Analysis of Wastewater and Sludge/Biosolids for Pharmaceuticals and Personal Care Products (PPCPs)

1. INTRODUCTION

First established by the *Department of the Environment Act* in 1971, Environment and Climate Change Canada's (ECCC's) role is to assess, monitor and protect the environment, and to provide weather and meteorological information to keep Canadians informed and safe.

ECCC's Acts outline the Department's obligations and authorities to conduct and publish research, monitor and publish environmental indicators, make regulations to protect the environment, and consult with partners. ECCC administers or shares responsibility for over two dozen Acts addressing issues as diverse as pollution prevention, weather modification, wildlife protection and emergency management.

Water quality is defined in terms of the chemical, physical, and biological content of water. The Federal government, particularly ECCC, plays a leading role in scientific research and monitoring of water quality. The Chemicals Management Plan (CMP, www.chemicalsubstances.gc.ca) provides a transparent, systematic, scientifically-based program to assess and manage the risks posed by chemical substances to the health of Canadians and their environment, including monitoring of wastewater inputs into receiving waters.

2. BACKGROUND

Pharmaceuticals and personal care products (PPCPs) enter the aquatic and terrestrial environment via effluent discharges and land application of biosolids from Canadian wastewater treatment plants (WWTPs). ECCC developed a monitoring program to determine the occurrence and fate of PPCPs during the wastewater treatment process. This program requires high-quality chemical analysis of many PPCPs that may be present at trace levels in wastewater raw influent, treated effluent, raw sludge, and treated biosolids. The results of this program contribute to sound decisions on the assessment and management of PPCPs in Canada.

3. OBJECTIVE

The objective of this work is to obtain high-quality chemical analysis of 177 PPCPs in raw influent, treated effluent, raw sludge and treated biosolids from selected WWTPs in Canada as part of a monitoring program on the occurrence and fate of chemical substances in municipal wastewater.

4. DEFINITIONS / ACRONYMS

CAS #	Chemical Abstract Service number (www.cas.org)
Method Detection Limit (MDL)	a statistically determined decision point determined according to the procedure described in "United States Environmental Protection Agency definition and procedure for the determination of the method detection limit, revision 1.11. 40 CFR Part 136, Appendix B". https://www.law.cornell.edu/cfr/text/40/part-136/appendix-B
Quarterly	Canada defines the quarterly periods as follows: 1st Quarter 1 April to 30 June 2nd Quarter 1 July to 30 September 3rd Quarter 1 October to 31 December

	4th Quarter 1 January to 31 March
Reporting Limit (RL)	3 times the signal to noise ratio in the target channel converted to an equivalent sample concentration, or the concentration equivalent to the lowest calibration standard, whichever is greater.

5. SCOPE OF WORK

5.1 Summary

The Technical Authority will provide a sampling plan to the Contractor within one week of contract award and updated on a quarterly basis. The sampling plan will be used to determine the quantity and type of sample container and shipping container to be provided by the Contractor, as detailed below.

The Contractor will receive 24-hour equal volume refrigerated composite samples of wastewater and grab samples of solids for 3 consecutive days from approximately 16 Wastewater Treatment Plants (WWTPs) per year in Canada.

Generally, two WWTPs will be sampled per sampling trip, which will take place between April and November of each year. Samples will be shipped (postage paid) by the Technical Authority to the Contractor on Tuesday, Wednesday, and Thursday afternoons for overnight delivery. The maximum number of samples to be shipped per sampling trip will be 12 wastewater and 12 solids samples per substance.

All of the PPCPs of interest to the program are included in this contract, however not every compound will be measured each year.

5.2 Sample Description

Treated wastewater effluents can contain suspended solids up to 60 mg/L depending on the treatment type. Raw wastewater influents can contain suspended solids up to 200 mg/L. These solids are an integral part of the sample because they may contain significant levels of the compounds of interest, particularly if the compounds are hydrophobic. Therefore, sample preparation and extraction methods that are able to accommodate the solids (e.g. liquid/liquid extraction) are preferred where possible. However the specified analytical method for this work (see section 5.6) requires the solids to be removed by filtration prior to solid phase extraction. The Contractor is not expected to conduct separate analysis of the filtered solids. All results from wastewater influent and effluent samples must be reported on a mass/volume basis (e.g. ng/L or µg/L).

Raw sludge and treated biosolids samples can contain anywhere from 2% to 30% solids, and 50% to 75% organic material. The solids are the important phase of these samples; therefore if phase separation is required for sample preparation and extraction the Contractor must analyse the solid phase. However sample preparation and extraction methods that avoid the need for phase separation are preferred where possible. All results from raw sludge and treated biosolids must be reported on a mass/mass and dry weight basis (e.g. ng/g or µg/g).

5.3 Sampling Protocol

The Contractor must provide a sampling protocol for collection of wastewater and solids samples. The sampling protocol must specify the type of container to use for collection of samples for PPCPs, and the

required sample volume to achieve the reporting limits stipulated in Table 1, and any preservation requirements to maintain sample integrity during transit.

5.4 Submission Forms

The Contractor must provide submission forms for collection of wastewater and solids samples. Submission forms must include fields for Project Name; Client name, address and phone; Client Sample Identification; Matrix, Sampling Date; Container Type; Analyses Requested; Relinquished by with Date; Received by with Date.

5.5 Containers

The Contractor must provide sampling containers (e.g., bottles or jars) and shipping containers (e.g., coolers) as part of the contract. The number of containers and coolers will be dictated by the container type and volume requirements as described in the Contractor's sampling protocol. All sampling and shipping containers will be delivered to the Technical Authority.

5.6 Analyses

The Contractor must use analytical methods based on United States Environmental Protection Agency Method 1694: Pharmaceuticals and Personal Care Products in Water, Soil, Sediment, and Biosolids by HPLC/MS/MS (https://www.epa.gov/sites/production/files/2015-10/documents/method_1694_2007.pdf).

The Work includes the analysis and reporting of concentrations of 177 PPCPs in raw influent, treated effluent, raw sludge, and treated biosolids samples. The selected compounds are listed in Table 1. PPCPs for which accreditation is available in water and solids matrices from the Canadian Association for Laboratory Accreditation (CALA, http://cala.ca) are highlighted in Table 1.

The Contractor's analytical methods must achieve Reporting Limits (RLs) equal to or lower than those listed in Table 1 for each listed compound in the water and solids matrices, and the methods must employ, at a minimum, the labeled surrogate standards listed in Table 1 for analyte quantification.

Table 1: Pharmaceuticals and Personal Care Products (PPCPs) to be monitored in wastewater influent, effluent, sludge and biosolids

Name	CAS #	Required reporting limit in water (ng/L)	Required reporting limit in solids (ng/g)	Labeled surrogate for quantification
1,7-Dimethylxanthine (paraxanthine)	611-59-6	1000	100	
10-hydroxy-amitriptyline		10	10	
2-Hydroxy-ibuprofen	51146-55-5	1000	500	
4-Epianhydrochlortetracycline	158018-53-2	1000	500	
4-Epianhydrotetracycline	4465-65-0	500	100	
4-Epichlortetracycline	14297-93-9	100	50	
4-Epioxytetracycline	14206-58-7	50	50	
4-Epitetracycline	23313-80-6	100	50	
Acetaminophen	103-90-2	5000	100	13C2-15N-Acetaminophen
Albuterol	18559-94-9	10	10	D3-Albuterol

Alprazolam	28981-97-7	10	10	d5-Alprazolam
Amitriptyline	50-48-6	10	10	d6-Amitriptyline
Amlodipine	88150-42-9	50	10	
Amphetamine	300-62-9	50	10	D5-Amphetamine
Amsacrine	51264-14-3	10	10	
Anhydrochlortetracycline	4497-08-9	500	100	
Anhydrotetracycline	4496-85-9	500	50	
Atenolol	29122-68-7	100	10	D7-Atenolol
Atorvastatin	134523-00-5	50	10	
Azathioprine	446-86-6	50	100	13C4-Azathioprine
Azithromycin	83905-01-5	50	100	
Benztropine	86-13-5	10	10	d3-Benztropine
Betamethasone	378-44-9	100	10	
Bupropion	31677-93-7	10	50	d9-Bupropion
Busulfan	55-98-1	100	500	d8-Busulfan
Carbadox	6804-07-5	50	10	
Carbamazepine	298-46-4	100	10	
Carmustine	154-93-8	500	5000	
Cefazolin	27164-46-1	1000	1000	13C2,15N-Cefazolin
Cefotaxime	63527-52-6	500	500	
Cefprozil	92665-29-7	500	50	
Chlorambucil	305-03-3	100	100	
Chloramphenicol	56-75-7	5000	5000	
Chlortetracycline	57-62-5	100	10	
Cimetidine	51481-61-9	50	10	D3-Cimetidine
Ciprofloxacin	85721-33-1	100	100	13C3-N15-Ciprofloxacin
Citalopram	59729-33-8	500	10	D6-Citalopram
Clarithromycin	81103-11-9	100	10	
Clinafloxacin	105956-97-6	100	100	
Clonidine	4205-90-7	100	10	D4-Clonidine
Clopidogrel	113665-84-2	10	10	d3-Clopidogrel
Clopidogrel carboxylic acid	144457-28-3	10	10	d4-Clopidogrel Carboxylic Acid
Clotrimazole	23593-75-1	10	50	d5-Clotrimazole
Cloxacillin	61-72-3	100	10	
Codeine	76-57-3	100	10	D6-Codeine
Colchicine	64-86-8	100	100	d6-Colchicine
Cyclophosphamide	50-18-0	50	50	D4-Cyclophosphamide
Cyclosporin A	59865-13-3	100	100	
Cyclosporin E	63798-73-2	100	100	
Daunorubicin	20830-81-3	100	500	13C-d3-Daunorubicin
Decoquinate	18507-89-6	10	10	d5-Decoquinate
Dehydronifedipine	67035-22-7	100	10	
Demeclocycline	127-33-3	100	50	
Desmethyldiltiazem		10	10	
Diatrizoic acid	117-96-4	500	500	D6-Diatrizoic acid
Diazepam	439-14-5	10	10	d5-Diazepam
Diclofenac	15307-86-5	10	50	13C6-Diclofenac
Digoxigenin	1672-46-4	1000	100	
Digoxin	20830-75-5	100	50	
Diltiazem	42399-41-7	10	10	
Diphenhydramine	58-73-1	10	10	
Doxorubicin	23214-92-8	100	5000	
Doxycycline	564-25-0	100	50	

Drospirenone	67392-87-4	500	1000	13C3-Drospirenone
Enalapril	75847-73-3	50	10	D5-Enalapril
Enrofloxacin	93106-60-6	50	10	
Eprosartan	13304-01-4	10	10	d3-Eprosartan
Erythromycin	114-07-8	10	10	13C2-Erythromycin-H2O
Etoposide	33419-42-0	100	100	d3-Etoposide
Fenofibrate	49562-28-9	10	10	d6-Fenofibrate
Fenofibric acid	42017-89-0	10	10	d6-Fenofibric Acid
Flumequine	42835-25-6	50	10	
Fluocinonide	356-12-7	100	50	
Fluoxetine	54910-89-3	10	10	D5-Fluoxetine
Fluticasone propionate	80474-14-2	50	10	
Furosemide	54-31-9	500	100	
Gabapentin	60142-96-3	100	50	d4-Gabapentin
Gemfibrozil	25812-30-0	50	10	D6-Gemfibrozil
Glipizide	29094-61-9	50	10	D11-Glipizide
Glyburide	10238-21-8	50	10	D3-Glyburide
Griseofulvin	126-07-8	100	100	
Hydrochlorothiazide	58-93-5	100	50	
Hydrocodone	125-29-1	1000	10	D3-Hydrocodone
Hydrocortisone	50-23-7	1000	500	d4-Hydrocortisone
Ibuprofen	15687-27-1	500	100	13C3-Ibuprofen
Iopamidol	60166-93-0	1000	1000	D8-Iopamidol
Iopromide	73334-07-3	50	100	d3-Iopromide
Irbesartan	138402-11-6	10	10	d7-Irbesartan
Isochlortetracycline	514-53-4	50	10	
Lamotrigine	84057-84-1	50	50	13C3-Lamotrigine
Lamotrigine 2-N-glucuronide	133310-19-7	10	10	
Lincomycin	154-21-2	50	10	
Lomefloxacin	98079-51-7	50	10	
Lomustine	13010-47-4	500	1000	
Maduramicin	79356-08-4	10	10	
m-Chlorophenylpiperazine	13078-15-4	10	10	d8-m-Chlorophenylpiperazine
Mechlorethamine	55-86-7	100	100	
Medroxyprogesterone	71-58-9	100	100	d6-Medroxyprogesterone Acetate
Melengesterol acetate	2919-66-6	10	10	d3-Melengestrol Acetate
Melphalan	148-82-3	1000	5000	d8-Melphalan
Meprobamate	57-53-4	50	10	
Metformin	657-24-9	1000	10	D6-Metformin
Methylprednisolone	83-43-2	500	10	d2-Methylprednisolone
Metoprolol	51384-51-1	50	10	d7-Metoprolol
Metronidazole	443-48-1	100	100	d4-Metronidazole
Miconazole	22916-47-8	50	10	
Minocycline	10118-90-8	500	500	
Moxifloxacin	151096-09-2	100	500	13C-d3-Moxifloxacin
Mycophenolate Mofetil	128794-94-5	10	10	d4-Mycophenolate Mofetil
Mycophenolic acid	24280-93-1	50	10	d3-Mycophenolic Acid
Naproxen	22204-53-1	100	10	13C-D3-Naproxen
Norethindrone	68-22-4	1000	1000	D6-Norethindrone
Norfloxacin	70458-96-7	100	100	
Norfluoxetine	126924-38-7	50	10	d5-Norfluoxetine
Norgestimate	35189-28-7	100	10	
Norquetiapine		10	10	

Norverapamil	67018-85-3	10	10	
Ofloxacin	82419-36-1	50	50	
Ormetoprim	6981-18-6	100	10	
Oxacillin	66-79-5	100	50	
Oxazepam	604-75-1	100	500	d5-Oxazepam
Oxolinic Acid	14698-29-4	50	50	
Oxycodone	76-42-6	50	10	D6-Oxycodone
Oxytetracycline	79-57-2	100	10	
Paroxetine	61869-08-7	50	10	d6-Paroxetine
Penicillin G	61-33-6	50	10	
Penicillin V	87-08-1	100	10	
Phenobarbital	50-06-6	100	100	
Phenytoin	57-41-0	100	100	
Pravastatin (sodium salt)	81131-70-6	100	10	d3-Pravastatin
Prednisolone	50-24-8	100	50	
Prednisone	53-03-2	500	100	
Promethazine	60-87-7	10	10	d4-Promethazine
Propoxyphene	469-62-5	10	10	d5-Propoxyphene
Propranolol	525-66-6	50	10	d7-Propranolol
Quetiapine	111974-69-7	10	10	d8-Quetiapine
Ramipril	87333-19-5)	10	10	d5-Ramipril
Ramiprilate	87269-97-4	50	10	d5-Ramiprilat
Ranitidine	66357-35-5	50	10	
Rosuvastatin	287714-41-4	500	500	d6-Rosuvastatin
Roxithromycin	80214-83-1	10	10	
Sarafloxacin	98105-99-8	100	50	
Sertraline	79617-96-2	10	10	
Simvastatin	79902-63-9	100	50	
Streptozocin	18883-66-4	100	100	
Sulfachloropyridazine	80-32-0	50	10	
Sulfadiazine	68-35-9	50	10	
Sulfadimethoxine	122-11-2	50	10	
Sulfamerazine	127-79-7	50	10	
Sulfamethazine	57-68-1	100	50	13C6-Sulfamethazine
Sulfamethizole	144-82-1	50	10	
Sulfamethoxazole	723-46-6	50	10	13C6-Sulfamethoxazole
Sulfanilamide	63-74-1	100	50	
Sulfathiazole	72-14-0	50	10	
Tamoxifen	10540-29-1	10	10	D5-Tamoxifen
Telmisartan	144701-48-4	10	10	d3-Telmisartan
Teniposide	29767-20-2	100	100	
Tetracycline	60-54-8	50	10	
Theophylline	58-55-9	1000	500	13C1-15N2-Theophylline
Thiabendazole	148-79-8	50	10	D6-Thiabendazole
Tilmicosin	108050-54-0	10	10	
Topiramate	97240-79-4	10	10	d12-Topiramate
Trazadone	19794-93-5	10	10	d6-Trazodone
Trenbolone	10161-33-8	50	10	
Trenbolone acetate	10161-33-8	10	10	
Triamterene	396-01-0	10	10	
Triclocarban	101-20-2	50	50	13C6-Triclocarban
Triclosan	3380-34-5	100	100	13C12-Triclosan
Trimethoprim	738-70-5	50	10	13C3-Trimethoprim

Tylosin	1401-69-0	50	10	
Valsartan	137862-53-4	100	10	
Venlafaxine	93413-69-5	50	50	D6-Venlafaxine
Verapamil	52-53-9	10	10	
Virginiamycin	11006-76-1	500	50	
Warfarin	81-81-2	100	10	D5-Warfarin
Zalcitabine	7481-89-2	100	100	
Zidovudine	30516-87-1	500	1000	d3-Zidovudine

The Contractor must communicate any anomalous situations with respect to sample integrity or analytical challenges to the Technical Authority by email within 3 business days of discovering such situation.

5.7 Storage and Disposal

The Contractor must adhere to the maximum sample holding time and storage conditions as specified in the analytical method.

5.8 Quality Assurance/Quality Control (QA/QC)

Samples are to be analyzed in a batch system, with each batch consisting of a method blank, spiked blank, and replicate sample. These QA/QC elements must comprise 5% or more of each analytical batch, i.e. every batch of 20 samples or fewer must contain a blank, spike, and replicate. Blank corrections or blank subtractions must not be used.

Field duplicates and equipment blanks submitted by ECCC will be considered as samples. Method blanks, spiked blanks, and laboratory replicate analyses will be conducted as part of the Contractor's Quality Assurance/Quality Control (QA/QC) program and are not considered as samples submitted.

Laboratory raw data, chromatograms, and all relevant laboratory notes must be retained by the Contractor for a minimum period of 36 months following submission of samples. Raw data must include chromatograms and area tables for all instrument calibrations including linearity, resolution, and sensitivity checks showing date and time of analysis, and evidence that all QA/QC specifications have been met; and aliquot masses, volumes, suspended solids content and moisture content for all samples, including original and re-analyses, dilutions, and other details of the analytical procedure.

The Contractor will provide consultation on sampling procedures, delivery schedules, unexpected analytical results, and other contingencies as requested by the Technical Authority.

5.9 Reports

Sample submittal confirmation must be provided electronically to the Technical Authority within five business days of sample receipt.

<u>Sample Data Reports</u>

Sample Data reports must be delivered to the Technical Authority within six (6) weeks following receipt of samples. Reports must include the following:

- concentrations of each analyte in the samples and replicates;
- concentrations of each analyte in the method blank;
- per cent recoveries in spiked blanks;
- the reporting limit for each analyte; and,

- percent recovery of surrogates.

Any problems with samples or data, including corrective actions taken, resolutions, and explanation of flagged data must be documented with the data reports.

Final Reports

The final report will include the project name, sample site name, date of sample receipt, sample temperatures upon receipt, reporting conventions and laboratory qualifiers, QA/QC notes, analytical discussion, correlation table showing client and Contractor sample identifiers, and analysis reports for each sample and substance. Final reports must be delivered within 2 weeks of the sample data report.

6. TECHNICAL ENVIRONMENT

Data reports must be delivered in spreadsheet format, Microsoft Excel or equivalent compatible format. Data reports must be separated by sampling site, i.e. WWTP. Final data reports must be delivered in PDF format including a cover letter signed by the analyst in Microsoft Word. Reports should be submitted electronically to the Technical Authority.

7. LANGUAGE OF WORK

All written and verbal communication will be in English.

8. DELIVERABLES

The deliverables from this Work will be the analytical results, including QA/QC reports.

Sampling protocol	within one week of contract award
Submission forms	within one week of contract award
Sample containers	as per the quarterly sampling plan
Sample Data Reports	within six weeks of sample receipt
Final Report	within four weeks of Sample Data Report

9. WORK LOCATION / TRAVEL

The work will take place at the Contractor's facilities. The Contractor's representative may be required to travel to the Canada Centre for Inland Waters, 867 Lakeshore Road, Burlington ON annually to provide updates and present findings, including any technical issues.