2012

TOXICOLOGY CENTRE SELF-ASSESSMENT DOCUMENT

UNIVERSITY OF SASKATCHEWAN

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A. Introduction

Toxicology is the science that deals with the adverse effects of chemical and physical agents on living organisms and biological systems. The University of Saskatchewan (U of S) first formally recognized the need for developing expertise in this area in 1975, when a coordinator of toxicology research on campus was appointed with the specific mandate to foster toxicology research, and to work towards the establishment of a toxicology centre. In 1978, the College of Graduate Studies and Research approved the terms of reference for the establishment of the Toxicology Group, whose members were and still are comprised of scientists with academic or research interests in toxicology at the University, or at any of the Federal and Provincial agencies on and near campus. The broad expertise of the Toxicology Group provided the foundation for the development of an Interdisciplinary Graduate Program in Toxicology, the first of its kind in Canada, which the University approved in 1980. Further support for toxicology was achieved in 1982, when the Government of Saskatchewan and the University of Saskatchewan entered into an agreement to establish the Toxicology Research Centre, with Dr. Bruno Schiefer appointed as Director. The Centre was located on campus at 44 Campus Drive in an existing building; the building was partly renovated in 1986 with the assistance of a $2 million contribution from the Federal Government. This building is still the location of the current Toxicology Centre.

In 1988, Toxicology Centres at the Universities of Guelph, Montreal and Saskatchewan formed the Canadian Network of Toxicology Centres (headquartered in Guelph). This Network was active for nearly 15 years and funded numerous research projects and graduate students at the U of S and at other universities across Canada. While the network is no longer active, the relationships that were developed through the network continue to benefit the Toxicology Centre today.

In 1996, the U of S Toxicology Research Centre, the Toxicology Group, and the Toxicology Graduate Program were amalgamated into a single functional unit, the Toxicology Centre, with the goal of providing long-term stability to and a focus for toxicology activities on campus. That year also marked the appointment of Dr. Karsten Liber as the Centre's Director, succeeding Dr. Schiefer after his many years of service. Dr. Liber's expertise in environmental toxicology expanded the Centre's existing capabilities in traditional clinical and biomedical toxicology research and training, and changed the direction in which the Centre was headed, both from the perspective of research focus and the development of academic programs.

University Council approved the implementation of the Northern Ecosystems Toxicology Initiative (NETI) in December 2000, as the second Priority Determination project at the U of S (one of only four such projects chosen to strengthen institutional priority programs, and the only one of those four still in existence today). Briefly, the objectives of NETI are: (i) to evaluate the ecotoxicological and human health risks associated with northern resource development, (ii) to provide the next generation of toxicologists with the required training to address northern ecotoxicology issues and other emerging concerns, and (iii) to disseminate toxicological information to relevant government agencies and the people of Saskatchewan’s and Canada’s North.

The plan put forward to meet these objectives, which continues to somewhat evolve, includes: (i) developing the best undergraduate toxicology program in the country and the first in western Canada, (ii) strengthening the existing Toxicology Graduate Program to make it the most comprehensive in Canada, (iii) building a unique collaborative toxicology research program focusing on northern ecosystems and

people, and (iv) creating a public outreach and communication program to disseminate toxicological risk information to Aboriginal people and others living in, or concerned with, Saskatchewan's and Canada's North. The initiative was built around the existing U of S Toxicology Centre, Toxicology Group, Toxicology Graduate Program, and various academic departments with existing environmental toxicology strengths (Biology, Geological Sciences, Soil Science, Veterinary Pathology, and Veterinary Biomedical Sciences), with expansion (faculty hires) into four critical areas (aquatic vertebrate toxicology, wildlife toxicopathology, inorganic biogeochemistry [later changed to analytical toxicology], and contaminant fate and transport), thus enhancing existing research expertise and course offerings. A fifth focus (watershed and food-web assessment) was added in 2011. The current NETI faculty consist of Dr. Som Niyogi (Biology), Dr. Steve Siciliano (Soil Science), Dr. Paul Jones (Environment and Sustainability), Dr. Natacha Hogan (Animal and Poultry Science), and Dr. Tim Jardine (Environment and Sustainability).

Renovation and significant expansion of the Toxicology Centre began in 2006 (completed in 2008), in conjunction with the recruitment of Dr. John Giesy as a Tier 1 Canada Research Chair. The $11.8-million project, partly funded by a Canada Foundation for Innovation grant, provided the Centre with unique facilities and capabilities that now make it the foremost university-based toxicology centre in Canada, and one of the best in the world, specifically in the area of water pollution research. The new Aquatic Toxicology Research Facility (ATRF) built as part of the expansion is unique in Canada and one of only a few such facilities in the world, and allows the U of S to pursue its goal of becoming the national and international leader in aquatic toxicology research and training. Accompanying research laboratories consist of analytical, wet chemistry, biochemistry, molecular biology, aquatic, and general toxicology laboratories. Renovation of existing facilities also provided critically needed office and student space.

B. Mandate and Goals

The primary mandate of the Toxicology Centre essentially remains the same as when the Centre was created:

(i) to promote research in toxicology, including interdisciplinary research amongst faculty and with external organizations;
(ii) to oversee and advance the U of S academic programs in toxicology; and
(iii) to promote growth of toxicology as a discipline on and off campus.

Added to that original mandate, are the goals of becoming the undisputed leader in interdisciplinary toxicology research and training among academic institutions in Canada and one of the top toxicology programs in the world, specifically in the field of environmental toxicology. Recently (Fall 2012) re-drafted Vision and Mission statements for the Toxicology Centre and associated academic programs are as follows:

Vision (*draft*):
To be widely recognized as the top institution in North America, and one of the best in the world, for advanced toxicology research, academic and professional training, and stakeholder engagement, with a primary focus on interdisciplinary environmental and comparative biomedical toxicology issues of global significance.

Mission (*draft*):
The Toxicology Centre is the hub of research and administrative support for the U of S Toxicology Program. Through the Centre and the related toxicology academic programs, we will train world-class toxicologists who are sought after by society to address current human and environmental health issues,

and provide regional, national and international leadership in the practice of toxicology through public and technical outreach, and stakeholder engagement.

C. Governance

The Toxicology Centre is led by a director, Dr. Karsten Liber, who reports directly to the Office of the Vice-President Research.

The Toxicology Centre is governed by the Toxicology Advisory Board which is comprised of 12 members including: Dean, College of Graduate Studies and Research; Dean, Western College of Veterinary Medicine; two members representing the private sector; two members representing the Government of Saskatchewan; two members elected by the Toxicology Group; President of the Toxicology Graduate Student Association; and three *ex-officio* members including the Associate Vice-President Academic, the Vice-President Research (or designate), and the Director of the Toxicology Centre. Board members serve for three-year renewable terms.

The Terms of Reference for the Toxicology Advisory Board states that the Board shall:

- be chaired by a member of the Advisory Board selected at the first annual meeting;
- meet at least once each year to review the mandate and status of the Toxicology Centre and supporting activities as presented by the Director;
- make recommendations to the Director and to the University on matters relating to the operation of the Toxicology Centre; and
- provide advice on the role of the Toxicology Centre in the Province of Saskatchewan.

Academic programs in toxicology are overseen by the Toxicology Centre Director, but managed by academic committees: in the case of the undergraduate program by the Toxicology Undergraduate Program Administrative Committee, and in the case of the graduate program by the Toxicology Program Graduate Committee. The undergraduate program is offered through the College of Arts and Science, and thus reports to that college through a designated dean (the Dean of the Western College of Veterinary Medicine) and the Toxicology Centre director. The graduate program is offered as an interdisciplinary program through the College of Graduate Studies and Research and reports to the dean of that college through the Toxicology Centre director.

The core faculty in the Toxicology Program (those directly involved with the teaching of Toxicology courses and with supervising Toxicology students, undergraduate and graduate) comprise the Toxicology Faculty Council. This council meets monthly (except for July and August) at faculty meetings chaired by the Toxicology Centre Director. All significant programmatic changes and initiatives are discussed at the Council; decisions are made my majority vote.

The Toxicology Group is an interdisciplinary body under the umbrella of the College of Graduate Studies and Research coordinated and managed by the Toxicology Centre. It consists of faculty members from a number of University departments, as well as scientists from various research centres located on or near campus. Scientists with academic or research interests in toxicology, who work at the U of S or any of the federal and provincial agencies or private sector laboratories on or near campus, are eligible to become members of the Group. Two types of membership may be granted: *full members* are those currently involved in research or teaching specifically related to toxicology; *associate members* are those who have an interest in toxicology, but are not presently engaged in active research or teaching in the field of toxicology.

The mandate of the Toxicology Group is to:

- maintain and support academic programs in toxicology at the U of S;
- promote and facilitate research in toxicology;
- promote public awareness and engage in community consultation on important issues in the area of toxicology;
- work cooperatively and collaboratively with all academic units participating in toxicology; and
- address difficulties when they arise in matters involving shared resources.

The Group is headed by a Chair, who is the Director of the Toxicology Centre, or his/her designate. The Chair is assisted by an Executive Committee, elected every three years by the membership. The Executive Committee consists of an Academic Coordinator, two members-at-large elected by the membership, one member-at-large elected by the Toxicology Centre, and the Dean, College of Graduate Studies and Research (*ex officio*). Members of the Toxicology Group are eligible to serve as supervisors for students enrolled in MSc and PhD programs in Toxicology, pending approval by the College of Graduate Studies and Research, and are engaged in research across a broad spectrum of toxicology sub-disciplines. A list of current Toxicology Group members can be found in Appendix 1. Those presently comprising the Toxicology Faculty Council are listed in bold italics.

D. Infrastructure

The 2006-08 renovation and expansion of the Toxicology Centre, and subsequent instrument acquisitions, have provided the Centre with unique infrastructure and strong analytical and experimental facilities. Highlights are provided below.

The Aquatic Toxicology Research Facility

The Aquatic Toxicology Research Facility (ATRF) is one of very few laboratories in Canada where researchers can study the adverse effects of chemical and physical agents on aquatic organisms under a wide variety of controlled environmental conditions. Many aspects of the facility are unique.

The ATRF is a self-sufficient, multi-user facility available for use by both Canadian and international investigators through research partnerships with Toxicology Centre scientists. The 650 m^2 facility was designed to simultaneously provide water with different water quality characteristics to different sections of the facility. Water temperatures can range from 5 to 45°C in order to perform both static and continuous flow toxicology experiments with a broad range of freshwater organisms including algae, crustaceans, insects, amphibians, and both small and large fish species. In addition to a multitude of large tanks for holding fish, the facility includes walk-in, controlled-environment chambers and self-contained proportional dilutor systems for conducting both acute and chronic aquatic toxicity tests with freshwater invertebrates, small fish and algae.

The ATRF consists of separate rooms for animal holding/culture and experimentation/chemical exposure, and for the pre- and post-treatment of water. The ATRF produces high quality water and has the ability to provide researchers with virtually any freshwater characteristics for their animal husbandry requirements and experiments. The ATRF routinely houses common laboratory species such as frogs, zebrafish, fathead minnows, and rainbow trout, but also enables researchers to house and rear more regionally-relevant aquatic species (e.g., walleye, northern pike, sturgeon, lake chub) that are required to answer key regional environmental questions.

Due to its flexible design, the ATRF can be adapted to work with almost any experimental design and equipment configuration. Separate water lines enable the delivery of a wide range of water quality including varying water hardness, pH and temperature, in addition to precise photoperiod control. The facility contains a large number of tanks (ranging in volume from 9 to 2000 litres) and specialized equipment to further optimize aquatic animal housing and experimentation. In addition, specialized plumbing allows for collection and treatment of any hazardous wastewater generated.

Analytical Laboratories

The Environmental Toxicology Laboratory contains one of the most extensive suites of mass spectrometry systems in academic research centres in Canada. Instruments range from high resolution magnetic sector and time-of flight mass spectrometers, to several low resolution quadrapole systems coupled to a variety of chromatographic systems. With this extensive suite of instruments the laboratory is able to take on even the most challenging analytical projects. Recent studies have used high resolution gas chromatography coupled to a high resolution mass spectrometer to measure ultra-trace concentrations of dioxins and PCBs in a variety of environmental samples from China, Korea, the USA, and Canada's Northwest Territories. The system used is the only instrument of its kind in Saskatchewan. The instrument has also been used to assist a private company in the development of treatments for agricultural seed protection.

Liquid chromatography systems coupled to high resolution time-of-flight mass spectrometry are being used to seek out and, if present, measure a variety of water borne contaminants including algal biotoxins, antibiotics and pharmaceuticals in Lake Diefenbaker, Saskatchewan's largest source of drinking water. Low resolution MS and MS/MS systems are being used in ongoing studies on perfluorinated compounds in samples from around the world. When coupled to gas chromatography systems, these instruments are also being used to measure pesticides and PCBs in a variety of wildlife samples from around the province.

The Water Quality Laboratory specializes in inorganic analysis (trace elements, major ions) of water, sediment and tissue samples from both laboratory and field studies conducted at the Centre and at field locations around the country. Instrumentation includes an inductively coupled plasma mass spectrometer, an inductively coupled plasma optical emission spectrometer, an ion chromatography system, an automated water quality titrator, and a wide array of smaller water quality analysis instruments.

Additional laboratories at the Centre are fully equipped for physiology, biochemistry and molecular analyses, and include equipment such as: atomic absorption spectrometers (including FAAS, GFAAS, and HGAAS), capillary electrophoresis with UV/Vis, PDS and LiF detectors, HPLC with UV and fluorescence detectors, cold vapor-atomic fluorescence system (CV/AFS), hydride generation-atomic fluorescence detector (HG/AFS), automatic gamma counter, accelerated solvent extractor, scintillation counter, ultra centrifuge, robotic ELISA and Illumina systems, gel electrophoresis and western blotting, molecular imaging system, real-time PCR machine, fluorescence microscope, epifluorescence microscope, micromanipulation and microinjection system, and two advanced biosafety cabinets (level I + II).

E. Academic Programs

Toxicology Undergraduate Program

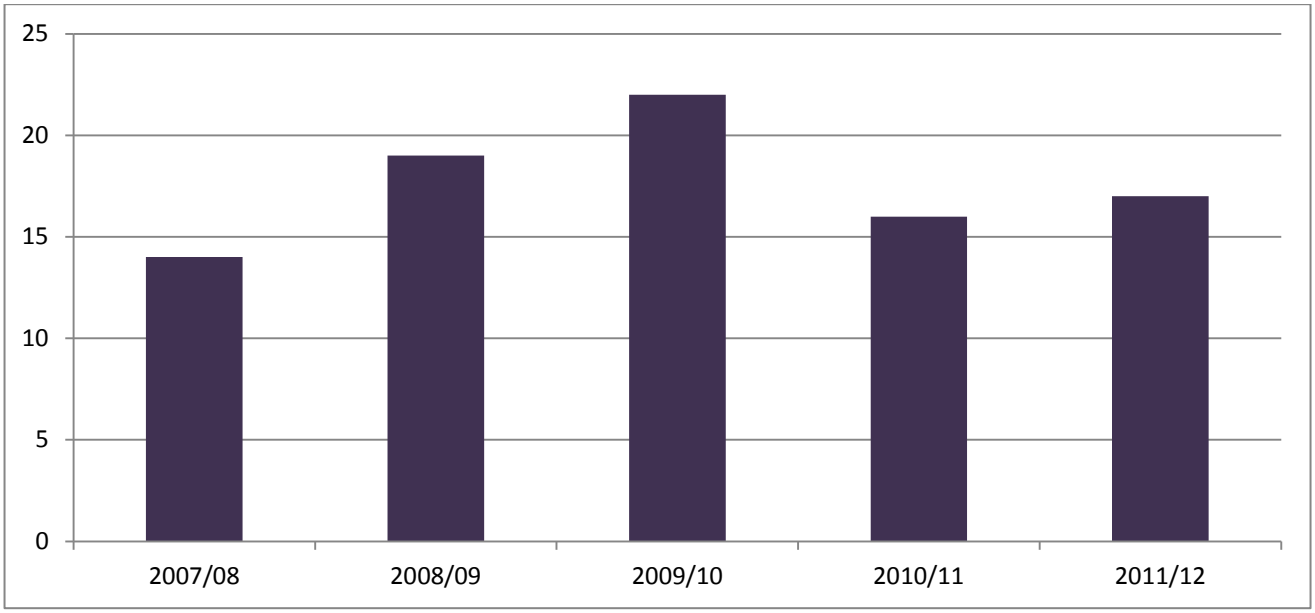
The Interdisciplinary Undergraduate Program in Toxicology at the U of S is the only program of its type in western Canada and the most comprehensive interdisciplinary undergraduate toxicology program the

country. The program commenced in September of 2002 as a result of a successful submission (Northern Ecosystems Toxicology Initiative, NETI) to the University of Saskatchewan's Priority Determination process, a competitive process that aimed to identify a small number of strategic areas that the University wanted to pursue for national leadership. The undergraduate program has direct involvement from various disciplines at the U of S, including many departments in the College of Arts and Science who deliver most of the courses offered in Years 1 and 2 of the program. The first Toxicology classes were offered in the fall of 2002, with an initial graduating class in 2004 of six students. During the 2011-2012 academic year there were approximately 60 declared Toxicology majors in the undergraduate program; the 2011-12 graduating class was comprised of 17 students. Since there are always a large number of undeclared majors in Years 1 and 2 of the program, best estimates of the total undergraduate student population pursuing a degree in Toxicology in any one year is somewhere between 80 and 100 students.

The Toxicology Undergraduate Program has been designed to provide students with a basic understanding of how toxic substances behave in the body and in the natural environment, how and by what mechanisms toxicants may adversely affect individuals, populations and ecosystems, and how to measure toxicants and their potential effects. It consists of a core of toxicology courses, with additional required courses from a few other departments (Appendix 2). It allows students to choose from a large number of electives so that they can focus their undergraduate program to emphasize either environmental toxicology or biomedical toxicology. Given the multidisciplinary nature of toxicology, students in the first two years of the program receive a broad education in the natural and life sciences. Required courses include Biology, Genetics, Cell Biology, Organic Chemistry, General Chemistry, Physics, Ecology, Biochemistry, Environmental Chemistry, Statistics, Laboratory Techniques, and Physiology. Courses focusing specifically on toxicology are taught in years three and four of the program. A list of core undergraduate toxicology courses with the numbers of students enrolled each year is provided in Appendix 3. It is worth noting that two of our faculty (M. Wickstrom, 2010; B. Blakley, 2011) were awarded a University of Saskatchewan Student's Union Award for Teaching Excellence (only 10 such awards are given annually campus-wide). Other Toxicology faculty have been nominated.

Undergraduate courses are being regularly evaluated and revised as necessary. Two new courses were introduced in 2009-10 (Inhalation and Environmental Toxicology of Air Pollutants, and Soil Ecotoxicology and Risk Assessment [renamed Contaminated Site Management and Remediation in 2012-13]). A new course in Aquatic Toxicology is being delivered for the first time in term 2 of the 2012-13 academic year. Two additional new courses (Environmental Pollution and Public Policy [title tentative] and Quantitative Toxicology) are planned for delivery in 2013-14. Several undergraduate toxicology courses have been popular among students from other academic units for many years. For example, TOX 300 (General Principles of Toxicology) and TOX 301 (Environmental Toxicology) are heavily subscribed by non-majors from various colleges. The latter course has recently been included as a required course in the U of S Environmental Engineering Program. Currently, enrollment in both of these courses has to be capped, with blocks of seats reserved for Toxicology majors. Possible expansion of these courses to meet increasing enrolment demand is presently under evaluation. Overall, the Toxicology Undergraduate Program has developed into a very successful interdisciplinary program. The number of graduates earning a BSc in Toxicology has leveled off at approximately 15-20 per year over the last five years (Figure 1).

Figure 1 – Toxicology Undergraduate Program Graduates (last five years).



Upon completion of the undergraduate program, students can receive either a BSc Four-year or a BSc Honours degree. Graduates with a major in Toxicology find work with industry, environmental consulting firms, and federal and provincial government research laboratories and regulatory departments. Job opportunities range from laboratory and field work, to regulatory and consulting positions. Alternatively, students with an undergraduate degree in Toxicology can pursue graduate studies in toxicology or other programs at the MSc or PhD level. They also meet the course requirements for admission to medicine, veterinary medicine, pharmacy, and dentistry (pending their choice of electives).

The Toxicology Undergraduate Program is overseen on a day-to-day basis by the Toxicology Undergraduate Program Advisory Committee (TUPAC) and strategically by the Toxicology Centre director; the degree is conferred by the College of Arts and Science. The Toxicology Centre provides the focal point for the program and serves as the program's coordinating and administrative unit. Development of a new undergraduate student lounge within the Centre is presently being pursued.

A recognized shortfall in the Toxicology Undergraduate Program is the lack of laboratory-based courses to provide students with hands-on experience in subjects such as analytical toxicology and toxicity testing. Some core courses (e.g., BIOL 475 and EVSC 420) have computer-based modeling labs, and CHEM 375 (Environmental Chemistry) provides some exposure to analytical instrumentation for contaminant quantification. However, students can enhance their practical skills during completion of an undergraduate honours thesis research project (TOX 480/481 – Toxicology Research), or through summer student research assistant positions within the Toxicology Centre and with core Toxicology faculty based outside of the Centre. The Toxicology Centre makes an effort to employ as many summer student assistants as possible each year, with the majority being Toxicology majors (on average 6-10 each year). However, additional faculty and financial resources, and access to an undergraduate teaching laboratory, would be required to deliver new laboratory-based toxicology courses in the Toxicology Undergraduate Program.

Toxicology Graduate Program

The Toxicology Graduate Program, introduced in 1980, was the first of its kind in Canada and is the longest standing interdisciplinary graduate program at the U of S. The Program is led and administered by the Toxicology Centre, but relies on members of the Toxicology Group to deliver courses and supervise graduate students. The primary objective of the Toxicology Graduate Program is to provide high quality toxicology education and training, thus enabling students to develop into highly qualified toxicology professionals. Students enrolled in the Toxicology Graduate Program can specialize in the areas of environmental toxicology or biomedical toxicology, although many skills and techniques are common to both. Due to the interdisciplinary nature of the program, students can receive training and education in a variety of areas associated within toxicology, including: analytical toxicology, aquatic toxicology, wildlife toxicology, ecotoxicology, forensic toxicology, biomedical toxicology, immunotoxicology, molecular/biochemical toxicology, nutritional toxicology, radiation/radionuclide toxicology, and veterinary toxicology. Moreover, students have access to world-class research facilities at the Toxicology Centre, Western College of Veterinary Medicine, College of Pharmacy and Nutrition, College of Agriculture and Bioresources, College of Arts and Science, National Hydrology Research Institute (NHRI), National Research Council (Plant Biotechnology Institute), and Canadian Light Source Synchrotron.

The Toxicology Graduate Program offers degrees at the MSc and PhD levels. A Postgraduate Diploma (PGD; a non-thesis, course-based program) was initially offered as part of the Program. Although this diploma is no longer offered, there is currently a proposal being developed to replace the PGD with a non-thesis MSc in 2013-14. A wide range of courses are presently being offered within the Toxicology Graduate Program (Appendix 4a) which allows students to specialize in various areas of toxicological interest. Program requirements vary depending on whether a student pursues an MSc or PhD degree. MSc candidates are required to complete 9 credit units of core toxicology courses and must write and defend a thesis as a fulfillment of their MSc program. Course requirements for PhD students are 15 credit units (5 courses) for students without a previous MSc in toxicology, and 6 credit units for students holding a MSc in toxicology or a similar discipline. Moreover, all PhD students must complete a qualifying examination, which consists of an oral defence of a written PhD proposal. A comprehensive examination is also required, which usually occurs about 2-3 years into the PhD program, after the students' coursework has been completed. Finally, PhD students must write and successfully defend a thesis based on their research project.

Upon entry into the Toxicology Graduate Program, all students are provided stipends from research grants or scholarships – all students are fully funded to the minimum levels of $17,400 for MSc students and $20,400 for PhD students. Graduate student numbers (Figure 2a) vary somewhat from year to year, but overall student recruitment into the Toxicology Graduate Program has been enhanced since initiation of the Toxicology Undergraduate Program in 2002. To date, 17 graduates from the BSc program in Toxicology have entered the Toxicology MSc or PhD programs. On average, there have been about 40 students enrolled in the Graduate Program in any one year, with approximately 35% enrolled in the PhD Program (Figure 2b). Every year there are significantly higher numbers (between 100-200) of inquiries from both national and international students than can be accepted into the Program. The graduate student population is diverse and consists of students from Saskatchewan, other Canadian provinces, and foreign countries. It should be noted that Toxicology Program faculty have academic homes in various academic units across campus. As a result, most faculty also supervise students in both the graduate and undergraduate programs of those home departments. The total number of graduate students supervised by core Toxicology faculty is thus approximately two times the numbers presented here.

Figure 2a – Number of Students Who Graduated with MSc and PhD Degrees in Toxicology

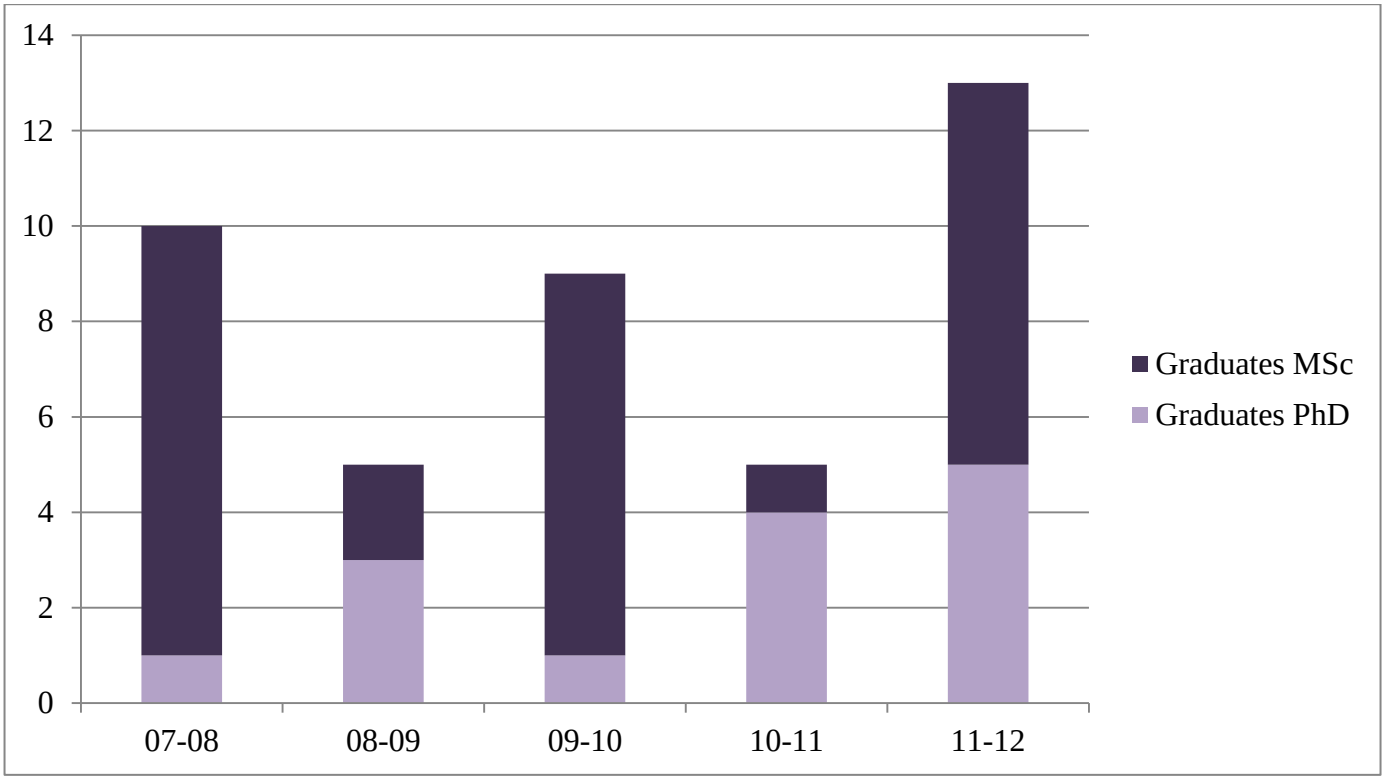
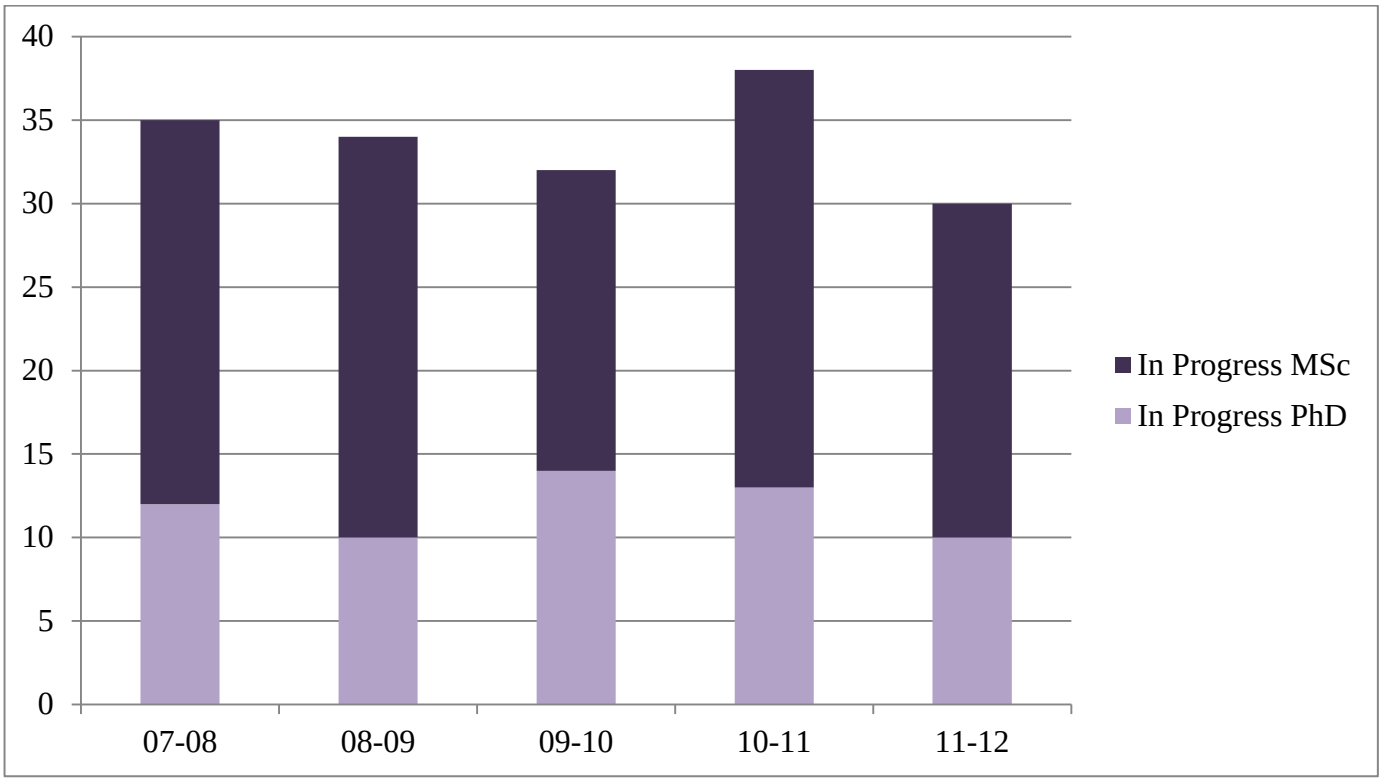


Figure 2b – Number of Students Enrolled in the Toxicology Graduate Program



Graduates from the program are in high demand and many receive job offers before they complete their degrees. While attractive from the students perspective, it does often result in longer than desired times to completion of their graduate programs. That said, it is worth noting that 100% of the students who have graduated from to Toxicology Graduate Program since its inception have moved on to either employment or further study in the field of toxicology or a closely related discipline. A list of alumni and their current or last known place of employment is provided in Appendix 5.

As of 2010, graduate students (primarily PhD students) now also have the opportunity to receive supplemental, specialized training through the Collaborative Research and Training Experience in Human and Ecological Risk Assessment (CREATE HERA) Program, which is a unique NSERC-funded academic initiative, focused on training future risk assessors. The CREATE HERA Program is offered as a supplement to their degree program and is composed of four distinct components: (1) advanced specialized course work (see Appendix 4b), (2) a Summer Institute of Risk course (in 2012 offered by Dr. Susan Cormier, US EPA in combination with the SETAC Prairie Northern regional chapter meeting in Saskatoon), (3) work placement (e.g., with consulting companies such as Intrinsik and Stantec), and (4) professional development (e.g., communication and interpersonal skills, leadership, and research/project management training). In September 2010, the CREATE HERA Program launched its first course offerings with 10 students enrolled, representing both the U of S and other Canadian universities. All students receive a certificate at program completion. CREATE HERA students must take five graduate courses (see Appendix 4b) to complete their program. These courses can count towards their academic degree requirements.

Historically, the Toxicology Graduate Program was largely managed by the Graduate Chair and the Toxicology Centre director, with input from the Toxicology Group Executive. However, after a Graduate Program review (conducted in March 2011), which concluded that the "Program and the Toxicology Centre easily rank within the top five toxicology programs at the international level", minor adjustments to management of the Graduate Program were undertaken (largely in response to the recommendations of the review panel). As a result, a Graduate Program Committee, comprised of four elected Toxicology faculty members including the Graduate Chair, was established. This committee is responsible for overseeing the day-to-day activities of the graduate program and making recommendations to the Toxicology Faculty Council for changes they feel are needed to the program. In addition, the chairing of student advisory committees has now (as of 2011) been delegated to members of the Toxicology Group. The Graduate Chair no longer chairs all committees (as was historically the case), but now primarily oversees the administrative and academic duties of the Program, including acting as the primary point of contact for admission inquiries, recruitment, submission and approval of applications, submission of progress reports to the College of Graduate Studies and Research, scholarship nominations, and facilitating of the PhD qualifying and comprehensive examinations. The Graduate Chair also chairs a number of the PhD student committees. From 2007 to 2012, the Assistant Director of the Toxicology Centre (a position which no longer exists due to lack of adequate financial resources) served in a similar capacity for all MSc students, with the exception of admissions. The Graduate Secretary assists the Graduate Chair by managing the University's Graduate Student Information System, updating student files, grade entry, corresponding with committee members and students, scheduling committee meetings, and setting examination dates.

Over the years, the Toxicology Graduate Program has grown into one of the strongest interdisciplinary toxicology graduate programs in North America. Students receive excellent training and are very competitive for national scholarships and awards. Over the past five years, 12 students received national scholarships (NSERC), including the prestigious NSERC Canada Graduate Scholarships (4 students).

Additional noteworthy awards and activities include:

- Shane Journeay, who represented Canada at the International Space University in Strasbourg, France.
- Brian Laird and Alexis Schafer who both received the Garfield Weston Award for Northern Research ($40,000 each).
- Charlene Burnett and Julie Anderson, who each were elected as one of two student representatives from across Canada to serve on the Aquatic Toxicity Workshop Board of Directors.
- Raymond Kwong was the recipient of the Chris Lee Award from Society of Environment Toxicology and Chemistry (SETAC).
- Jocelyn Kelly, Meghan Goertzen, and Eric Franz each received the Rick Playle Award from the Canadian Aquatic Toxicity Workshop (ATW) for best MSc student thesis (offered since 2007 to one student from any Canadian university annually at the MSc and BSc level). Over a dozen students have won presentation awards at ATW over the years.
- Juliska Princz was elected to serve as the North American student representative on the Board of Directors of the Society of Environmental Toxicology and Chemistry (SETAC).
- Shawn Beitel and Landon McPhee won student presentation awards at this year's SETAC meeting (2012): 1st place poster and 2nd place platform (MSc category), respectively.

In addition, the Toxicology Program offers a number of student awards on an annual basis, most of which have been created through efforts lead by the Toxicology Centre.

- AREVA Award for Academic Excellence, Toxicology Undergraduate Program.
- Fisher Scientific Undergraduate Toxicology Research Award.
- Fisher Scientific Undergraduate Toxicology Presentation Award.
- Dr. Chatur Sisodia Graduate Scholarship.
- H.B. (Bruno) Schiefer Graduate Student Travel Award.
- Toxicology Graduate Student's Association Travel Award.
- Alberta Innovates Technology Futures Graduate Student Poster Competition Award.
- Doug Hancock Memorial Award.

International Graduate Student Exchange Program

The Toxicology Centre has over the past eight years established an informal graduate student exchange program with several European (RWTH Aachen, Germany; Ghent, Belgium; Juensuu, Finland; Umeå, Sweden; Aarhus and Roskilde, Denmark), Asian (City University and University of Hong Kong; Nanjing, Shanxi and Xiamen, China) and American (Baylor, TX; Clemson, SC) universities that have similarly strong reputations for research and teaching in environmental toxicology. Partnerships center on research collaborations and training of graduate students, especially PhD students.

The philosophy behind the international graduate student exchange program is three-fold: (1) in order to set our graduate program apart from other competitive programs in Canada and elsewhere, we must offer students graduate training opportunities that are different from what students can obtain at other institutions; (2) environmental toxicology is a broad-ranging and multidisciplinary field -- issues are often global in nature and in today's global economy, professionals in the field must have an international appreciation for how such concerns are viewed and addressed; and (3) students graduating with such international experience should be more marketable, thus broadening both the national and international value of their graduate training.

Partnerships are limited to a simple agreement between participating units to create opportunities for graduate students, especially PhD students, to visit the respective unit for the purpose of participating in research or other related activities at that institution. Such activities can include, but are not limited to: learning new techniques or methods used in environmental toxicology, participating in a research project(s) related to their own graduate research, broadening their view of attitudes and approaches in ecotoxicology in different countries, and broadening their general international experiences. Some funding is provided through the Toxicology Centre to facilitate student exchanges (partly sponsored by AREVA Resources Canada Ltd.). Visits can take any length practical and affordable, but most visits range from two to four weeks in duration. Although there are no firm commitments to the frequency of exchanges, participating units agree to aim for a minimum of one exchange each every two to three years.

In addition to the student exchange program described above, these international partnerships have created a network of international faculty who are interested in collaborating with Toxicology Program faculty and who are occasionally available to provide guest lectures or seminars in the Toxicology Program. The Toxicology Centre coordinates many of these activities and facilitates many international faculty visits. The Centre has it as a priority to become a hub for environmental toxicology faculty who want to spend some or all of their sabbatical leave at the U of S. The intent is to bring internationally-recognized faculty to the Centre on a regular basis where our faculty and students can benefit from interaction with these faculty and where the Toxicology academic programs can benefit from guest lectures and seminars provided by the visiting faculty. Efforts are currently under way to establish a fund that will allow the Centre to pay visiting faculty an honorarium for the “services” they would provide to the Toxicology Program.

F. Research Programs

Research programs within the Toxicology Group are as diverse as the research interests of the faculty and scientists comprising the Group. In general terms, research projects cover toxicology sub-disciplines as diverse as analytical toxicology, aquatic toxicology, wildlife toxicology, ecotoxicology, forensic toxicology, immunotoxicology, molecular/biochemical toxicology, nutritional toxicology, radiation/radionuclide toxicology, and veterinary toxicology. Within the Toxicology Centre, the research strength is largely environmental and more specifically aquatic toxicology, areas where the Centre has worked hard to develop superb capacity. Through its faculty and scientists, the Centre can provide expertise covering nearly every aspect of environmental toxicology, from molecular and biochemical assessments, to community and ecosystem assessments. The Centre’s research facilities are extensive and provide nearly “one stop shopping” for even complex, multidisciplinary projects (most analytical and experimental facilities required can be found within the Centre and the laboratories of its associated faculty). A partial list of current and very recently completed research projects run through the Toxicology Centre are provided below as examples of the type of research currently conducted at the Centre. All programs are designed around student involvement. In addition, the Toxicology Centre makes a concerted effort to hire as many undergraduate summer students each year as possible in order to supplement their academic experience with hands-on training. It is also noteworthy that all except one of the 14 core faculty within the Toxicology Program (8 based directly out of the Centre) have been hired since 1996, representing a substantial investment in this priority program by the University of Saskatchewan. The result is that, today, the Toxicology Centre is one of the leading research institutions in the field of environmental toxicology in North America.

Current Toxicology Centre Research Projects

- In Land and Life: Cadmium and Health Implications for Indigenous Communities in Central Alberta. National First Nations Environmental Contaminants Programme Health Canada.
- Contaminant Analysis of Fish Collected From the Slave River NWT in Fall and Winter 2011-2012. Aboriginal Affairs and Northern Development Canada.
- Vanadium Toxicity to Aquatic Organisms Representative of the Athabasca Oil Sands Region. Syncrude Canada Ltd.
- A Paleolimnological Assessment of Lake Diefenbaker Sediment: A Reconstruction of Historical Contaminant Trends. U of S Global Institute for Water Security.
- Exotic Chemical Contaminants in the South Saskatchewan River. U of S Global Institute for Water Security.
- Cellular Mechanisms and Ecophysiological Consequences of Selenium Toxicity in Fish. NSERC.
- Investigation of Temporal and Spatial Distribution, Fate and Biological Effects of Selenium in a Boreal Aquatic Ecosystem. NSERC–CRD Program and Cameco Corporation.
- Assessing Links Between Water, Animals and People in the Saskatchewan River Delta. U of S Global Institute for Water Security.
- Measuring Growth Rates of Tropical Fishes over Seasonal and Environmental Gradients Using RNA: DNA ratios. Griffith University/James Cook University.
- Contamination of Country Foods by Oil Sands Activities. Boreal SongBird Initiative.
- Interactions between Cold Adaptation and Chemical Sensitivity. University of Saskatchewan NSERC Bridge Fund.
- Remediation of Oil Sands Process Water and Predicting and Monitoring of Environmental Effects. Alberta Water Resource Institute.
- Upper Columbia River Remedial Investigation/Feasibility Study (RI/FS): Assessment of Sediment Toxicity to White Sturgeon (*Acipenser transmontanus*) in the Upper Columbia River. Teck Cominco America Inc.
- Bioaccessibility of Polycyclic Aromatic Hydrocarbon (PAH) Mixtures in Incidentally Ingested Brownfield Soils. Health Canada, National Contaminated Sites Program.
- Expansion and Commercialization of *in vitro* Screening Assays for the Detection and Assessment of Endocrine Disrupting Potentials of Chemicals, Waste- and Drinking-Water. Communities of Tomorrow.
- Endocrine Disrupting Chemicals: Potential Effects on Female Reproductive Health in Saskatchewan. Royal University Hospital Foundation.
- Functional Transcriptomics of Native Canadian Fish Species. NSERC.
- The Application of Near Infrared Reflectance Individual Seed Sorting to Remove Fusarium Contaminated Seeds from Wheat and Barley. Agriculture Development Fund.
- The Fate and Toxicity of Arctic Soil Pollutants: How Humans Poison Arctic Soils and How Arctic Soils Poison Humans. NSERC.
- Mycoremediation of Total Petroleum Hydrocarbons Under Oxygen Limited Conditions. NSERC
- Proof of Principle that Animal Models Can be Used to Adjust F3 Hydrocarbon Fractions at a Contaminated Site. NSERC.
- Northern Biochar for Northern Restoration. NSERC.
- Incorporating the Simulated Earthworm Gut into Site Specific Remedial Objectives. Communities of Tomorrow.
- Eco-restoration of Large-scale Anthropogenic Disturbances in the Boreal Shield. NSERC.
- Regulation of Trace Metal Uptake and Metabolism in Freshwater Fish. NSERC.

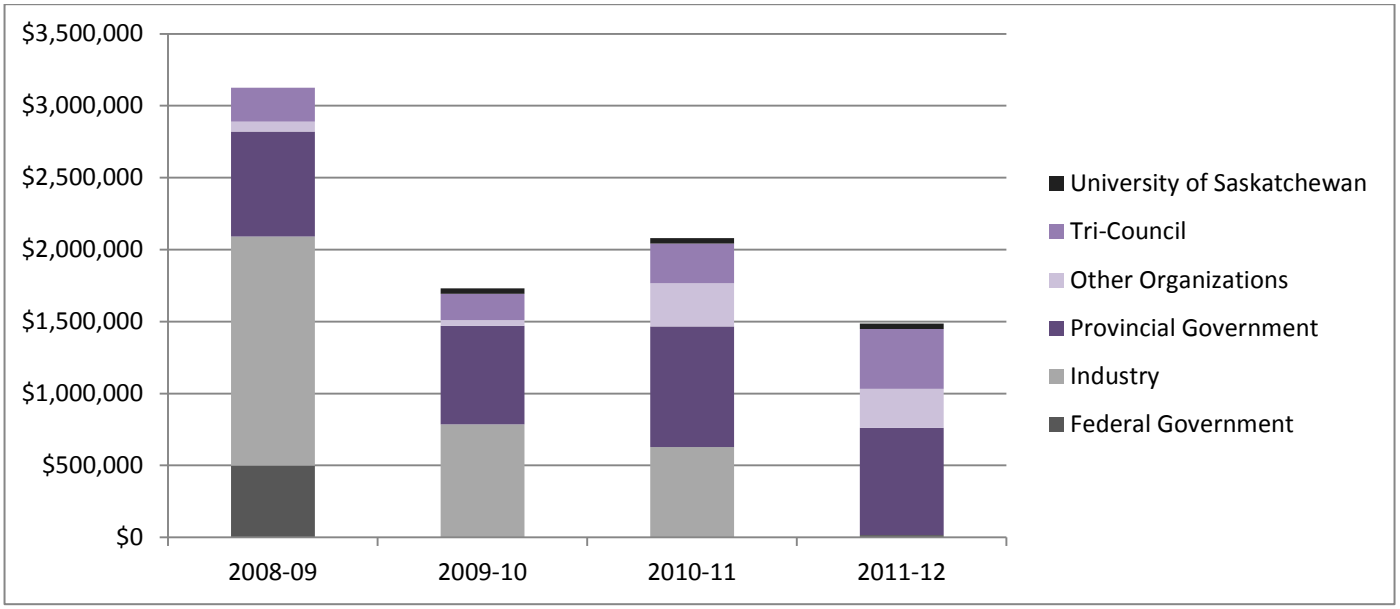
- Examination of the Effects of Mixtures, Metals, and Toxicity Modifying Factors on Fathead Minnow. VALE INCO.
- Using Toxicogenomics in Amphibians and the Adverse Outcome Pathway for Environmental Effects Monitoring of Oil Sands Industrial Development. Strategic Technology Applications of Genomics in the Environment (STAGE).
- Thyroid Hormone Influence on Gonadal Function and Development: An Amphibian Model. NSERC.
- Examination of the Health of White Sucker in Response to Oil Sands Reclamation-Affected Waters. NSERC.
- Immune Effects in Fishes Exposed to Oil Sands Process Affected Waters. NSERC
- Assessment of Sampling Methods for the Diagnosis of Ranavirus in Amphibians. Atlantic Veterinary College Research Fund.

In addition to the projects listed above, many of the Centre's faculty are involved in international collaborative research projects, especially in Europe and China, thus providing a more global context to the Centre's research profile and reputation. A partial list of those projects include:

- Health Risk Assessments of Residents in the Pearl River Delta Exposed to Brominated Flame Retardants (BFRs). State Key Laboratory for Marine Pollution, City University, Hong Kong.
- Development of Novel Technology for Early Diagnosis and Monitoring of Immuno-Toxic Pollutants in the Marine Environment. State Key Laboratory for Marine Pollution, City University, Hong Kong.
- Unraveling Tissue-Specific Mechanisms for *in vivo* Regulation of Estrogen Target Genes in Medaka. State Key Laboratory for Marine Pollution, City University, Hong Kong.
- Understanding the Estrogen Dynamics and Longevity Gender Gap in Medaka. State Key Laboratory for Marine Pollution, City University, Hong Kong.
- Sino-Canadian Cooperation and Phytoremediation Technologies for Clean-Up of PAH and Heavy Metal Contaminated Soils in Shanxi Industrial Regions. Shanxi Science and Technology Department, Taiyuan, Shanxi, P.R. China.
- Network on Environmental Impact Assessment of Industry-Contaminated Areas in the Arctic. Nordic Council of Ministers' Arctic Co-operation Programme, Copenhagen, Denmark.
- Variability of Hormonal Stress Markers and Stress Responses in a Large Cross-Sectional Sample of Elephant Seals. United States Department of Defence, Office of Naval Research.
- Pathophysiology of Stress in Wild and Managed-Care Bottlenose Dolphins. United States Department of Defence, Office of Naval Research.
- FLOODSEARCH II – Integrated assessment of flood consequences as a new field of competence at the RWTH between flood risk, sediment dynamics, sediment quality and global change. Boost Fund, RWTH Aachen, Germany.

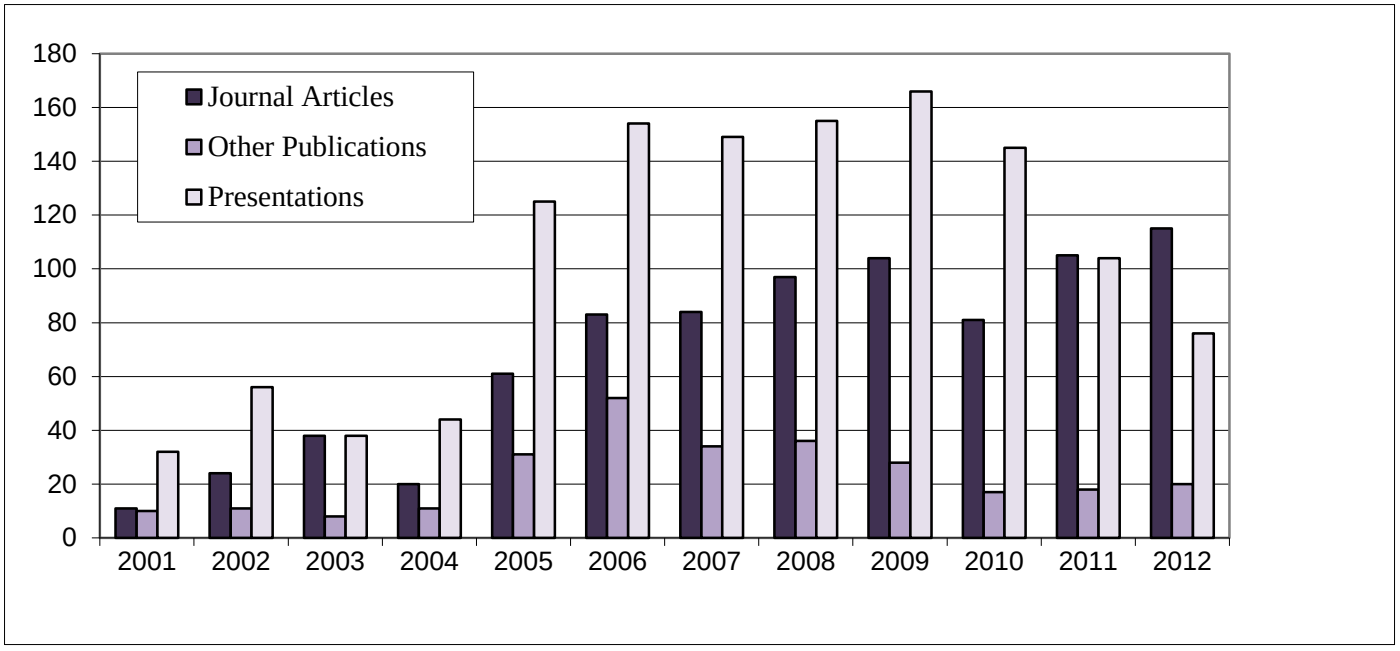
As indicated above, the Toxicology Centre core faculty consistently bring in research revenue from a variety of sources, including tri-council, other government departments and private industry. A summary of research funding run through the Centre, and general funding sources, over the past four years is provided below (Figure 3). It should also be noted that most Toxicology Program faculty run additional projects through their home academic units. As a result, the contribution of Toxicology faculty to the gross research revenue of the U of S exceeds the levels reported here.

Figure 3 – Toxicology Core Faculty Research Revenue



Research findings are primarily published in peer-reviewed scientific journals. The number of journal articles, other publications and external presentations produced annually by the Centre's core faculty has risen substantially over the last decade (Figure 4). In 2009, the number of presentations delivered at the SETAC North America conference by faculty and students from the U of S Toxicology Program outnumbered contributions of any other university globally. This trend has continued to this day (at the recent 2012, 2,250 delegate strong SETAC North America meeting, U of S Toxicology Group faculty and students contributed 45 presentations). In addition, two Toxicology graduate students won presentation awards at this year's SETAC meeting: 1st place poster, MSc category (S. Beitel) and 2nd place platform, MSc category (L. McPhee).

Figure 4 – Toxicology Core Faculty Publications and Presentations



Advisory Boards and Committees

Core Toxicology faculty routinely serve on a variety of national and international advisory boards and committees. Most also serve as editor or associate editor for various journals in the field of environmental science (not listed here). A list of key appointments held over the past four years include:

- Chair, Board of Review on Siloxanes, Environment Canada.
- Advisory Board, Pest Management Advisory Council, Health Canada.
- Executive Committee, Science Advisory Board, US Environmental Protection Agency (EPA).
- Standing Committee, Science and Technology Awards, US EPA.
- Board of Directors, Society of Environmental Toxicology and Chemistry (SETAC) North America.
- Board of Directors, SETAC Foundation for Environmental Education.
- Science Committee, SETAC-North America.
- Nominations Committee, SETAC-North America.
- Regional Chapters Committee, SETAC-North America.
- Student Travel Awards Committee, SETAC-North America.
- Board of Directors, International Society for Ecotoxicology and Environmental Safety (SECOTOX).
- President and Board of Directors, Christian Veterinary Mission Canada.
- President and Chief Operating Officer, Canada Ecotoxicity Testing & Screening (CETES).
- US EPA Non-Animal Validation and Management Testing Group, OECD.
- Chair, Water Monitoring Data Review Committee, Alberta Ministry of Environment.
- North American Metals Council, Selenium Working Group.
- Board of Directors, Canadian Network of Toxicology Centres.
- Board of Directors, Canadian Aquatic Toxicity Workshop (ATW).
- Grant Selection Committee, Strategic Projects and Networks, NSERC.
- Grant Selection Committee, Major Resources Support Program, NSERC.
- Advisory Committee, University-Industry Grants, NSERC.

G. Financial Overview

The Toxicology Centre operates under a hybrid financial model where part of the Centre's operating budget comes from the University and another from the Centre's activities. The University provides an operating budget for the Centre that includes salary costs for the director, key administrative staff (2.0 FTE), and 50% of two core faculty and Toxicology Executive members (B. Blakley and M. Wickstrom; 1.0 FTE). Non-salary items account for less than $40,000 per year. The day-to-day operation of the Centre is supplemented with revenue generated from research overhead recovery and other external sources. In addition to the Centre's core operating budget, the University provides an operating budget for the Northern Ecosystems Toxicology Initiative (NETI) which primarily covers the salaries of the five NETI faculty (5.0 FTE). The NETI budget also covers part of the salary (0.5 FTE) for the undergraduate secretary who assists with the administration of the Toxicology Undergraduate Program created under NETI. Consolidated financial statements for the past four years (Toxicology Centre and NETI operating budgets) are provided in Appendix 6. These budgets have not changed substantially over the years; only institutionally-standardized salary raises have contributed to increases in the salary components of the budgets. The non-salary component of the Centre budget has not increased in 10 years.

H. Contribution to the U of S (fit with strategic research plan)

Through substantial and ongoing strategic investments in expertise, programs and facilities, the U of S has over the last decade made transformative advancements in the broad areas of water security, ecotoxicology and environmental research. The fields of water resources, water quality and environmental toxicology represent key initiatives within the Environment and Natural Resources theme of the University's Strategic Research Plan. Water security is one of six Signature Areas at the Institution, areas the University wants to be known for nationally and internationally. Key institutional strengths upon which this Signature area was built include the Toxicology Centre and the Centre for Hydrology, both of which have gained international prominence and experienced tremendous success over recent years.

The U of S has been investing heavily in water- and ecotoxicology-based research chairs over the past decade, including four CRCs (J. Giesy, J. Pomeroy, I. Pickering, M. Hecker), and two NSERC-Industrial Research Chairs (J. Hendry and L. Barbour). A fifth CRC (G. George) works closely with Pickering and others on water-related projects, and a sixth (M. Dubé) left the University in 2011. The recently awarded Canada Excellence Research Chair (CERC) in water security forms the capstone of this substantial investment in water research. Toxicology Centre director, K. Liber, played a key role in securing this chair. Other recent investments to the institutional water research capacity include two new faculty appointments (in addition to three existing appointments) as part of the Northern Ecosystems Toxicology Initiative, three research scientist appointments within the Toxicology Centre, and six new faculty positions in water, hydrological and atmospheric sciences within School of Environment and Sustainability (all related to the CERC initiative). Overall, more than 70 full-time, university faculty are actively engaged in water-related research at the U of S and that number is still growing. These faculty members are joined by adjunct faculty from organizations such as Environment Canada's National Water Research Institute and National Hydrology Research Centre, the Saskatchewan Research Council, Saskatchewan Environment, the Saskatchewan Watershed Authority, and local natural resource industries and consulting firms. These scientists span a research spectrum that covers the fields of hydrology, water quantity and model development; aquatic biology, ecology and toxicology; water quality and environmental chemodynamics; sub-surface hydrology, water flow and contaminant transport; mine site reclamation; and use of synchrotron radiation techniques in studying metal speciation, fate and toxicity in the environment. In 2006-08 the university completed an $11.8-million, 2,000 m^2 expansion and renovation of the Toxicology Centre, which now houses the largest university-based group of aquatic toxicologists in Canada. This extensive centre now includes one of the most sophisticated aquatic toxicology research facilities in the country and laboratories equipped with more than $7 million of state-of-the-art analytical and experimental equipment.

I. Challenges

A number of challenges face the Toxicology Centre over the next few years, but none are insurmountable. The key challenges fall under four categories: (i) operational structure, (ii) financial resources, (iii) human resources, and (iv) student enrollment.

Operational Structure: Alignment of Centre accountabilities and authorities

The Toxicology Centre does not fit the typical centre model at the U of S. Centres are typically not in charge of academic programs, but more commonly focus on research and community engagement, with academic roles managed through academic departments and colleges. The Toxicology Centre, on the other hand, oversees the management of the Toxicology Undergraduate Program (while the program is run through the College of Arts and Science, the Centre handles all aspects of the program except

conferring of the degree) and all aspects of the Toxicology Graduate Program (on behalf of the College of Graduate Studies and Research). While unconventional, this model has worked well and, with a few important exceptions, continues to work well. The key challenge is that all of the Centre's faculty have academic appointments in an academic unit (and hence associated responsibilities there) and thus the Centre has little academic authority over the faculty who deliver the academic programs despite being responsible for those programs. For example, it has been very difficult to ensure that the NETI faculty who are paid 100% through the Toxicology Program are in fact contributing an expected 50% of their time and activities to Toxicology; this has especially been a challenge during the pre-tenure years for some faculty, but the challenge continues. In addition, the Toxicology Centre/Program is unable to approve appointments of adjunct professors without running such appointments through another unit. This often makes it difficult to expand the use of adjunct faculty on graduate student committees, etc.

Financial Resources

The Centre is presently in strong financial shape (on its year-to-year standard operating costs), except for a multi-million dollar debt that resulted from a short-fall in the projected funding sources for the 2006-08 building expansion. There is currently no solution to covering this entire debt, but options are being explored. Presently, nearly all research overhead revenue generated through the Centre goes towards paying down this debt. In addition, the University is entering into a new financial era with the implementation of its Transparent Activity Based Budgeting System (TABBS). This model is intended to allow revenue to flow into units based entirely on their teaching and research success, not based on historical agreements, and out of units based on the unit's fair share of fixed institutional costs such as space allocation and central administrative support services. This model will be appropriate for the Centre if, and only if, the model is implemented so that the Centre receives credit for an appropriate and fair proportion of the research and teaching activities of the Toxicology faculty. Since all faculty are appointed through other units, negotiations need to take place to allow both revenue and expenses to flow fairly and "transparently" to both the Centre and partner academic units. These discussions and negotiations are presently being pursued. Without the Centre receiving appropriate credit for the Toxicology teaching and research activities of the core Toxicology faculty, the Centre and associated Toxicology Programs will be severely compromised. A contingency fund has been carefully maintained to see the Centre through this period (next two years) of uncertainty. This fund must be safeguarded, especially since there is no other way to pay critical staff members over the coming years.

Human Resources

Operationally, the Toxicology Centre is appropriately staffed. However, a number of critical staff positions (as mentioned above) are funded through non-base budget means. The two key positions are the Centre's clerk/receptionist (who also serves as the undergraduate secretary) and the manager of the Aquatic Toxicology Research Facility (ATRF). The clerk is presently paid from contingency funds and this must continue until TABBS is fully implemented. It is anticipated that if TABBS is implemented in a manner that appropriately reflects the activities of the Toxicology Centre and associated faculty, then the revenue flowing to the Centre will be able to cover the clerk position in a few years. Overhead revenue is not available for this purpose since it basically all flows towards paying down the debt on the building. The ATRF manager has for the past five years (until March 2013) been paid entirely from external sources. The last of these sources runs out in five months. Contingency funds have been set aside to pay for this position for two years, which is hopefully enough time to secure additional external funds and determine if resources flowing to the Centre from TABBS will allow for at least partial support for this position. It should be noted that the position of ATRF manager is essential for compliance with both institutional and national animal care and use regulations, and for maintenance of the facility in research-ready shape. The facility is too large and complex for faculty and students to manage all components needed for their various experiments. Appropriate oversight is essential.

Student Enrollment

Both the Toxicology undergraduate and graduate programs have experienced either a slight reduction, or at best reached a plateau in, student enrollment over the past couple of years. This is largely the result of having a key NETI faculty member (J. Smits) and a Canada Research Chair (M. Dubé) leave the University between 2008 and 2010 for other opportunities. However, this situation was remedied in 2010-11 with N. Hogan and T. Jardine joining the program as new NETI faculty. This has resulted in a re-invigoration of Systematic Toxicology (Hogan), the development of a new course, Aquatic Toxicology (Jardine), for our undergraduate program, and the development of two new graduate student-based toxicology research programs. In addition, the Centre now again has full-time leadership with K. Liber returning in 2012 as Director after having served as Executive Director for the new School of Environment and Sustainability from 2008 to 2011. As a result, efforts and activities are now being implemented to revise and enhance the academic programs, and to better promote the Toxicology Centre and Programs locally, nationally and internationally. A new advertising and recruitment campaign is planned for the winter of 2012-13, including a redesign of the Centre's webpage. The Toxicology Program is also considering the development of a non-thesis Masters program in Risk Assessment that could be launched as early as 2013-14. The results of these efforts will hopefully become evident within the next few years, including an increase in student enrollment.

APPENDICES

Appendix 1 – Toxicology Group Members

(Members listed in ***bold italics*** comprise the current Toxicology Faculty Council)

Analytical and Forensic Toxicology

- George, G. Heavy metal and metalloid chemical toxicology using synchrotron based spectroscopic probes and imaging methods. Metalloprotein active site structure and function, and toxic effects due to metal ion dyshomeostasis.
- Headley, J. Environmental mass spectrometry; oil sands naphthenic acids. (Environment Canada)
- McKay, G. Development and application of high sensitivity analytical procedures with focus on pharmaceuticals.
- Pickering, I. Synchrotron speciation and microscopic localization of metals and metalloids in environmental and human toxicology.

Biomedical and Human Toxicology

- Alcorn, J. Infant exposure to xenobiotics; maturation of clearance mechanisms; toxicokinetics.
- Berry, M. Endogenous regulators of CNS neuronal activity; cell death mechanisms in neurones; regulation of cell death in normal and cancer cells.
- Bharadwaj, L. Drinking water quality and public health, Community-based participatory research, Water regulations and First Nations Health Equity and Promotion, Human and Environmental Risk Assessment
- Blakley, P. Clinical teratology; Fetal Alcohol Syndrome; genetic predisposition to teratogenesis.
- Hiebert, L. Vascular biology/toxicology; injury by free radicals.
- Krol, E. Xenobiotic metabolism of naturally occuring phenols; reactive intermediates.
- Krone, P. Endocrine modulation/developmental toxicology; use of stress proteins as biomonitors of toxicity in fish embryos.
- Paterson, P. Biochemical and physiological functions of trace elements; nutrition and eye function; effects of nutrients on antioxidant pathways in stroke.
- Nazarali, A. Teratogenicity; DNA-protein interactions; transcriptional factors; expression of developmental genes in mice embryos.
- Rosenberg, A. Environmental toxin exposure and induction of autoimmunity.
- Singh, B. Nanotoxicology and nanomedicine; molecular mechanisms of lung inflammation.
- ***Weber, L.*** Tobacco smoke and air pollution effects on cardiovascular disease; pathophysiological mechanisms of toxicity; toxicity of polycyclic aromatic hydrocarbons.
- Whiting S. Nutritional toxicology; diet and osteoporosis, with emphasis on nutrition-bone relationship; safety of foods produced through biotechnology.
- Xiao, W. Mechanisms of action of genotoxic chemicals and cellular responses to DNA damage.
- Zello, G. Protein and amino acid metabolism in humans and animals investigated using stable isotope methodology; effects of drugs on protein metabolism, drug-nutrient interactions.

Veterinary and Wildlife Toxicology

- ***Blakley, B.*** Immunotoxicology - environmental aspects, nutritional states; applied veterinary toxicology; heavy metal toxicity (Pb, Cd).
- Leighton, F. Wild animal disease surveillance, including poisonings; diagnosis of anti-cholinesterase pesticide poisoning; petroleum oil toxicity to birds.

- ***Morrissey, C.*** Avian ecology and ecotoxicology. Testing biomarkers of exposure (ecophysiological, stable isotope methods) and effects of pollutants in wild birds.
- ***Wickstrom, M.*** Effects of pesticides and metals in wildlife; cyanobacterial toxins; clinical veterinary toxicology; environmental risk assessment.

Ecological and Aquatic Toxicology

- Cessna, A. Atmospheric transport and fate of pesticides; transport of pesticides in runoff waters and subsurface waters. (Environment Canada)
- Davies, J-M. Nutrient impacts on algal ecology; contaminant impacts on benthic communities; drinking water quality. (Saskatchewan Watershed Authority)
- Evans, M. Biomagnification of persistent organochlorine compounds and mercury. (Environment Canada)
- Farrell, R. Metal speciation and bioavailability in soils and sediments; phytoremediation systems for TPH and metal contaminated sites.
- ***Giesy, J.*** Discovery and assessment of emerging contaminants of concern, including perfluorinated compounds (PFCs); development of novel bioanalytical tools; biochemical indicators of stress in aquatic organisms; assessment of endocrine modulating compounds.
- ***Hecker, M.*** Development, validation and application of novel bioanalytical techniques; endocrine disruption and reproductive toxicology in oviparous vertebrates; ecotoxicological risk assessment of persistent organic compounds, pesticides and metals in vertebrates.
- ***Hogan, N.*** Immune toxicology and disease emergence in fish and amphibians, Endocrine regulation of development and disruption by environmental contaminants, Mechanisms and impacts of nutritional toxicants on domestic animal health.
- ***Janz, D.*** Reproductive physiology and endocrinology of oviparous vertebrates; endocrine toxicity; biochemical toxicology; mechanisms of toxicity; cytochrome P450; selenium toxicity in fish.
- ***Jardine, T.*** Comparison of mercury and selenium biomagnification rates through aquatic food webs at local and global scales, Investigations of hydrological and food-web connectivity between rivers and floodplains in Australia's wet-dry tropics.
- ***Jones, P.*** Fate and effects of organic pollutants in the environment and wildlife; use of biochemical and molecular biology techniques in environmental toxicology.
- ***Liber, K.*** Metal bioavailability and toxicity in aquatic ecosystems, especially in sediments; mining impacts on aquatic ecosystems; pesticide ecotoxicology.
- ***Niyogi, S.*** Assessment of waterborne metal bioavailability and toxicity using the Biotic Ligand Model approach; uptake, regulation, and toxicity of dietary metals in freshwater fish.
- Raine, J. Developmental physiology and endocrinology; endocrine disruption; mechanisms of toxicity; thyroid hormone regulation and signaling
- ***Siciliano, S.*** Soil ecotoxicology, investigation of trace contaminant effects in northern terrestrial ecosystems using molecular tools.
- Somers, C. Environmental exposures and DNA damage in wildlife and indicator species. Processes in the germline that contribute to trans-generational effects due to contaminant exposure.
- ***Thomas, P.*** Environmental transport and food chain transfer of radionuclides; radiation dosimetry and risk assessment; radiation biology of animal and human cell types.

Appendix 2 – Toxicology Undergraduate Program Courses

TOX 300.3 General Principles of Toxicology 1(3L)
An introduction to the general principles of toxicology. Salient topics include: dose-response relationships, toxicokinetics, target toxicity, mechanisms of toxic action, general principles of toxicity testing, and mechanisms of action of antidotes.
Prerequisite(s): BMSC 224.3/BIOL 224.3 or PHSI 208.6.
Note: Open to all students. Students with credit for VBMS 300 may not take this course for credit.

TOX 301.3 Environmental Toxicology 1/2(3L)
A discussion of major environmental pollutants, their sources, interactions with atmospheric, terrestrial and aquatic systems, exposure of people, animals and other biota, and their dose-response relationships. Some of the physical and chemical changes induced in the environment by pollutants, contaminant fate and transport, and bioremediation are also discussed.
Prerequisite(s): BIOL 120 and 121 and CHEM 112.

TOX 302.3 Introduction to Aquatic Toxicology 1/2
This course will provide an overview of the sources, fate and effects of toxicants in the aquatic environment. Material will center around prevailing issues reported in the popular news media associated with modern and legacy contaminants, and will illustrate how laboratory and field testing can be combined to assess and predict effects.
Prerequisite(s): BIOL 120.3 and 121.3, CHEM 112.3, TOX 300.3 (recommended)

TOX 310.3 Radiation and Radionuclide Toxicology 1/2(3L-2T)
Discusses natural and artificially produced radionuclides, units of radiation measurement, processes of decay and fission, interaction of radiation with matter, doses, risks of effects, and radionuclide transfer through ecosystems. Provides students with the knowledge to assess potential environmental impacts and health hazards from exposure to ionizing radiation from natural background, uranium mining and medical courses. A 2 hour tutorial once a week is included.
Prerequisite(s): BIOL 120; BIOL 121; and CHEM 112 or PHYS 115.

TOX 320.3 Inhalation and Environmental Toxicology of Air Pollutants 1/2(2L)
Covers the sources, types, behavior and toxic effects of major air pollutants. It is based on four units: 1) atmospheric structure, evolution, energy balance (including indoor air quality concerns), environmental behavior and effects; 3) the respiratory system as a target for toxic agents, mechanisms of damage and standardized inhalation toxicity testing; and 4) students debates on current topics in air pollution and inhalation toxicology.
Prerequisites: BIOL 120.3, BIOL 121.3, CHEM 112.3, and CHEM 115.3

TOX 321.3 Risk Assessment and Regulatory Toxicology 1/2(3L)
An introduction to human health and ecological risk assessment and an overview of Canadian and international regulatory requirements for the registration of new products, focussing on safety assessment/toxicity testing of pesticides and human pharmaceuticals, and basic principles of occupational health and industrial hygiene.
Prerequisite(s): 6 credit units BIOL and 6 credit units CHEM.
Note: TOX 300 and TOX 301 recommended.

TOX 402.3 Systemic Toxicology 1/2(3L)
An overview of the types of injury produced in specific vertebrate, especially mammalian, organ systems by toxic agents and how such injury alters their functions and the overall effect on the body.
Prerequisite(s): TOX 300.

TOX 403.3 Biotoxins 1/2(3L)
An overview of the occurrence, mechanisms of action and clinical effects of commonly encountered plant toxins, mycotoxins, poisonous mushrooms, algal toxins, bacterial toxins, and zootoxins (venomous and poisonous snakes, fish, arthropods, and marine invertebrates).
Prerequisite(s): TOX 300.

TOX 412.3 Toxicology of Industrial Pollutants 1/2(3L)
An introduction to major categories, sources, routes of exposure, metabolism, mechanisms of action and toxic effects on people and ecosystems of common industrial organic chemicals, pesticides and metals. Emphasis will be placed on pollutants and industries of relevance to Canada.
Prerequisite(s): TOX 300.
Note: TOX 301 recommended.

TOX 461.3 Applied Toxicology 1/2(1L-2S/T)
Provides students an opportunity to evaluate practical toxicology/ecotoxicology problems associated with Saskatchewan and northern ecosystems. Students will be presented with specific toxicological questions or case studies of current relevance which will be examined using research data and library facilities. Written and oral presentations will be required for each problem.
Prerequisite(s): TOX 300 and 301.

TOX 480.3 Toxicology Research 1/2 (6P)
Students will work on a laboratory, field, library, or theoretical study under the supervision of a faculty member from the Toxicology Group. Each individual project requires approval of a research proposal by the Toxicology Undergraduate Program Advisory Committee in the term preceding registration before permission will be granted. A thorough, written report in manuscript format describing the project and the summarized results submitted at the end of the project will be evaluated by a faculty committee. Note: Students with credit for TOX 481.6 may not take this course for credit.
Prerequisite(s): TOX 300.3, TOX 301.3, and permission of the Academic Advisor.

TOX 481.6 Toxicology Research 1 & 2 (6P)
Students will work on a toxicology research project under the supervision of a faculty member from the Toxicology Group. Each project requires approval of a research proposal by the Toxicology Undergraduate Program Advisory Committee prior to registration. A written report in manuscript format must be submitted at the end of the project. Note: Students with credit for TOX 480.3 may not take this course for credit.
Prerequisite(s): TOX 300.3, TOX 301.3, and permission of the Academic Advisor.

TOX 490 Toxicology Seminar 1 & 2 (1S)
Seminar presentations by visitors, faculty and students on a broad selection of toxicology issues. Fourth-year students in the Undergraduate Toxicology Program will be required to present one seminar and attend all seminars throughout the full academic year.
Prerequisite(s): TOX 300.3, TOX 301.3, and permission of the Academic Advisor.

TOX 498 Special Topics in Toxicology 1/2 (1S)
This course is offered occasionally by visiting faculty and in other special situations to cover, in depth, toxicology topics that are not thoroughly covered in regularly offered courses. Students interested in this course should contact the Toxicology Academic Advisor for more information and approval prior to registration.
Prerequisite(s): Permission of the Academic Advisor.

BIOL 475.3 Ecological Toxicology 1/2(3L-3P)
An introduction to the principles of ecological toxicology, including: population modelling, experimental design and interpretation of field studies, and contaminant impact assessment on populations, communities and ecosystems. Computer laboratory exercises will be used to model populations and ecosystems and analyze changes in populations and communities resulting from contaminant impacts.
Prerequisite(s): BIOL 120 and 121 (formerly BIOL 110) and BIOL 228 (formerly BIOL 253) and 6 additional credit units of senior BIOL courses and a course in statistics; or permission of the instructor.
Note: TOX 301 is recommended.

EVSC 420.3 Environmental Fate and Transport of Toxic Substances 1/2 (3L-2P)
Lectures will address the fate and transport of toxic substances in the atmosphere, the hydrosphere and the geosphere. Emphasis will be on actual transport processes (e.g., sorption, dry deposition, rain-out) and degradation (e.g., photo-oxidation, radioactive decay, microbial transformation) over time. Modelling programs such as STELLA will be used to illustrate fundamentals of transport processes within and between ecosystems.
Prerequisite(s): 60 credit units in a science-based program (e.g., BSc, BSA, BE) including MATH 110 and PHYS 115 or EVSC 210 or the instructor's permission.

EVSC 421.3 Contaminated Site Management and Remediation
This course will focus on the how contaminated sites are managed and remediated for new land uses. Students will learn: the theory of how sites are investigated and characterized, how toxicological information is used to estimate risk to humans and ecosystem, how threats to groundwater are assessed and finally, methods by which these risks and threats are mitigated through remediation approaches. The course will provide students with the skill set necessary to assess, manage and reduce human and ecological risk at a contaminated site.
Prerequisite(s): EVSC 210 or 3 credit units 100-level PHYS, STAT 245 or PLSC 314 and one of EVSC 220, SLSC 240 or RRM 215.
Prerequisite(s) or Corequisite(s): One of TOX 321, GEOG 386, BLE 481, SLSC 313 or SLSC 322.

GEOG 386.3 Environmental Impact Assessment 1/2 (3L)
A practicial and theoretical introduction to environmental and socioeconomic impact assessment. Emphasis is placed on the principles and characteristics of impact assessment process as set out under Canadian and Saskatchewan guidelines and legislation, and the lessons learned from selected case study applications.
Prerequisite(s): GEOG 280.3 or equivalent, or the instructor's permission.

Appendix 3 – Enrollment in Core Toxicology Undergraduate Program courses during the past five academic years.

Course Title	Enrolment				
	2007-08	2008-09	2009-10	2010-11	2011-12
General Principles of Toxicology [1]	54	50	50	57	44
Environmental Toxicology [1]	50	55	49	61	62
Radiation & Radionuclide Toxicology	28	23	27	25	27
Risk Assessment and Regulatory Toxicology	26	31	34	33	30
Systemic Toxicology	18	20	16	26	15
Biotoxins	not offered	34	31	20	20
Toxicology of Industrial Pollutants	23	32	20	20	14
Environmental Fate and Transport of Toxic Substances	19	22	22	16	not offered
Contaminated Site Management and Remediation	not offered	not offered	not offered	10	8
Applied Toxicology	10	17	19	8	17
Ecological Toxicology	not offered	22	not offered	22	23
Inhalation and Environmental Toxicology of Air Pollutants	not offered	not offered	24	17	8
Toxicology Research [2]	6	8	9	6	11
Toxicology Seminar	15	26	24	13	21

[1] Total enrollment is capped at 50 students with additional overrides provided for Toxicology Program majors only.
[2] Undergraduate thesis research projects open to fourth-year honours students only.

Appendix 4a – Toxicology Graduate Program Courses

TOX 810.3 Radiation and Radionuclide Toxicology – 1/2 (3L)
Discusses natural and artificially produced radionuclides, units of radiation measurement, processes of radioactive decay and fission, interaction of radiation with matter, radiation doses, risks of effects at both an organism and a cellular level and movement of radionuclides in the environment. Provides students with the knowledge to assess potential environmental impacts and health hazards from exposure to ionizing radiation from natural background, uranium mining and medical sources.
Prerequisite(s): Minimum of one university-level course in any four of physics, chemistry, microbiology, statistics, cell biology, or ecology.

TOX 820.3 Exposure Assessment – 1/2 (3L)
The objectives of this course is to discuss how exposure to chemical hazards is estimated and evaluated from a modeling and observational approach. Students will become familiar with applications of local, regional and global environmental fate models and how this links to human and ecosystem exposure. Following this, techniques and approaches used to evaluate exposure to human populations will be explored with an emphasis on how spatial and global trends influence human susceptibility to hazards.
Prerequisite(s): None

TOX 821.3 Human Health Chemical Risk Assessment – 2 (3 L)
Exposure and risk estimates are subject to considerable uncertainty due to: chemical concentration heterogeneity in the environment; natural variation in the characteristics and behaviours of people that lead to exposure; inter-individual variability in contaminant bioavailability and toxicology; chemical environmental fate and transport; degree of exposure and numerous other factors. The course objective is to provide the basic knowledge to conduct, evaluate and interpret exposure and risk assessments of chemicals present in the natural and built environments.
Prerequisite(s): None.

TOX 840.3 Wildlife Toxicology and Ecological Risk Assessment - Spring (1 week short course)
This course is intended to provide a broad exposure to general principles of terrestrial toxicology, with an emphasis on mammalian and avian species. Topics to be covered include: effects of common environmental contaminants on wildlife populations; factors affecting soil toxicity, contaminant bioavailability and fate; common in vitro and in vivo methods to assess toxicity and sublethal exposure (biomarkers); and ecological risk assessment.
Prerequisite(s): *TOX 300* and *TOX 301,* or permission from the instructor.

TOX 842.3 Biochemical Toxicology – 2 (2L)
The objective of this course is to provide students with a comprehensive understanding of various biochemical mechanisms of toxicity, from both biomedical (human) and ecotoxicological perspectives. The focus will on applying basic knowledge of biochemistry and physiology to the science of toxicology. Classes will involve discussions on topics related to the text and supplemental journal articles.
Prerequisite(s): Background knowledge in toxicology.

TOX-843.3 Environmental Chemodynamics – 2 (3L)
This course will supply the student with an understanding of the processes that control the movement of organic and inorganic contaminants in the atmosphere, hydrosphere and lithosphere and will also provide an understanding of the methods used to monitor environmental behavior of potentially toxic contaminants in biotic and abiotic matrices.
Prerequisite(s): One course in ecology or environmental biology; one course in general or environmental chemistry or permission from the instructor and students course advisor.
Prerequisite(s): None.

TOX 844.3 Toxicology Techniques – 1 (1L-3P)
This course provides theoretical background and hands-on experience in methods and techniques typically applied by toxicology professionals in academia, industry, and government. It covers a broad spectrum of procedures, ranging from proper handling of field equipment to biological test methods and analytical processing of samples.
Prerequisite(s): Successful completion of Laboratory Safety Course and GSR 962 (Ethics in Animal Research). Permission of the Course Coordinator.

TOX 850.3 Aquatic Toxicology – 1 (3L-2P)
Provides a broad background on general principles of aquatic toxicology, with emphasis on aquatic ecotoxicology. Covers common laboratory and field assessment techniques, factors affecting toxicity in aquatic systems, fate and bioavailability of contaminants in the environment, and design and analysis considerations in ecotoxicological studies.
Prerequisite(s): Permission of the instructor or registration in the Toxicology Graduate Program.

TOX 860.3 Applied Toxicology – 1&2 (1L-S/T)
Other courses in Toxicology are highly desirable. Provides students an opportunity to evaluate practical problems associated with various aspects of toxicology. Students will be presented with specific toxicological questions or concerns which will be examined using research information and library facilities.
Prerequisite(s): Permission of the instructor or registration in the Toxicology Graduate Program.

ACB 821.3 Advanced Topics in Developmental Biology – 1/2 (4S)
A review of recent advances in the study of developmental biology. Special emphasis is placed on the contributions of different experimental animal systems to research in a variety of areas in the field.
Prerequisite(s): ACB 330; or equivalent and permission of the instructor.

BIOL 898.3 Physiology and Toxicology of Aquatic Animals – 2 (1L)
Designed to explore the fundamental aspects of how aquatic animals function and respond when exposed to natural and/or anthropogenic stresses. The primary emphasis is placed on understanding the physiological mechanisms by which aquatic animals acclimate or adapt to a challenging environment as well as the physiological perturbations induced by stressors that lead to the onset of toxicity.
Prerequisite(s): Animal Physiology and Environmental Toxicology at Undergraduate level and permission of the Instructor.

ENVS 898.3 Environmental Issues and Negotiations – 2 (1L)
The course aims to expose students to the different view-points and approaches used by the different stakeholders typically involved with the negotiation and assessment of environmental issues. Several experts from local, provincial or federal agencies as well as experts in the areas of environmental journalism, law, and industry will give presentations on specific topics. Furthermore, an overview of the

concept of risk assessment will be given, and similarities and differences between human and environmental risk assessments will be explored.
Prerequisite(s): None.

MCIM 820.3 DNA Repair & Mutagenesis – 1 (3L)
Explores the process of DNA damage, repair, mutagenesis and impacts on cell survival, molecular evolution and human diseases. Emphasis is given to molecular, cellular, genetic and biochemical analysis of each repair pathway in various organisms. Students are expected to be familiar with the technologies and strategies in the investigations.

PHAR 848.3 Advanced Pharmacokinetics and Pharmacodynamics – 2 (3L-2P)
Qualitative and quantitative aspects of drug absorption, disposition, metabolism and excretion, and drug pharmacodynamics. The course emphasizes the use of pharmacokinetic/pharmacodynamic equations and the analysis of the data.
Prerequisite(s): Basic course in pharmacokinetics or permission of the instructor.

PHAR 854.3 Metabolic Transformation of Xenobiotics – 1/2 (3L)
An advanced study of the basic principles of the metabolism of foreign compounds in mammals. The xenobiotics covered will include drugs, food additives, agricultural chemicals, and industrial chemicals. The detoxification and toxicological implications of metabolism are emphasized.

PHAR 898.3 Analytical Mass Spectrometry – 2 (2 L)
This course will cover modern state-of-the-art mass spectrometry techniques and their usefulness in research and discovery. The course will examine instrumentation-related topics, such as ionization sources, mass analyzers and hybrid tandem mass spectrometers. The advantages of each technique will be highlighted and discussed. A second portion of the course will focus on mass spectra interpretation and the various applications of applied mass spectrometry, namely structural elucidation, quantification, proteomics, and related biomedical and environmental applications. The course will also include practical demonstration of the use of tandem mass spectrometry.
Prerequisite(s): None.

VBMS 833.3 Subclinical Toxicology – 1/2 (3L-1S)
Discusses subclinical manifestations to toxic agents. The emphasis will be on immunological and behavioral alterations produced by a variety of chemical agents. Animal models and testing methods used to evaluate the effects will be discussed, along with various public health considerations and significance.
Prerequisite(s): Permission of the instructor or registration in the Toxicology Graduate Program.

VBMS 840.3 Vascular Biology and Toxicology – 2 (3L)
This course examines the physiology of blood vessels at the tissue, cellular and molecular level. The interaction of blood vessels with blood, the pathophysiology of common vascular diseases and the effect of toxicants on the circulation are discussed.
Prerequisite(s): None, Permission of the Instructor.

VBMS 855.3 Integrative Cardiovascular Physiology & Toxicology – 2 (1L)
The course will build on the content of VBMS 840 (Vascular Physiology & Toxicology) which is focused strictly on vascular tissue, examine ventricular/arterial coupling as well as how cardiac, pulmonary, renal, endocrine and/or neural systems integrate with cardiovascular responses for homeostatic control of blood pressure, examine how these homeostatic mechanisms are altered in pathological processes associated

with major human diseases and toxic agents encountered by humans. Relative emphasis on disease versus toxicants will be adjusted according to students' backgrounds each year.
Prerequisite(s): *VBMS 840*, Permission of the Instructor.

In addition to these core courses, the following special topics courses are occasionally offered:

TOX/ENVB 6530.3 Toxicological Risk Characterization – 3 (3 L)
A biologically based, advanced course that will give students working knowledge of current processes and techniques for toxicological risk characterization. The course material will cover the topics: Problem definition; effect characterization; exposure characterization; risk assessment; and risk management decision making.
Prerequisite(s): None.

TOX 899.6 Special Topics in Toxicology
Created under special circumstances only.

ANSC 825.3 Nutritional Toxicology – 1 (3L)
Naturally occurring toxicants. Bacterial toxins and mycotoxins. Additives and residues. Contaminants. Drug-nutrient interrelationships. Nutrient toxicity. Safety and regulatory aspects.
Prerequisite(s): Undergraduate biochemistry and nutrition courses and permission of the instructor.

APMC 825.3 Carcinogens and Mutagens – 2 (2L-1S)
Provides some understanding of carcinogens and mutagens, their mechanism of action at organismic, cellular, and molecular levels, and of their testing and assessment. Short seminar discussions of current developments will be included.
Prerequisite(s): One course in each of biochemistry, cell biology (e.g., *ANAT 201*), and general microbiology, and permission of the instructor.

BIOE 850.3 Synchrotron X-Ray Imaging – 1/2 (3L)
Will introduce some synchrotron specific imaging modalities such as K-edge subtraction, diffraction enhanced imaging, and phase contrast imaging with connections Made to conventional imaging. The first part of the course will cover x-ray interactions, Detection, dose estimation and source properties (conventional and synchrotron).
Prerequisite(s): Permission of the instructor.

GEOL 898.3 Advanced X-Ray Absorption Spectroscopy – 2 (3 L)
The course will describe the physical principals, experimental technique and data analysis of X-ray absorption spectroscopy. Frequent reference to practical applications will be included, and relevant synchrotron technology will also be reviewed. This course will equip the student with a practical working knowledge of the technique and its capabilities.
Prerequisite(s): Permission of the instructor.

PHAR 856.3 Forensic Toxicology – 1 (3L-4P)
Deals with the analytical procedures involved in the detection of chemicals and drugs in the body tissues and fluids, and the identification of drugs of abuse. Appropriate analytical chemical techniques are discussed and used during the practical component of the course.

VTPA 841.3 Toxicologic Pathology – 2 (1L-1S-2P)
Covers mechanisms of toxicology as well as basic pathology, focusing on several major organ systems. The students' understanding of how clinical, environmental or pharmacological toxicants damage specific organs will be supported through didactic instruction, case studies, web-based cases, directed readings and structured group discussion.
Prerequisite(s): *VTPA 342* & *343*, or equivalent; or, *TOX 402* & *PATH 205*, or permission of the instructor.

Required courses in which students must maintain continuous registration for the duration of their program:

TOX 990 Toxicology Seminar
Reviews of literature and recent investigations. Graduate students are required to attend and to present seminars.

TOX 994 Research
Students working towards a Master's Thesis must register for this course.

TOX 996 Research
Students working towards a PhD Thesis must register for this course.

Appendix 4b – CREATE HERA Required Courses

TOX 821.3 Human Health Chemical Risk Assessment – Term 2 (3 L)
Exposure and risk estimates are subject to considerable uncertainty due to: chemical concentration heterogeneity in the environment; natural variation in the characteristics and behaviours of people that lead to exposure; inter-individual variability in contaminant bioavailability and toxicology; chemical environmental fate and transport; degree of exposure and numerous other factors. The course objective is to provide the basic knowledge to conduct, evaluate and interpret exposure and risk assessments of chemicals present in the natural and built environments.
Prerequisite(s): None.

TOX 840.3 Wildlife Toxicology and Ecological Risk Assessment - Spring (1 week short course)
This course is intended to provide a broad exposure to general principles of terrestrial toxicology, with an emphasis on mammalian and avian species. Topics to be covered include: effects of common environmental contaminants on wildlife populations; factors affecting soil toxicity, contaminant bioavailability and fate; common in vitro and in vivo methods to assess toxicity and sublethal exposure (biomarkers); and ecological risk assessment.
Prerequisite(s): *TOX 300* and *TOX 301*, or permission from the instructor.

TOX-843.3 Environmental Chemodynamics – Term 2 (3L)
This course will supply the student with an understanding of the processes that control the movement of organic and inorganic contaminants in the atmosphere, hydrosphere and lithosphere and will also provide an understanding of the methods used to monitor environmental behavior of potentially toxic contaminants in biotic and abiotic matrices.
Prerequisite(s): One course in ecology or environmental biology; one course in general or environmental chemistry or permission from the instructor and students course advisor.
Prerequisite(s): None.

EVSC 420.3 Environmental Fate and Transport of Toxic Substances – Term 1 (2L)
In this lecture/practicum based course, students will learn how to construct a multi-media environmental model using freely available software. Students will be exposed to the fundamental theory of environmental fate modeling with a focus on how contaminant movement and transformation in the atmosphere, hydrosphere, biosphere and geosphere are incorporated into long term environmental fate models. The course is located in a computer lab and the emphasis is on practical construction, implementation and interpretation of fugacity based environmental fate models. Each lecture period consists of a brief theoretical overview followed by application and implementation of the equations into the student's fate model.
Prerequisite(s): MATH 104 or 110; PHYS 115 or EVSC 210; successful completion of 60 credit units of university level courses.

ENVS 898.3 Environmental Issues and Negotiations – Term 2 (1L)
The course aims to expose students to the different view-points and approaches used by the different stakeholders typically involved with the negotiation and assessment of environmental issues. Several experts from local, provincial or federal agencies, and industry, as well as experts in the areas of environmental journalism and law will give presentations on specific topics. Furthermore, an overview of the concept of risk assessment will be given, and similarities and differences between human and ecological risk assessments will be explored.
Prerequisite(s): None.

Appendix 5 – Toxicology Graduate Student Alumni

GRADUATE STUDENT	GRADUATED	LAST KNOWN EMPLOYER
Magnuson, Berna; M.Sc.	1985	Senior Toxicologist, Burdock Group, Washington, DC
Buzik, Shirley; Ph.D.	1985	Unknown
Lim, Heng-Keang; M.Sc.	1985	Unknown
Tomar, Rajpal; Ph.D.	1985	Scientific Affairs Division, California Environmental Protection Agency
Schappert, Keith; Ph.D.	1985	Unknown
Hiebert, Linda; PGD	1986	Associate Professor, Department of Veterinary Biomedical Sciences, University of Saskatchewan
Martz, Valery; PGD	1987	Quality Manager, Canadian Food Inspection Agency, Saskatoon, SK
Moosa, Adel; M.Sc.	1987	Unknown
Segal, Larry; Ph.D.	1987	Director, Toxicology, GSK Biologicals, Belgium
Vanderkop, Perry; M.Sc.	1988	Unknown
Korchinski, Mark; M.Sc.	1988	DABT Clinical Evaluator, Marketed Health Products Directorate, Health Canada, Ottawa, ON
Bjarnason, Stephen; M.Sc.	1989	Toxicologist, Medical Therapy Group, Chemical and Biological Defence Section, DRDC
Nihei, Michelle; PGD & M.Sc.	PGD 1988/ M.Sc. 1990	Unknown
Couillard, Catherine; Ph.D.	1990	Unknown
Kim, Jin-Suk; M.Sc. & Ph.D.	M.Sc. 1988/ Ph.D. 1990	Unknown
Kala, Geeta; Ph.D.	1991	Unknown
Duffy, Mary; Ph.D.	1991	Unknown
MacNabb, Linda; M.Sc.	1992	Unknown
Uwiera, Richard; M.Sc.	1992	Unknown
Mayers, Daryl; M.Sc. & Ph.D.	M.Sc. 1988/ Ph.D. 1992	Unknown
Kerviche, Annette; PGD & M.Sc.	PGD 1989/ M.Sc. 1993	Unknown
Lintott, Darlene; M.Sc.	1993	Unknown
Burn, John; M.Sc.	1993	Unknown
Mostrom, Michelle; Ph.D.	1993	Unknown
Bharadwaj, Lalita; Ph.D.	1997	Associate Professor, School of Public Health, University of Saskatchewan
Eizadi-Mood, Nastaran; Ph.D.	1998	Associate Professor, Isfahan University of Medical Sciences, Isfahan, Iran
Siciliano, Steven; Ph.D.	1998	Professor, Department of Soil Science, University of Saskatchewan
Plante, Amanda; M.Sc.	1999	Research Administration, University of Saskatchewan

Sobey, Kirk; M.Sc.	1999	Provincial Fur Program Biologist, Ontario Ministry of Natural Resources, Peterborough, ON
Wivcharuk, Kyle; M.Sc.	1999	Research and Policy Analyst, Environmental Health, Region of Peel, ON
Willey, Jeff; M.Sc.	2000	Biologist, Air Quality Assessment Section, Air Health Effects Division, Safe Environments Programme, Health Canada, Ottawa, ON
George, Tara; M.Sc.	2001	Surface Water Specialist, Ministry of Environment, Thunder Bay, ON
Blechinger, Scott; M.Sc.	2002	Scientific Evaluator, Existing Substances Division, Health Canada, Ottawa, ON
de Rosemond, Simone; M.Sc.	2002	On Leave
Froese, Jennifer; M.Sc.	2002	Contaminated Sites Officer, Environment Canada, Edmonton, AB
Serben, Kerrie; M.Sc.	2002	Environmental Scientist, Golder Associates, Ltd. Saskatoon, SK
Weese Maley, Sharleen; PGD	2002	Clinical Research Associate, Saskatchewan Drug Research Institute, Saskatoon, SK
Rogers, Vince; M.Sc. & Ph.D.	M.Sc. 1998/ Ph.D. 2003	Research & Operations Officer, Alberta Diabetes Institute, Edmonton, AB
Doig, Lorne; Ph.D.	2004	Research Scientist, Toxicology Centre, University of Saskatchewan
Hruska, Kimberly; M.Sc.	2004	Instructor, Department of Biology, Langara College, Vancouver, BC
Irvine, Michelle; M.Sc.	2004	On Leave
Kallas, Melissa; M.Sc.	2004	Medical student, University of Calgary, AB
Palasz, Filip; M.Sc.	2004	Senior Manager, Drug Utilization and Agreements, Pharmaceutical Funding and Guidance Branch, Alberta Health and Wellness
Phaneuf, Marcelle; M.Sc.	2004	Environmental Risk Assessment Officer, Directorate of Environmental and Radiation Protection and Assessment, Canadian Nuclear Safety Commission, Ottawa, ON
Siggers (nee Cleave), Jayda; M.Sc.	2004	Owner, EatWHOLE BeVITAL Nutrition, Ottawa, ON
Smida, Andrea; M.Sc.	2004	Biosafety Manager, University of Saskatchewan, SK
Chandraratne, Saminda; PGD	2004	Unknown
May, Victoria; M.Sc.	2005	Research Technician, Diagnostic Lab, PDS, Western College of Veterinary Medicine
Carmalt (nee Rosel), Kathryn; M.Sc.	2005	DVM Student, Western College of Veterinary Medicine
Bechtel, Dan; M.Sc & Ph.D.	M.Sc. 1993/ Ph.D. 2005	Owner/Private Consultant, PRTox Consulting Inc., Saskatoon, SK

Bennett, Pamela; M.Sc.	2006	Ecologist/Environmental Scientist, AREVA Resources Canada Inc., Saskatoon, SK
Chung, Angela; M.Sc.	2006	RCMP Forensic Laboratory, Winnipeg, MB
Salisbury, Heather; M.Sc.	2006	Administrator, Student Disability Centre, University of Saskatchewan
Robertson, Erin; M.Sc.	2006	Environmental Specialist, K & S Potash, Saskatoon, SK
Stoughton, Sarah; M.Sc.	2006	Ecologist/Environmental Scientist, AREVA Resources Canada Inc., Saskatoon, SK
Rickwood, Carrie; Ph.D.	2006	Research Scientist, Natural Resources Canada, Ottawa, ON
Doetzel, Lyndsay; M.Sc.	2007	Aquatic Scientist, EDI Environmental Dynamics Inc., Whitehorse, YT
Pollock, Brady; M.Sc.	2007	Unknown
Beaulac (nee Juneau), Vanessa; M.Sc.	2007	Senior Scientific Evaluator, Air Health Science Division, Health Canada, Ottawa ON
Journey, Shane; Ph.D.	2007	Chief Executive Officer & President, Nanotechnology Toxicology Consulting & Training, Toronto, ON
McGuigan, Claire; M.Sc.	2007	PhD Candidate, University of Alberta
Olsgard-Dumanski, Mandy; M.Sc.	2007	Toxicologist, WorleyParsons, Edmonton, AB
Lin, Leo; M.Sc.	2007	ApoPharma, Toronto, ON
Gunness, Patrina; M.Sc.	2007	Unknown
Kelly, Jocelyn; M.Sc.	2007	On Leave
Boyd, Erin; M.Sc.	2007	Unknown
Stoddart, Reagen, M.Sc.	2007	Shell Canada, Calgary, AB
Sokoro, AbdulRazaq; Ph.D.	2007	Clinical Biochemist, Diagnostic Services, Winnipeg, MB
Kuchta, Sandra; M.Sc.	2008	Scientific Evaluator, Health Canada, Ottawa, ON
Anaka, Alison; M.Sc.	2008	ENMAX, Calgary, AB
Spencer, Paula; M.Sc.	2008	Unknown
Matz, Carlyn; Ph.D.	2008	Health Canada, Ottawa, ON
Hughes (Nee Armstrong), Sarah; Ph.D	2008	Ecotoxicologist, Shell Health – Americas, Houston, TX
Hersikorn, Blair; M.Sc.	2009	Environmental Scientist, Golder Associates, Saskatoon, SK
Bugiak, Brandie; M.Sc.	2009	Lab Technician, Department of Biological Sciences, University of Alberta
McEwen, Barbara; M.Sc.	2009	Contaminated Sites Officer, Environment Canada, Winnipeg, MB
Driedger, Kimberlea: M.Sc.	2009	Aquatic Biologist, Golder Associates, Saskatoon, SK
Gupta, Niti, M.Sc.	2009	Northern Gold Mining, Wolfville, NS
Heggstrom, Michelle; M.Sc.	2009	WSEP - Bio Safety Division, University of Saskatchewan
Yang, Yinfei; M.Sc.	2009	Quantum Genetix, Saskatoon, SK

Higley, Eric, M.Sc.	2009	On Leave
Billinsky, Jennifer; Ph.D.	2009	Postdoctoral Fellow, College of Pharmacy & Nutrition, University of Saskatchewan
Muscatello, Jorgelina; M.Sc. & Ph.D.	M.Sc 2004/ Ph.D. 2009	Stantec Consulting, Vancouver, BC
Gentner, Nicole; M.Sc.	2010	Compliance & Audit Specialist, Bayer CropScience, Saskatoon, SK
Carlson, Ruth; Ph.D.	2010	Instructor, Georgia Gwinnett College, Atlanta, GA
Laird, Brian, Ph.D.	2010	NSERC Postdoctoral Fellow, University of Ottawa, ON
Al-Dissi, Ahmad; Ph.D.	2011	Assistant Professor, Department of Veterinary Pathology, University of Saskatchewan
Harvey-Schafer, Alexis; Ph.D.	2011	Environmental Consultant, Saskatoon, SK
Kwong, Wai Man; Ph.D.	2011	Postdoctoral Fellow, Department of Biology, University of Ottawa, ON
Rozon-Ramilo, Lisa; M.Sc.	2011	Environmental Consultant, Stantec, Guelph, ON
Goertzen, Meghan; M.Sc.	2011	Environmental Toxicologist, Lorax Environmental, Vancouver, BC
Anderson, Julie; M.Sc.,	2011	Research Associate, University of Guelph, ON
Burnett-Seidel, Charlene; M.Sc.	2011	Environmental Scientist, Cameco Corporation, Saskatoon, SK
Liu, Fengyan; M.Sc.	2011	Forensic Laboratory Assistant, Gamma Dynacare, Edmonton, AB
Driessnack, Melissa; M.Sc.	2011	Ph.D. candidate, University of Saskatchewan
Naile, Jonathon; Ph.D.	2011	Postdoctoral Fellow, United States Environmental Protection Agency, National Exposure Research Laboratory Ecosystems Research Division, Athens, GA
Squires, Allison; M.Sc. & Ph.D.	M.Sc. 2005/ Ph.D. 2011	Owner of Upland Organics, Wood Mountain, SK
Phibbs, Jamie, M.Sc.	2011	Environmental Scientist, AECOM, Winnipeg, MB
Puttaswamy, Naveen; Ph.D.	2011	Research Scientist, Department of Environmental Health and Engineering, Sri Ramachandra University, Porur, Chennai
Toor, Navdeep; Ph.D.	2011	Environmental Scientist, Summit Environmental Consultants, Saskatoon, SK
Vardy, David; M.Sc.	2011	Ph.D. candidate, University of Saskatchewan
Franz, Eric; M.Sc.	2012	Aquatic Ecologist, Canada North Environmental Services, Saskatoon, SK
Ofukany, Amy; M.Sc.	2012	Aquatic Biologist, Golder Associates, Saskatoon, SK
Hursky, Olesya; M.Sc.	2012	Saskatchewan Research Council, Saskatoon, SK
Shitut, Mithila; M.Sc.	2012	Administration, University of Saskatchewan
James, Ashley; M.Sc.	2012	Ph.D. candidate, University of Saskatchewan
Goff, Kira; M.Sc.	2012	Ph.D. candidate, University of Saskatchewan
Tompsett, Amber; Ph.D.	2012	On Leave

Appendix 6 – Toxicology & NETI Consolidated Operating Budgets (2009-2012)

	2009			2010			2011			2012		
	Toxicology	**NETI**	**TOTAL**	**Toxicology**	**NETI**	**TOTAL**	**Toxicology**	**NETI**	**TOTAL**	**Toxicology**	**NETI**	**TOTAL**
Revenue												
Operating Budget	$ 562,851	$442,740	$1,005,591	$ 446,895	$493,159	$940,054	$ 433,260	$509,501	$942,760	$ 431,302	$537,042	$968,344
Expenditures												
Salaries	360,159	402,638	762,797	332,331	434,994	767,325	323,960	398,122	722,082	316,730	500,441	817,171
Benefits	42,457	54,981	97,438	40,428	57,878	98,306	42,212	53,099	95,311	43,769	72,826	116,595
Scholarships, Bursaries, Transfers	1,500	-	1,500	1,500	-	1,500	950	5,000	5,950	12,344	1,495	13,839
Supplies and Consumables	30,862	4,265	35,127	23,797	16,896	40,693	20,628	5,667	26,295	17,418	293	17,711
Equipment and Faculty Start up Funding	6,668	48,682	55,350	3,782	36,268	40,050	1,385	4,125	5,510	2,479	7,065	9,544
Travel and Hospitality	1,253	15,566	16,819	2,837	4,455	7,292	-	-	-	3,035	8,001	11,036
Renovation (including building/facility maintenance)	10,228	21,124	31,352	9,084	19,087	28,171	8,199	49,161	57,360	8,377	22,720	31,097
Total Expenditures	**453,127**	**547,256**	**1,000,383**	**413,759**	**569,578**	**983,337**	**397,334**	**515,174**	**912,508**	**404,152**	**612,841**	**1,016,993**
Total Revenue less Expenses	**109,724**	**-104,516**	**5,208**	**33,136**	**-76,419**	**-43,283**	**35,926**	**-5,673**	**30,252**	**27,150**	**-75,799**	**-48,649**

Note: A carefully managed contingency fund held with the Toxicology Centre helps cover annual overexpenditures.