

Introduction to Food Toxicology

Food Toxicology
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Learning Objectives

- Introduce the course and course expectations.
- Define toxicology and food toxicology.
- List the course of study.
- Examine the interaction of toxicology and risk analysis.
- Define risk assessment, risk communication, risk management.
- Examine the fundamentals of human health risk assessment.
- Discuss risk perception.
- List the course goals.

Course

- Introductions.
- Enrollment.
 - Drop/add deadlines.
 - Reading, homework assignments, assessment.
 - Student projects.
 - Exams.
 - Graduate credit.
 - Honor code.
- Web site; Web access via student portal; WebCT
- <http://www.agls.uidaho.edu/foodtox>

Role of Science

“Science is first of all a set of attitudes. It is a disposition to deal with the facts rather than what someone has said about them...Science is a willingness to accept facts even when they are opposed to wishes... the opposite of wishful thinking is intellectual honesty. Scientists have simply found that being honest - with oneself as well as others - is essential to progress. Experiments do not always come out as one expects, but the facts must stand and the expectations fall.

The subject matter, not the scientist knows best.”

--Skinner, 1953,
Science and Human Behavior

My Expectations

- Mortality and morbidity.
 - Respect for life and the unfortunate people and animals in case study depictions of toxicosis.
- Tolerance.
 - Respect for different points of view and the passions that drive them.
- You will do the hard work of learning.
- Patience with technical failure.

Toxicology

- The science that deals with the adverse effects of chemicals on living organisms and assesses the probability of their occurrence.

Toxicology

- The interface of chemistry and biology.
 - Pharmacology: therapeutic effect
 - Toxicology: toxicosis or disease effect

Food Toxicology

- Food toxicology is the study of the nature, properties, effects, and detection of toxic substances in food, and their disease manifestation in humans.

Historical Context of Toxicology

- From earliest times people have been aware that some plants are poisonous and should be avoided as food. Other plants were found to contain chemicals that have medicinal, stimulatory, hallucinatory, or narcotic effects.
 - Historical timeline of toxicology.

Course of Study

- Introduction to Food Toxicology
- History of US Food Regulation
- Concepts of Toxicology
- Pesticide Residues in Food

- Dose-Response Relationships
- Absorption of Toxicants
- Distribution and Storage of Toxicants
- Biotransformation and Elimination of Toxicants
- Target Organ Toxicity

Course of Study

- Teratogenesis, Mutagenesis, and Carcinogenesis
- Food Allergy
- Food Intolerance and Metabolic Disorders
- Food Additive Safety Assessment
- Toxicology of Selected Food Additives
- Genetically Modified Organisms in Food
- Food Irradiation
- Natural Toxins in Plants and Fungi:
The Ecological Biochemistry of Food
- Toxic Mold and Mycotoxins

Course of Study

- Marine Toxins in Food
- Naturally Occurring Toxicants as Etiologic Agents of Foodborne Disease
- Bacterial Toxigenesis
- Animal Drug Residues in Food
- Toxicants Formed During Food Processing
- Dioxin and Related Compounds in the Human Food Chain
- Risk Assessment of Lead and Arsenic in the Human Food Chain
- Mercury in the Human Food Chain
- Frontiers of Food Toxicology

Toxicology: Basic and Applied Science

- Basic: fundamental work on the molecular and biological processes of toxic substances.
- Applied: applying scientific knowledge to practical problems.
- Risk analysis uses applied toxicology to examine the practical problem of humans thriving in the presence of chemicals, natural and anthropogenic.

Toxicology and Risk Analysis

- Risk analysis is broadly defined to include risk assessment, risk characterization, risk communication, risk management, and policy relating to risk.

Toxicology and Risk Analysis

- Risk assessment
 - Scientific evaluation of the probability of harm resulting from exposure to toxic substances.
 - Risk characterization
 - A description of the nature and magnitude of health risk that combines results of exposure assessment and hazard identification and describes the uncertainty associated with each step.
- Risk communication
 - The science of communicating effectively in situations that are of high concern, sensitive, or controversial. Risk communication principles serve to create an appropriate level of outrage, behavior modification, or mitigating response, that is in direct proportion to the level of risk or hazard.
- Risk management
 - Risk management is the decision-making process involving considerations of political, social, economic and science/engineering factors with relevant risk assessments relating to a potential hazard so as to develop, analyze and compare options and to select the optimal response for safety from that hazard.

Human Health Risk Assessment

- Predictive modeling of the threat to human health posed by the exposure to toxicants.
- For constituents that are systemic toxicants, the threat can be expressed in terms of a hazard quotient.
- Hazard Quotient = Dose ÷ Toxicity Factor.
 - Toxicity factor can be “maximum safe intake”
 - A hazard quotient ≤ 1.0 is typically regarded as acceptable

Fundamentals of HHRA

- Systemic toxicity is a threshold phenomenon.
 - Increasing exposure (dose) of a chemical will cross a threshold when biological effects will start to occur.
 - The dose is the total dose attributable all routes of exposure.
- Cancer: non-threshold
- Toxicity factors for systemic toxicants are reference doses.
 - i.e., the “no effect” level.
- Dose and reference dose units.

- mg of constituent per kg receptor body weight per day, or mg/(kg·d).

Fundamentals of HHRA

Dose is modeled with the following general equation (unit conversion factors are used as needed):

$$\text{Dose} = \text{CC} \times \text{CR} \times \text{EF} \div (\text{BW} \times \text{UCF})$$

- CC — constituent concentration in the medium of potential concern (e.g., mg/L).
- CR — contact rate with the medium of potential concern (L/d).
- EF — exposure frequency with the medium of potential concern (d/yr).
- BW — body weight (kg).
- UCF — unit conversion factor (e.g., d/yr).

Risk Models

- Deterministic: point estimates
 - Straight-forward; easier risk communication
- Probabilistic (stochastic): distributions
 - Uncertainty quantified; statistical representations

Risk Models: Deterministic vs. Probabilistic

Risk Triad

Risk: Perceptions and Preferences

- Experts and the public often disagree about risk.
- People will accept risks 1,000 greater if they are voluntary (e.g. driving a car) than if they are involuntary (e.g. a nuclear disaster) [Starr 1969].
- Risk attributes that lead to cognitive bias:
 - Availability
 - Imagining scenarios
 - Anchoring
 - Background knowledge
 - Gain/Loss asymmetry
 - Loss is value greater
 - Threshold
 - Adverse to uncertainty

Perceptions About Chemicals

- What drives our perceptions?
- Involves subjective judgments.
- Are chemicals bad?
 - Natural vs. synthetic

Natural Carcinogens in Coffee

- Acetaldehyde
- Benzaldehyde
- Benzene
- Benzofuran
- Benzo[a]pyrene
- Caffeic acid
- Catechol
- 1,2,5,6 Dibenz-anthracene
- Ethanol
- Ethylbenzene
- Formaldehyde
- Furan
- Furfural
- Hydrogen peroxide
- Hydroquinone
- Limonine
- Styrene
- Toluene
- Xylene

Perception vs. Reality

- Perception:
 - Pollution is a significant contributor to cancer and that cancer rates are soaring.
- Reality:
 - Life expectancy increasing in industrialized countries.
 - Cancer (non-smoking) death rates steady or going down.

Cancer Death Rates - Male Cancer Death Rates - Female Perception vs. Reality

- Perception
 - High dose animal cancer tests tell us the significant cancer risks for humans.
- Reality
 - Half of all chemicals-natural or synthetic-tested in standard animal cancer tests have turned out to be carcinogenic.
 - Near toxic doses-the maximum tolerated dose, can cause

chronic cell wounding or
mitosis – risk for cancer.

Perception vs. Reality

- Perception
 - Human exposures to carcinogens and other toxins are nearly all due to synthetic chemicals.
- Reality
 - Amount of synthetic pesticide residues in plant foods is insignificant compared to the amount of natural plant pesticides.
 - 5-10,000 natural pesticides consumed, totaling 1500 mg/day.

Perception vs. Reality

- Perception
 - Synthetic toxins pose greater carcinogenic hazards than natural toxins.
- Reality
 - Proportion of natural chemicals that is carcinogenic when tested in both rats and mice is the same as for synthetic chemicals-roughly half.
 - All chemicals are toxic at some dose.
 - 99.9% of chemicals ingested are natural.

Perception vs. Reality

- Perception
 - Toxicology of man-made chemicals is different from that of natural chemicals.
- Reality
 - Humans have many general, natural defenses that make us well buffered against normal exposures to toxins, both natural and synthetic.

Perception vs. Reality

- Perception
 - Correlation implies causation.
- Reality
 - No persuasive evidence from either epidemiology or toxicology that pollution is a significant cause of cancer for the general population.

Toxicology Issues Beyond Cancer

- Workplace exposure.
- Endocrine disruption.
- Sub-clinical effects.
- Developmental effects.
- Sensitive populations.
- Multiple exposures.
- Unknown effects.

Complex Modifiers to Risk Perception

- Trust and violated trust
- Dread (visceral, uncontrollable, fatal)
- Fear of the unknown
- Stigma and social structures

Course Goals

- To provide a broad foundation of knowledge about the sources, pathways, receptors, and controls of toxicants in the human food system.
- To assist students in achieving a high-level of understanding and interpretative capacity in food toxicology.
- To help develop critical thinking skills about the risks of foodborne toxicants.