Canadian Perspective for the Removal of Micropollutants in Wastewater Treatment

Wayne Parker
Civil and Environmental Engineering
University of Waterloo
Waterloo, Ontario

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Canada vs the EU

Population:
EU: 491 M
Canada: 32 M

Some statistics

- Water availability per person per year
  - Canada: 94,353 m^3 per capita-year
  - Germany: 1,878 m^3 per capita-year
- Population Density
  - Canada: 3.2/km^2
  - Germany: 230/km^2

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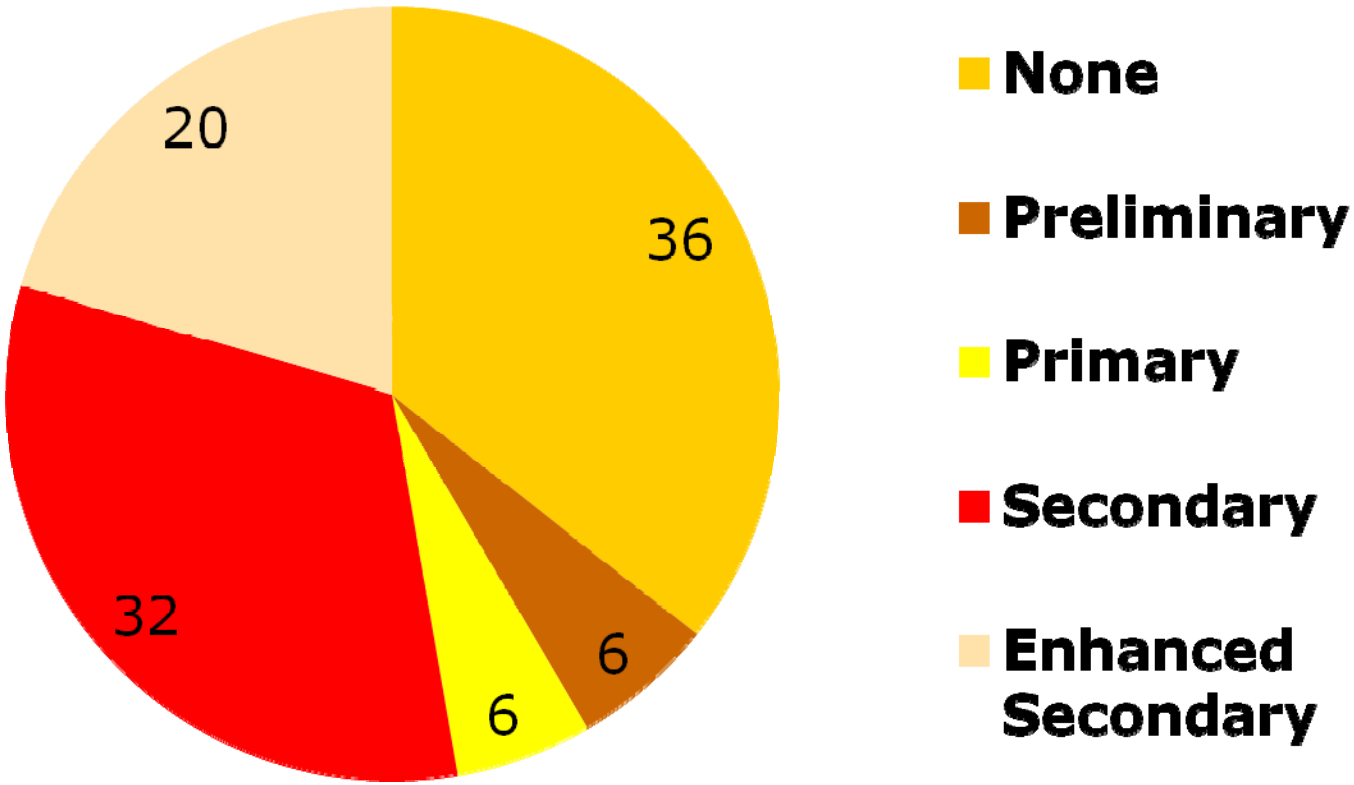
Wastewater Treatment in Canada



Source: CWWA (2001)

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Biosolids

- Land application of municipal biosolids to agricultural fields is widely practiced
  - A controlled practice
  - Winter application not permitted
- Approximately 40% of biosolids in Ontario go to land
- Run-off and tile drain discharges

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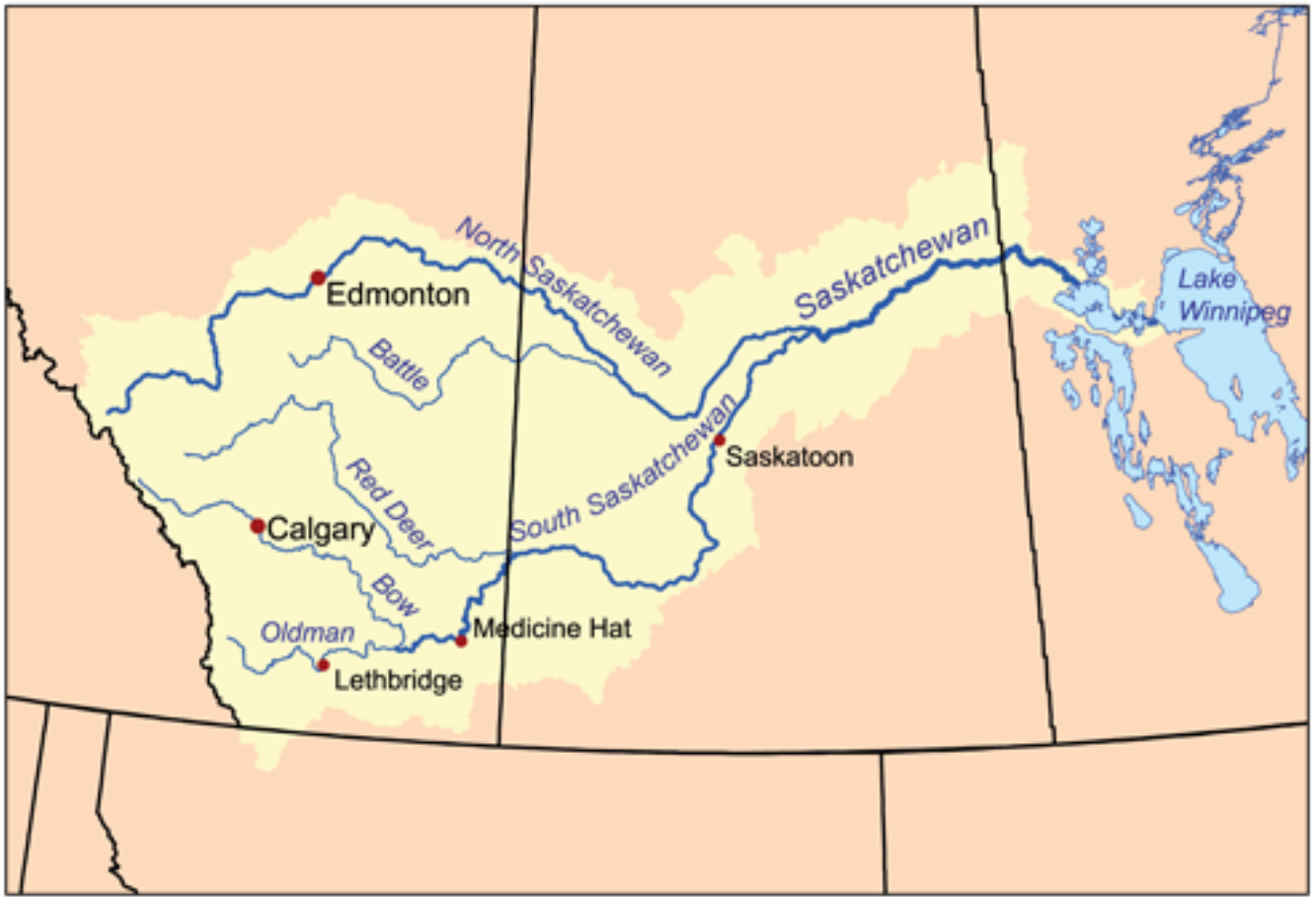
Not all regions are equivalent: Saskatchewan River



Water Availability (Avg)

7300 m^3/capita year

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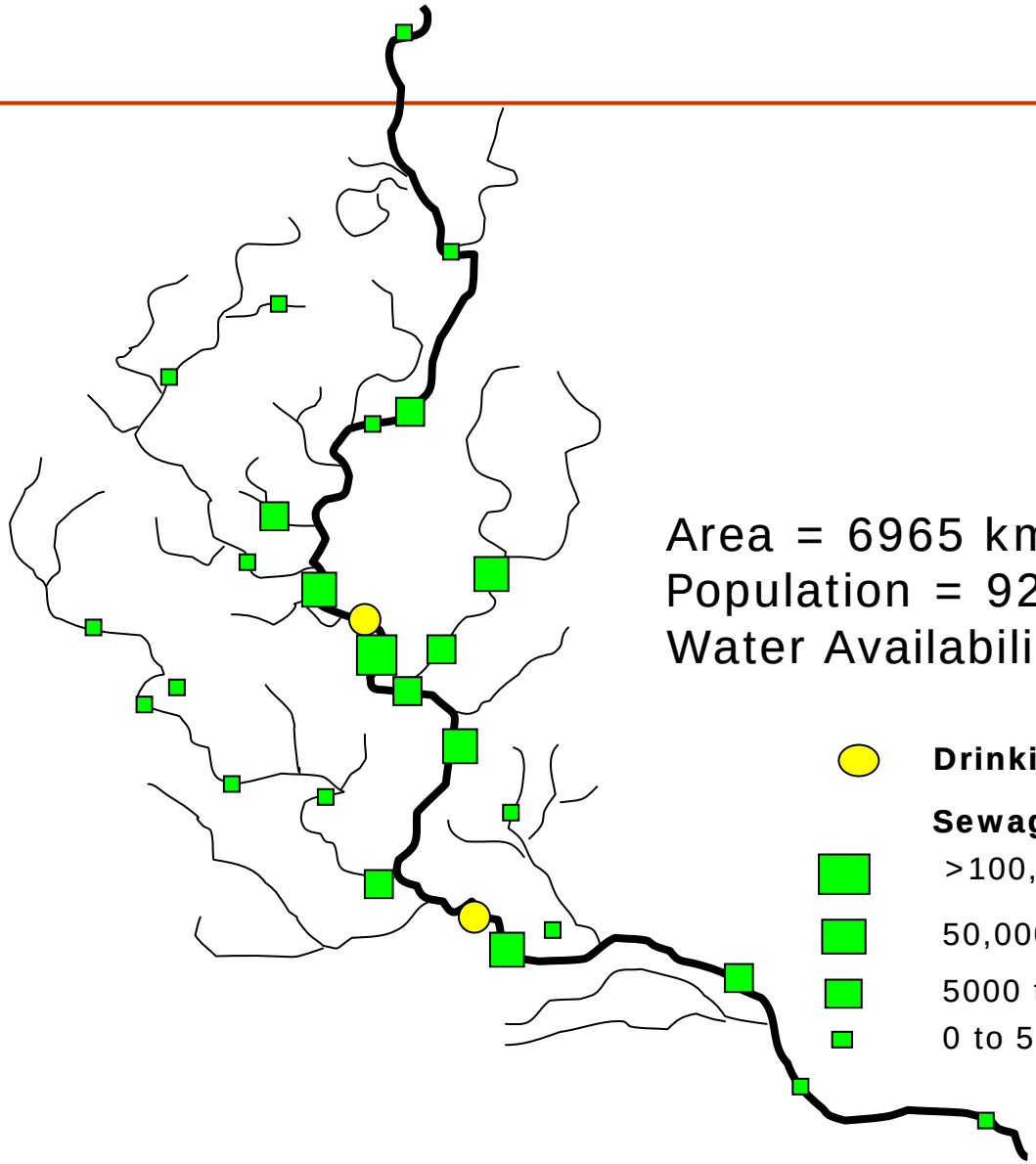
The Grand River: An Impacted Watershed



Area = 6965 km^2
Population = 925000
Water Availability = 7025 m^3/capita-yr

Drinking Water Treatment Plant

Sewage Treatment Plants

- >100,000 people served
- 50,000 to 100,000 people served
- 5000 to 50,000 people served
- 0 to 5000 people served

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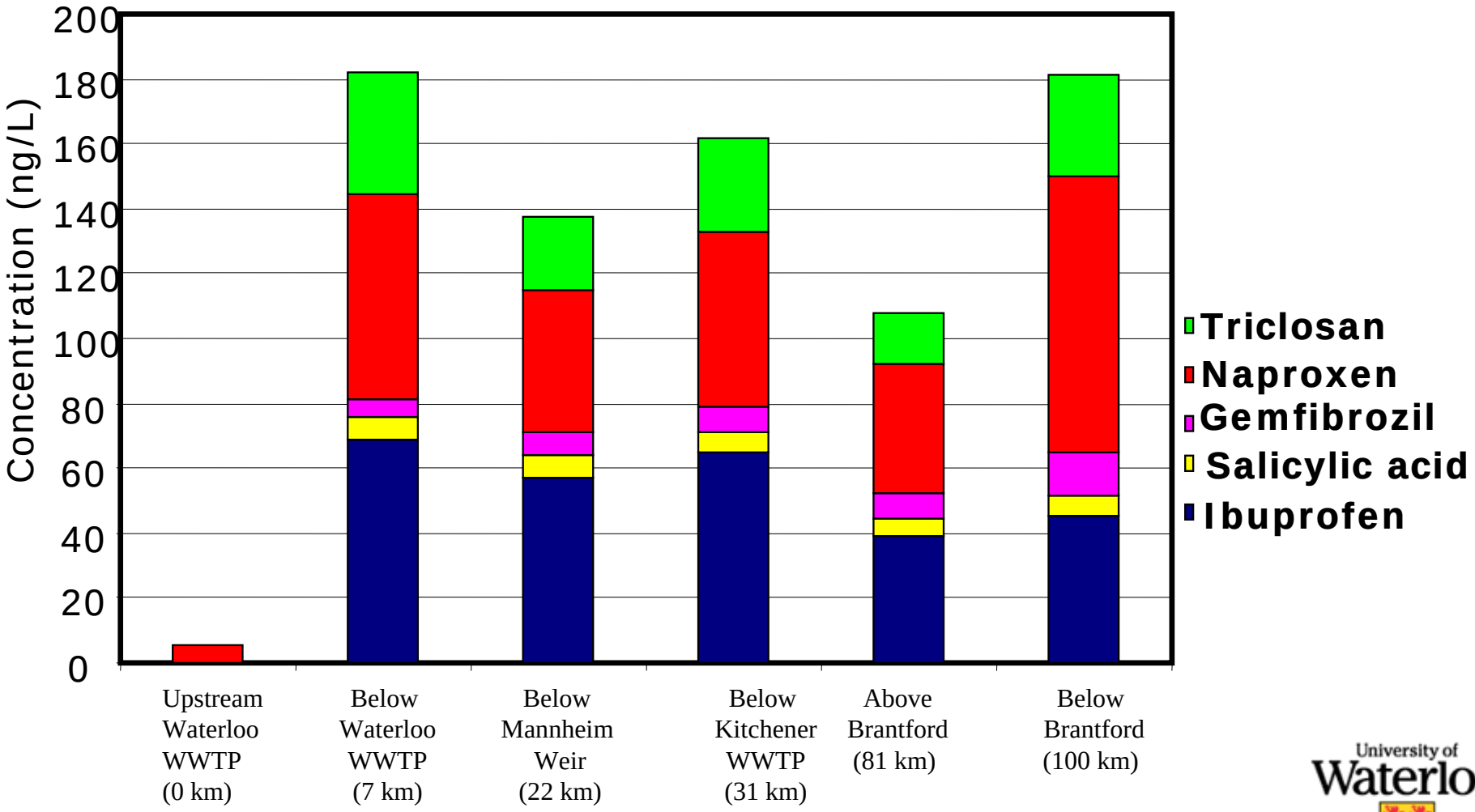
Pharmaceuticals and Personal Care Products in the Grand River (2003-2004)



D. Bennie, NWRI

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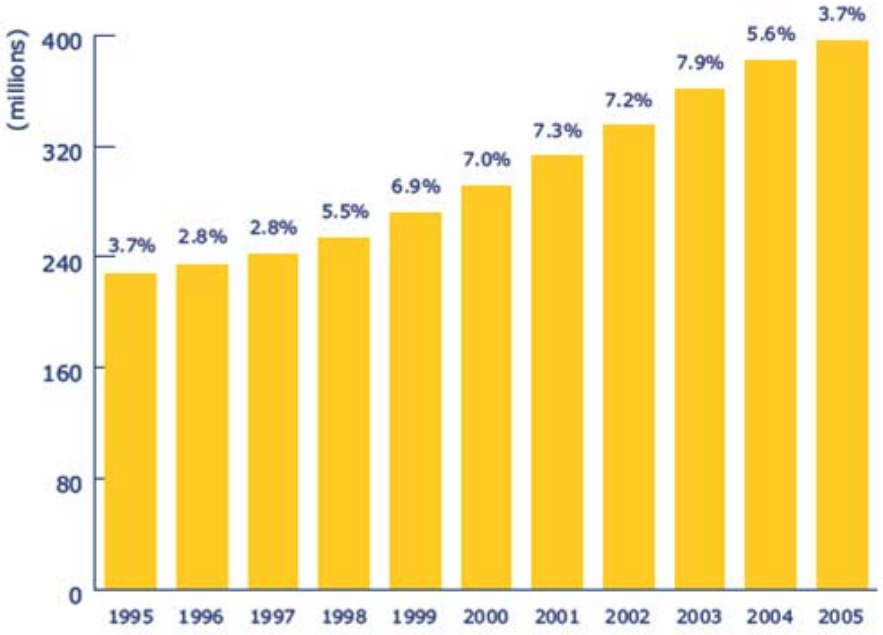
Pharmaceutical trends

Drug store and hospital purchases*, Canada, 1996-2005

Pharmaceutical trends

Retail prescriptions* dispensed in Canada, 1995-2005



Source IMS HEALTH Canada
http://www.imshealthcanada.com/web/channel/0,3147,77303623_63872702_77770072,00.html

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Centre for Control of Emerging Contaminants

CCEC

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CCEC Mission & Objectives

Mission: Promote and coordinate fundamental and applied research into water and wastewater treatment as related to control of emerging contaminants.

Objectives:

- Provide a central point of contact for Researchers, Regulators and Technology Implementers interested in control of emerging contaminants
- Provide administrative and technical support for multi-disciplinary & multi-institutional research projects
- Contribute to science-based policies related to control of ECs
- Improve and maintain research infrastructure

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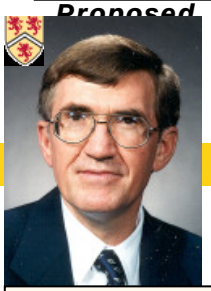
CCEC Members

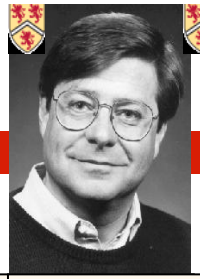
Wayne Parker
Civil & Environmental Engr.
Wastewater Treatment
***Proposed* Scientific**



Peter Huck and Sigrid Peldzus
Civil & Environmental Engr.
NSERC Chair in Water Treatment

Mark Servos
Biology
CRC Water Qua
Protection

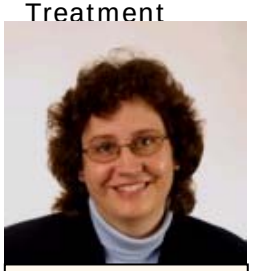
Barry Warner
Earth & Environm
Science
Wetlands



David Blowes and Carol Ptacek
Earth & Environmental Science
Groundwater Remediation

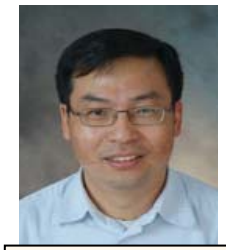
Ray Legge
Chemical Engr.
Wetlands

Dave Rudolph
Civil & Envir.
Ground Water



Robin Slawson
Biology

Wilfrid Laurier University



Hongde Zhou
School of Engine
Wastewater

Ed McBean
School of Engr.
CRC Water

University of

Susan Andrews, Bob Andrews and Ron Hofmann
Civil Engineering
Drinking Water Research Group
University of Toronto

Chris Metcalfe
Worsfold

Trent University

University of Waterloo

Partners

Institutional

Universities of Waterloo, Toronto, Guelph, Trent & Wilfrid Laurier
Alberta Nano Institute
Flemming College

Government

Ontario Ministry of Research and Innovation
Ontario Ministry of the Environment
Environment Canada
Public Health Agency of Canada

Municipalities

Region of Waterloo
City of Guelph
Halton Region
Toronto
Durham Region
Parry Sound
Peterboro
Niagara Region

Private Sector

Ontario Clean Water Agency / Agence Ontarienne Des Eaux
American Water Canada
Associated Engineering
amec
PhRMA
Stantec
Zenon – Water for the World
RAL Engineering
ALS
ebpi
TrojanUV – Water Confidence
CRA Conestoga-Rovers & Associates
Calgon Carbon
EPCOR
Hydromantis, Consulting Engineers
Hydroxyl – Water Results

Recent and Ongoing Studies: CCEC Members and Partners

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Full-Scale Assessment of the Removal of PPCP from Wastewater

David M. Andrews

Sigrid Peldzus

Peter Huck

University of Waterloo

Project Objectives

- **To identify the impact of HRT on the removal of a select group of PPCPs**
- **To assess the inherent abilities of Sequencing batch Reactors (SBRs) to alter HRT along with the subsequent impact on the removal of recalcitrant organic compounds**
- **To evaluate the impact of seasonal effects on PPCP removal**
- **To assess the impact of individual treatment processes on PPCP removal**

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Wastewater Treatment Plant

New Hamburg WWTP

- Sequencing Batch Reactor with Filtration and UV Disinfection
- Design Capacity – 5,200 m^3 per day
- Utilization – 60%
- Population Served – 8,495

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Operating Conditions for Study

- **Reference –** 8 Hour HRT
- **Extended –** 24 Hour HRT

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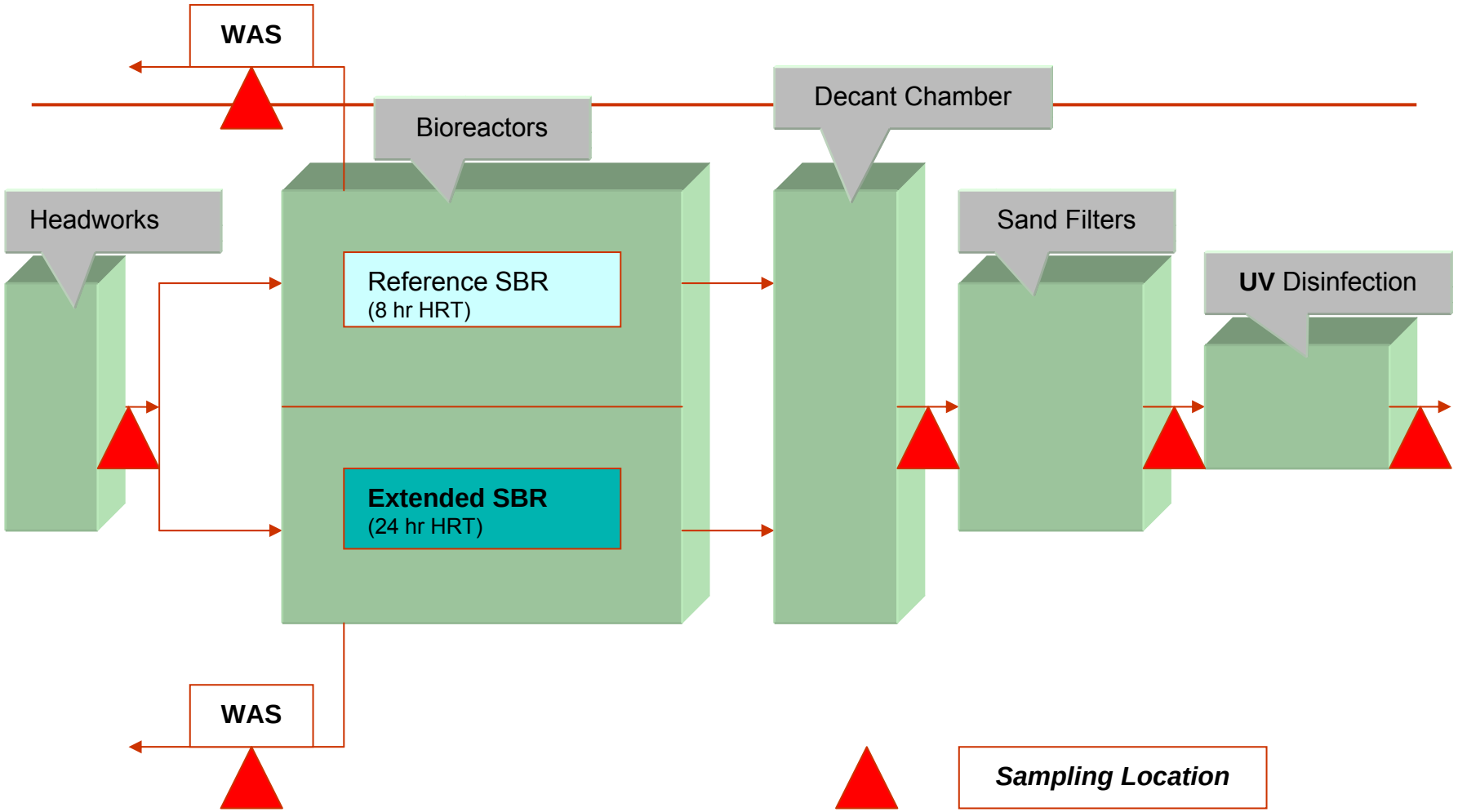

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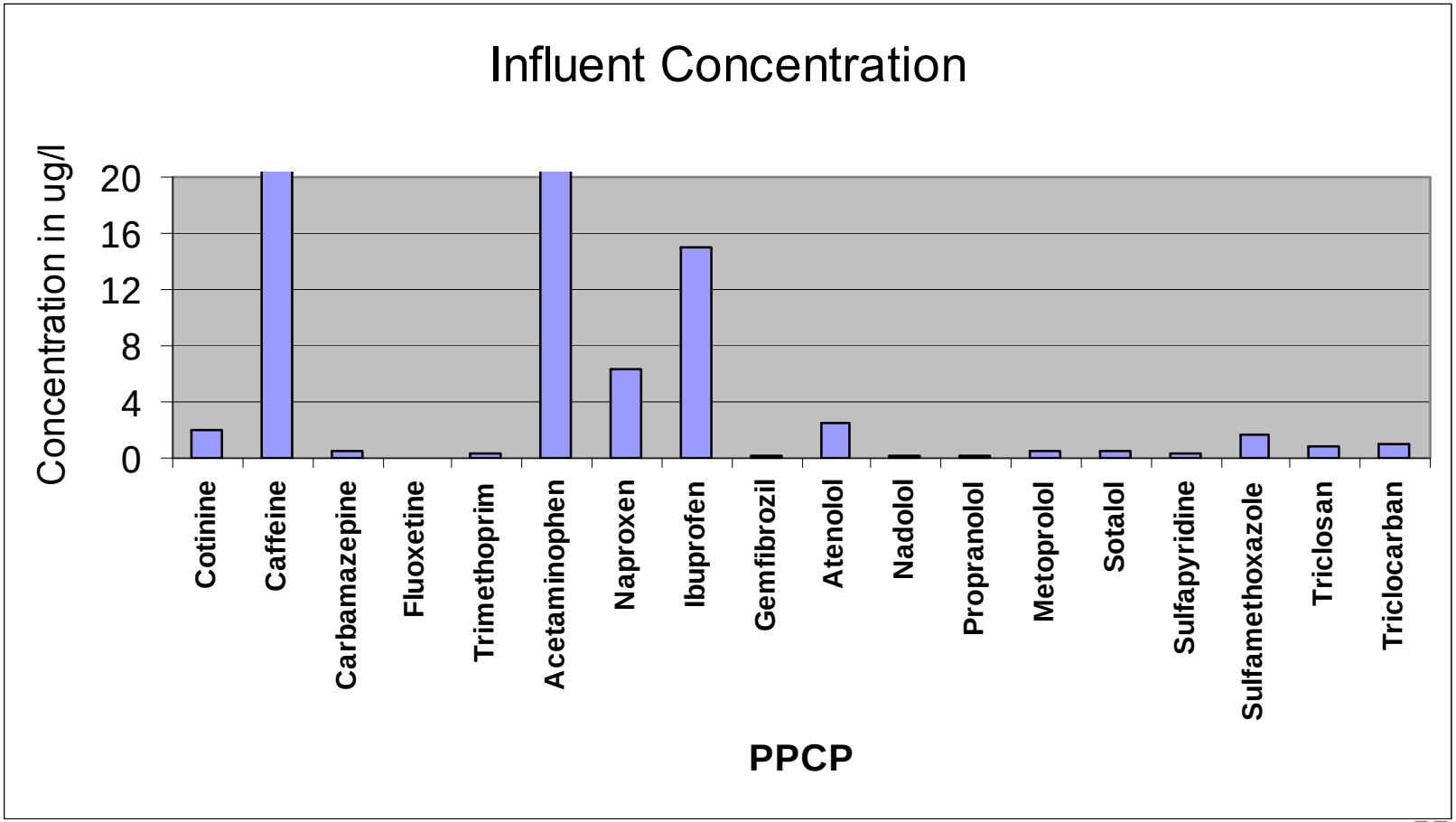
Target PPCPs

- Criteria for target PPCPs:
  - frequency of detection
  - variations in reported removals
  - range of chemical and physical properties.

Neutral drugs	Cotinine Caffeine Carbamazepine Fluoxetine Trimethoprim	Nicotine Metabolite Stimulant Antiepileptic Antidepressant Antibiotic
Acidic drugs	Acetaminophen Naproxen Ibuprofen Gemfibrozil	Analgesic Anti-inflammatory Anti-inflammatory Lipid Regulator
Beta-Blockers	Atenolol Nadolol Propranolol Metoprolol Sotalol	Antiadrenergenic Antiadrenergenic Antiadrenergenic Antiadrenergenic Antiadrenergenic
Sulfonamides	Sulfapyridine Sulfamethoxazole	Antibiotic Antibiotic
Antimicrobials	Triclosan Triclocarban	Antiseptic Antiseptic

PPCP Concentration



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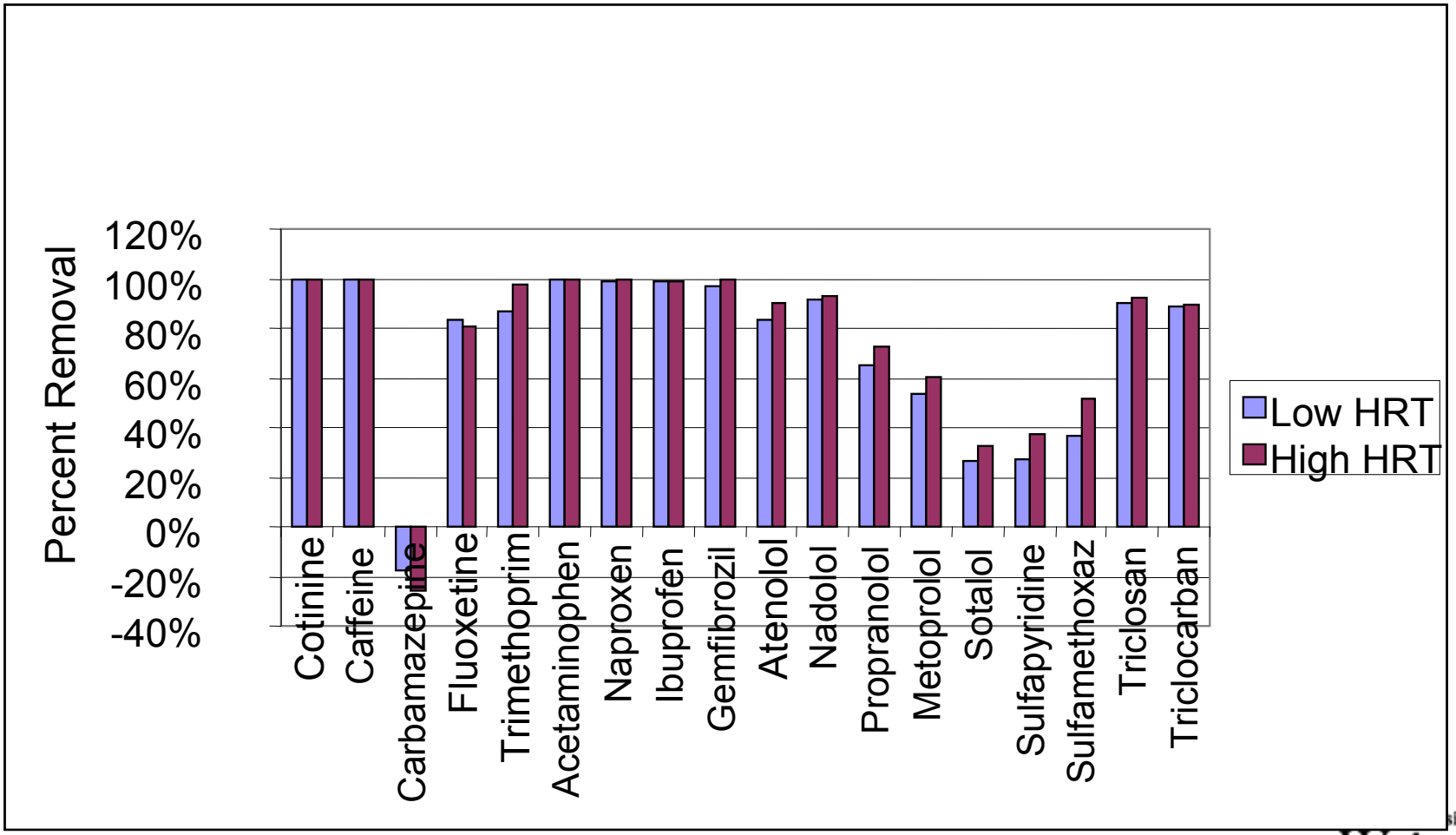
Impact of Hydraulic Retention Time



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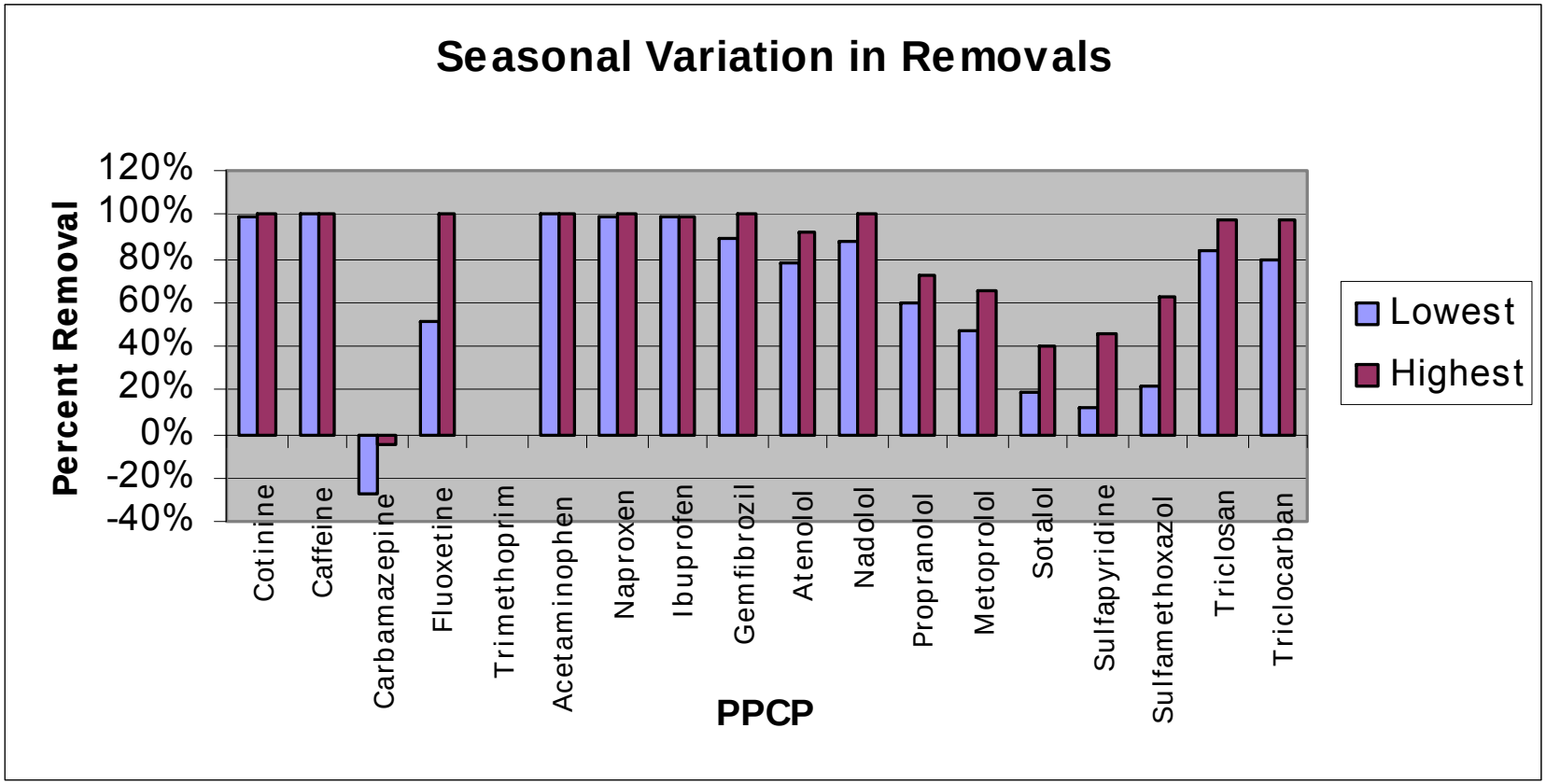
Seasonal Impact



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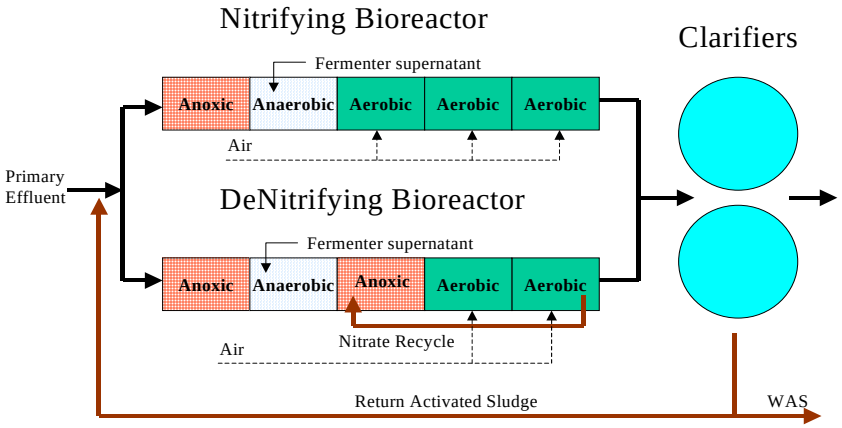
Additional Investigations

- Solids Retention Time
  - Tertiary CAS WWTP
  - Parallel evaluation of 5 and 10 day SRT
  - 3 seasonal events completed
- Redox Conditions
  - BNR WWTP
  - Parallel evaluation of nitrification and denitrification



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Modeling the Fate of Estrogenic Hormones in Wastewater Treatment

Hugh Monteith,
Hydromantis, Inc.

Wayne Parker
University of Waterloo

University of Waterloo

Target Hormones

- Abbreviations
  - E1 = Estrone (CAS# 53-16-7)
  - E2 = 17β – estradiol (CAS# 50-28-2)

  } Natural

  - EE2 = 17α – ethinylestradiol (CAS# 57-63-6)

→ Synthetic

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Fate in Wastewater Treatment

- Sorption to solids
- Biotransformation (including metabolites)
- Transfer to gas phase (not important for hormones)
- Hydrolysis and other abiotic mechanisms
  - Not accounted for in fate models

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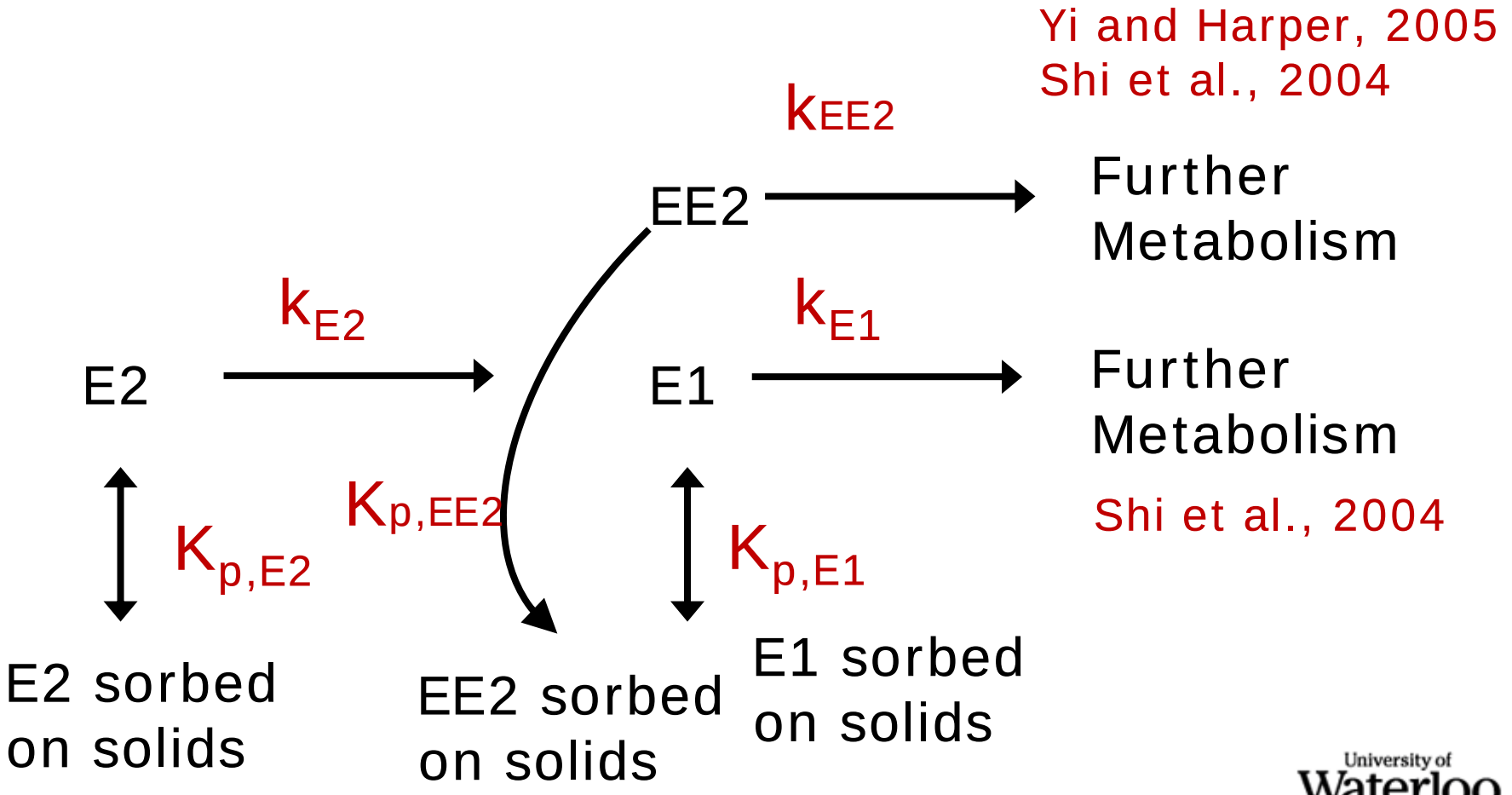
Aerobic Biotransformation in Wastewater Treatment



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Modeling Approach

- Combine properties of dynamic wastewater simulator (GPS-X), with mechanistic fate model TOXCHEM+ for micro-constituents

- Modeling faciliates:
  - Evaluation of the impact of alternative designs and operating conditions on substances
  - Quantitative analysis to better understand processes impacting fate

- A preliminary exercise to demonstrate concept and identify knowledge gaps

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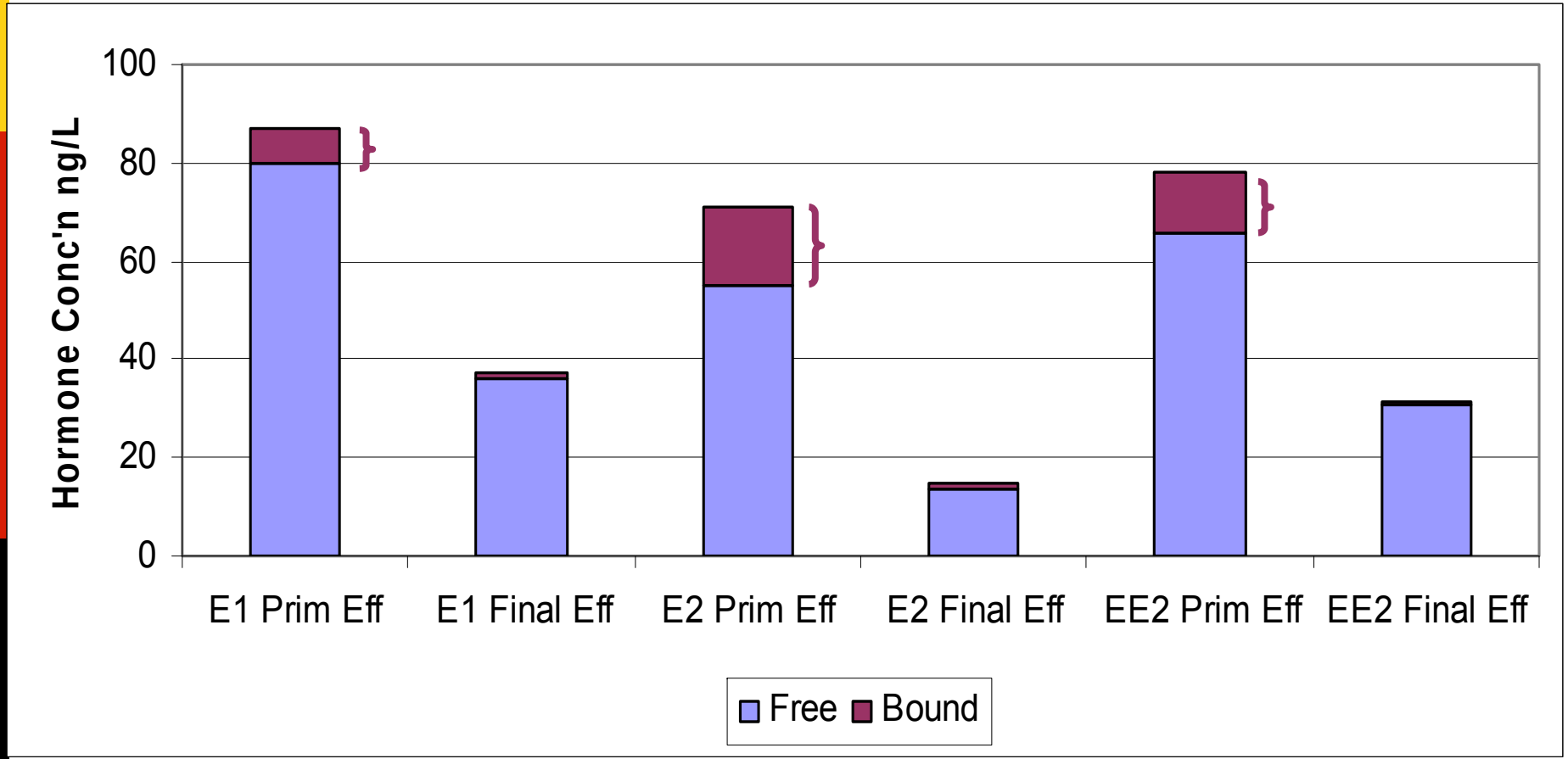
Predicted Free and Bound Hormone Concentrations



- Bound hormone fraction is significant in primary effluent

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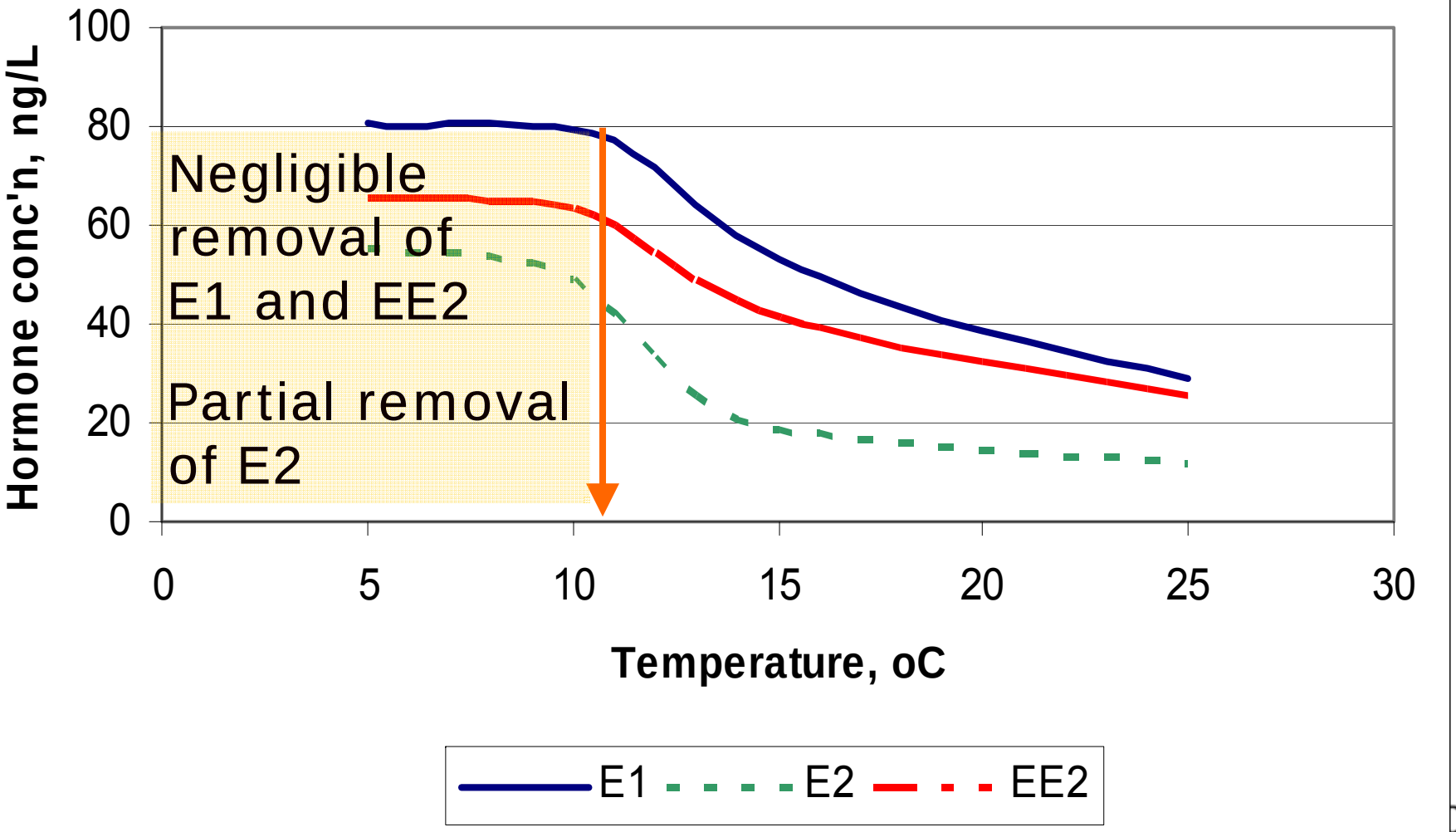
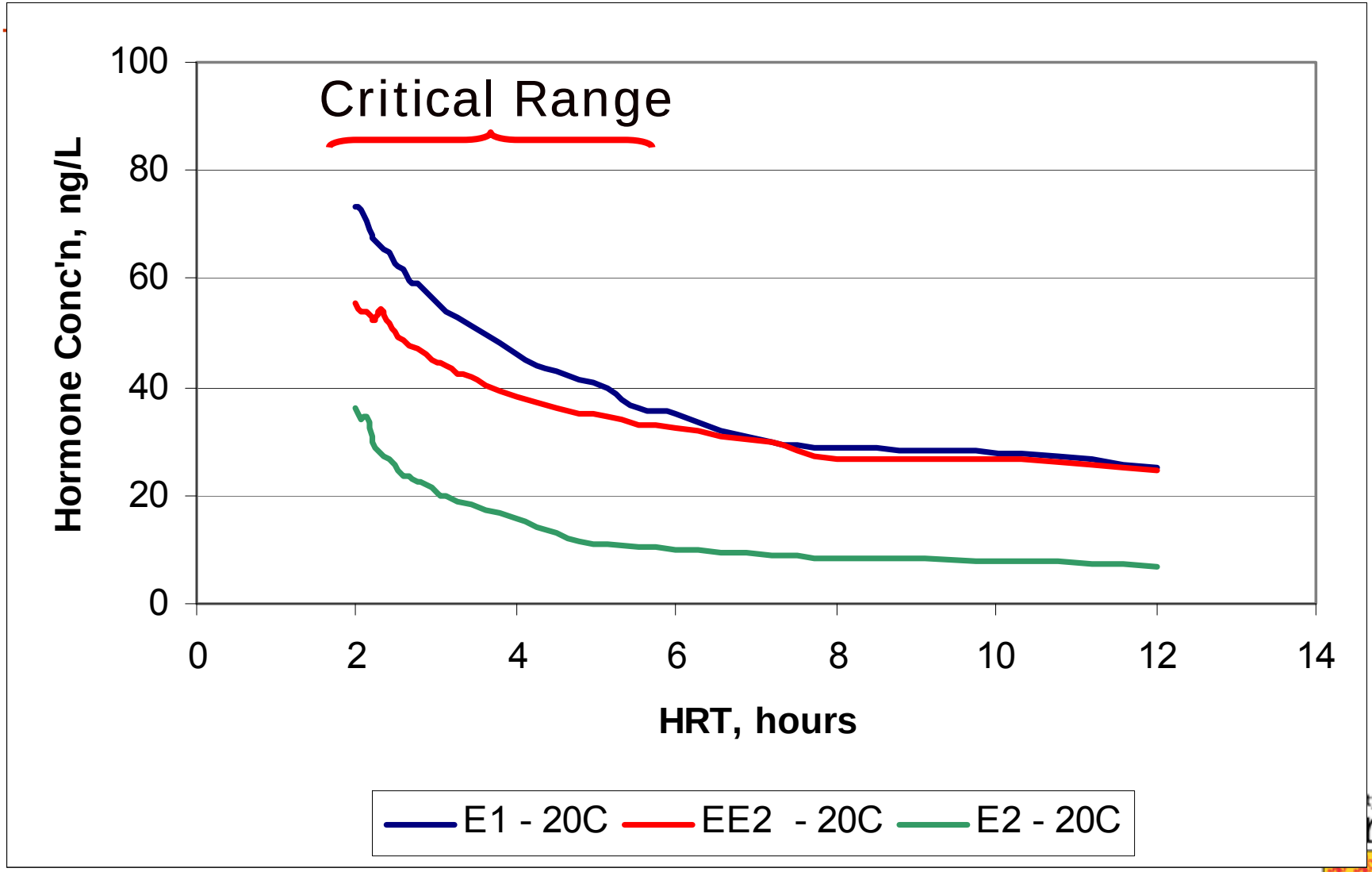
Effect of Temperature



Effect of HRT, 20°C



Modeling Limitations to Date (I)

- Calibration and validations based on limited operating and design data
- Importance of autotrophs and heterotrophs in hormone removal not clear
- Metabolites and pathways are not completely understood
- Additional testing of alternative aerobic, anoxic and anaerobic conditions required

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Modeling Limitations to Date (II)

- Uncertain sorption relationships
- Sorption characteristics of different types of biomass?
- No solids treatment processes or return of sidestreams (supernatant, centrate etc.)

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Chemicals Management Plan

Wastewater Monitoring Workplan

Shirley Anne Smyth

Water Science & Technology Directorate

Environment Canada

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Wastewater Monitoring Objectives

- Temporal trends in influents (warm, cold)
- Fate of compounds in typical wastewater treatment processes: disappearance, partitioning to solids
- Concentrations entering environment
- Baseline data to evaluate future control measures

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Criteria for Selection of WWTPs

- Proximity to water quality monitoring sites
- Proximity to shellfish monitoring sites
- Coordinate with Arctic wastewater working group
- Risk assessment recommendations
- Representative of typical Canadian treatment processes
- Representative of geographical variations
- Large volume discharges

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Criteria for Selection of WWTPs

- 20 WWTPs
- At least 1 per province and territory
- 1 aboriginal
- 1 federal house
- Primary, secondary, advanced, and lagoon treatment

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Analytes: Phenols and Drugs

*Bisphenol A	Clofibric acid
Methyl paraben	Ibuprofen
Ethyl paraben	Salicyclic acid
Propyl paraben	Gemfibrozil
Butyl paraben	Fenoprofen
2-phenylphenol	Naproxen
*4-tert-octylphenol	Ketoprofen
*4-nonylphenol	Tolfenamic acid
*Triclosan	Diclofenac
*In sludge	Indomethacin

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Analytes: Perfluorinated Compounds

Perfluorobutanoate	Perfluoroundecanoate
Perfluoropentanoate	Perfluorododecanoate
Perfluorohexanoate	Perfluorobutanesulfonate
Perfluoroheptanoate	Perfluorohexanesulfonate
Perfluorooctanoate	Perfluorooctanesulfonate
Perfluorononanoate	Perfluorooctane sulfonamide
Perfluorodecanoate	

Wastewater and sludge

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Analytes: Brominated Flame Retardants

- Di, tri, tetra, penta, hexa, hepta, octa, nona, and deca-substituted polybrominated diphenyl ethers
- 40 congeners
- 4 other brominated flame retardants
- Wastewater and sludge

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Analytes: Metals

Aluminum	Copper	Nickel
Arsenic	Iron	Selenium
Bismuth	Lead	Silver
Cadmium	Manganese	Thallium
Chromium	Mercury	Vanadium
Cobalt	Molybdenum	Zinc

Chosen from AB, ON, QC, NS, and CMP lists
Wastewater and sludge

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Analytes: Conventionals

pH	Ammonia
Alkalinity	Nitrate
Total Suspended Solids	Total Kjeldahl Nitrogen
Chemical Oxygen Demand	Phosphorus
5-day carbonaceous Biochemical Oxygen Demand	
Total Solids in sludge	Volatile Solids in sludge

Context for occurrence and fate of chemical substances

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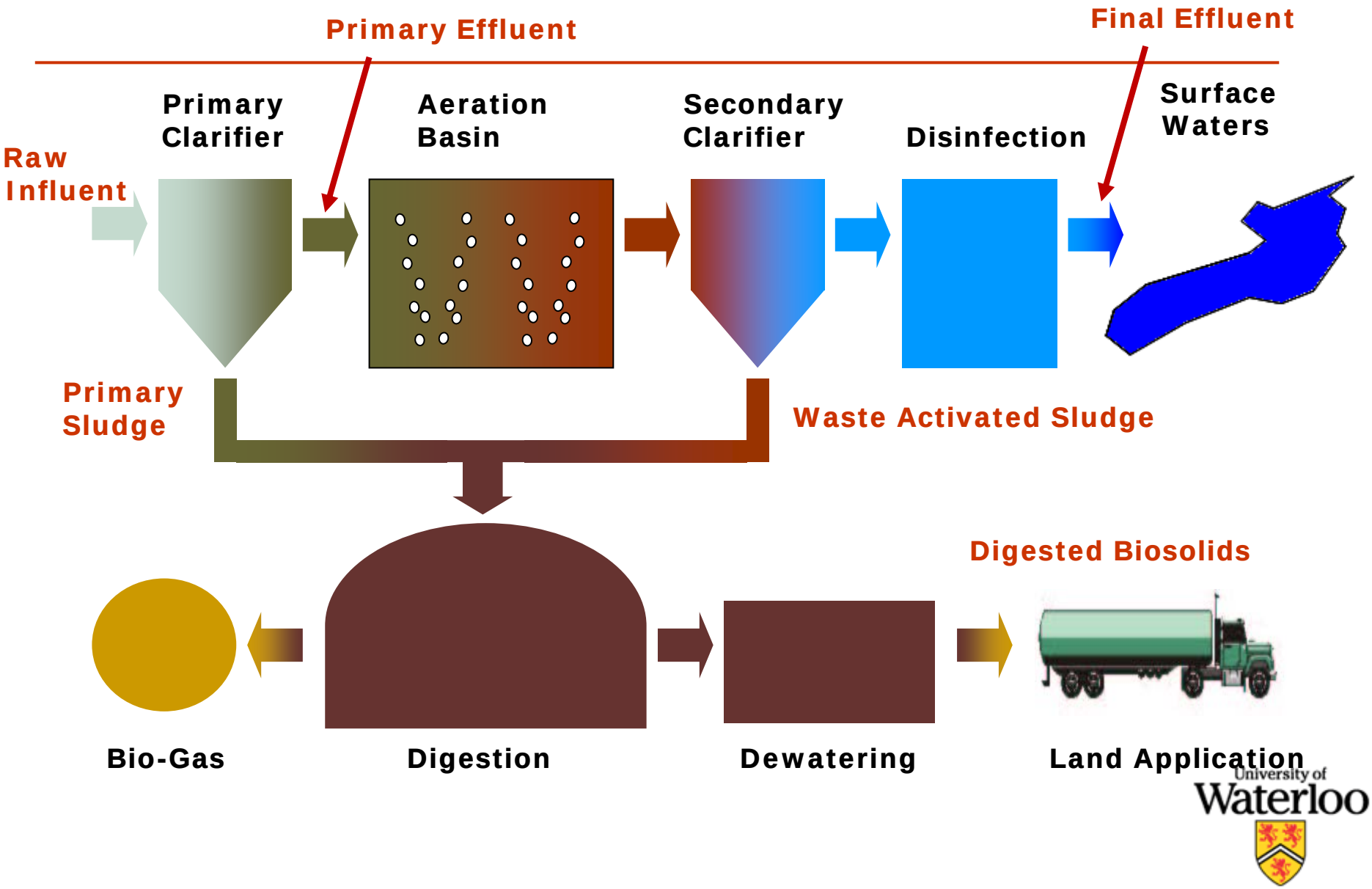
Sampling Plan



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Sampling Times and Methods

- Cold temperatures (January to April)
- Warm temperatures (August to November)

- Liquid: 24-hour equal volume composite, refrigerated autosamplers
- Solids: grab
- 3 consecutive days per plant per temperature

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Biosolids

REVIEW OF STATE OF KNOWLEDGE OF BIOSOLIDS SCIENCE AND RESEARCH: CONTAMINANT INVENTORY

Hydromantis, Inc.
University of Waterloo
Trent University

Supported by: **Canadian Council of Ministers of the Environment**

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Projects in Development

- PPCPs in advanced sludge digestion processes
- Integration of biofilms into suspended growth wastewater treatment processes for PPCP control
- Further integration of contaminant fate models and process simulation models

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Summary

- Low population density and substantial water availability in Canada

- Some areas of Canada have substantial wastewater discharges into low flow rivers
  - Southern Ontario
  - Parts of Western Canada

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Summary

- Generation of information for risk assessments under Canadian conditions
  - Characterization of treatment plant performance
  - Characterization of biosolids quality
  - Modeling
- An interest in optimizing existing facilities for control of ECs

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1st Annual CCEC/CWN Workshop on the Control of Emerging Contaminants in Water and Wastewater

Renaissance Hotel and Conference Centre,
Toronto Pearson Airport

June 3rd and 4th, 2009.

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Fate and Removal of Emerging Contaminants in Water and Wastewater Treatment – an Overview

- **Dr. Thomas Ternes**

Head

Water Chemistry Department

Federal Institute of Hydrology

Koblenz, Germany

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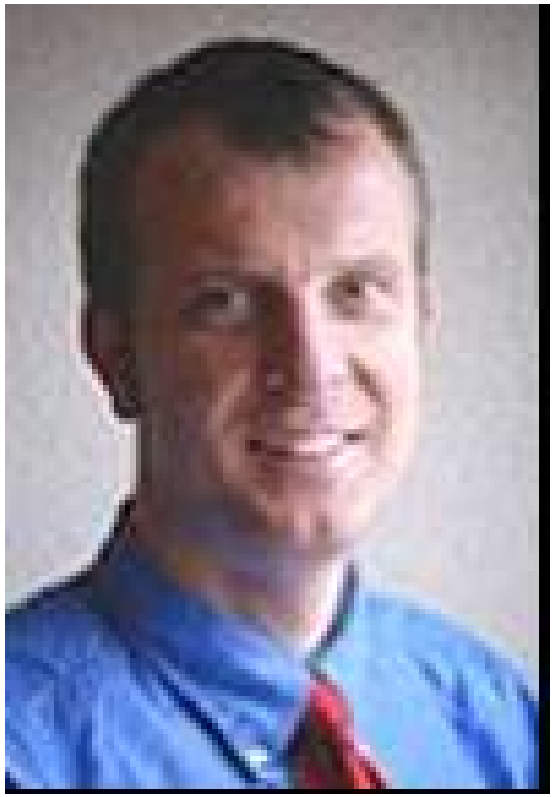
Contributions of Emerging Contaminants to Sewage and Their Relevance to Municipal Wastewater Systems and the Environment

- Dr. Jörg E. Drewes
  Director Aqwatec
- Assoc. Professor
  Environmental
  Science & Eng.
  Colorado School of
  Mines



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EC Removal Technologies, Oxidation/Advanced Oxidation Processes

Dr. Urs von Gunten

Deputy Head of Department,
Water Resources and
Drinking Water,

Swiss Federal Institute for
Environmental Science and
Technology

University of Waterloo

Communicating Risks Associated with Emerging Contaminants

Dr. Rula Deeb
Senior Associate and
Applied Research
and Technology
Leader,
Malcolm Pirnie, Inc

University of Waterloo

Collapse of a fish population after exposure to a synthetic estrogen

Dr. Karen Kidd

Canada Research Chair in Chemical Contamination of Food Webs

Department of Biology,

University of New Brunswick

University of Waterloo

Drinking Water Treatment

Dr. Sigrid Peldszus	**UV based advanced oxidation of selected pharmaceuticals at environmental relevant concentrations**
Dr. Ron Hofmann	**Advanced oxidation to control taste and odor-causing compounds in drinking water**
Elisa Garvey	**Removal of NDMA, EDCs and PPCPs from San Francisco South Delta Waters**
Xiaohui Jin	**Using QSPR to predict the efficiency of AOPs and ozone for Control of EC's**
Hong Zhang	**Influence of drinking water distribution system conditions on nitrosamines**
Ray Yu	**Granular activated carbon absorbers for the removal of selected PhACs and an EDC**
Joules Carlson	**The removal of pharmaceuticals using UV Treatment**
Cynthia Halle	**Removal of PhACs and EDCs by biological filtration – results of a long-term bench-scale study**
Dr. Sigrid Peldszus	**Nanofiltration for EC removal from natural waters**
MOE,	**How Science Informs Policy from a provincial perspective**

Wastewater

Sonya Kleywegt Ontario MOE	**Survey of the occurrence of pharmaceuticals and other EC's in untreated source and finished drinking waters in Ontario**
Dr. Carol Ptacek	**Fate of septic-system derived pharmaceutical compounds in shallow sand aquifers**
Dr. Hongde Zhou	**Sorption and Biodegradation of EC in Membrane Bioreactor Processes Used for Municipal Wastewater Treatment**
Hugh Monteith Hydromantis	**Modeling of PPCP fate in wastewater treatment**
Shirley Anne Smith Environment Canada	**"ECs in Canadian Municipal Wastewater", recent studies on PPCPs in full scale wastewater treatment systems and sludge, and current work under the Chemicals Management Plan**
Dave Andrews	**Impact of changes in full scale wastewater operations on pharmaceutical removals**
Kela Weber	**Community Profiling and Hydrological Characterization of Constructed Wetland Mesocosms during start-up**
Dr. Chris Metcalfe	**Evaluation of low-tech solutions for removal of EC's in engineered wetlands**
Dr. Ed McBean	**Benchmarking Procedures for Monitoring EC's from Waste Disposal Activities**
Dr. Mark Servos	**Application of SPMEs to measure ecologic effects of ECs**

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THANK YOU

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