Water Security Challenges in a Growing Economy: Emerging Contaminants.

Markus Hecker

& John Giesy

ENTRIX
Down to Earth. Down to Business.℠

UNIVERSITY OF SASKATCHEWAN

CETES
Canada Ecotoxicity Testing & Screening

Chemicals in Society

- Current use ~ 87,000 chemicals
  - 900 pesticide active ingredients
  - 2,500 other pesticide formulate ingredients
  - 75,500 industrial chemicals
  - 8,000 cosmetics, food additives and nutritional supplements

University of Saskatchewan

CETES
Canada Ecotoxicity Testing & Screening

ENTRIX
Down to Earth. Down to Business.

Many End Up in Our Water

Emerging Chemicals of Concern

Nanoparticles

Pesticides

Pharmaceuticals

- Birth control
- DES
- Cimetidine

Household products/cleaners

Heavy metals

- Cadmium
- Mercury
- Lead

Plasticizers leaching from most plastic products

- Bisphenol A
- Phthalates

University of Saskatchewan

CETES
Canada Ecotoxicity Testing & Screening

ENTRIX
Down to Earth. Down to Business.

Endocrine Disruption

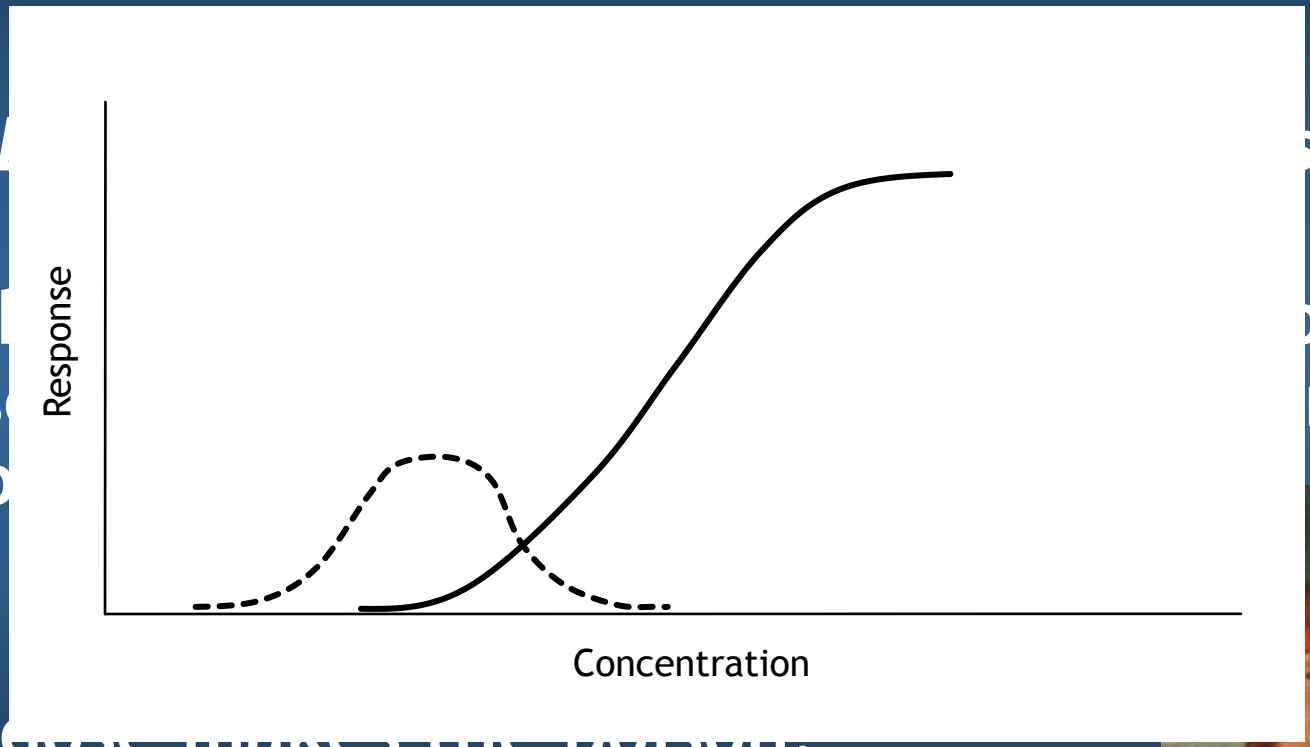
- Increasing concern about the possible impacts of chemicals in the environment on endocrine and reproductive systems in humans and wildlife because:
  - Potential low-level effects

The Concept of Dose-Response

"Alle *allein*
die *st."*

"All t* *out*
pois* *not to*
be p*

"The dose makes the poison."



Paracelsus (1493-1541)

University of Saskatchewan

CETES
Canada Ecotoxicity Testing & Screening

ENTRIX
Down to Earth. Down to Business.

Endocrine Disruption

- **Increasing concern about the possible impacts of chemicals in the environment on endocrine and reproductive systems in humans and wildlife because:**
  - Potential low-level effects
  - Interaction with processes that may affect crucial physiological functions

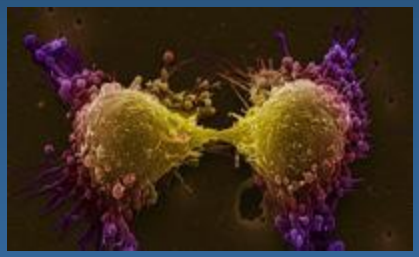
Human & Environmental Health Effects

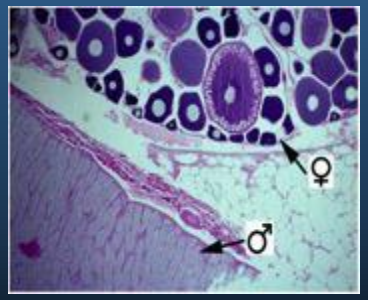
3

Endocrine disruption as a potential human and environmental health issue:

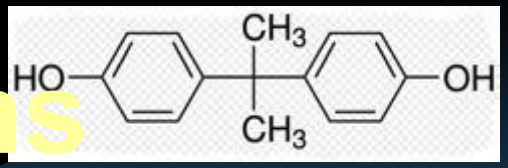
- ü Breast cancer
- ü Prostate cancer
- ü Sperm count decline
- ü Infertility

- Intersex
- Imposex
- Demasculinization
- Feminization
- Impaired development





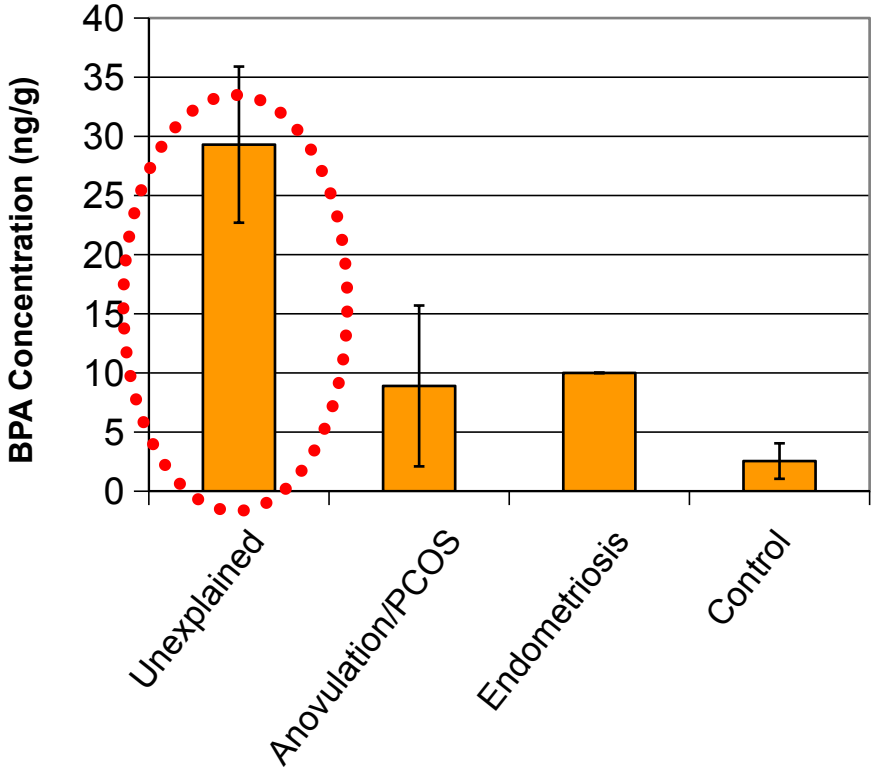
Human Health Concerns

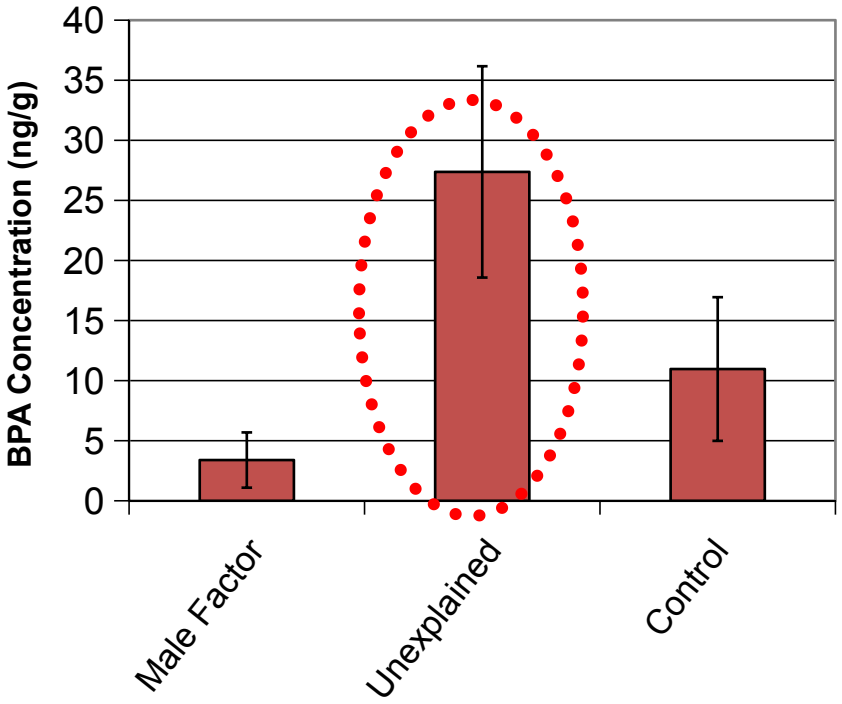


- **Example: Bisphenol A**
  - ü Used as a plasticizer to make polycarbonate plastics and epoxy resins
  - ü Weak xeno-estrogen and promoter of endogenous E2 production
  - ü Possible relationship to female infertility?
  - ü Has been banned in certain applications (e.g. baby bottles) in Canada and some other countries

Human Health Concerns

Association between BPA concentrations in plasma and infertility of female human subjects.





Endocrine Disruption

- **Increasing concern about the possible impacts of chemicals in the environment on endocrine and reproductive systems in humans and wildlife because:**
  - Potential low-level effects
  - Interaction with processes that may affect crucial physiological functions
  - Ubiquitous

Sources of Contaminants

Industrial byproducts:

- ü Oilsands process water (naphthenic acids)
- ü Pulp & Paper mill effluents
- ü Mining and other industrial effluents

Sources of Contaminants

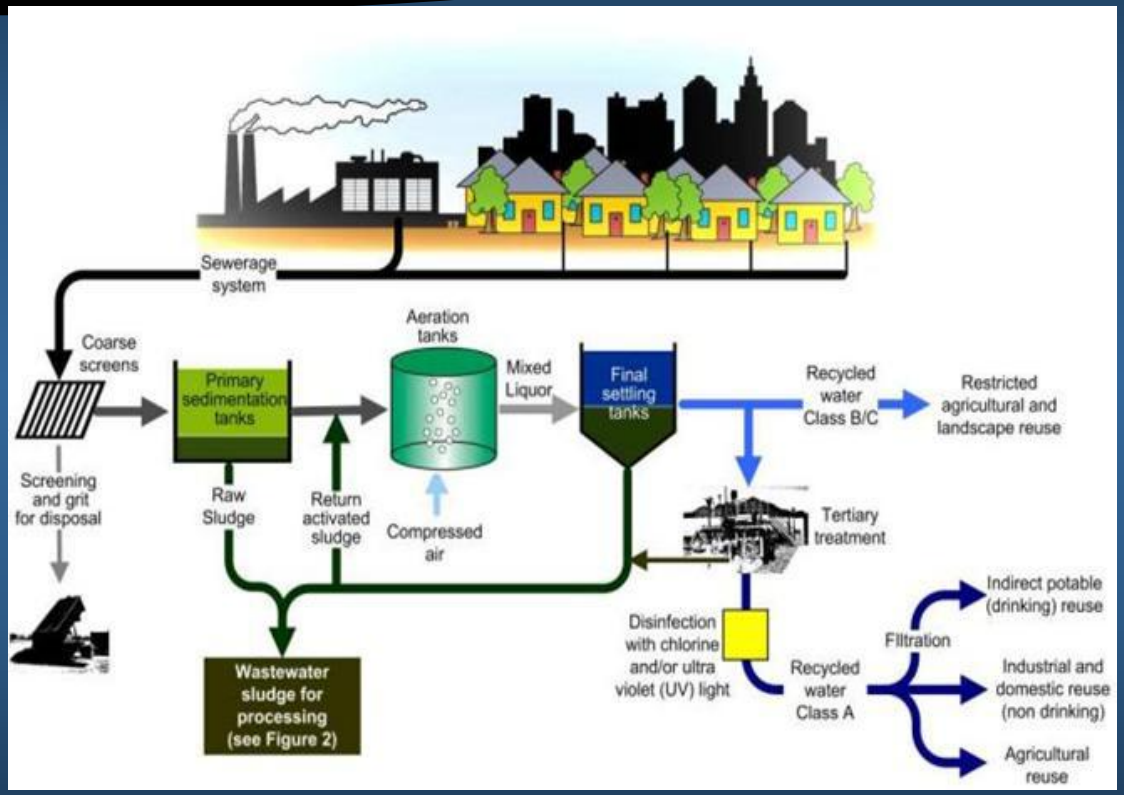
Intense Life-Stock Operations

- Contain hormones, nutrients and pharmaceuticals

Sources of Contaminants

- Industrial chemicals such as polychlorinated biphenyls (PCBs) and dioxins

Sources of Contaminants



Sewage Treatment Plants

- ü Incomplete elimination of:
  - Hormones
  - Pharmaceuticals
  - Other chemicals

Water & Pollution - Main Concerns

- Human Health
  - Drinking Water
  - Agriculture
  - Recreational Use
- Ecological/Wildlife

Current Challenges - Canada

- Outdated wastewater treatment technologies across Canada
- Insufficient monitoring data, particularly in the Prairie Provinces => What is the true status of water quality?
  - Given the multitude of chemicals it is difficult to pinpoint causative agents

University of Saskatchewan

CETES
Canada Ecotoxicity Testing & Screening

ENTRIX
Down to Earth. Down to Business.

Current Challenges - Canada

- **Significant economic growth = Massive increase in water demand due to:**
  - ü Industrial activities (e.g. mining)
  - ü Increase in population
- **Rural communities**

University of Saskatchewan

CETES
Canada Ecotoxicity Testing & Screening

ENTRIX
Down to Earth. Down to Business.

Addressing Concerns …

- Canadian Council of Ministers of the Environment (CCME)
  - ü Environmental Effects Monitoring Program (EEM)
  - ü Recognized the potential environmental issues resulting from exposure to EDCs and other emerging contaminants downstream of WWTPs
  - ü Agreed in November 2003 to develop a Canada-wide strategy for municipal wastewater effluent (MWWE)

Addressing Concerns …

- **Multi-stakeholder projects to characterize current status of water quality and effluent treatment**
  - ü Canadian Municipal Water Consortium (multiple projects across Canada to assess novel tool-boxes for characterization of effects of emerging contaminants from municipal wastewater effluents)
  - ü SHRF Safe Water for Health Team
  - ü Global Institute for Water Security (GIWS)

University of Saskatchewan

CETES
Canada Ecotoxicity Testing & Screening

ENTRIX
Down to Earth. Down to Business.

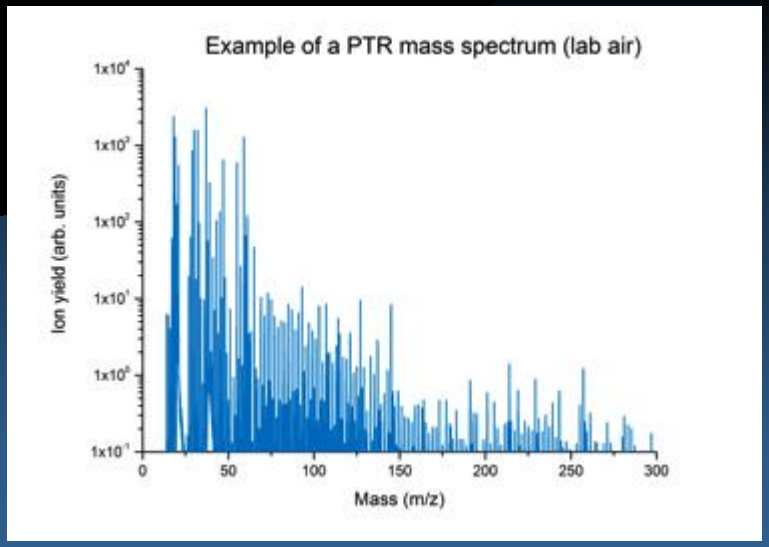
Addressing Concerns … Examples

- SHRF Safe Water for Health Team (Project Lead: L. Bharadwaj, UofS)
  - ü Summarize and map existing data on drinking water quality
  - ü Evaluate most plausible associations between water quality and chronic disease using environmental exposure and health data
  - ü Community-based risk assessment to characterize challenges associated with access to clean drinking water

Addressing Concerns … Examples

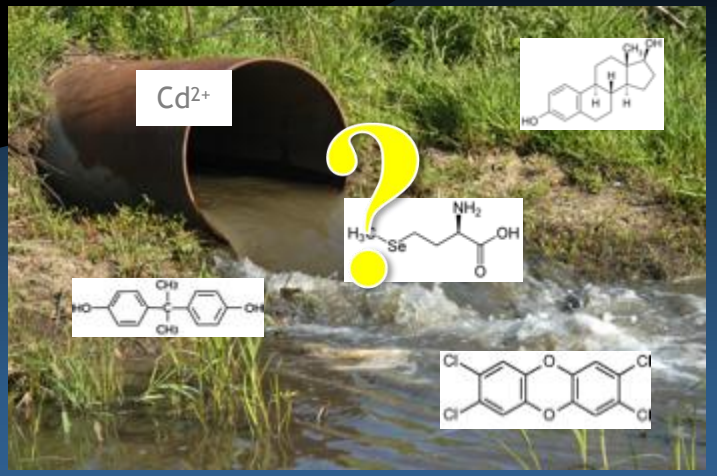
- **CWN Aquatic Impact Assessment of Municipal Effluents (AIME) (Project Lead: M. Hecker, UofS)**
  - ü Optimize and validate a screening and prioritization approach ("toolbox") to:
    - Characterize exposure to emerging contaminants (Endocrine Disruptors) in municipal effluents using effect directed analysis
    - Identify potential hazards to local ecosystems
    - Assess efficiency of removal of emergent contaminants

Addressing Concerns … Examples



- **Exposure assessment challenge**
  - ü Typically, exposure scenarios are characterized by complex mixtures of chemicals
  - ü Traditional approaches used analytical chemistry to characterize exposure, but …

Addressing Concerns … Examples



- Chemical analysis requires a priori understanding of the type of
- Ignores
- Very expensive
- Difficult to assess biological hazard

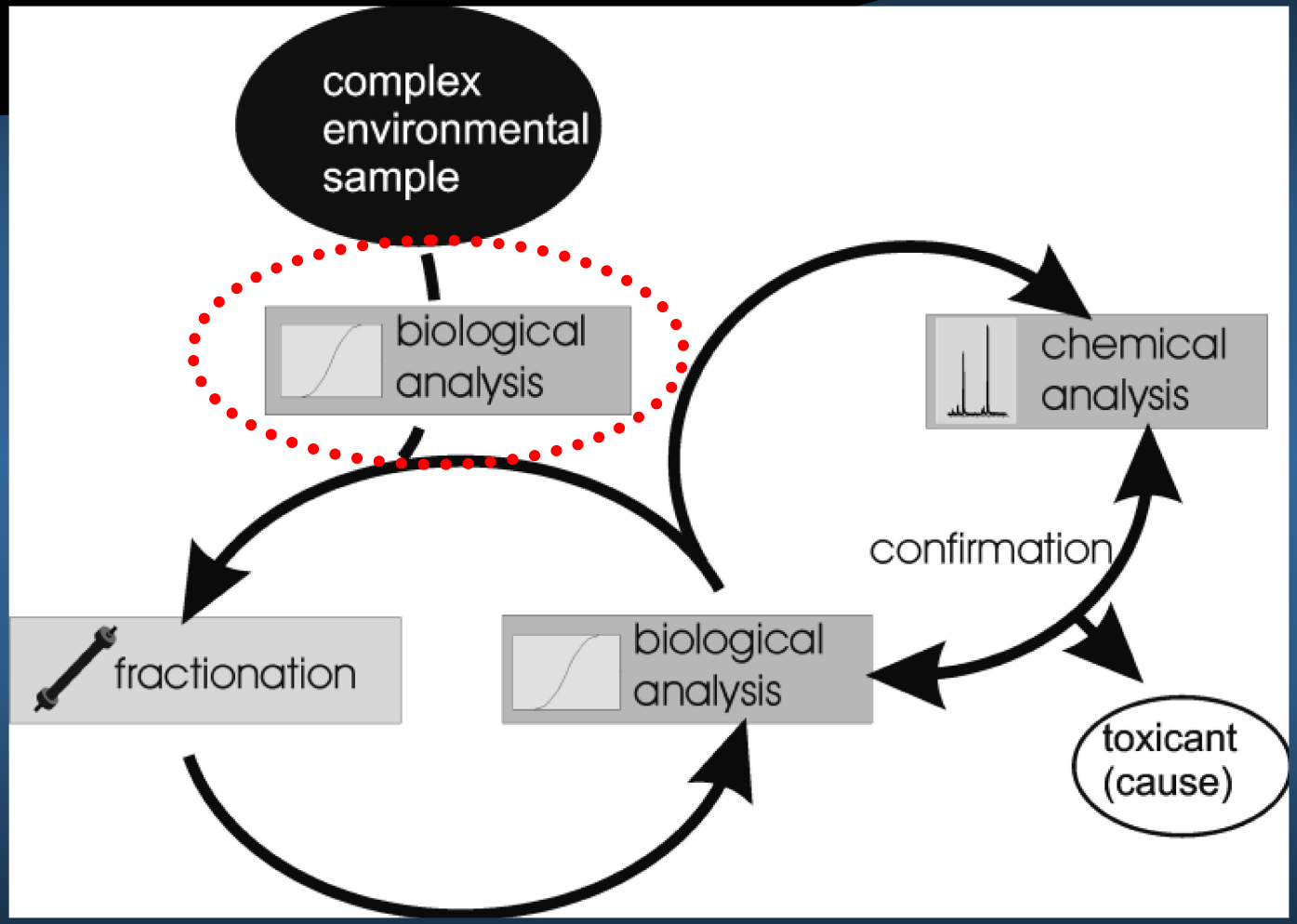
Effect Directed Analysis

University of Saskatchewan

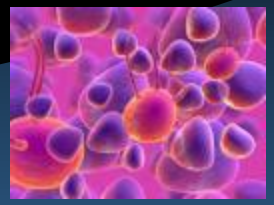
CETES
Canada Ecotoxicity Testing & Screening

ENTRIX
Down to Earth. Down to Business.

Effect Directed Analysis

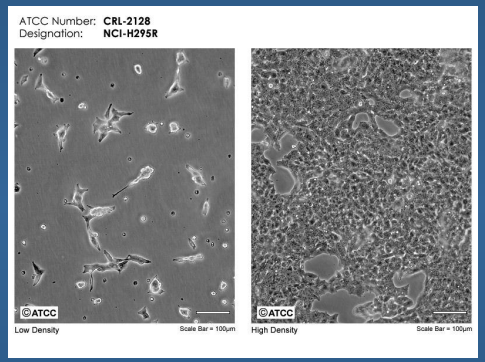


Effect Directed Analysis



STEP I:

- Uses biology to characterize type of contamination
  - ü *In vivo* assays
  - ü *In vitro* assays



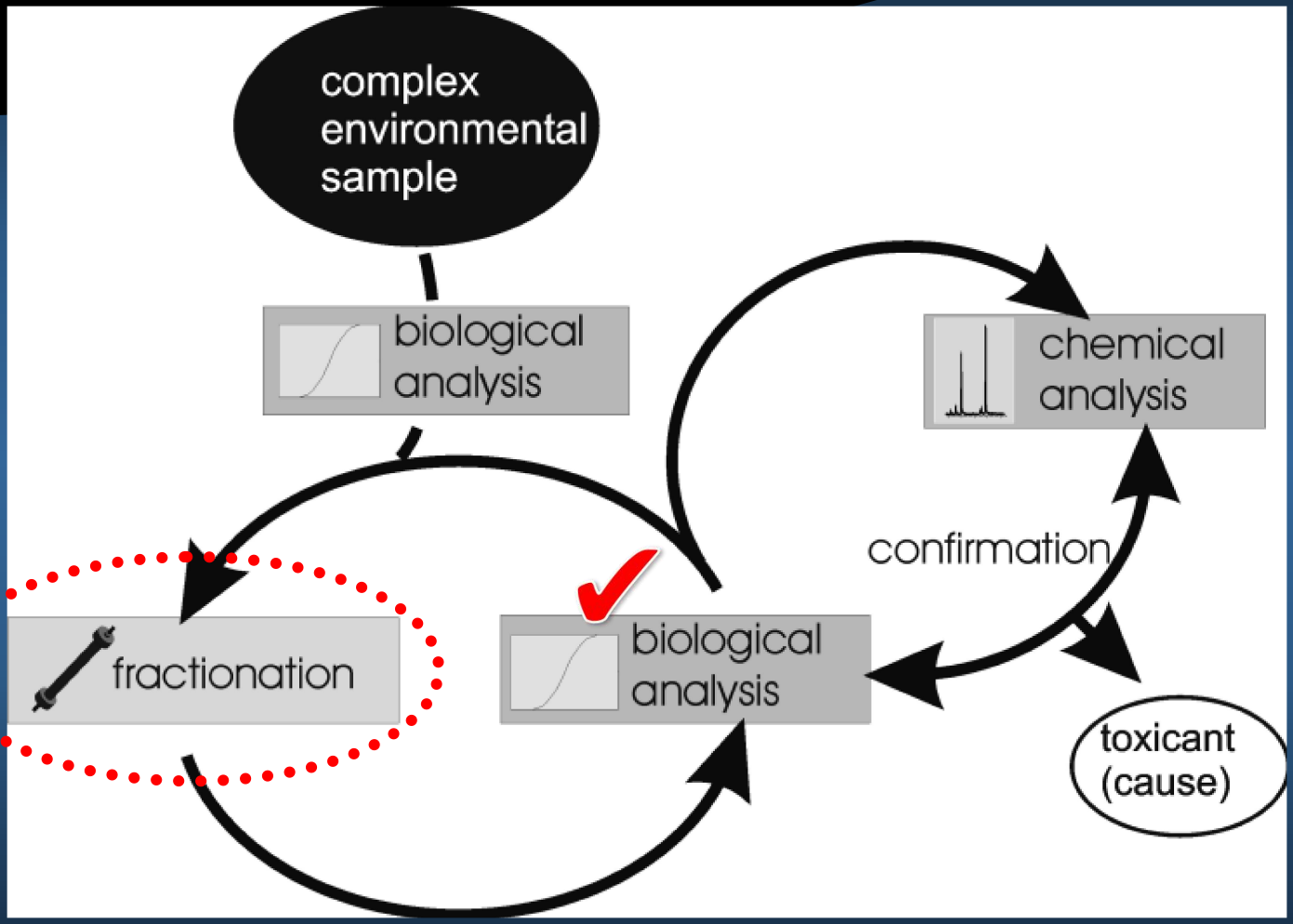
- Example Effects
  - ü (Anti)androgenicity
  - ü (Anti)estrogenicity
  - ü Hormon production disruption
  - ü AhR receptor (dioxin-like)
  - ü Genotoxicity/mutagenicity
  - ü General cytotoxicity

University of Saskatchewan

CETES
Canada Ecotoxicity Testing & Screening

ENTRIX
Down to Earth. Down to Business.

Effect Directed Analysis

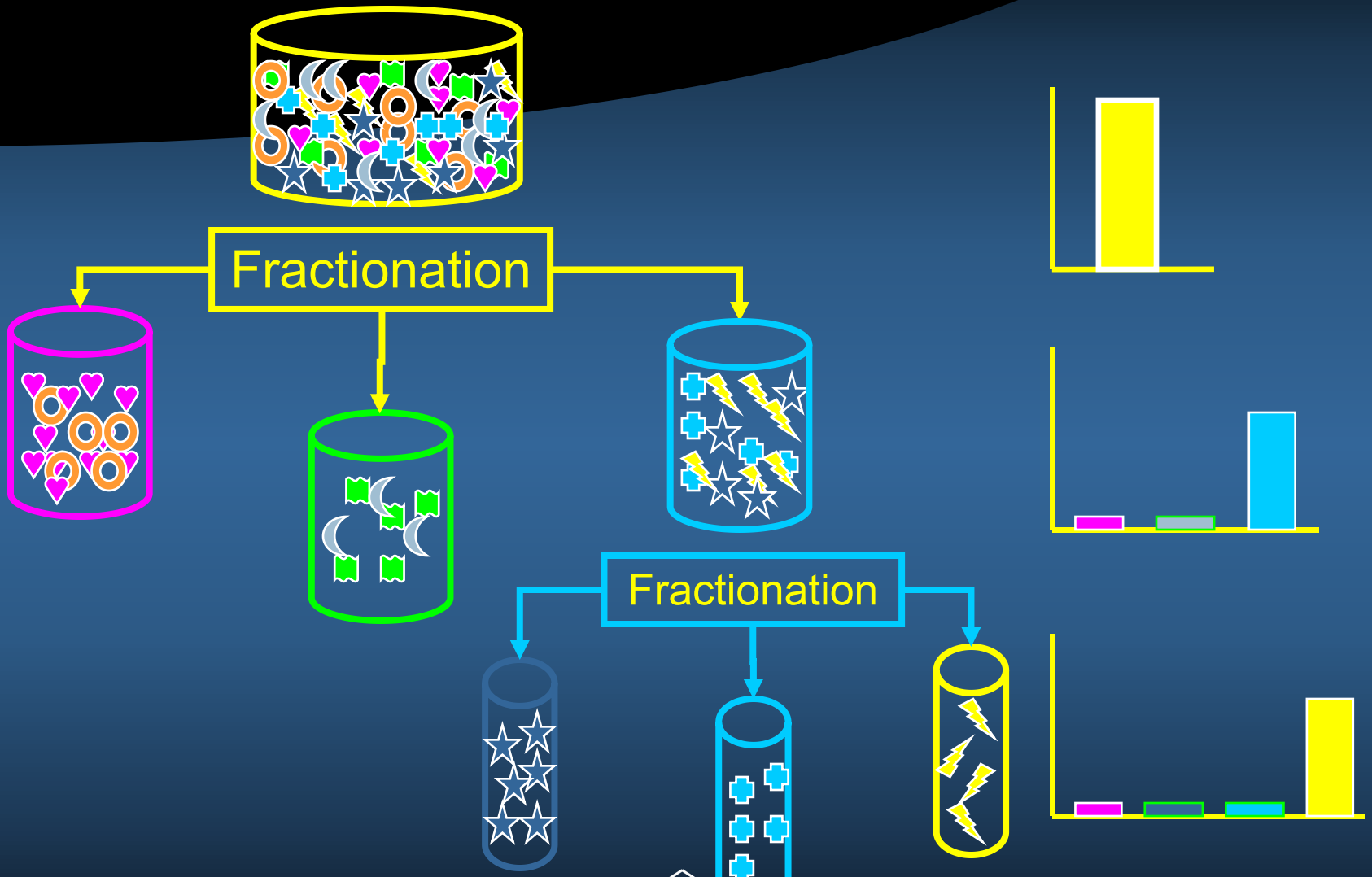


Effect Directed Analysis

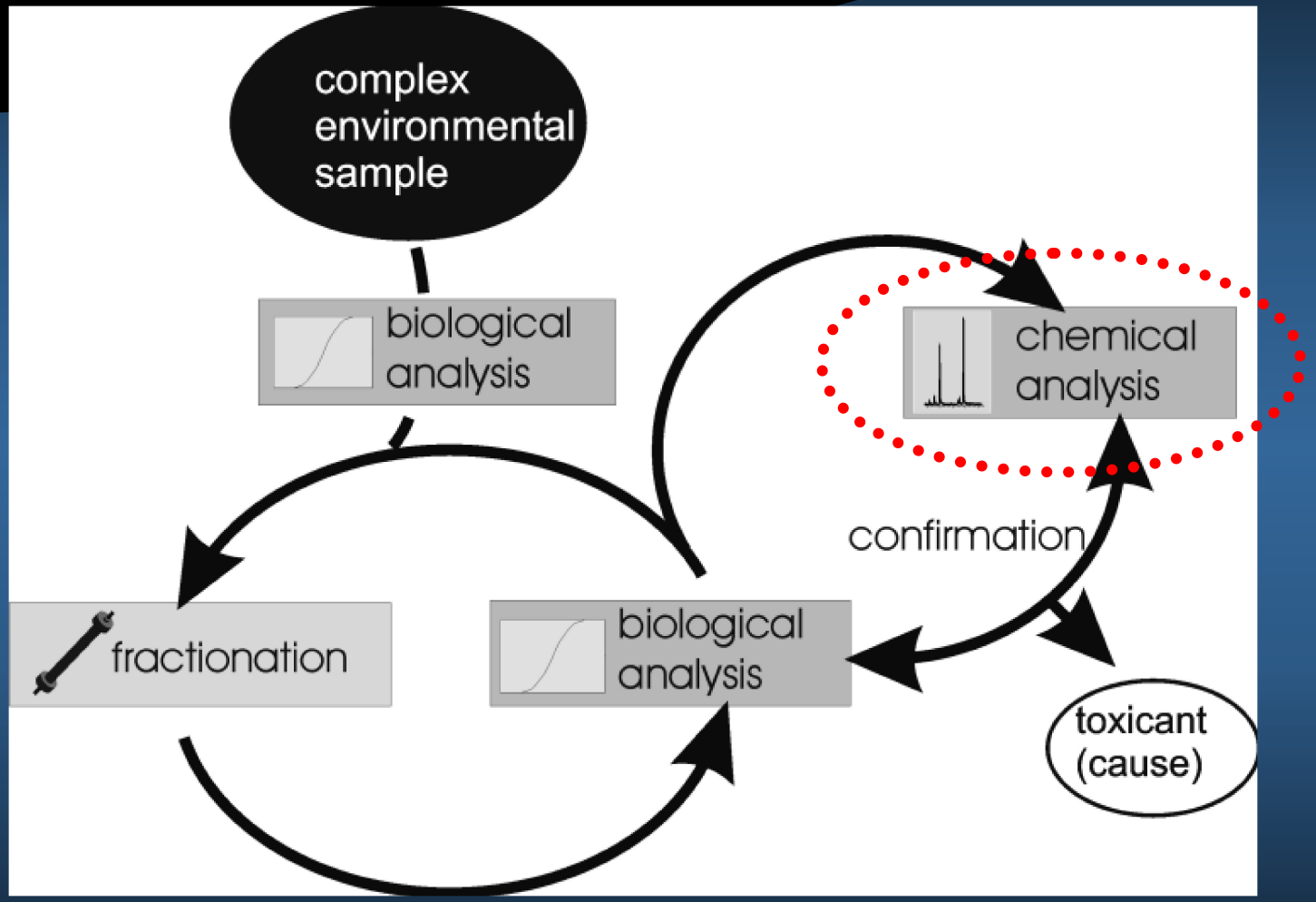
STEP II:

- Biologically active samples are then separated into multiple fractions to separate chemicals based on specific physico-chemical properties
- Fractions are tested again to identify those containing biological activity

Bioassay-directed fractionation

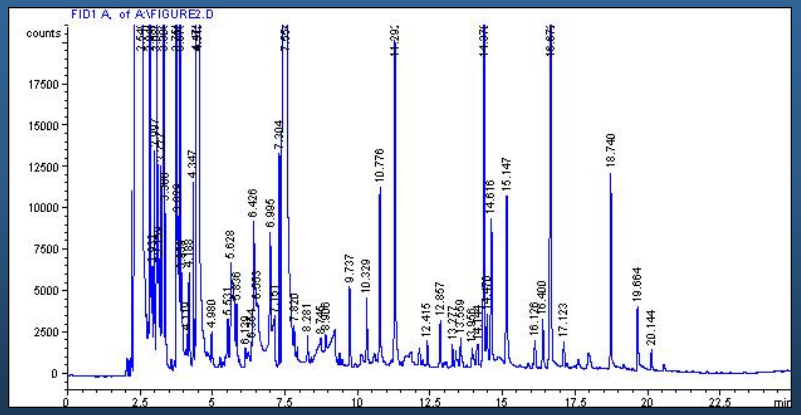


Effect Directed Analysis



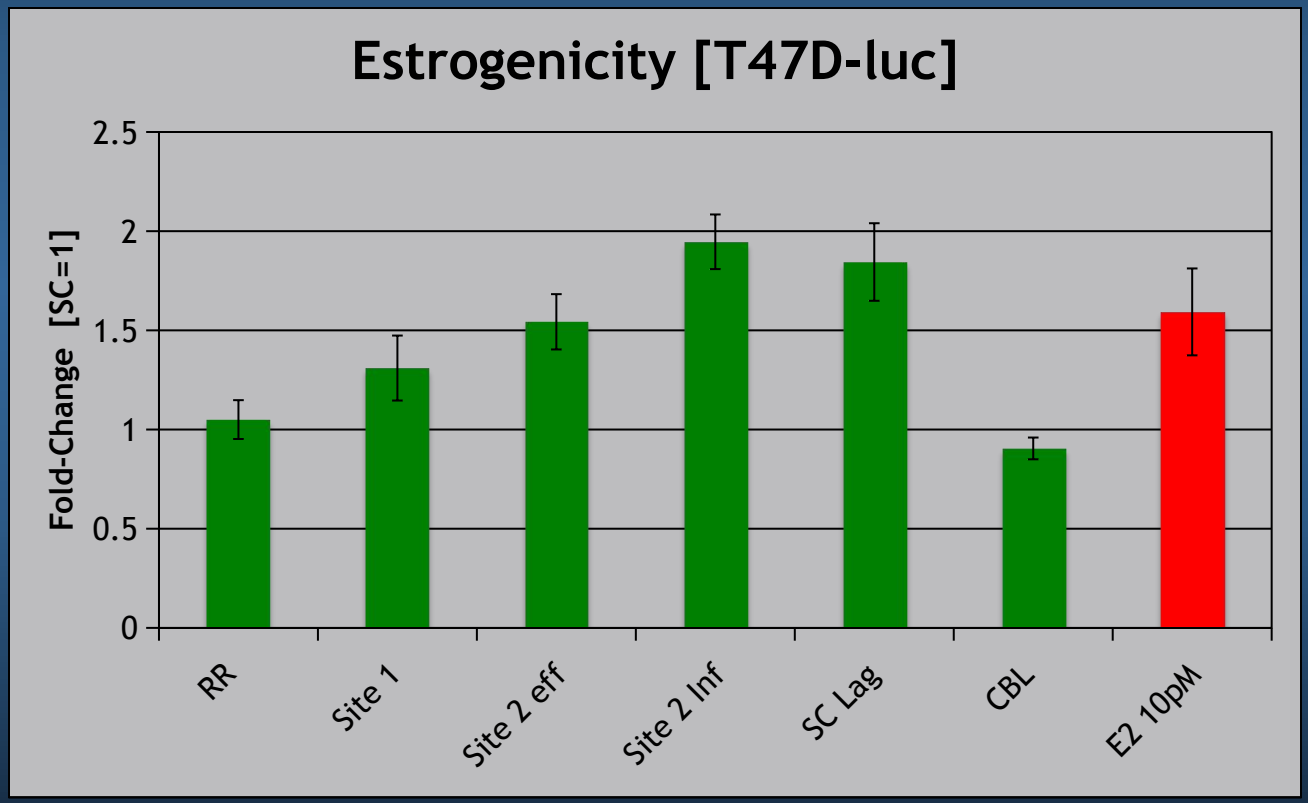
Effect Directed Analysis

- Type of biological effect observed (e.g. estrogenic properties) will then inform chemical quantification



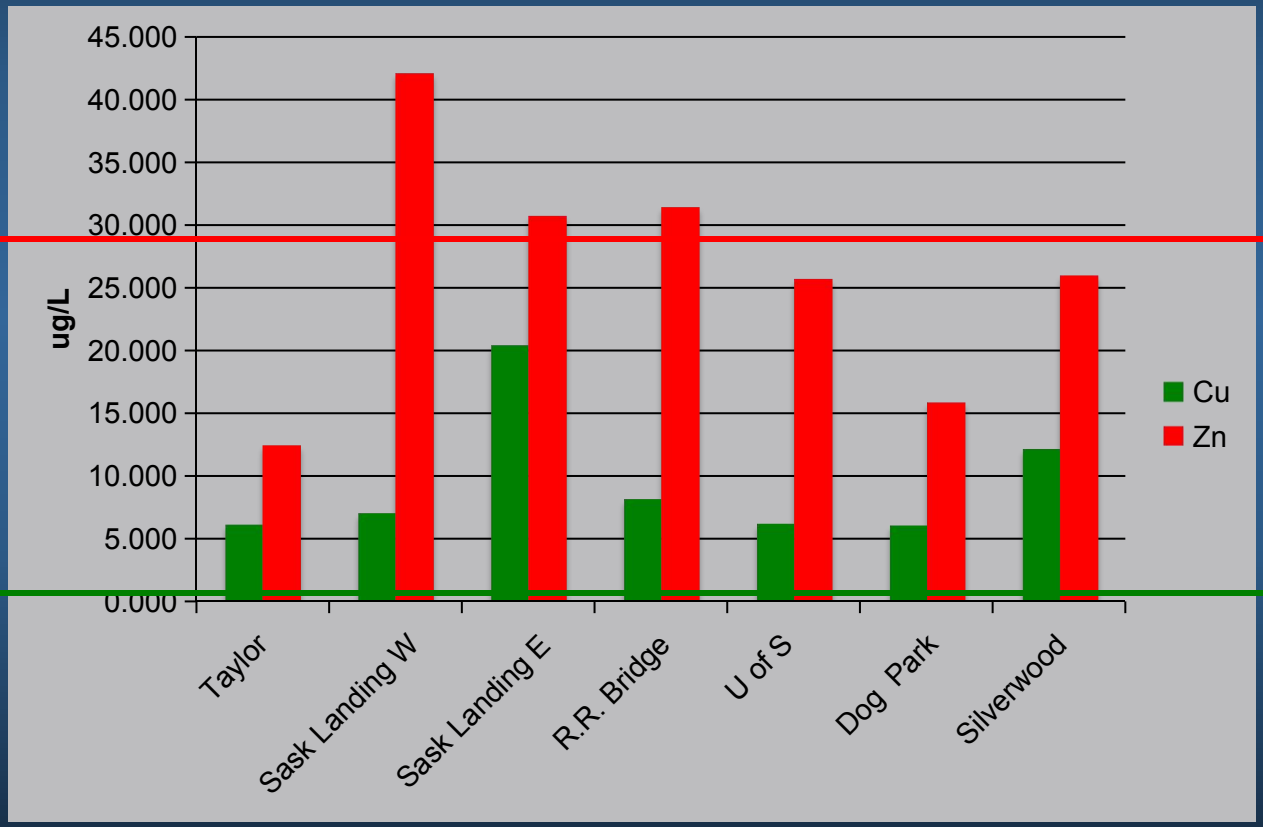
Effect Directed Analysis

- Example Data: Swift Current Creek, SK

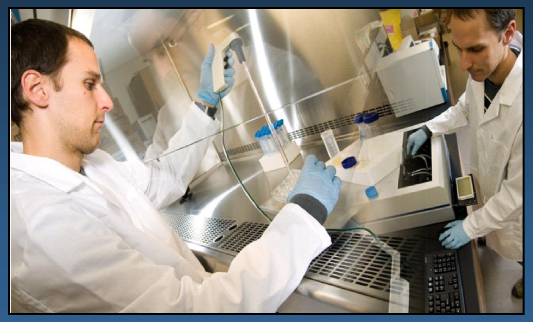


Effect Directed Analysis

3 Example Data: Metals in Saskatoon Stormwater, SK



CETES - Background

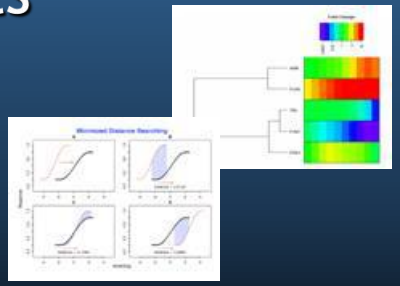


- Canada Ecotoxicity Testing & Screening, Inc. (UofS owned)
- Founded in response to the upcoming screening and testing requirements
- Provides clients solutions in support of their chemical or environmental testing requirements

CETES
Canada Ecotoxicity Testing & Screening

CETES – Services

- **Testing & Consultation to Characterize Assess Water Quality and Associated Health Concerns**
  - Conduct of *in vitro* and *in vivo* screening assays to assess potential exposure & risks due to contaminants
  - Data Interpretation & Potential Environmental Risks
  - Implications for Future Testing Requirements
  - Representation before Regional, National & Global Regulatory Authorities



University of Saskatchewan

CETES
Canada Ecotoxicity Testing & Screening

ENTRIX
Down to Earth. Down to Business.

Thank You!

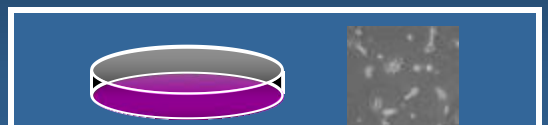
Dr. Markus Hecker
Associate Professor & Canada Research Chair
Toxicology Centre
44 Campus Drive
University of Saskatchewan
Saskatoon, Sk S7N 5B3
Phone: (306) 966-5233
Email: markus.hecker@usask.ca

University of Saskatchewan

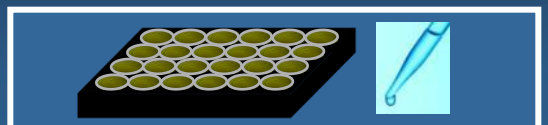
CETES
Canada Ecotoxicity Testing & Screening

ENTRIX
Down to Earth. Down to Business.

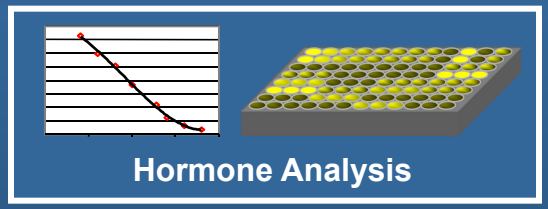
H295R Steroidogenesis Assay

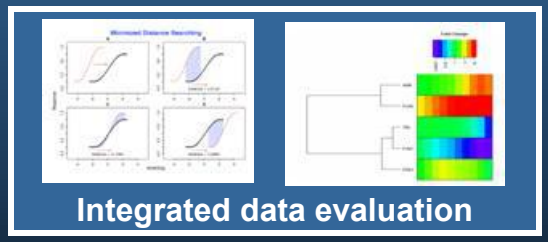

Culture cells for > 5 passages

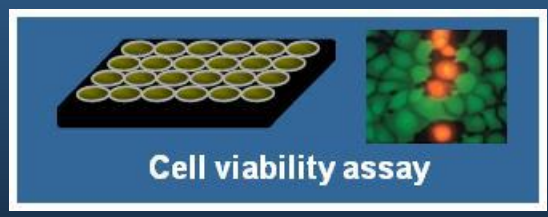

Seed plate at 300,000 cells/mL & incubate at 37 C for 24 h


Dose cells after 24 h at 37°C & incubate at 37 C for 48 h


Remove medium & extract in preparation for hormone analysis


Hormone Analysis


Integrated data evaluation


Cell viability assay


Aromatase Activity Assay

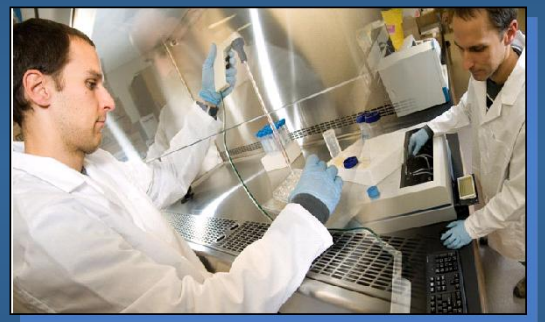
CETES
Canada Ecotoxicity Testing & Screening

University of Saskatchewan

ENTRIX
Down to Earth. Down to Business.

CETES – Advantages

- Comprehensive understanding of the required screening assays
- Trained laboratory professionals with modern facilities & equipment
- Ability to interpret data results (all inclusive package)



- Association with Cardno ENTRIX: track record in representing crop protection companies, chemical manufacturers & consumer product companies for over 30 years.

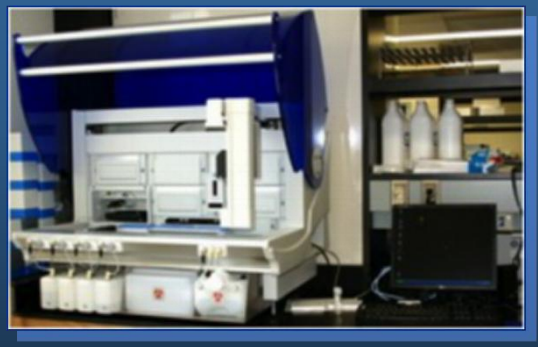
University of Saskatchewan

CETES
Canada Ecotoxicity Testing & Screening

ENTRIX
Down to Earth. Down to Business.

CETES – Advantages

- Excellent "State of the Art" laboratory facilities
- GLP compliance
- Lead by experts well known to government and other regulatory organizations
- Pending patents of improved screening assays: unique on market
- No need for initial investment as equipment has been established through WED grants to the Toxicology Centre



University of Saskatchewan

CETES
Canada Ecotoxicity Testing & Screening

ENTRIX
Down to Earth. Down to Business.

CETES – Long Term Goals

- Capture large portion of future screening programs (>10,000 chemicals)
- Use as platform to capitalize novel technologies developed at the U of S
- Expand beyond University level and possibly privatize
- Explore global markets through existing contacts in Asia and Europe

University of Saskatchewan

CETES
Canada Ecotoxicity Testing & Screening

ENTRIX
Down to Earth. Down to Business.

Endocrine Disruption - Concerns

- Interaction with processes that may affect crucial physiological functions:
  - Reproduction
  - Development
  - Growth
  - Energy
  - Internal homeostasis