals projects include a multitude of matrices including process water, organics rich soil and sediments, tissues, hair, rock, dross, pure metals (aluminum, iron ore, etc.), air, saline water, concentrated salt ponds, ad infinitum. Management of most complex projects necessitates the absolute understanding of species interaction with the matrices to identify method limitations and required modifications to provide representative results. Mr. Gerads is actively involved with a significant amount of internal method development at Applied Speciation and Consulting., as well as external collaborations with academic institutions such as: San Diego State University, Ohio state University, University of Waterloo, University of Utah, University of Florida, California Institute of Technology, University of Oregon, Northwestern University, and others.

In 2002, the Pacific Northwest Clean Water Association invited Mr. Gerads to present on the determination and application of ultra trace arsenic speciation. The New Jersey Department of Environmental Protection also invited Mr. Gerads to present in 2003 regarding arsenic speciation technology and real world applicability for regulatory purposes. He has also presented and directed internal conferences and presentations while at Applied Speciation and Consulting as well as being an instructor for short courses.

Selected Publications /Presentations of Mr. Russell Gerads

Zavala, Y., Gerads, R., Gürleyük, H., Duxbury, J. Arsenic in Rice: II. 2008. Arsenic Speciation in USA Grain and Implications for Human Health. *Environmental Science and Technology*, 42:3861-3866.

Zavala, Y., Gerads, R., Gürleyük, H., Duxbury, J. Arsenic in Rice: III. A Greenhouse Evaluation of Water Management on Arsenic Uptake. *Environmental Science and Technology*, In Press.

Corbin, E., Seeley, E., Raab, A., Feldmann, J., Gerads, R. 2008. Metal chelation as a defense strategy to prevent bacterial growth in tissue abscesses. *Science*.319: 962-965.

Gerads, R.T.2002. “Ultra Trace Level Arsenic Speciation: Determination and Application,” invited presentation for Pacific Northwest Clean Water Association, Yakima, Washington.

Gerads, R.T.2003. “Trace Analysis of Arsenic in Drinking Water” invited presentation for New Jersey Department of Environmental Protection, Trenton, New Jersey.

Gerads, R.T, Johnson, M.2004. “Ultra-Clean Sampling Protocols and Techniques in Water” presentation for Pacific Northwest Clean Water Association Western Washington Regional Short School and Trade Show.

Garcia, J., Howard, C., Gerads, R., Hensman, C., and Gürleyük, H., (2004) “Speciation Analysis and its Role in Waste Treatment & Remediation Technology” Proceedings of the 8th International Symposium on Environmental Issues and Waste Management in Energy and Mineral Production.

Coe, M., J. Surico-Bennett, M. Vicario-Fisher, D. Crane, R. Gerads. 2004. “Contaminants in tilapia (*Oreochromis mossambicus*) from the Salton Sea, California, in relation to human health, piscivorous birds and fish meal production”. *Hydrobiologia* (in press).

Gürleyük, H., Gerads, R. 2005 “Determination of Arsenic, Selenium, and Chromium Species in Waters and Soils – Analytical Methods, Issues, and Solutions.” 16th Annual Conference of the Association for Environmental Health and Sciences, Amherst, MA.

Moreau, M. F., J. Surico-Bennett, M. Vicario-Fisher , R. Gerads, R. M. Gersberg, and S. H. Hurlbert. 2006. “Selenium, arsenic, and other contaminants in three fish species in the Salton Sea, California, and their potential impact on human consumers and wildlife.” *Hydrobiologia* (in press).

Gerads, R. 2006 “Analytical and Preparatory Issues Associated with Total and Speciation Analysis of Selenium” Invited Talk at the International Water Conference, Pittsburgh, PA.

Gerads, R. 2006 “A Complete Method for Total Selenium Quantification of Aqueous Matrices ” Invited Talk at The National Environmental Monitoring Conference (Organized by the U.S. Environmental Protection Agency), Washington, DC.

Gerads, R.. 2006 “Analytical and Preparatory Issues Associated with Total Selenium and Selenium Speciation Analysis” Invited Talk at The National Environmental Monitoring Conference (Organized by the U.S. Environmental Protection Agency), Washington, DC.

Gerads, R.. 2006 “Routine Arsenic Speciation Analysis by IC-ICP-MS? Are we there yet?” Invited Talk at The National Environmental Monitoring Conference (Organized by the U.S. Environmental Protection Agency), Washington, DC.

Gerads, R. 2006 “Analytical Methods for Selenium Speciation: The Good, The Bad, and The Ugly!” National Environmental Monitoring Conference (Organized by the U.S. Environmental Protection Agency), Washington, DC.

Gürleyük, H. 2005 “Metals, Metalloids and Speciation by ICPMS: What is trace? What is state-of-the-Art?” Invited Talk at the AOAC Annual Meeting, Tacoma, WA.

Hakan Gürleyük, Ph.D., *Senior Scientist*

Hakan Gürleyük has developed various methods for speciation analysis using ion chromatography coupled to an ICP-MS detector. These methods provide extremely low detection limits (1-10 ng/L for each species) and are used routinely at various laboratories for chromium, arsenic, selenium, mercury and cyanide speciation in liquid and solid matrices.

In addition, he has been working on improving the determination of trace elements in difficult matrices by ICP-MS. He has developed a method that uses an ICP-MS instrument equipped with a dynamic reaction cell to provide detection limits much lower than those achieved by most analytical laboratories while ensuring accuracy by eliminating false-positives.

For his Ph.D. research, Dr. Gürleyük worked on developing HPLC separations for the speciation of arsenic with HG-AAS, HG-ICP-MS and ICP-MS as detectors. For characterization of the behavior of arsenic in soils, he developed methods for its extraction and speciation using combinations of slurry sampling, flow injection, microwave-assisted extraction, hydride generation, and ICP-MS. He also designed a new nebulizer that is more efficient and less expensive than commercially available sample introduction devices for plasma-based detectors.

Dr. Gürleyük has many publications and presentations, is frequently asked to peer-review articles by various prestigious journals and invited to present his findings in reputable conferences. He is a member of the International Society of Environmental Forensics and appointed on the editorial board for the Environmental Forensics Journal. He is a member of the ASTM committee E50.06 (Forensic Environmental Investigations), setting ASTM standards for environmental forensic investigations. He has also served on the American Water Works Association Research Foundation Project Advisory Committee on Hexavalent Chromium.

He also teaches courses focused on the determination of arsenic, selenium and chromium species in environmental and industrial samples at the Winter Conference on Plasma Spectrochemistry and at the Annual AEHS Meeting & West Coast Conference on Soils, Sediments, and Water. He frequently provides analytical consulting to his clients most of which are listed as top 100 consulting firms in the world. Currently, he is working on collaborative research with other scientists from NOAA, University of Kentucky, Sam Houston State University, and Trent University.

Honors and Awards

Appointed to the Editorial Board for Environmental Forensics Journal (2006).

Selected as a member for ASTM committee E50.06 (Forensic Environmental Investigations). (2005)

Received a \$100,000 Small Business Innovated Research grant sponsored by NIH/CDC (partnership with Trace Detect) for the determination of arsenic using a portable voltammetry detector (2003).

Best Paper of the Conference Award at the 8th Federation of the European Chemical Societies Conference, September 2002, Greece.

Received a \$70,000 Small Business Innovated Research grant sponsored by the US Environmental Protection Agency (2002).

Best Presentation Award at the Winter Conference on Plasma Spectrochemistry, February 2001, Norway.

Louis Quinn Award for Excellence in Graduate Research at the 11th Annual Chemistry Department Research Symposium 2000, University of Massachusetts.

Graduate Fellowship from Texas Research Institute for Environmental Studies, 1995 and 1996, Huntsville, Texas.

Publications

Published Articles

Pace, M.N., Mayes, M.A., Jardine, P.M., McKay, L., Yin, X., Melhorn, T.L., Liu, Q., Gürleyük, H., (2005) "Unraveling the Fate and Transport of Sr²⁺ and SrEDTA²⁻ in the Hanford Vadose Zone" Journal of Contaminant Hydrology. In Press

O'Connor, R., O'Connor, M., Irgolic, K., Sabrsula, J., Gürleyük, H., Brunette, R., Howard, C., Garcia, J., Brien, J., Brien, J., and Brien, J., (2005) "Transformations, Air Transport and Human Impact of Arsenic from Poultry Litter" Environmental Forensics, 6:83-89, 2005

Hollibaugh, J.T., Vasquez, L., Leclair, G., Carini, S., Joye, S.B., Jellison, R.E., Gürleyük, H. & Wallschläger, D. (2005) "Arsenic speciation in an alkaline, hypersaline, meromictic lake in response to the seasonal progression of water column stratification and redox conditions" Geochim. Cosmochim. Acta, Vol69, No. 8, pp. 1925-1937

Gürleyük, H. and Howard, C., Brunette, R.C., Schneider, C., Thomas, R. "Using Dynamic Reaction Cell ICP MS Technology to Determine the Full Suite of Elements in Rainwater Samples" Spectroscopy, January 2005

Garcia, J., Howard, C., Gerads, R., Hensman, C., and Gürleyük, H., (2004) "Speciation Analysis and its Role in Waste Treatment & Remediation Technology" Proceedings of

the 8th International Symposium on Environmental Issues and Waste Management in Energy and Mineral Production.

Hensman, C., Meyer, J., Kilner, P., and Gürleyük, H., (2004) "Trace-metal remediation strategies in complex matrices using organo-thiols" Proceedings of the 8th International Symposium on Environmental Issues and Waste Management in Energy and Mineral Production.

Gürleyük, H. and Wallschläger, D. 2001 "Determination of Chromium(III) and Chromium(VI) in Waters Using Suppressed Ion Chromatography Coupled to Inductively Coupled Plasma Mass Spectrometry" *J. Anal. Atom. Spectrom.* 16: 926-930.

Yehl, P.M., Gürleyük, H., Tyson, J.F., Uden, P.C. 2001 "Microwave-Assisted Extraction of Monomethyl Arsonic Acid from Soil and Sediment Standard Reference Materials" *Analyst* 126: 1511-1518.

Gürleyük, H., Tyson, J.F., and Uden, P.C. 2000 "Determination of Extractable Arsenic in Soils Using Slurry Sampling - On-Line Microwave - Assisted Extraction - Hydride Generation - Atomic Absorption Spectrometry" *Spectrochim. Acta Part B* 55: 935-942.

Gürleyük, H., Van Fleet-Stalder, V. and Chasteen, T.G. 1997 "Confirmation of the Biomethylation of Antimony Compounds" *App. Organometal. Chem.* 11: 471-483.

Van Fleet-Stalder, V.H., Gürleyük, H., Bachofen, R., and Chasteen, T.G. 1997 "Effects of Growth Conditions on Production of Methyl Selenides in Cultures of *Rhodobacter sphaeroides*" *Indust. Microbiol. Biotechnol.* 19: 98-103.

Selected Presentations

Gürleyük, H. 2006 "Analytical and Preparatory Issues Associated with Total and Speciation Analysis of Selenium" Invited Talk at the International Water Conference, Pittsburgh, PA.

Gürleyük, H. 2006 "Routine Arsenic Speciation Analysis by IC-ICP-MS? Are we there yet?" Invited Talk at the The National Environmental Monitoring Conference (Organized by the U.S. Environmental Protection Agency), Washington, DC

Gürleyük, H. 2006 "Analytical and Preparatory Issues Associated with Total Selenium and Selenium Speciation Analysis" Invited Talk at the The National Environmental Monitoring Conference (Organized by the U.S. Environmental Protection Agency), Washington, DC

Gürleyük, H. 2006 "A Complete Method for Total Selenium Quantification of Aqueous Matrices" National Environmental Monitoring Conference (Organized by the U.S. Environmental Protection Agency), Washington, DC

Gürleyük, H. 2006 "A Analytical Methods for Selenium Speciation: The Good, The Bad, and The Ugly!" National Environmental Monitoring Conference (Organized by the U.S. Environmental Protection Agency), Washington, DC

Gürleyük, H. 2005 “Metals, Metalloids and Speciation by ICPMS: What is trace? What is state-of-the-Art?” Invited Talk at the AOAC Annual Meeting, Tacoma, WA

Gürleyük, H. 2004 “Speciation Analysis and its Role in Waste Treatment & Remediation Technology” 8th International Symposium on Environmental Issues and Waste Management in Energy and Mineral Production, Antalya, Turkey.

Gürleyük, H. 2003 “Chicken feed additives: Another source of arsenic contamination?” 5th Int. Symp. on Speciation of Elements in Biol., Environ. Toxicol. Sci., Almuñecar, Spain

Wallschläger, D. & Gürleyük, H. 2003 “Arsenic speciation and cycling in a meromictic soda lake – a model system for arsenic-contaminated ground waters” 5th Int. Symp. on Speciation of Elements in Biol., Environ. Toxicol. Sci., Almuñecar, Spain

Wallschläger, D., Gürleyük, H. & Hollibaugh, J.T. 2003 “Arsenic speciation and cycling in a permanently-stratified soda lake” invited oral presentation at the 39th IUPAC Congress, Ottawa, Canada

Gürleyük, H. 2003 “Understanding the Behaviour of Metals by Speciation Analysis” Mining and the Environment, Sudbury, Canada

Gürleyük, H. 2003 “Determination of Trace Elements in Difficult Matrices by Inductively Coupled Plasma – Dynamic Reaction Cell – Mass Spectrometry” Winter Conference on Plasma Spectrochemistry, Garmisch-Partenkirchen, Germany.

Gürleyük, H. 2003 “Extraction and Determination of Hexavalent Chromium in Fish Tissue” Winter Conference on Plasma Spectrochemistry, Garmisch-Partenkirchen, Germany (poster).

Gürleyük, H. 2003 “Low-Level Cyanide Speciation Analysis by IC-ICP-DRC-MS” Winter Conference on Plasma Spectrochemistry, Garmisch-Partenkirchen, Germany (poster).

Gürleyük, H. 2003 “Speciation Analysis of Arsenic by IC-ICP-DRC-MS” Winter Conference on Plasma Spectrochemistry, Garmisch-Partenkirchen, Germany (poster).

Gürleyük, H. 2002 “Interfacing Analytical Chemistry with Environmental Sciences” Invited Talk at Koc University, Istanbul, Turkey.

Gürleyük, H. 2002 “Determination of Trace Elements in Seawaters by Inductively Coupled Plasma - Dynamic Reaction Cell - Mass Spectrometry.” 29th Annual Conference of the Federation of Analytical Chemistry and Spectroscopy Societies.

Gürleyük, H. 2002 “Determination of Hexavalent Chromium in Drinking Waters by Ion Chromatography – Inductively Coupled Plasma Mass Spectrometry (IC-ICP-MS).” American Water Works Association Inorganic Contaminants Workshop, San Diego, CA.

Gürleyük, H. 2002 “Determination of Various Trace Elements in Seawater by Inductively Coupled Plasma - Dynamic Reaction Cell - Mass Spectrometry.” Winter Conference on Plasma Spectrochemistry, Scottsdale AZ (poster).

- Gürleyük, H. 2002 "Evaluation of the Dynamic Reaction Cell Technology for the Speciation Analysis of Chromium Using IC-ICP-MS." Winter Conference on Plasma Spectrochemistry, Scottsdale AZ (poster).
- Gürleyük, H. 2001 "Determination of Chromium(III) and Chromium(VI) in Waters by Ion Chromatography - Inductively Coupled Plasma - Dynamic Reaction Cell - Mass Spectrometry." 28th Annual Conference of the Federation of Analytical Chemistry and Spectroscopy Societies.
- Gürleyük, H. 2001 "Determination of Hexavalent Chromium in Waters by Ion Chromatography – Inductively Coupled Plasma Mass Spectrometry." Winter Conference on Plasma Spectrochemistry, Norway (poster).
- Gürleyük, H. 2001 "Determination of Trace Elements in Seawater by Inductively Coupled Plasma – Dynamic Reaction Cell - Mass Spectrometry." 28th Annual Conference of the Federation of Analytical Chemistry and Spectroscopy Societies.
- Gürleyük, H. 2001 "Slurry Sampling – On-Line Microwave Extraction Coupled with ICP-MS Detection as an Alternative to TCLP." Winter Conference on Plasma Spectrochemistry, Norway (poster).
- Gürleyük, H. 2001 "Speciation of Chromium in Waters Using Ion Chromatography Coupled to Inductively Coupled Plasma Mass Spectrometry." Winter Conference on Plasma Spectrochemistry, Norway.
- Gürleyük, H. 2000 "Determination of Extractable Trace Elements in Soils by Slurry Sampling-Flow Injection-Microwave Assisted Extraction Followed by On-line Filtering and ICP-MS Detection." Pittcon 2000.
- Gürleyük, H. 2000 "Double Capillary Nebulizer for Sample Introduction in Plasma Spectrometry." Pittcon 2000.
- Gürleyük, H. 2000 "Speciation of Arsenic in Soils Using Various Combinations of Slurry Sampling, Flow Injection, Microwave Assisted Chemistry, Hydride Generation, and ICP-MS." 2000 Winter Conference on Plasma Spectrochemistry (poster).
- Gürleyük, H. 1999 "Determination of Arsenic in Soils Using Slurry Sampling - On-Line Microwave-Assisted Extraction – Hydride Generation - Atomic Absorption Spectrometry." 31st Colloquium Spectroscopicum International.
- Gürleyük, H. 1998 "Speciation of Arsenic Compounds in Soils by Liquid Chromatography with Element-Specific Detection." 25th Annual Conference of the Federation of Analytical Chemistry and Spectroscopy Societies.
- Gürleyük, H. 1996 "Calculating the Total Biological Production of Volatile Sulfur and Selenium Compounds by Determining their Henry's Law Constants." 211th National American Chemical Society Meeting (poster).
- Gürleyük, H. 1996 "Determination of Organic Compounds of the Green Alga *Halimeda* Using Supercritical Fluid Extraction (SFE) and Gas Chromatography - Mass Spectrometry (GC/MS)." Annual Texas Academy of Science Meeting.

Gürleyük, H. 1996 “Investigation of the Biologically Reduced and Methylated Compounds of Antimony.” 211th National American Chemical Society Meeting (poster).

Gürleyük, H. 1996 “Physiological Aspects of Selenium Oxyanion Reduction and Methylation by *Rhodobacter sphaeroides*.” 211th National American Chemical Society Meeting (poster).