Laboratory Procedure Manual

Analyte: **Personal Care and Consumer Product Chemicals and Metabolites: benzophenone-3, bisphenol A, bisphenol F, bisphenol S, 2,4-dichlorophenol, 2,5-dichlorophenol, methyl-, ethyl-, propyl-, and butyl parabens, triclosan, and triclocarban**

Matrix: **Urine**

Method: **On line SPE-HPLC-Isotope dilution-MS/MS**

Method No: **6301.05**

As performed by:

Organic Analytical Toxicology Branch
Division of Laboratory Sciences
National Center for Environmental Health

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Important Information for Users

The Centers for Disease Control and Prevention (CDC) periodically refines these laboratory methods. It is the responsibility of the user to contact the person listed on the title page of each write-up before using the analytical method to determine if changes have been made and what revisions, if any, have been incorporated.

Public Release Data Set Information

This document details the Lab Protocol for testing the items listed in the following table:

DATA FILE NAME	VARIABLE NAME	ANALYTE
EPHPP_I	URX14D	Urinary 2,5-dichlorophenol (ng/ml)
	URXDCB	Urinary 2,4-dichlorophenol (ng/ml)
	URXBPA	Urinary Bisphenol A (ng/mL)
	URXBPF	Urinary Bisphenol F (ng/mL)
	URXBPS	Urinary Bisphenol S (ng/mL)
	URXBP3	Urinary Benzophenone-3 (ng/mL)
	URXTRS	Urinary Triclosan (ng/mL)
	URXTLC	Urinary Triclocarban (ng/mL)
	URXMPB	Urinary Methyl paraben (ng/ml)
	URXEPB	Urinary Ethyl paraben (ng/ml)
	URXPPB	Urinary Propyl paraben (ng/ml)
	URXBUP	Urinary Butyl paraben (ng/ml)

1. Clinical Relevance and Summary of Test Principle

A. Clinical Relevance

This method is used to monitor select environmental phenols, triclocarban, and parabens in biological matrices to evaluate the prevalence of human exposure to these compounds or their precursors. Human exposure may result from industrial pollution, pesticide use, food consumption, and use of consumer and personal care products. Bisphenol A (BPA) is used in the manufacture of polycarbonate plastics and epoxy resins, which can be used as protective coatings on food containers, and as composites and sealants in dentistry; BPA may also be used in the thermal paper and polyvinyl chloride industries.[1] In recent years, BPA analogs, such as bisphenol S (BPS, 4,4'-sulfonyldiphenol) and bisphenol F (BPF, 4,4′-dihydroxydiphenylmethane) have been introduced in the market to replace BPA.[2] Chlorophenols have been used in the wood preservation industry, as intermediates in the production of pesticides, and as disinfectants or fungicides for industrial and indoor home use. The manufacture of other chlorinated aromatic compounds can produce chlorophenols as byproducts. Other chlorinated organic compounds (i.e., triclosan, triclocarban) are used as bactericides. Phenols are also used as sunscreen agents for skin protection, and as UV filters in cosmetic products and plastics to improve stability (e.g., benzophenone-3 [BP-3]). Parabens, a group of alkyl (e.g., methyl, ethyl, propyl, butyl) esters of *p*-hydroxybenzoic acid, are widely used as antimicrobial preservatives in personal care products; parabens can also be used in pharmaceuticals, and in food and beverage processing.[3-6]

Many of the above-mentioned organic chemicals and their environmental precursors have been on the market for decades. With scientific studies suggesting the potential endocrine activity of several environmental chemicals, including some used in personal care and consumer products, the number of chemicals under investigation has increased.

Because of the widespread use and potential adverse health effects, biomonitoring of phenols, parabens and triclocarban is of public health interest.

B. Test Principle

We developed a sensitive method for measuring BPA, BP-3, triclosan, 2,4-dichlorophenol (2,4-DCP), and 2,5-dichlorophenol (2,5-DCP).[7] We later updated the method to include four parabens (methyl-, ethyl-, propyl-, and butyl paraben), BPS, and BPF[8, 9] and, most recently, triclocarban. These methods use on-line solid phase extraction (SPE) coupled to high-performance liquid chromatography–isotope dilution tandem mass spectrometry (MS/MS) with peak focusing.[7-9] Briefly, the conjugated species of the organic chemicals in 100 µL of urine are enzymatically hydrolyzed; this deconjugation step is omitted when measuring the concentrations of the free species. After hydrolysis, samples are acidified with 0.1 M formic acid; target analytes are preconcentrated by online SPE, separated by reversed-phase HPLC, and detected by atmospheric pressure chemical ionization (APCI)–MS/MS.

2. Safety Precautions

A. Reagent Toxicity or Carcinogenicity

Some of the reagents used are toxic. Special care should be taken to avoid inhalation, eye or skin contact to the reagents used throughout the procedure. Avoid use of the organic solvents in the vicinity of an open flame, and use solvents only in well-ventilated areas. Care should be exercised in handling of all chemical standards.

β-Glucuronidase/sulfatase and formic acid are known sensitizers. Prolonged or repeated exposure to sensitizers can cause allergic reactions in certain sensitive individuals.

Note: Laboratory personnel are advised to review the Material Safety Data Sheets (MSDS) for the chemicals and solvents used in this procedure can be found on the internet (https://www.msdsonline.com/msds-search/) before using the chemicals or reagents. The hard copy may be found in the binder in the laboratory. Laboratory personnel are advised to review the MSDS before using chemicals.

B. Radioactive Hazards

None.

C. Microbiological Hazards

The possibility of being exposed to various microbiological hazards exists when handling biological samples. Appropriate personal protective measures should be taken to avoid any direct contact with biological specimens (i.e., utilize gloves, chemical and/or biological hoods). A Hepatitis B vaccination series is recommended for health care and laboratory workers who are exposed to human fluids and tissues. Laboratory personnel handling human fluids and tissues are required to take the “Bloodborne Pathogens Training” course offered at CDC to insure proper compliance with CDC safe work place requirements.

D. Mechanical Hazards

There are only minimal mechanical hazards when performing this procedure using standard safety practices. Laboratorians should avoid any direct contact with the electronics of the mass spectrometer, unless all power to the instrument is off. Generally, only qualified technicians should perform the electronic maintenance and repair of the mass spectrometer. Contact with the heated surfaces of the mass spectrometer should be avoided; also, care must be taken to avoid puncture wounds from the corona discharge needle when removing the APCI interface.

E. Protective Equipment

Standard safety personal protective equipment (PPE) should be utilized when performing this procedure. This includes lab coat, safety glasses, and nitrile or latex gloves.

F. Training

Anyone using this procedure should have training in the use of a HPLC system and a triple quadrupole mass spectrometer. Operators are required to read and follow the laboratory standard operating procedures manual. Formal training is not necessary; however, an experienced user should train all of the operators.

G. Personal Hygiene

Care should be taken in handling any biological specimen. Routine use of gloves and proper hand washing should be practiced. No food or drink is allowed in laboratory areas.

H. Disposal of Waste

Solvents and reagents are disposed of in an appropriate container clearly marked for waste products. Containers, glassware, etc., that come in direct contact with the specimen are either autoclaved or decontaminated with 10% bleach. Contaminated analytical glassware is treated with bleach, washed and reused; disposable labware is autoclaved prior to disposal. To insure proper compliance with CDC requirements, laboratory personnel are required to take annual hazardous waste disposal courses.

3. Computerization; Data-System Management

A. Software and Knowledge Requirements

All samples are queued for analysis in a database created using Microsoft Access. Mass spectrometry data are collected and stored using the Analyst software (Applied Biosystems, Ontario, Canada). During sample preparation and analysis, samples are identified by their Sample Name and Sample ID. The Sample Name is a number that is unique to each sample during the sample preparation and the mass spectrometry measurement. The unique Sample ID, included on the label of each sample vial, is used to identify each specimen. In the case of repeated measurements, the sample can have more than one Sample Name, but only one Sample ID in the database. The Sample ID links the laboratory information with the demographic data recorded by the sample takers. All raw mass spectral data are archived for future reference. Raw data files are analyzed using the Analyst/Quantitation Wizard program, which allows automatic and manual peak selection and area integration. Alternatively, automated data processing could be performed using a cloud-based software “ASCENT” provided by Indigo BioAutomation solutions (Indianapolis, IN). Processed data file results (peak area, peak height, retention time, analyte name, MRM name) are exported to the Access database which allows for data storage and future retrieval. This Access database is stored on the secure DLS-PC network as well as in several archive locations. Statistical analysis of the data, programming, and reporting are performed using the Statistical Analysis System (SAS) software (SAS Institute, Cary, NC). Knowledge and experience with these software packages (or their equivalent) are required to utilize and maintain the data management structure.

B. Sample Information

Sample Names and Sample IDs, sample volume and study number are entered into the Access database before sample preparation. If possible, for unknown samples, the sample IDs are read in by a barcode reader directly from the sample vials. Sample IDs for the quality control materials (QCs) are entered manually. The Sample Log Sheet containing Sample Names and Sample IDs is printed from the Access database and is used to record information during the sample preparation. When Tecan, the robotic liquid handling system, is used for sample preparation, the barcodes of samples and QCs are all automatically read by the bar code reader of Tecan into the sample login file by the Tecan operating software. The login file is then exported into the Access database for batch file creation or future retrieval. After MS data collection and peak integration, the processed data are exported into either a text file (from Analyst software) or an excel file (from Indigo Ascent software) which is then imported into the Access database.

C. Data Maintenance

All sample and analytical data are checked after being entered into the database for transcription errors and overall validity. The database is routinely backed up onto a computer hard drive and onto a network drive. Data from completed studies are saved on a network drive. Additionally, final reports can be saved as paper copy as an official government record.

4. Procedures for Collecting, Storing, and Handling Specimens; Criteria for Specimen Rejection

A. Sample Collection

Urine specimens are collected from subjects in standard urine collection cups. Samples should be refrigerated as soon as possible. Preferably, the specimen should be transferred to specimen vials within 4 hours of collection. If at all possible, at least five milliliters of urine is collected, and can be stored frozen in borosilicate glass, polypropylene vials or specimen cups. Teflon coated stoppers can be used, but crimped caps with rubber stoppers should not be used because of potential contamination with target analytes. The specimens are then labeled, frozen, and stored on dry ice for shipping. Special care must be taken in packing to protect urine containers from breakage during shipment. All samples should be stored frozen until analysis.

B. Sample Handling

Samples are thawed, aliquoted, and the residual specimen is stored frozen.

5. Procedures for Microscopic Examinations; Criteria for Rejecting Inadequately Prepared Slides

Not applicable for this procedure.

6. Preparation of Reagents, Calibration (Standards), Controls, and All Other Materials; Equipment and Instrumentation

A. Reagents and Sources

Methanol (MeOH) (Optima LC/MS grade) was purchased from Fisher Scientific (Pittsburgh, PA). Formic acid and water (Tedia; Fairfield, OH) were analytical or HPLC grade. BPA, BPF, BPS, triclosan (5-chloro-2-(2,4-dichlorophenoxy)phenol), triclocarban (3, 4, 4'-trichlorocarbanilide), 2,4-DCP, 2,5-DCP, methyl-, ethyl-, propyl-, and butyl parabens, solid β-glucuronidase/sulfatase (*Helix pomatia*, H1), liquid β-glucuronidase/arylsulfatase (BGALA-RO from *Helix pomatia*), ammonium acetate, 4-methylumbelliferyl glucuronide and 4-methylumbelliferyl sulfate were purchased from Sigma Aldrich Laboratories, Inc. (St. Louis, MO). BP-3, (2-hydroxy-4-methoxybenzophenone, Eusolex 4360) was provided by EMD Chemicals Inc. (Hawthorne, NY). $^{13}C_{12}$-BPA, $^{13}C_6$-triclocarban, $^{13}C_6$-2,4-DCP, $^{13}C_6$-2,5-DCP, and $^{13}C_4$-4-methylumbelliferone were obtained from Cambridge Isotope Laboratories Inc. (Andover, MA). $^{13}C_{12}$-triclosan was purchased from Wellington laboratories Inc. (Ontario, Canada). D_3,^{13}C-BP3 was obtained from Los Alamos National Laboratory (Los Alamos, NM), D_4-methyl paraben from CDN Isotopes (Quebec, Canada), and $^{13}C_{12}$-BPS, $^{13}C_{12}$-BPF, D_4-ethyl, D_4-propyl, and D_4-butyl parabens from CanSyn Chem Corp. (Toronto, Canada). Solvents and other reagents (but not standards) of similar specifications but from other sources may also be used.

B. Working Solutions

(1) 1.0 M Ammonium acetate buffer, pH 5.0

Weigh 77.08 g of ammonium acetate into a 1000 mL beaker. Add 800 mL HPLC-grade H_2O and mix vigorously until all ammonium acetate is dissolved. Adjust pH to 5.0 (±0.1) with glacial acetic acid. Transfer the solution into a 1000 mL volumetric flask, and fill to volume with HPLC-grade H_2O. The buffer is prepared as needed and stored under refrigeration.

(2) 1.0 M formic acid solution

3930 µL of formic acid (96%) is diluted to 100 mL with HPLC grade water. Prepare as needed and store in refrigerator.

(3) Enzyme

a) Liquid β-glucuronidase/arylsulfatase

(BGALA-RO from *Helix Pomatia*)

A fresh solution for each run is prepared using the following procedure. Gently mix 3 mL of β-glucuronidase /arlysulfatase liquid enzyme (stored refrigerated) with 7 mL of ammonium acetate buffer (1M, pH 5.0±0.1) solution. Add 100 µL of this enzyme solution to the urine prior to incubation for hydrolysis (≥30 units/µL of urine).

b) Solid β-glucuronidase/sulfatase

(Helix Pomatia, H1)

Alternatively, a fresh solution for each run is prepared using the following procedure. Add 0.12 g of β-glucuronidase/sulfatase (glucuronidase activity ≥2.5 million units/gram) to 10 mL of 1M ammonium acetate buffer solution. Mix gently to prevent deactivation of the enzyme. 100 µL of this enzyme solution will be used for incubation of each sample (≥30 units/µL of urine). Note if the glucuronidase activity in particular Lot of enzyme is <2.5 million units/gram, the amount of β-glucuronidase/sulfatase needed would increase.

(4) HPLC Mobile Phase

HPLC grade water is used as mobile phase A (aqueous); HPLC grade MeOH is used as mobile phase B (organic) for both SPE and HPLC pumps. MeOH and water are stored at room temperature.

C. Standards Preparation

(1) Stock Solutions and Analytical Standard Solutions

Initial stock solutions are prepared by dissolving measured amounts of the target analytes in methanol. Serial dilutions of these stock solutions are made in methanol to create eleven mixed standard stock solutions containing all analytes of interest. 100-µl aliquot of this mixed stock solution to 100 µL urine will result in the desired concentration range. The native standard solutions are then dispensed into 1.5 mL glass autosampler vials, and stored frozen until use.

(2) Internal Standard (IS) Solution

Initial stock solutions for all isotope labeled compounds are prepared by dissolving measured amounts of the solid compounds in MeOH. The internal standard working solution is prepared by diluting the stock solutions in MeOH, so that a 50-µL aliquot in 100 µL urine resulted in an appropriate concentration level for each compound.

(3) Deconjugation Standard Solution

4-methylumbelliferyl sulfate, 4-methylumbelliferyl glucuronide, and $^{13}C_4$-4-methylumbelliferone are used as deconjugation standards to monitor the extent of the enzymatic reaction. The individual stock solution is prepared by dissolving measured amounts of 4-methylumbelliferyl glucuronide, 4-methylumbelliferyl sulfate, and $^{13}C_4$-4-methylumbelliferone in MeOH. The final deconjugation standard solution contains 4-methylumbelliferyl sulfate (0.5 ppm), 4-methylumbelliferyl glucuronide (0.5 ppm), and $^{13}C_4$-4-methylumbelliferone (0.5 ppm), and is made by diluting the original stock solution with HPLC grade H_2O.

(4) Mixture of IS Working Solution and Deconjugation Standard Solution

The mixture of IS and deconjugation standard solution is prepared by mixing equal volumes of IS standard and deconjugation standard (1:1). The mixture is dispensed into 15 mL glass vials, and stored in the refrigerator until use. 100 µL of this mixed solution is used for each sample during preparation.

(5) MS Instrument Operational Check Standard

A reagent blank (QCB) that contains 100 µL of the mixture of IS and deconjugation standard solution is used as the MS instrument check standard. This solution is used to check the sensitivity of the mass spectrometer before starting each run every day. The same sample can be also used to check the resolution of the HPLC system by checking the retention times of the isomers included in the method.

(6) In-house Proficiency Testing (PT) Standards

Aliquot of each standard stock solution is added to 100 mL urine pools to produce PT standards of 3 different concentrations. The spiked pools are mixed overnight, aliquoted into vials, and frozen until needed. The PT standards are characterized by at least 20 repeat measurements to determine the mean and standard deviation for each analyte.

D. Materials

(1) HPLC conical silanized glass autosampler vials (1.5 mL, ThermoFisher, San Jose, CA)
(2) Tip ejector variable volume micropipettes (Wheaton, Millville, NJ), and disposable pipette tips (Rainin Instruments Co., Woburn, MA).
(3) LiChrosphere RP-18 ADS cartridge (25×4mm, Merck KGaA, Germany), and cartridge holder.
(4) Chromolith® High Resolution RP-18e (25 × 4.6 mm, Merck KGaA, Germany) HPLC column
(5) Chromolith® High Resolution RP-18e (100 × 4.6 mm, Merck KGaA, Germany) HPLC column.
(6) Zorbax XDB-C-18 Reliance Cartridge Guard Columns (4.6 mm id ×12.5mm) and guard column holder (Agilent Tech., Wilmington, DE).
(7) Betasil C18 (5um, 10x3mm) drop-in guard cartridges and Uniguard* Direct-Connection guard cartridge holder (ThermoFisher, San Jose, CA).
(8) Inline filters (2 µm and 0.5 µm, Upchurch)
(9) Solvent inlet frit (Agilent Tech., Wilmington, DE).
(10) Assorted glassware.

E. Equipment

(1) Agilent 1260 HPLC system (Agilent Tech., Wilmington, DE), which includes 2 binary pumps, 1 autosampler, and 1 column compartment with a 10-port switching valve.
(2) Surveyor Plus liquid chromatograph autosampler (ThermoFisher, San Jose, CA)
(3) High pressure mixing Tee.
(4) Applied Biosystems AB Sciex 5500 Q-trap or Applied Biosystems AB Sciex 5500 triple quad mass spectrometer (Applied Biosystems, Forster City, CA).
(5) Tecan Freedom EVO 150 robotic liquid handling system (Tecan Group Ltd., Switzerland).
(6) Sartorius Genius Series ME models electronic analytical & semi- microbalances (Sartorius AG, Goettingen, Germany).

(7) Sartorius top-loading balance (Sartorius AG, Goettingen, Germany).
(8) pH meter (AB 15 pH Meter, Fisher Scientific).
(9) Allegra 6 Centrifuge (Beckman Coulter)
(10) Vortexer (Fisher, Genie 2).
(11) Magnetic Stirrer (Corning).

F. Instrumentation

(1) On line SPE-HPLC-MS/MS Configuration

The on-line SPE-HPLC-MS/MS analytical system encompasses several Agilent 1260 modules coupled to an AB Sciex 5500 Q-trap/triple quad mass spectrometer equipped with an APCI interface.[7, 8] The on-line SPE-HPLC system consisted of two binary pumps with degassers, an autosampler with a 900-µL injection loop, a high pressure mixing Tee, and a column compartment with a ten-port switching valve. The mass spectrometer and HPLC modules were programmed and controlled using the Analyst 1.6.2 software (Applied Biosystems, Ontario, Canada). The SPE column was a LiChrosphere RP-18 ADS (25 × 4 mm, 25 µm particle size, 60 Å pore size, Merck KGaA, Germany), and the HPLC column was one Chromolith® High Resolution RP-18e column (100 × 4.6 mm; Merck KGaA, Germany).

The procedure for extracting target analytes from a urine sample involves concurrent SPE and HPLC-MS/MS cycles (Table 1). While the autosampler and Pump 1 are used for the SPE of one sample, the ten-port switching valve, Pump 2 and the mass spectrometer are used to acquire data from the previous sample. The HPLC-MS/MS acquisition method is built in ‘no sync’ mode (i.e., all devices are programmed to start at the same time). Different combinations of the autosampler valve, switching valve positions, and the timing of the gradient of the two binary pumps divide the single run into six periods to allow for concurrent regeneration and equilibration of the SPE column as well as for clean-up of the next sample, and for HPLC-MS/MS analysis (Table 1, Figure 1).

First, analytes from the previously injected sample that had been retained by the SPE column are eluted using 50% MeOH:50% water at 0.40 mL/min provided by pump 2. Through a mixing Tee, the 0.40 mL/min SPE elute is diluted with 100% water (0.55 mL/min) provided by pump 1, and then, the analytes are transferred to the HPLC column (Figure 1A, Table 1).

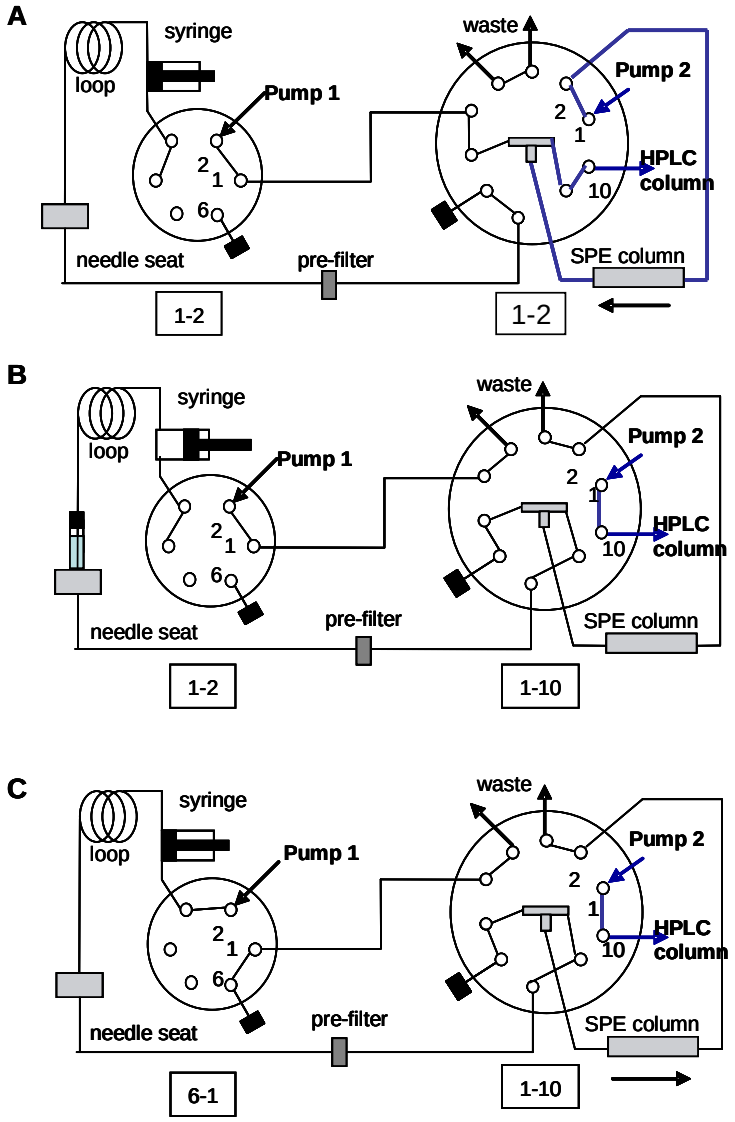
At 2 minutes, the collection of the HPLC-MS/MS data starts while the SPE column is regenerated and equilibrated with 100% MeOH (1 mL/min for 3 minutes) and 20% MeOH:80% water (1 mL/min for 4 minutes), respectively. The injection of sample is programmed as “350 µL sample draw” and “350 µL eject into the needle seat” commands in Analyst. Tube connections inside the autosampler are modified in-house to connect the needle seat directly to the SPE column. In this way, the execution of the “eject into the needle seat” command results in the loading of the sample directly onto the SPE column by the autosampler syringe (Figure 1B). A needle rinse, performed by lowering the needle into a vial containing MeOH, is included before the ejection. After the sample loading is complete, the SPE column with retained target analytes is

washed for 4 minutes using 20% MeOH:80% water at 1 mL/min flowrate while any unbound urine components are carried to waste (Figure 1C, Table 1). Sample analysis and data collection for a single HPLC-MS/MS run last for 18 minutes after which both HPLC pump and SPE pump are equilibrated for the next elution cycle (Table 1). To minimize ionization suppression through matrix effects and introduction of salt content into the mass spectrometer, the first three minutes of the HPLC eluent flow is discarded and diverted to waste.

Table 1. Concurrent SPE clean-up and HPLC-MS/MS analysis time line

Period			**1**	**2**	**3**	**4**	**5**		**6**
Time (min)		0	0.1-2.5	2.6 - 6	6.1 - 9	9 - 12	12-16	16-18	18.1-19
SPE of Sample N+1		Start	Analyte Transfer and dilution	Rege-nerate SPE colum n	Equi-librate SPE column	Sample loading	SPE column Wash	wait for equili-bration	Equi-librate SPE pump
	Auto-sampler valve	1-2	1-2	6-1	6-1	1-2	6-1	1-2	1-2
	mL/min **Pump 1** **MeOH%**	0	0.55 0%	1.0 100%	1.0 20%	1.0 20%	1.0 20%	1.0 20%	1.0 0%
HPLC of Sample N			Analyte Transfer		HPLC separation and MS/MS acquisition				Equi-librate Pump 2
	Ten-port valve	10-1	1-2	10-1					10-1
	mL/min Pump 2 **MeOH%**	0.4 50%	0.4 50%		0.90	HPLC gradient elution			0.90
				Time (min)	2.6-11	11.1-17	17-18		50 %
				MeOH%	50-65 (0.75 mL/min)	65-100	100		

Figure 1. Tubing set-up for the autosampler and ten-port valves with configurations for 3 selected periods of Table 4: A) Analyte transfer and dilution (Period 1), B) Sample loading (Period 4) and C) SPE column wash (Period 5).



(2) Mass Spectrometry

The AB Sciex 5500 Q-trap/triple quad mass spectrometer is used in negative ion APCI mode. Laboratory-grade air is used for both auxiliary gas and nebulizing gas. The negative fragment ions used for quantification and the retention time for the analytes are listed in Table 2.

Table 2. Analyte retention time (RT) and precursor ions -> product ion transitions monitored for quantitation (and confirmation) of native compounds and corresponding internal standards.

Analyte	RT (min)	Precursor Ion -> Product Ion (m/z)	
		Native Analyte	Internal Standard
Bisphenol S	5.5	249->156 (108)	261->162
Methyl paraben	6.6	151->92 (136)	155->96
Ethyl paraben	8.4	165->92 (137)	169->96
Bisphenol F	8.7	199->105 (93)	211->111
Propyl paraben	11	179->92 (136)	183->96
Bisphenol A	11.7	227->133 (212)	239->139
2,5-Dichlorophenol	11.8	161->125 (163-	167->131
2,4-Dichlorophenol	12.3	161->125 (163-	167->131
Butyl paraben	13.7	193->92 (136)	197->96
Benzophenone -3	15.7	227->183 (167)	231->183
Triclocarban	17.4	313->160 (126)	319->160
Triclosan	17.5	161->125 (252-216)	167->131 (264-228)

7. Calibration and Calibration-Verification Procedures

A. Mass Spectrometer

At least once per year, the mass spectrometer is calibrated and tuned by a qualified service engineer using a solution of polypropylene glycol polymer (PPG).

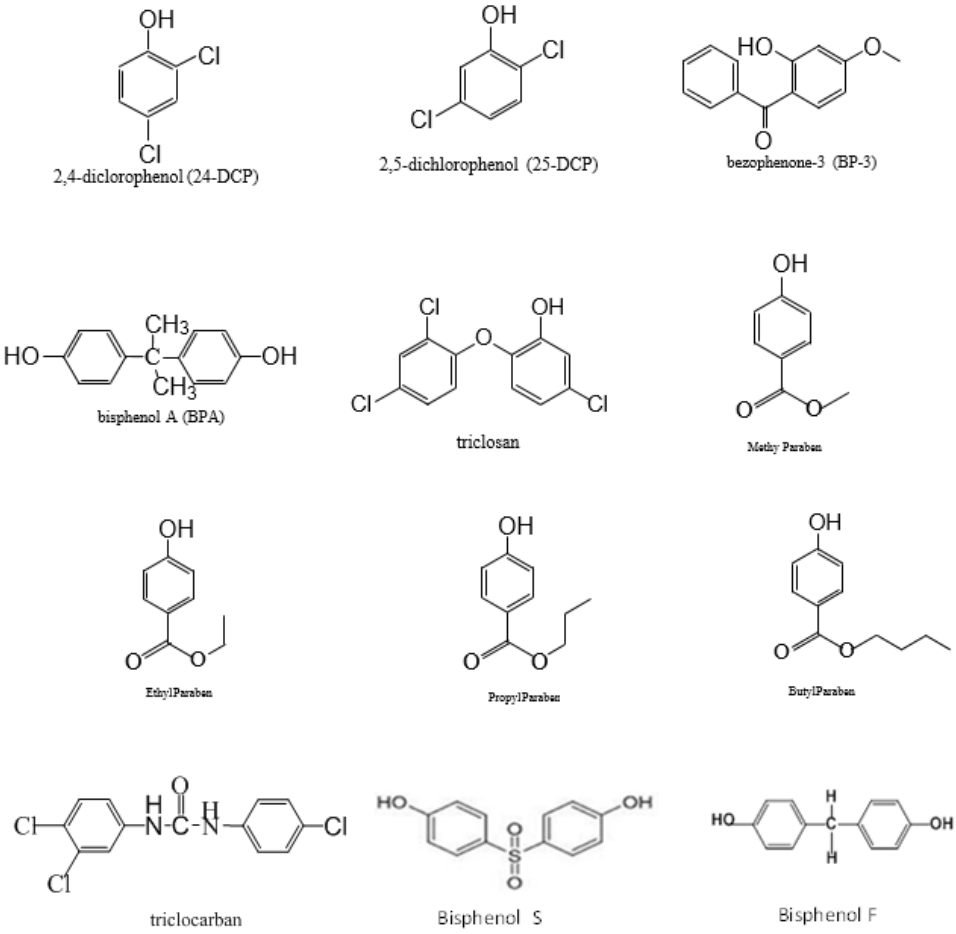
B. Calibration Verification

(1) Calibration verification is not required by the manufacturer. However, it should be performed after any substantive changes in the method or instrumentation (e.g., new internal standard, change in instrumentation), which may lead to changes in instrument response, have occurred.
(2) All calibration verification runs and results shall be appropriately documented.
(3) According to the updated Clinical Laboratory Improvement Amendments (CLIA) regulations-2003 the requirement for calibration verification is met if the test system's calibration procedure includes three or more concentrations of calibration material, and includes a low, a mid, and a high value, and is performed at least once every six months.
(4) All of the conditions above are met with the calibration procedures for this method. Therefore, no additional calibration verification is required by CLIA.

C. Proficiency Testing

(1) Three pools of proficiency testing (PT) samples encompassing the entire linear range of the method, are prepared in-house as described in the standard preparation section. Characterization of PT materials requires at least 20 separate determinations. Once the PT pools are characterized, the mean concentration and standard deviation of the PT materials are forwarded to a DLS representative responsible for executing the PT program (PT administrator). These PT samples are blind-coded by the PT administrator and returned to the laboratory staff for storage.
(2) Proficiency testing should be performed a minimum of once per 6 months. When proficiency testing is required, the laboratory supervisor or his/her designee will notify the PT administrator who will randomly select five PT materials for analysis. PT samples will be analyzed in exactly the same way as routine unknown samples. Following analysis, the results will be forwarded directly to the PT administrator for evaluation. A passing score is obtained if at least four of the five samples fall within the prescribed limits established by the PT administrator. The PT administrator will notify the laboratory staff of the PT results (i.e. pass/fail).
(3) All proficiency results shall be appropriately documented.
(4) In addition to the in-house PT program, we are participating in the ongoing German External Quality Assessment Scheme (G-EQUAS) organized and managed by the Institute and Outpatient Clinic for Occupational, Social and Environmental Medicine of the University of Erlangen-Nuremberg (Erlangen, Germany). A minimum of once per year since 2006, we analyze two reference urine samples fortified with select target phenols (e.g., BPA since 2009 as part of G-EQUAS 44 and triclosan since 2017 as part of G-EQUAS 59). The program, evaluation, and certification are based on the guidelines of the German Federal Medical Council. Since 2015, twice a year, we also participate in the ongoing External Quality Assessment Scheme for organic substance in urine (OSEQAS) (e.g., BPA and triclosan), conducted by the Institut National de Santé Publique du Québec (INSP) in Canada.

D. Analytes nomenclature and structures



8. Operating Procedures; Calculations; Interpretation of Results

A. Sample and standards preparation with Surveyor Plus Autosampler

(1) Preliminaries

a) Remove urine samples, standard stock solutions, deconjugation standard solution and quality control (QC) materials from the freezer or refrigerator.
b. Prepare enzyme/buffer solution. Gently mix the enzyme and transfer the enzyme solution to Reservoir B of the Surveyor autosampler
c. Load 20 mL of 1M formic acid to Reservoir C of the Surveyor autosampler.
d. Fill reservoir D with MeOH.
e. Mix equal volumes of methanol and premixed IS + deconjugation standard solution in a Falcon tube. Load 16 mL of the prepared mixture in Reservoir A of the Surveyor autosampler. To prevent the binding of IS to the surface of the glass reservoir, replace the reservoir and its cap with new ones for each batch.

f. Load an empty autosampler vial without the lid onto A1 position of the Surveyor autosampler.
g. Fill the wash bottle of the Surveyor autosampler with HPLC grade water.

(2) Preparation of samples with Surveyor Plus Autosampler

a) Include up to 50 unknown samples, 11 standards, 2 QC blanks, 2 empty vials (dummies), 2 QCs of low concentration (QCL) and 2 QCs of high concentration (QCH) in each batch. Label the autosampler vials. Print out the Sample Log Sheet with Sample Name and batch name.
b) Add 100 µL of urine or QC sample. For standards, add 100 µL of standard stock solution, and for the reagent blank (QCB), add 100 µL of HPLC grade water instead.
c) The vials are capped with Teflon-lined screw caps and loaded onto the sample trays of the Surveyor autosampler.
d) The autosampler tray is set at 5 ^{o}C.
e) 200 µL of premixed solution (50 % Methanol:50 % IS and deconjugation standard) and 100 µL of enzyme solution are automatically added to each vial. Because the deconjugation of triclocarban metabolites requires a larger amount of enzyme, we add 100 µL of MeOH to each sample to prevent potential binding of other deconjugated analytes (e.g., methyl paraben) to the enzyme.
f) The mixing step is carried on by withdrawing 100 µL of air from the empty vial at position A1 and dispensing 100 µL of air into each sample. The regular mixing command could cause carryover problems and therefore can't be used.
g) After IS, deconjugation standard, MeOH, and the enzyme are added to all of the samples, the temperature of the autosampler tray is set to 37 ^{o}C for 4 hrs.
h) After incubation, the temperature of the autosampler tray is set to 5 ^{o}C. Then, 80 µL of 1M formic acid, and 520 µL of H_2O are added automatically to stop the enzyme activity.
i) Alternative sample and standards preparation with Tecan Freedom EVO1500 system

(3) Sample and standard pretreatment by Tecan

a) Remove urine samples, standard stock solutions, deconjugation standard solution and quality control (QC) materials from the freezer or refrigerator. Thaw all vials to room temperature.
b) Fill the Tecan system liquid container with HPLC grade H_2O if necessary and ensure all lines are tight.
c) Turn (Julabo) recirculator and the thermostat ON. Press OK on the thermostat to set the temperature to 25^{o}C.
d) Add ~60-80 mL of 90% EtOH to Trough #4 (Right/Rear) and Trough #5 if 2+ batches are run.
e) Place QCs and STDs in the rack for the standards in the following order (from rear to front of Tecan): QCB, QCL, QCH, S1-S11, Dummy/H_2O. Ensure there is at least 300 µL of liquid in each glass vial.
f) Place UNKs in the sample rack sequentially, beginning from rear to front of Tecan. Ensure the UNK vials are loosely capped and the STD/QC vials

are snugly capped. The sample tubes should be placed in the rack so that the bar code faces to the front. .

g) Print labels and affix to blue-topped autosampler vials or use tube writer to print labels and then place vials in the destination racks in sequential order.
h) Turn on TECAN and open Program. If it is the first run of the day, run the "Daily Wash" script.
i) Run the "Phenol_2016" script and input the necessary information (File Name, Date, User ID, etc).
j) Enter number of UNK samples (# _____)
k) Begin TECAN run, entering run info in TECAN log.
l) Include up to 50 unknown samples, 11 standards, 2 QC blanks, 2 empty vials (dummies), 2 QCLs and 2 QCHs for each batch.
m) The Tecan software is programmed to add 100 µL of urine or QC sample, 100 µL of standards, and 100 µL of HPLC grade water for QCB and Dummy. 200 µL of premixed solution (50 % Methanol:50 % IS and deconjugation standard) and 100 µL of enzyme solution are then added to each vial.
n) After mixing step, the destination sample tray is then transferred to Surveyor autosampler for incubation followed by halting of the enzymatic process.

(4) Sample Incubation by Surveyor autosampler

a) Add 20 mL of 1.0 M formic acid to Reservoir C of the autosampler.
b) Add 20 mL of MeOH to Reservoir D.
c) Fill the wash bottle on top of the Surveyor with ≥ 18 MΩ·cm HPLC Grade H_2O and place the Reservoirs in the correct order inside the Surveyor.
d) Ensure the waste bottle beneath the Surveyor is not full; in the case that it is, empty and create a waste ticket.
e) Ensure the vial at position A1 is dry and empty.
f) For incubation, the temperature of the autosampler tray is set to 37 ^{o}C for 4 hrs to allow for the complete hydrolysis of the conjugates.
g) After incubation, the temperature of the autosampler tray is set to 5 ^{o}C. Then, 80 µL of 1M formic acid, and 520 µL of H_2O are added automatically to stop the enzyme activity.

B. Prepare the samples for LC/MS/MS analysis

Take out the samples from the Surveyor autosampler. Vortex, and centrifuge the samples at 2500 RPM for at least 10 min, and then transfer the samples to the Agilent autosampler for on-line SPE-HPLC-MS/MS analysis.

C. Analysis

(1) Check out the LC/MS interface

a) Check the build-up of the salt on the corona needle. This build-up could cause poor ionization for some analytes. Change or clean the corona needle as necessary.

b) Open the rough pump cabinet, check for oil leaks and unusual noise. Report anything unusual.

(2) Check out the LC system

(a) Refill the mobile phase for both HPLC and SPE pumps directly from the original 4 L brown MeOH reagent bottles or water deionizer so the possibility of solvent contamination from a third container is eliminated.
(b) Because trace amounts of target analytes can be present in the SPE or HPLC solvents, we add two Betasil C18 guard cartridges, one right before the SPE solvent purge valve and the other one right before the HPLC solvent purge valve, to eliminate potential interferences from the solvents. The guard cartridge before the SPE purge valve retains the target analytes during the sample loading, so any interferences from the solvent will not be loaded onto the SPE column. The guard cartridge before the HPLC purge valve delays the retention of any interferences from the solvent, so the quantitation of the target analytes is not compromised.
(c) Change two inline-filters, which are located before SPE and HPLC columns, before each batch of samples.
(d) Change guard column before the HPLC column (Chromolith high resolution RP18e 25 X 4.6 mm HPLC column) after fifteen batches of samples.
(e) Reverse the direction of the HPLC columns after each batch to extend the life of the columns. Generally, replace with a new HPLC column every 30 batches.
(f) Make sure the proper Acquisition Method and Vial Position are entered, and then submit the batch. Open a window to display the chromatogram after the first QCB has been acquired and note intensities of specific ions. If peaks appear distorted (long tail, after-peak, too broad etc.) check with the lab supervisor or his/her designee.

(3) Building the batch files for sample preparation by Surveyor autosampler

c) From Excel, open up the text file containing the batch table created by Access. This file should not require any editing. Save the edited table into the text file named import.txt into the batch directory (overwrite). Remember to CLOSE THE FILE IN EXCEL!! Go to the analyst and import the import.txt file (In Batch File: Add Batch, Add Sample, Import from File (select appropriate text file), then chose G1329A Autosampler).
d) Check and make sure that the proper Acquisition Method and Quantitation Method are entered.
e) In the batch file, always submit a dummy sample first with the vial position of the first real sample. Then submit the batch file with the vial position of each sample shifting by 1. For example, if the sample is in position N, then in the batch file, the vial position for this sample should be N+1. Remember to put an empty vial right next to the last sample on the autosampler tray, so when the MS acquires data for the last sample, the autosampler will withdraw the sample from this empty vial, otherwise the system will stop and display an error message (missing vial). The reasons for building the sequence file this way have been explained before in Section of Instrumentation/On line SPE-HPLC-MS/MS Configuration.

(4) Building the batch files for sample preparation by Tecan

a) Obtain a copy of the desired Excel file in the “Phenol Barcode” folder from the TECAN PC. In the event that the system is unable to read the barcode or the barcode scan recorded any alpha characters (non-numeric):

i. Copy the “extsamname” column (External Sample Name, Column C) from the barcode scan Excel file.
ii. Paste this column into column C of the file “TECAN_BC_Macro_Template.xls” to convert the scanned information to universal database ID format.
iii. Copy the converted values back into the barcode scan Excel file.

b) In the Phenol Analyst database, import the barcode scan Excel file into “tLogin12,” then select “Finish Temporary Login” to create a logtext file (*.txt).

c) Prepare the text file prior to importing into Analyst by:

i. Inserting a Dummy row (see *Step E* below)
ii. Adjusting vial position and data file numbering
iii. Copying the Sample ID column into the Sample Name column.

d) Follow the above procedure to build a batch file for sample preparation using the Surveyor (step 3, b and c) to create the batch file in Analyst.

D. Processing

(1) Quantification

Automated data processing is performed by the cloud-based software “ASCENT” provided by Indigo BioAutomation solutions (Indianapolis, IN). All raw data files and quantitation results are stored in the cloud for retrieval. All quantitation results are automatically named as the batch file name and stored in excel format created by the software. Alternatively, raw data files can also be analyzed using the Quantitation Wizard application in Analyst, which also allows both automatic and manual peak selection, and area integration. All information, including sample name, sample ID and calculated concentration are exported into a tab delimited text file with the name YYYY-MMDD.txt. Processed data (excel from Indigo or text from Analyst) including peak area, peak height, retention time, analyte name, MRM name are imported into the Access database which also allows for data storage and future retrieval.

(2) Statistical Analysis and Interpretation of Data

Data are exported from the Access database to a fixed ASCII text file and imported into SAS. For statistical analysis, use the concentrations calculated by Indigo or the Analyst software. Standard curve generation, QC analysis, blank analysis, limit of detection determination, unknown calculations, and data distribution programs have been created and may be executed in SAS when such information is needed.

a) Replacement and periodic maintenance of key components

The instrumentation used is serviced according to the manufacturer's guidance included in the instrument manuals or based on the recommendation of experienced analysts/operators after following appropriate procedures to determine that the instrument performs adequately for the intended purposes of the method.

(3) AB Sciex 5500 Q-trap/Triple quad Mass Spectrometer

At least once a year, a preventative maintenance of the system is performed by a qualified service engineer. In addition, to ensure proper performance of the system, a periodic maintenance of the system (e.g., cleaning the APCI probe, the corona needle, and the curtain plate) may be required.

a) When a partial blockage of the vacuum is suspected, the orifice is probed with a syringe-cleaning wire.
b) Cleaning the spray shield and the entrance end of the heated capillary, described in the AB Sciex 5500 Q-trap/Triple quad Hardware Manual, is performed as needed. First, wash with a solution of water: methanol (1:1), second with 100 % methanol, then wipe it using flake free paper wipes.
c) The pump oil is changed approximately every six months as part of the periodic maintenance conducted by the service engineer.

(4) Agilent 1260 on line SPE-HPLC

a) At least once a year, a preventative maintenance of the system is performed by a qualified service engineer.
b) The solvent frits from the HPLC and SPE pumps are replaced after every 30 batches as a preventive measure to avoid high pressure problems. Additional maintenance of the on line SPE-HPLC is only necessary if a decrease in the system performance (low sensitivity, low resolution, and/or low S/N ratio) is detected.
c) The HPLC column needs to be replaced if the chromatographic resolution begins to fail.
d) If the analyte peaks start to tail, the problem may be with the HPLC or SPE column. Check each one individually for peak shape and replace as needed.
e) If high pressure error messages are observed, systematically check the purge valve frit, the inline-filter, analytical column frit, HPLC lines, needle seat, or injector components to find out the source of the plug and replace the part with a new one.

f) Reestablishment of performance and calibration. Each time the system is down for cleaning or maintenance, a MS operational check standard is analyzed to assess the system performance. For the mass spectrometer rerun of the system may or may not be necessary. If the instrument does not pass this test, then the instrument is retuned using PPGs as described previously.

9. Reportable Range of Results

The linear range of the standard calibration curves and the method limit of detection (LOD) determine the reportable range of results. The reportable range must be within the range of the calibration curves. However, samples with analytical data values exceeding the highest reportable limit may be diluted, re-extracted, and reanalyzed so that the measured value falls within the range of the calibration.

A. Linearity Limits

The high linearity limit is determined by the highest standard analyzed in the method. The low end of the linear range is limited by the method LOD. Concentrations which are below the method LOD are flagged as non-detectable. Calibration curves with a minimum of nine standard points are calculated for each batch from the area ratios ([analyte peak area]/ [internal standard peak area]) from freshly analyzed standards and linear regression analysis where each concentration is weighed by 1/[measured concentration]. Acceptable calibration curves have correlation coefficients normally greater than 0.98; the lowest calibration point should be at or below the LOD and the highest calibration point has to be above the expected range of results for most samples. Samples with concentrations exceeding the highest calibration standard are re-extracted using less urine.

B. Analytical sensitivity

The LOD and linear range of each analyte are listed in Table 3.

Table 3. Linear Range* of the Calibration Curve

Analyte	Linear range (ng/mL) LOD - Highest Standard
Bisphenol A	0.2-100
Triclosan	1.7-2000
Benzophenone-3	0.4-2000
2,4-dichlorophenol	0.1-100
2,5-dichlorophenol	0.1-1000
Methyl paraben	1.0-3000 **
Ethyl paraben	1.0-500 **
Propyl paraben	0.1-3000 **
Butyl paraben	0.1-500 **
Bisphenol F	0.2-100
Bisphenol S	0.1-100
Triclocarban	0.1-200

*To achieve a wider linear range, we detuned several analytes (e.g., BP-3, 2,5-DCP, M-Pb, E-Pb and P-Pb) by adjusting the collision energy away from their optimized values on the AB Sciex 5500 Q-trap or AB Sciex 5500.

**The linear range of the parabens for Q1 is LOD-100 ppb. Use Q2 for quantitation when the calculated Q1 concentration is above 100 ppb.

C. Accuracy

The accuracy is calculated from repeated analyses of synthetic urine spiked with standards. We use the isotope-dilution technique with isotope-labeled analytes, which allows for automatic recovery correction for each sample and improves the method accuracy (Table 4).

Table 4. Spiked Recoveries (%) of the Standards

	Spiking level (ng/ml)		
Analyte	**1.0**	**5.0**	**10.0**
Bisphenol A	104	102	99
Triclosan	108	103	99
Benzophenone-3	86	106	105
2,4-dichlorophenol	118	99	102
2,5-dichlorophenol	83	101	109

Methyl paraben	99	104	105
Ethyl paraben	106	107	106
Propyl paraben	107	106	105
Butyl paraben	103	106	102
Bisphenol F	91	102	103
Bisphenol S	107	104	105
Triclocarban	101	103	105

D. Precision

The precision of this method is reflected in the variance of two quality control (QC) pools over time. The coefficient of variation (CV) of repeated measurements of these QC pools is used to estimate the method precision. Table 5 lists the CV % for QCL and QCH for each analyte.

Table 5. Precision at two concentration levels using urine QC pools

Analyte	**QC High**		**QC Low**	
	Mean	**CV %**	**Mean**	**CV %**
Bisphenol A	9.69	3.95	1.40	7.20
Triclosan	50.94	4.59	16.31	8.44
Benzophenone-3	43.49	3.79	9.41	7.68
2,4-dichlorophenol	8.76	3.24	1.67	3.37
2,5-dichlorophenol	51.07	2.42	5.21	3.55
Methyl paraben	43.82	2.84	6.07	13.26
Ethyl paraben	20.63	2.33	4.95	4.11
Propyl paraben	20.69	2.70	5.12	4.15

Butyl paraben	10.17	3.15	2.11	4.35
Bisphenol F	9.94	3.88	2.00	4.80
Bisphenol S	10.27	2.48	2.12	4.48
Triclocarban	7.79	6.03	1.28	7.51

E. Analytical Specificity

The method requires that the analytes 1) coelute with the corresponding isotope labeled internal standard analog; 2) elute at a specific retention time; 3) have precursor ions with specific mass/charge ratios; and 4) have two specific product ions formed from the precursor ion with specific mass/charge ratios. The quantitation and confirmation ions for each analyte are listed in Table 2.

10. QC Procedure

A. Individual samples (i.e., standards, unknown samples, and quality control (QC) materials) QC procedures

(1) The relative retention time (RT) (ratio of $RT_{analyte}$ and RT_{IS}) of standards, unknowns, and QCs should be 0.90-1.10. If the relative RT falls outside this range, check the RT(s) of the peaks of analyte and IS to make sure the program picked the correct signals for integration.
(2) The area counts of IS for unknown samples should not deviate more than 75% from the mean area counts of IS for standards within the same batch. Low IS area count could indicate strong ion suppression from the matrix or simply missing of IS (i.e., error in spiking). Depending on the findings, either re-extract the original sample or dilute the sample first and re-extract it.
(3) The 4-UMB/4-UMB (IS) area count ratio for unknown samples should be greater than 0.4. This area ratio is used to monitor the efficiency of the enzyme.
(4) The calculated concentration of the reagent blanks (QCB) should be less than three times the LOD. All standards, blanks and unknown samples are prepared following the same procedure, thus the background, represented as the intercept of the calibration curve, is automatically subtracted. If background levels are consistently high, the reagents used for sample preparation and (or) mobile phases need to be checked for potential contamination.
(5) The ratio of the calculated concentration of the quantitation ion (Q1) and the calculated concentration of the confirmation ion (Q2) should be 0.7-1.3 when the Q1 concentration is greater than 10 times the LOD.
(6) Carryover check for sample (A+1) run after a sample (A) which contained a high concentration (e.g., ppm levels) of a given analyte. If the measured concentration of sample (A+1) is greater than 10 times the LOD and the calculated carryover (which is instrument-dependent) is greater than 30% of the measured concentration for sample (A+1), then sample (A+1) needs to be reanalyzed.

(7) If a given analyte concentration in an unknown sample is above the highest calibration standard, the sample needs to be re-analyzed with a smaller amount of urine.

B. Analytical batch quality control procedures

(1) QC Materials
(2) Quality control (QC) materials are prepared in bulk from urine pools collected from several anonymous donors. These QC samples are analyzed along with unknown samples to monitor for accuracy and precision throughout the analytical run
(3) QC Pools
(4) The QC pools were mixed uniformly, and divided into two subpools. The subpools were enriched with the target analytes as needed to afford low concentration (QCL, ~ 1.8-24 ng/mL) and high concentration (QCH, ~ 8.8-68 ng/mL) subpools. The pools were dispensed into glass sample vials and frozen until needed. The spiked QC pools should not be stored in polypropylene vials to avoid potential binding of some of the more hydrophobic compounds (e.g., BP-3, triclosan) to the plastic.
(5) Characterization of QC Materials
(6) The QC pools were characterized to define the mean and the 95% and 99% control limits of the target analytes concentrations from 60 QCL and 60 QCH runs over 3 weeks (Table 5). In each run, one pair of QCL and one pair of QCH materials were analyzed and averaged. Using the pair average value from the 60 runs, we calculated the mean, and upper and lower 99% and 95% control limits
(7) Use of Quality Control Samples
(8) Each analytical run consists of 56 samples: 2 QCL, 2 QCH, 2 reagent blanks, and up to 50 unknowns. The concentrations of the two QCH and the two QCL are averaged to obtain one measurement of QCH and QCL for each batch.
(9) Final evaluation of Quality Control Results

Standard criteria for run rejection based on statistical probabilities are used to declare a run either in-control or out-of-control. [10] When using 2 QC pool levels per run, the rules are:

Two QC pools *per run* with one QC result *per pool*

(1) If both QC run results are within $2S_i$ limits, then accept the run.
(2) If 1 of the 2 QC run results is outside a $2S_i$ limit - reject run if:

a) Extreme Outlier – Run result is beyond the characterization mean +/- $4S_i$
b) 3S Rule - Run result is outside a $3S_i$ limit
c) 2S Rule - Both run results are outside the same $2S_i$ limit
d) 10 X-bar Rule – Current and previous 9 run results are on same side of the characterization mean
e) R 4S Rule – Two consecutive standardized run results differ by more than $4S_i$. (Note: Since runs have a single result per pool for 2 pools, comparison of results for the R 4S rule will be with the previous result within run or the last result of the previous run. Standardized results are used because different pools have different means.)

Two QC pools *per run* with two or more QC results *per pool*

(1) If both QC run means are within $2S_m$ limits and individual results are within $2S_i$ limits, then accept the run.

(2) If 1 of the 2 QC run means is outside a $2S_m$ limit - reject run if:

a) Extreme Outlier – Run mean is beyond the characterization mean +/- $4S_m$
b) 3S Rule - Run mean is outside a $3S_m$ limit
c) 2S Rule - Both run means are outside the same $2S_m$ limit
d) 10 X-bar Rule – Current and previous 9 run means are on same side of the characterization mean

3) If one of the 4 QC individual results is outside a $2S_i$ limit - reject run if:

a) R 4S Rule – Within-run ranges for all pools in the same run exceed $4S_w$ (i.e., 95% range limit). Note: Since runs have multiple results per pool for 2 pools, the R 4S rule is applied within runs only.

Abbreviations:

S_i = Standard deviation of individual results (the limits are not shown on the chart unless run results are actually single measurements).
S_m = Standard deviation of the run means (the limits are shown on the chart).
S_w = Within-run standard deviation (the limits are not shown on the chart).

11. Remedial Action if Calibration or QC Systems Fail to Meet Acceptable Criteria

If the QC systems or the calibrations failed to meet acceptable criteria, all operations are suspended until the source or cause of failure is identified and corrected. Check for any irregularities (e.g., low calibration curve regression coefficient, change in slope or intercept, high reagent blank concentration, low internal standard sensitivity). If the source of failure is easily identifiable, for instance, a pipetting error, the problem is immediately corrected. Otherwise, fresh reagents are prepared and the mass spectrometer is cleaned. Before beginning another analytical run, several QC materials (in the case of QC failure) or calibration standards (in the case of calibration failure) are reanalyzed. After calibration or quality control has been reestablished, analytical runs may be resumed.

12. Limitations of Method; Interfering Substances and Conditions

Occasionally, the concentration of an analyte in urine is much higher than the highest standard in the calibration curve, and 100 µL of urine may be too much to use. In this case, a smaller aliquot of urine can be used to successfully extract the analytes. To mitigate partially co-eluting interferences to certain analytes, extra pre-column filter or guard column can be added before the HPLC column for further cleanup. The on-set time of mobile phase gradient can be altered to shift the retention time of the interfering or analyte peak. To maintain the sensitivity of the MS for analytes of interest, the detector voltage, collision energy and/or injection volume can be up or down adjusted.

13. Reference Ranges (Normal Values)

The results from the National Health and Nutrition Examination Survey (NHANES) are used as the reference ranges among the general U.S. population [11].

14. Critical-Call Results ("Panic" Values)

Insufficient data exist to correlate urinary concentrations of these environmental chemicals with serious health effects in humans. Therefore, critical call values have not been established.

15. Specimen Storage and Handling During Testing

Stability studies suggest that the samples remain stable at room temperature for up to one week if the concentrations of total species (free +conjugates) will be measured.[12]

16. Alternate Methods for Performing Test and Storing Specimens if Test System Fails

Validated SPE/derivatization-GC/MS analysis protocols are available on site if necessary for certain analytes.[13] However, because the GC/MS method is no longer maintained, it would be preferable to wait until the LC-MS/MS system is fixed.

17. Test-Result Reporting System; Protocol for Reporting Critical Calls (If Applicable)

a) The data from analytical runs of unknowns are initially reviewed by the laboratory supervisor. The supervisor provides feedback to the analyst and/or his/her designee and requests confirmation of the data as needed.
b) The Quality Control officer reviews each analytical run and identifies the quality control samples within each analytical run and determines whether the analytical run is performed under acceptable control conditions.
c) One of the Division statisticians reviews and approves the quality control charts pertinent to the results being reported.
d) If the quality control data are acceptable, the laboratory supervisor or his/her designee generates a memorandum to the Branch Chief, and a letter reporting the analytical results to the person(s) who requested the analyses to be signed by the Division Director.
e) The data are sent (generally electronically by e-mail) to the person(s) that made the initial request.
f) All data (chromatograms, etc.) are stored in electronic format.
g) Final hard copies of correspondence are maintained in the office of the Branch Chief and/or his/her designee and with the quality control officer.

18. Transfer or Referral of Specimens; Procedures for Specimen Accountability and Tracking

Standard record keeping systems (i.e. notebooks, sample logs, data files, creatinine logs, demographic logs) should be employed to keep track of all specimens. Specimens will only be transferred or referred to CLIA certified laboratories. One spreadsheet form (CLIA Specimen Tracking Records) with information for receiving/transferring specimens is kept in the laboratory. In this form, the samples received are logged in when received

and when stored/transferred after analysis. For NHANES samples, the person receiving the specimens signs and dates the shipping manifests. The shipping manifests for NHANES and other samples are kept in a binder in the Laboratory.

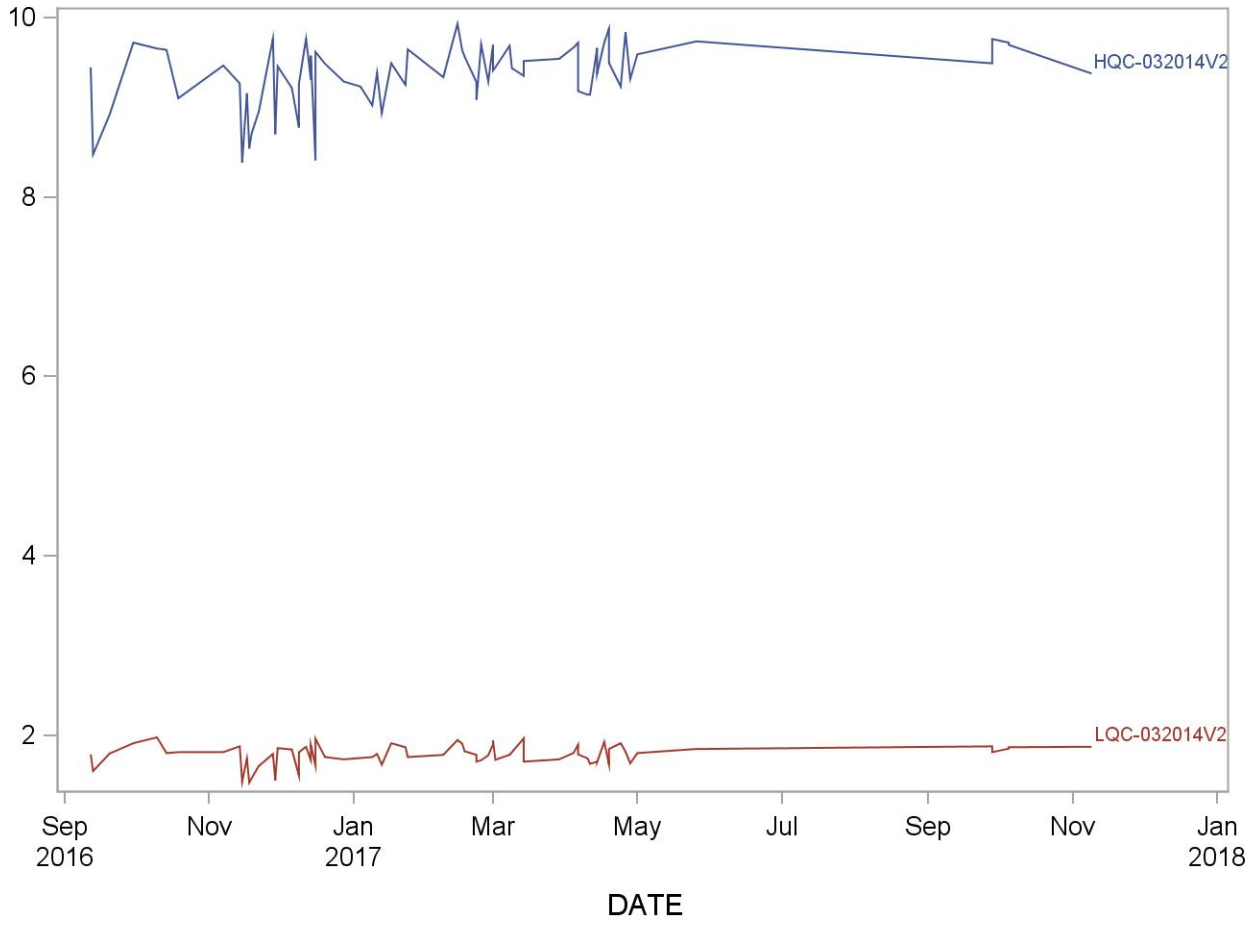
Use of trade names is for identification only and does not imply endorsement by the Public Health Service or the U.S. Department of Health and Human Services.

19. Summary Statistics and QC Charts

Please see following pages

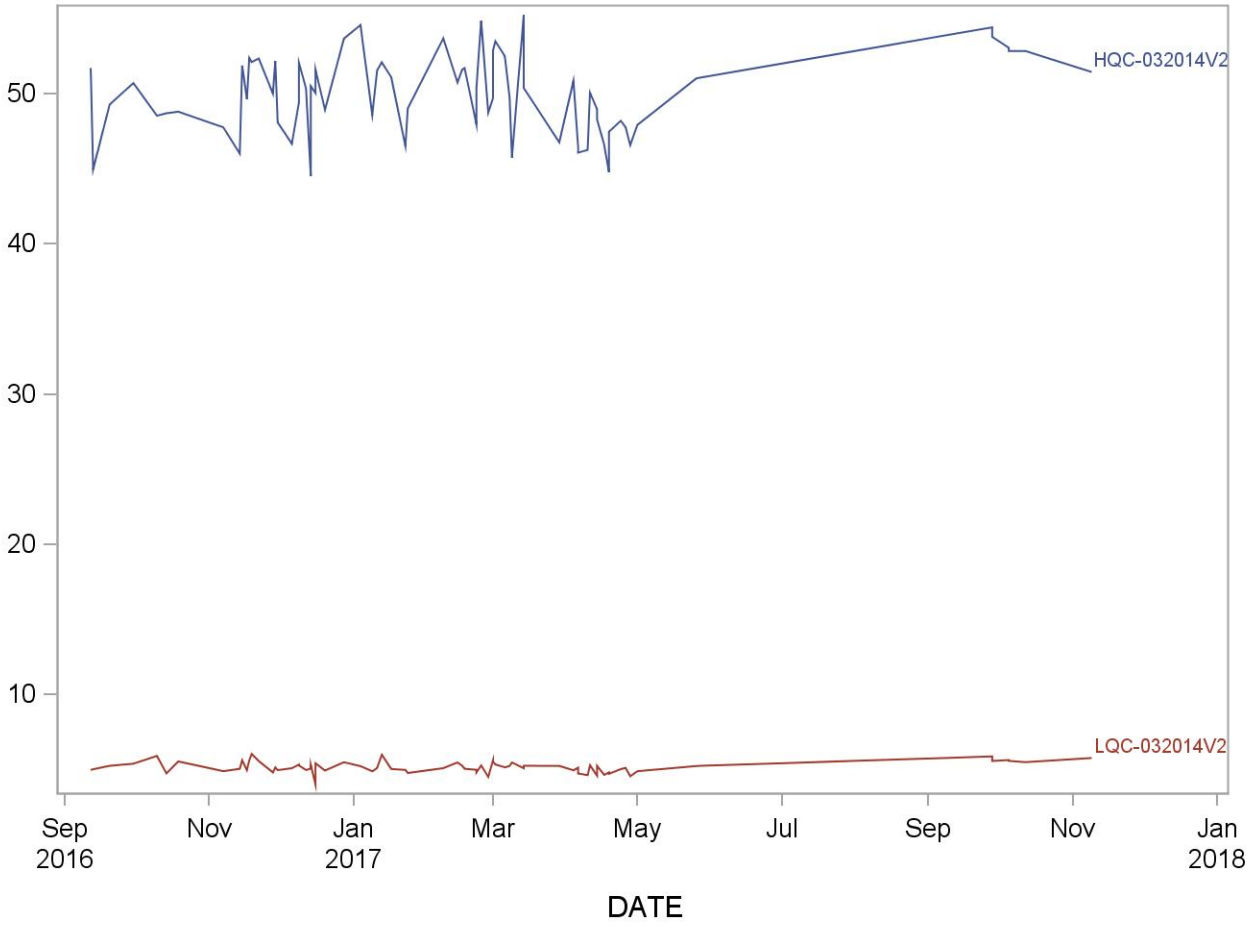
2015-2016 Summary Statistics and QC Chart for 2,4-dichlorophenol (ug/L)

Lot	N	Start Date	End Date	Mean	Standard Deviation	Coefficient of Variation
HQC-032014V2	70	12SEP16	09NOV17	9.37	0.36	3.8
LQC-032014V2	70	12SEP16	09NOV17	1.78	0.11	6.4



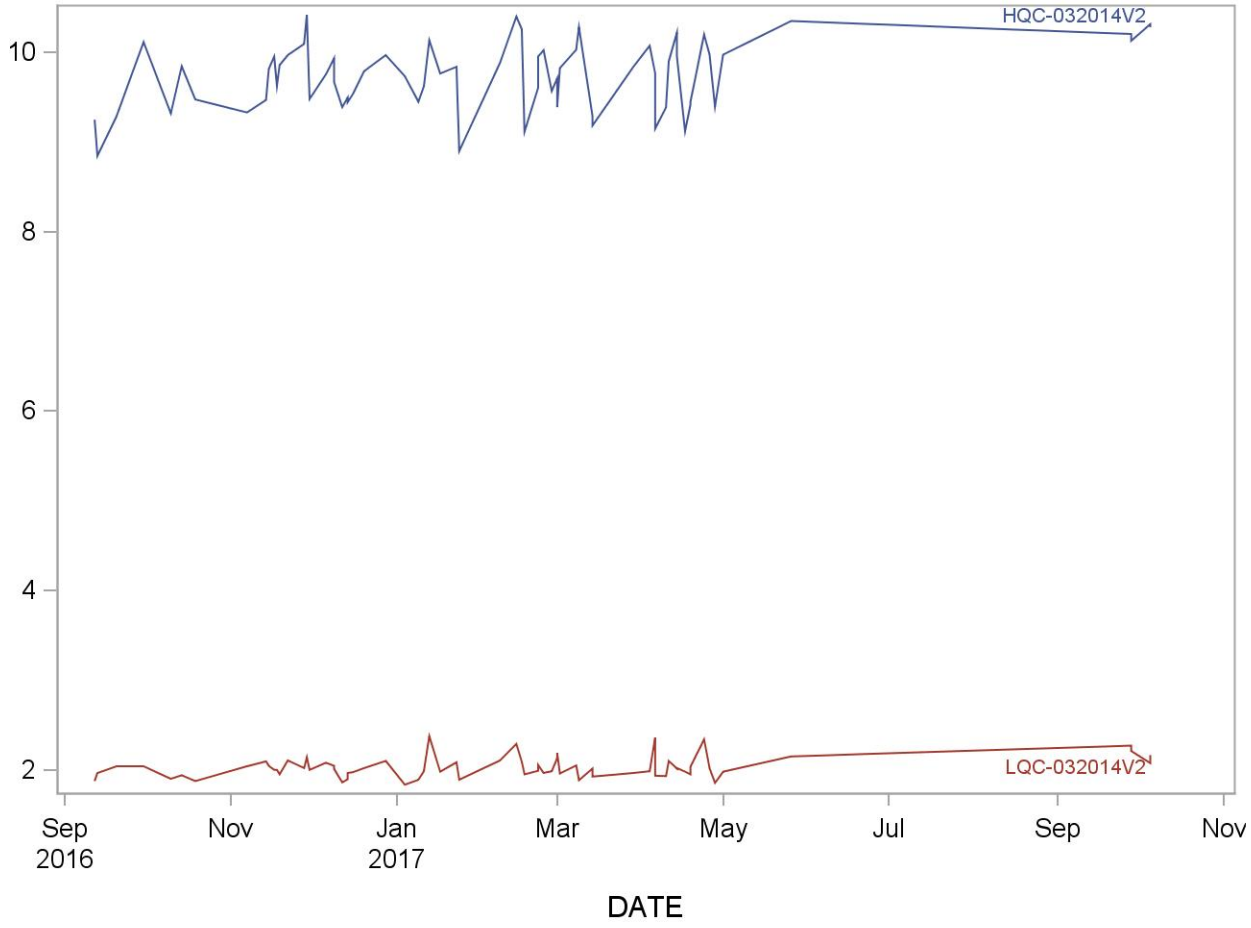
2015-2016 Summary Statistics and QC Chart for 2,5-dichlorophenol (ug/L)

Lot	N	Start Date	End Date	Mean	Standard Deviation	Coefficient of Variation
HQC-032014V2	72	12SEP16	09NOV17	49.97	2.66	5.3
LQC-032014V2	72	12SEP16	09NOV17	5.16	0.38	7.3



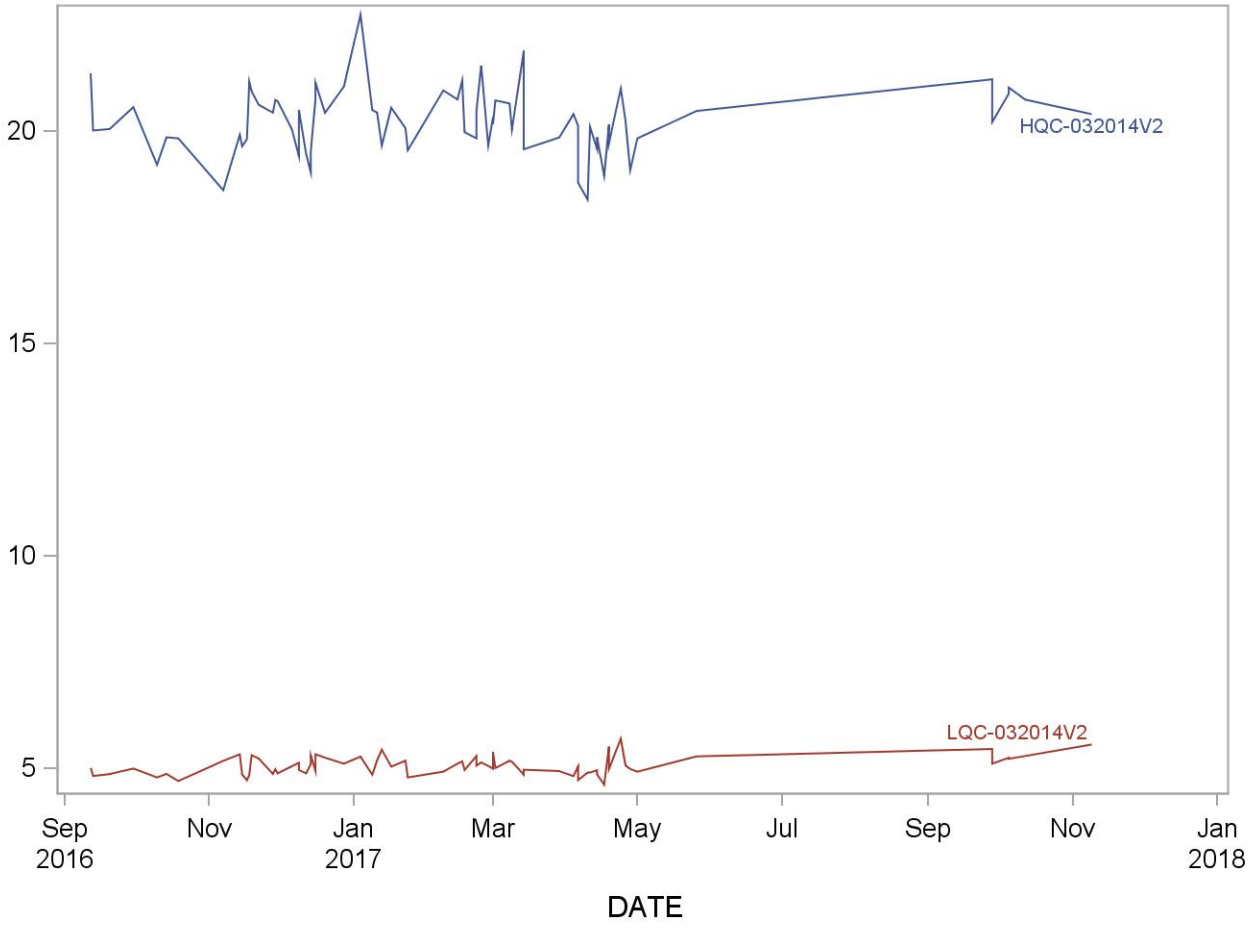
2015-2016 Summary Statistics and QC Chart for Butyl paraben (ng/ml)

Lot	N	Start Date	End Date	Mean	Standard Deviation	Coefficient of Variation
HQC-032014V2	68	12SEP16	05OCT17	9.74	0.38	3.9
LQC-032014V2	68	12SEP16	05OCT17	2.03	0.12	5.8



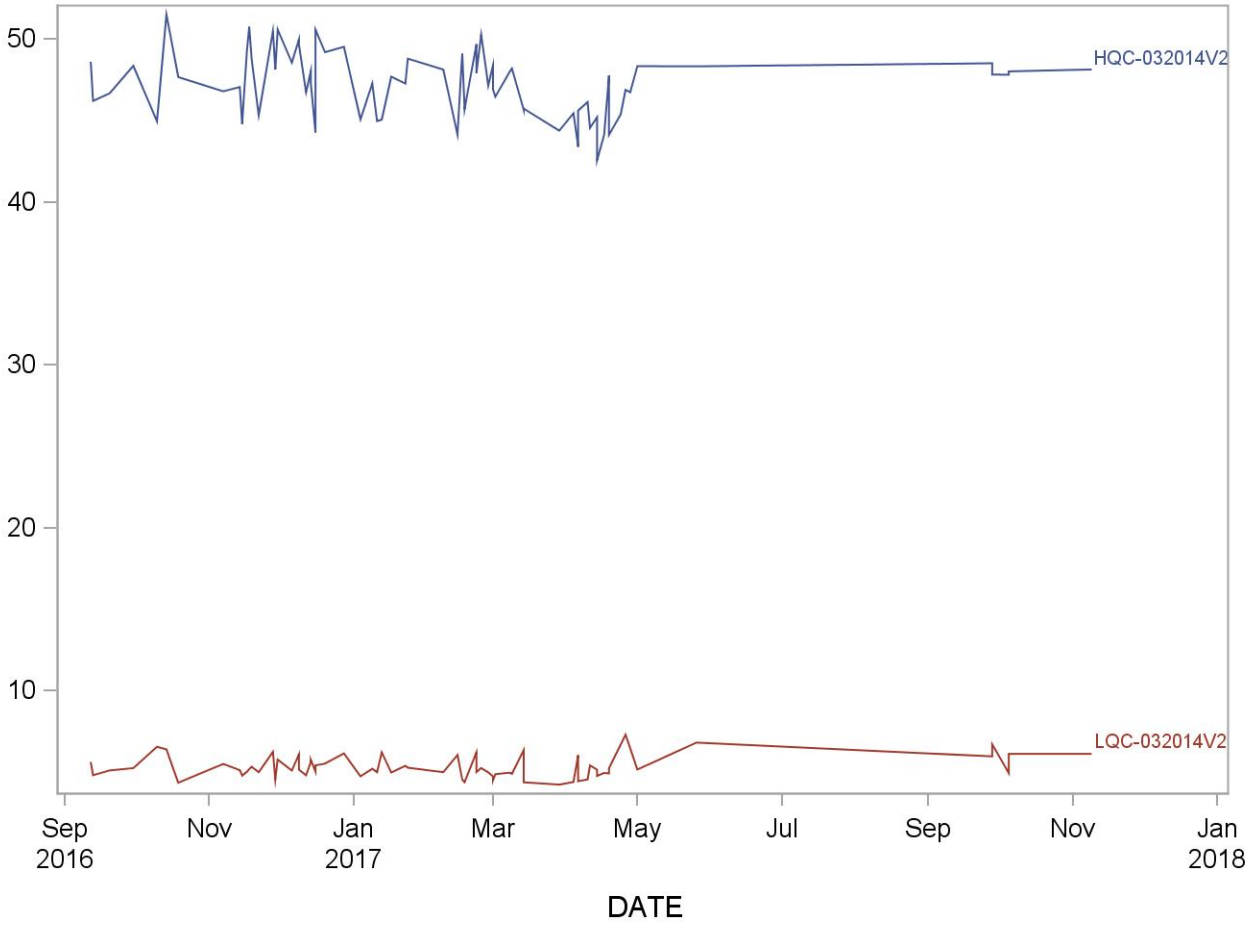
2015-2016 Summary Statistics and QC Chart for Ethyl paraben (ng/ml)

Lot	N	Start Date	End Date	Mean	Standard Deviation	Coefficient of Variation
HQC-032014V2	71	12SEP16	09NOV17	20.24	0.76	3.8
LQC-032014V2	71	12SEP16	09NOV17	5.06	0.22	4.3



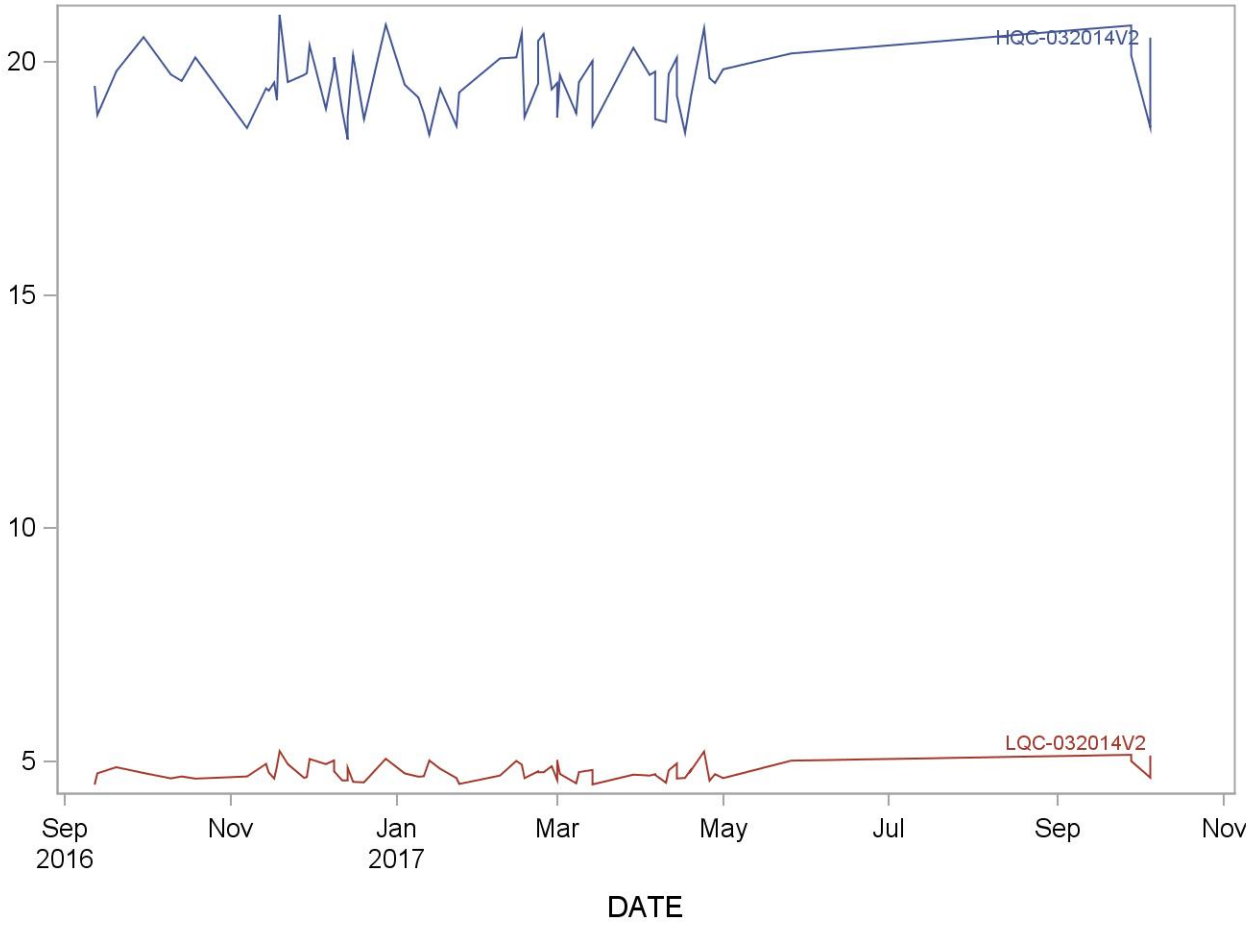
2015-2016 Summary Statistics and QC Chart for Methyl paraben (ng/ml)

Lot	N	Start Date	End Date	Mean	Standard Deviation	Coefficient of Variation
HQC-032014V2	70	12SEP16	09NOV17	47.22	1.99	4.2
LQC-032014V2	70	12SEP16	09NOV17	5.35	0.70	13.1



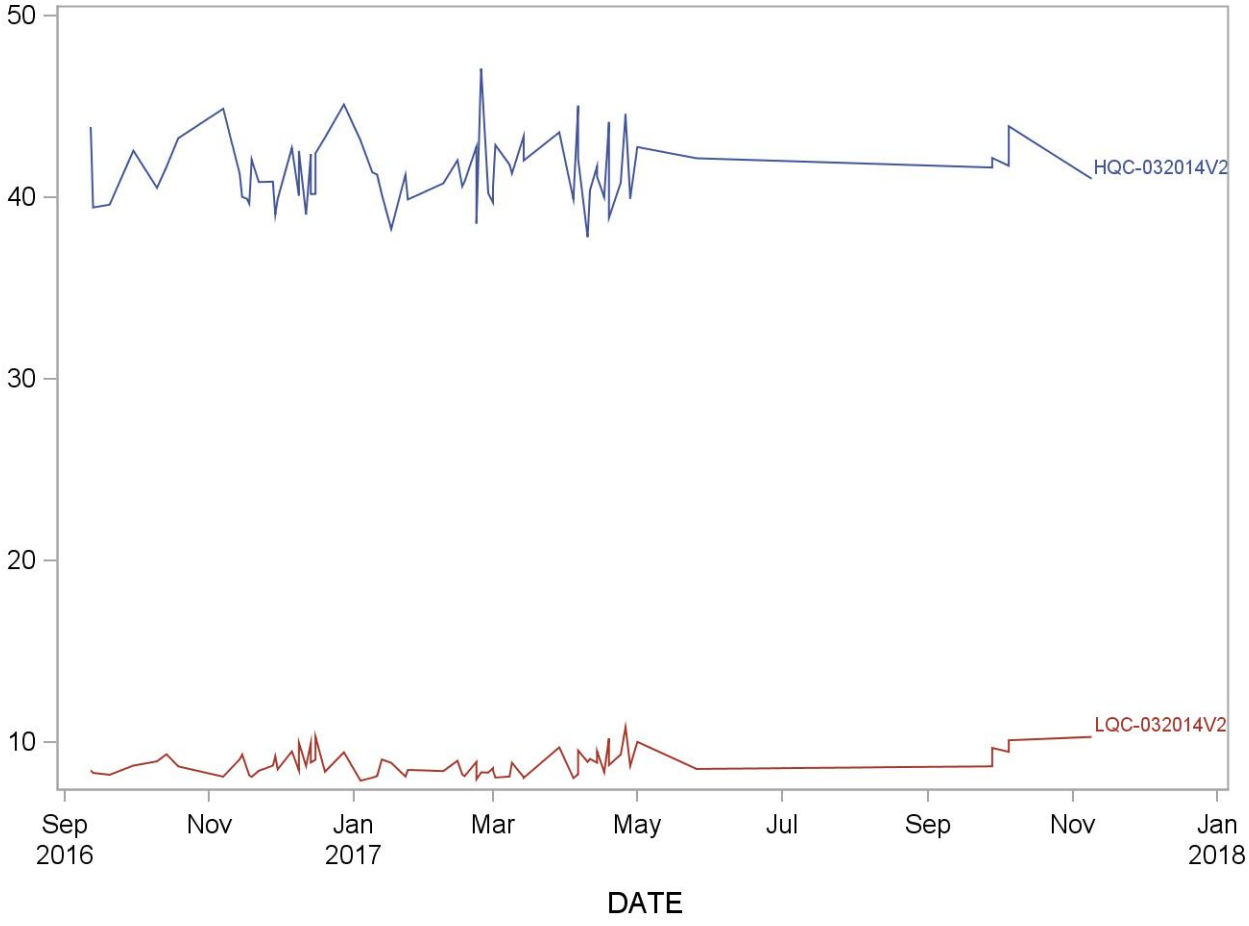
2015-2016 Summary Statistics and QC Chart for Propyl paraben (ng/ml)

Lot	N	Start Date	End Date	Mean	Standard Deviation	Coefficient of Variation
HQC-032014V2	68	12SEP16	05OCT17	19.58	0.67	3.4
LQC-032014V2	68	12SEP16	05OCT17	4.78	0.18	3.8



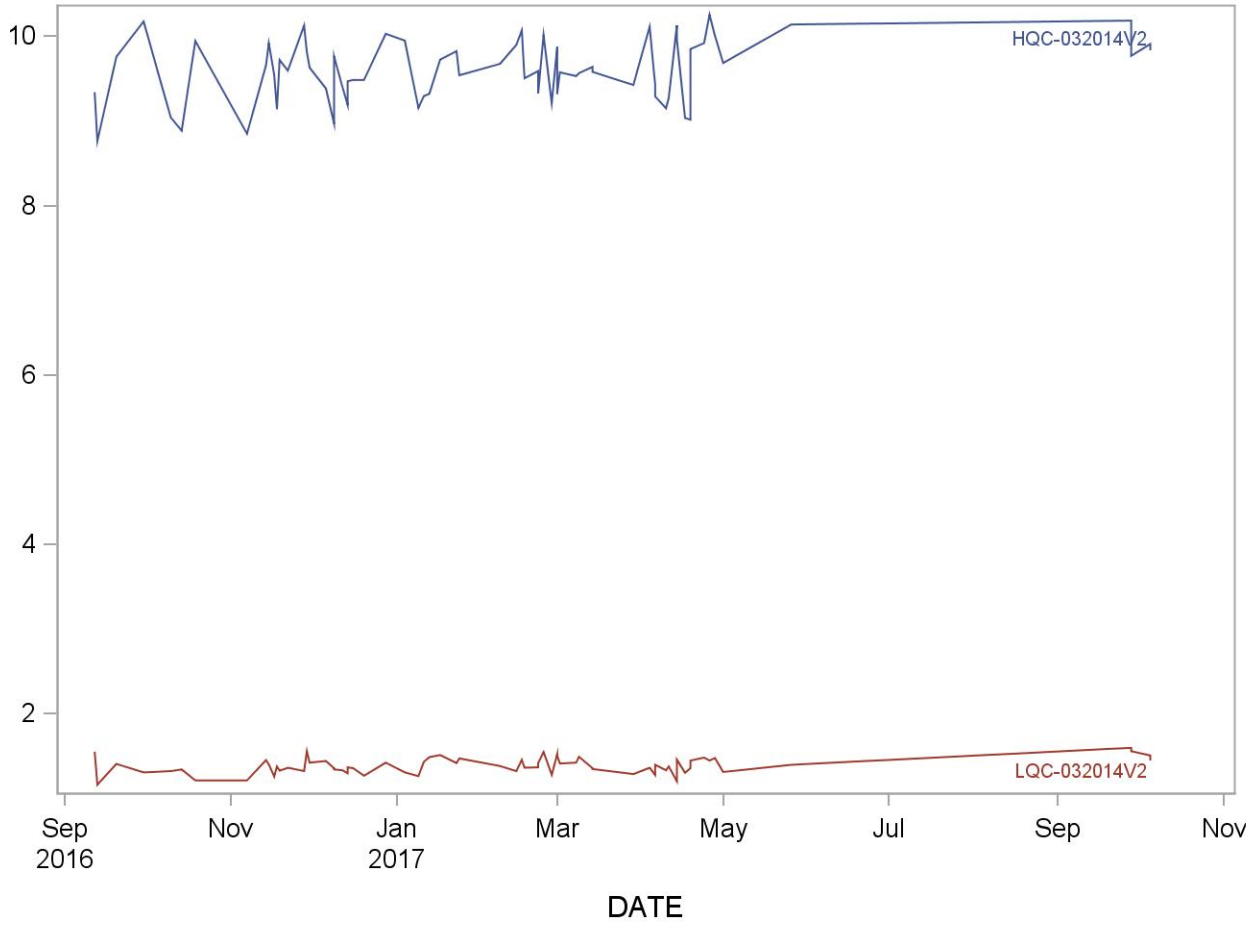
2015-2016 Summary Statistics and QC Chart for Urinary Benzophenone-3 (ng/mL)

Lot	N	Start Date	End Date	Mean	Standard Deviation	Coefficient of Variation
HQC-032014V2	70	12SEP16	09NOV17	41.46	1.80	4.3
LQC-032014V2	70	12SEP16	09NOV17	8.85	0.69	7.8



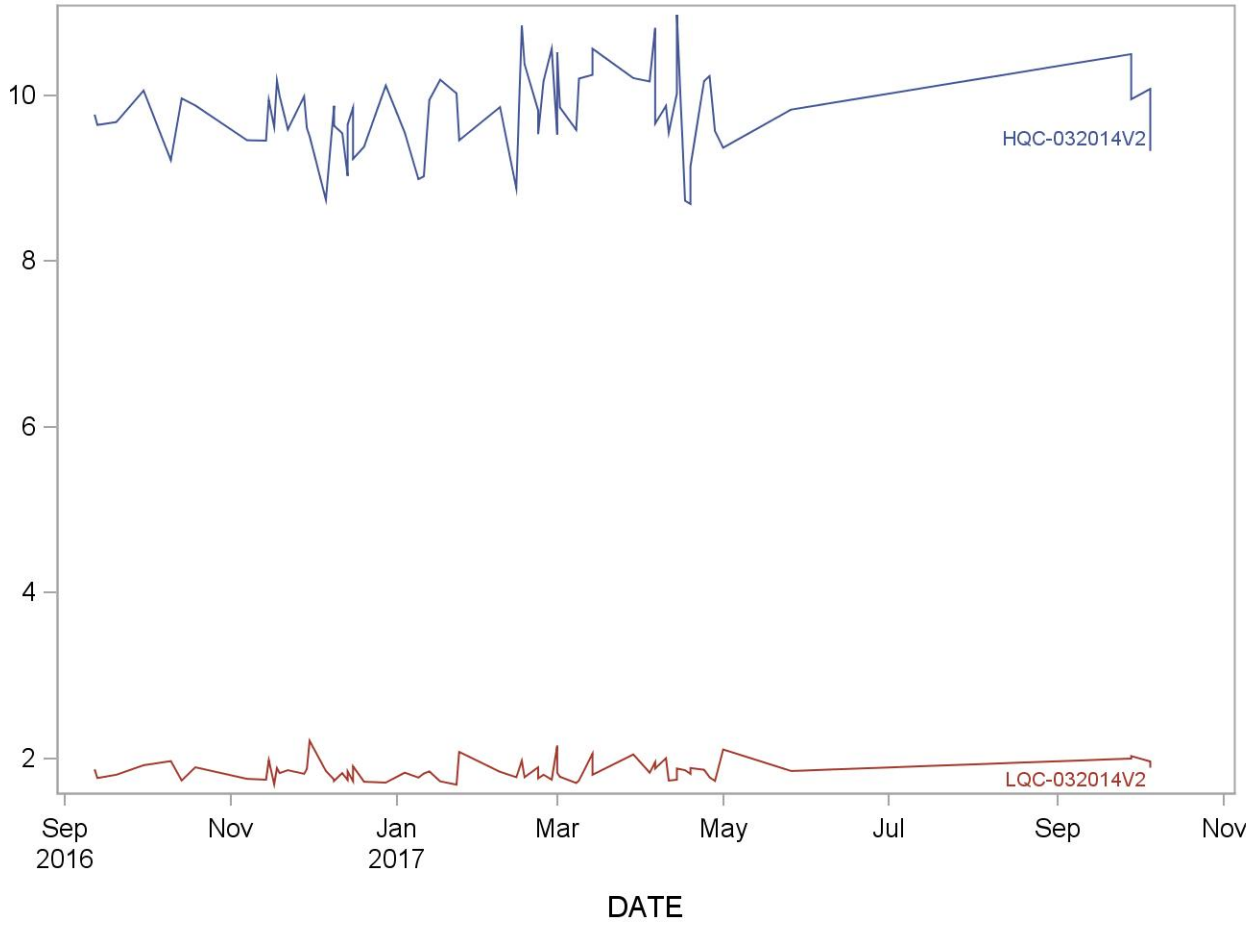
2015-2016 Summary Statistics and QC Chart for Urinary Bisphenol A (ng/mL)

Lot	N	Start Date	End Date	Mean	Standard Deviation	Coefficient of Variation
HQC-032014V2	68	12SEP16	05OCT17	9.60	0.37	3.8
LQC-032014V2	68	12SEP16	05OCT17	1.38	0.09	6.8



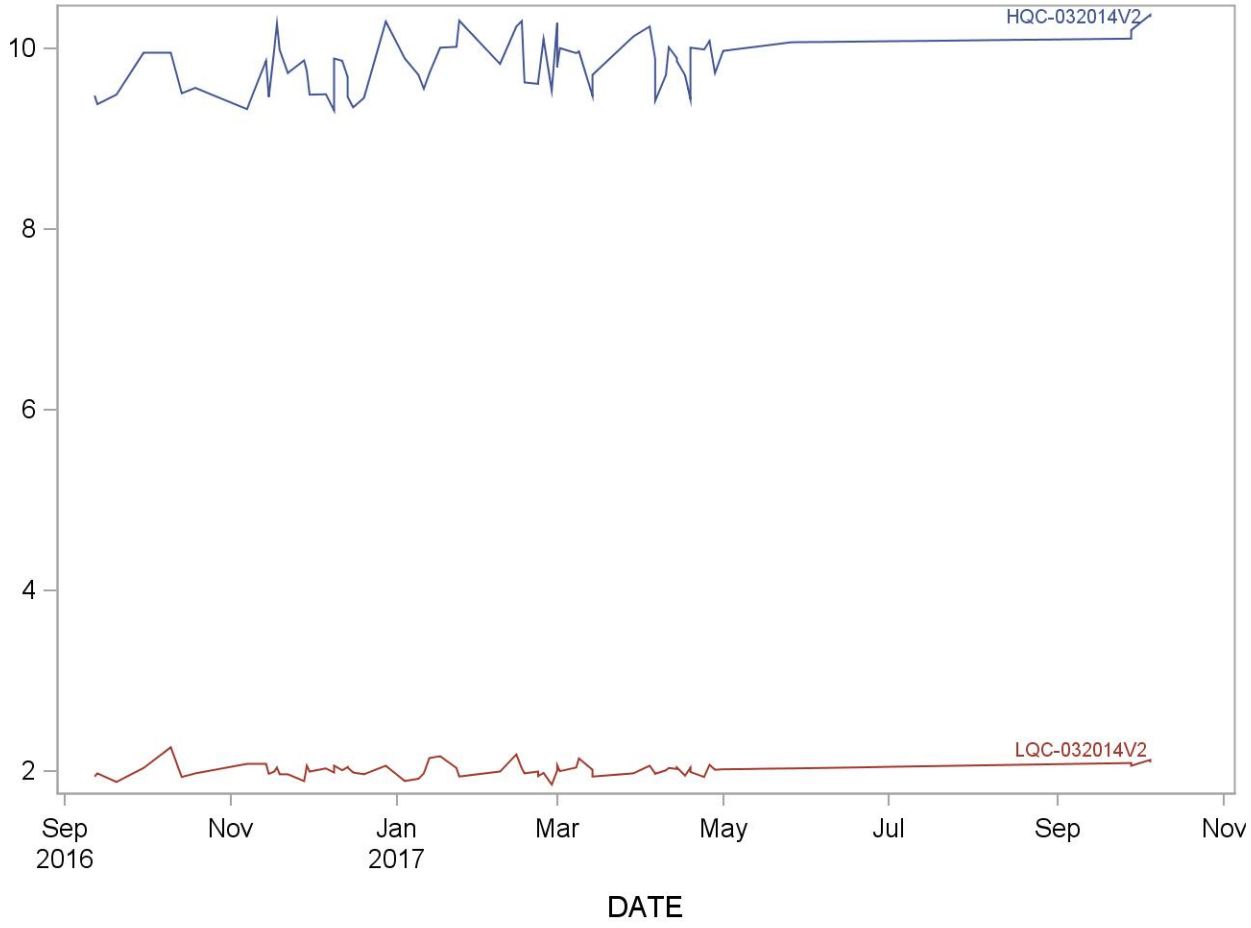
2015-2016 Summary Statistics and QC Chart for Urinary Bisphenol F (ug/L)

Lot	N	Start Date	End Date	Mean	Standard Deviation	Coefficient of Variation
HQC-032014V2	69	12SEP16	05OCT17	9.79	0.50	5.1
LQC-032014V2	69	12SEP16	05OCT17	1.85	0.12	6.3



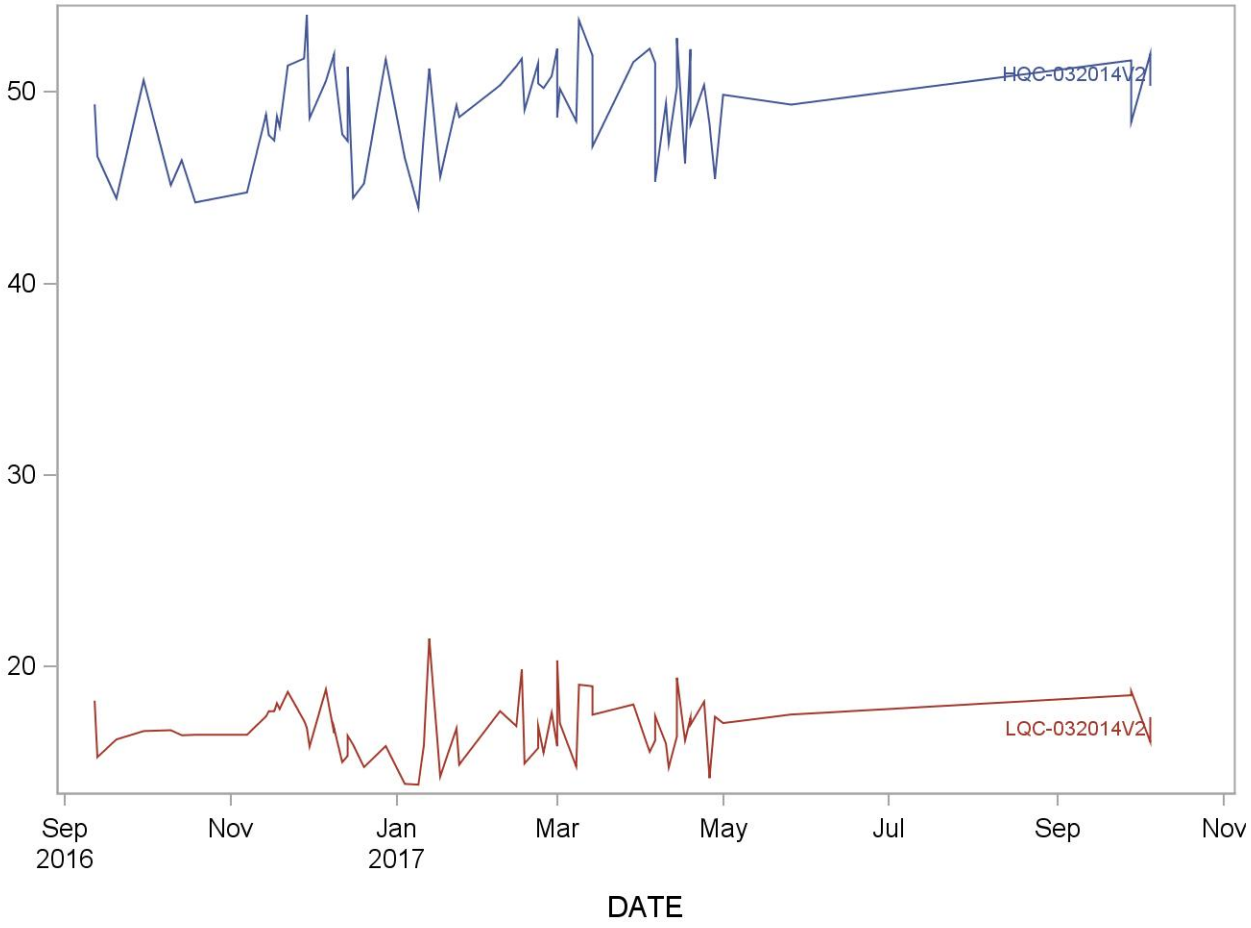
2015-2016 Summary Statistics and QC Chart for Urinary Bisphenol S (ug/L)

Lot	N	Start Date	End Date	Mean	Standard Deviation	Coefficient of Variation
HQC-032014V2	68	12SEP16	05OCT17	9.82	0.29	3.0
LQC-032014V2	68	12SEP16	05OCT17	2.01	0.07	3.6



2015-2016 Summary Statistics and QC Chart for Urinary Triclosan (ng/mL)

Lot	N	Start Date	End Date	Mean	Standard Deviation	Coefficient of Variation
HQC-032014V2	68	12SEP16	05OCT17	49.18	2.55	5.2
LQC-032014V2	68	12SEP16	05OCT17	16.78	1.54	9.2



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