College of Energy and Environmental Sciences

Department of Environmental Sciences

Environmental toxicology

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First lecture 3rd Stage

Environmental toxicology

Keywords: Environmental toxicology, environmental chemistry, toxicology, ecology, ecotoxicology

Environmental toxicology is the science that studies the fate and effects of potentially hazardous chemicals in the environment. It is a multidisciplinary field assimilating and building upon knowledge, concepts and techniques from other disciplines, such as toxicology, analytical chemistry, biochemistry, genetics, ecology and pathology.

Environmental toxicology emerged in response to the growing awareness in the second part of the 20th century that chemicals emitted to the environment can trigger hazardous effects in organisms living in this environment, including humans.

One way to depict the field of environmental toxicology is by a triangle consisting of chemicals, the environment and organisms (figure 1).

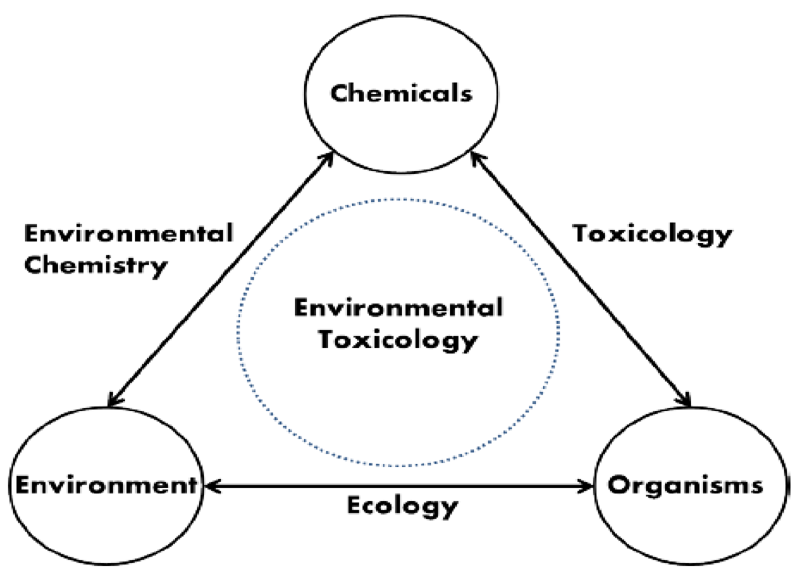

Figure 1: Environmental toxicology studies the interactions between chemicals, organisms and the environment making use of environmental chemistry, toxicology and ecology.

Source: Ad Ragas.

The triangle illustrates that the fate and potential hazardous effects of chemicals emitted to the environment are determined by the interactions between these chemicals, the environment and organisms. The fate of substances in the environment is the topic of **Environmental chemistry**, the effects of substances on living organisms is studied by **toxicology**, and the implications of these effects on higher levels of biological organization are analyzed by the field of **ecology**.

Another term widely used to refer to this field of study is **ecotoxicology**.The main distinction is the inclusion of human health as an endpoint in environmental toxicology, whereas ecotoxicology is restricted to ecological endpoints. Since the current book includes human health as an assessment endpoint for environmental contaminants, the term environmental toxicology is preferred over ecotoxicology.

Environmental chemists study the fate of chemicals in the environment, e.g. their distribution over different environmental compartments and how this distribution is influenced by the physicochemical properties of a chemical and the characteristics of the environment. They aim to understand the pathways and processes involved in the environmental fate of a chemical after it has been emitted to the environment, including processes such as advection, deposition and (bio)degradation. Within the context of environmental toxicology, the ultimate aim is to produce a reliable assessment of the exposure of organisms, an aim which is often complicated by the enormous heterogeneity of the environment.

Environmental chemists use a variety of tools to analyze and assess the fate of chemicals in the environment. Two fundamental tools are analytical measurements and mathematical modelling. Measurements are essential to acquire new knowledge and insight into the behavior of chemicals in the environment. e.g. measurements on emissions, environmental concentrations and specific processes such as biodegradation. These measurements are analyzed to discover patterns, e.g. between substance properties and environmental characteristics. Once revealed, such patterns can be integrated into a comprehensive mathematical model to predict the fate of and exposure to substances in the environment. If sufficiently validated, these models can subsequently be used by risk assessors to assess the exposure of organisms to chemicals, reducing the need for expensive measurements.

Toxicologists study the effects of chemicals on organisms, often at the individual level.

Fundamental toxicologists aim to understand the mechanisms involved in the toxicity of a compound, whereas more applied toxicologists are primarily interested in the relationship between exposure and effect, often with the aim of identifying an exposure level that can be considered safe. Within this context, the dose concept as introduced by Parcelsus at the start of the 16th century is essential i.e. the likelihood of adverse effects depends on the dose organisms are being exposed to.

The processes taking place after exposure of an organism to a toxicant are often divided into toxicokinetic and toxicodynamic processes.

Toxicokinetic processes are those that describe the fate of the toxicant in the organism, including processes such as absorption, distribution, metabolism and excretion (ADME). These toxicokinetic or ADME processes are sometimes collectively referred to as "What the body does to the substance" and determine the exposure level at the site of toxic action, or internal dose.

Toxicodynamic processes are those that describe the evolution of an adverse effect from the moment that the toxicant, or one of its metabolites, interacts with a molecular receptor in the body. This interaction is often referred to as the primary lesion or molecular initiating event (MIE). Toxicodynamic processes are sometimes collectively referred to as "What the substance does to the body" and the chain of events leading to an adverse outcome as the adverse outcome pathway (AOP).

The toxicity of a compound thus depends on toxicokinetic as well as toxicodynamic processes. Traditionally, this toxicity is being determined by exposing whole organisms in the laboratory to the substance of interest, and subsequently monitoring the health status of these organisms. However, as a result of the growing societal pressure to reduce animal testing, as well as the increased mechanistic understanding and improved molecular techniques, this so-called "black box approach" is more and more being replaced by a combination of **in vitro toxicity testing** and **"in silico" predictive** approaches. Physiologically based toxicokinetic (PBTK) models are increasingly used to model the fate of chemicals in the body, resulting in a prediction of the internal exposure. In vitro tests and advanced molecular techniques at the gene (genomics) or protein (proteomics) level may subsequently be used to determine whether these internal exposure levels will trigger adverse effects, although many challenges remain in the prediction of adverse effects based on in vitro test and omics information.

Ecologists study the interactions between organisms and their environment.

Ecology is an important pillar of environmental toxicology, because ecological knowledge is needed to translate effects at the individual level to the ecosystem level; an important endpoint of ecological risk assessments. Such a translation requires specific knowledge, e.g. on life cycles of organisms, natural factors regulating their populations, genetic variability within populations, spatial distribution patterns, and the role organisms play in processes like nutrient cycling and decomposition. Effects considered relevant at the individual level, such as a tumor risk, may turn out to be irrelevant at the population or ecosystem level. Similarly, subtle effects at the individual level may turn out to be highly relevant at the ecosystem level, e.g. behavioral changes after environmental exposure to antidepressants which may affect the population dynamics of fish species. In recent years, there is an increasing interest for the role of the landscape configuration, distribution patterns and their dynamics in environmental toxicology.

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Second lecture 3rd Stage

2.2. Rachel Carson

Is considered the mother of environmental toxicology, as she made it a distinct field within toxicology in 1962 with the publication of her book *Silent Spring*, which covered the effects of uncontrolled pesticide use. Carson's book was based extensively on a series of reports by Lucille Farrier Stickel on the ecological effects of the pesticide DDT*.

***Dichlorodiphenyltrichloroethane**, commonly known as **DDT**, is a colorless, tasteless, and almost odorless

Organisms can be exposed to various kinds of toxicants at any life cycle stage, some of which are more sensitive than others.

Toxicity can also vary with the organism's placement within its food web*.

*A **food web** is the natural interconnection of food chains and a graphical representation of what-eats-what in an ecological community. Another name for food web is **consumer-resource system**.

Bioaccumulation* occurs when an organism stores toxicants in fatty tissues, which may eventually establish a trophic cascade** and the biomagnification*** of specific toxicants.

***Bioaccumulation** is the gradual accumulation of substances, such as pesticides or other chemicals, in an organism.

****Trophic cascades** are powerful indirect interactions that can control entire ecosystems, occurring when a trophic level in a food web is suppressed.

*****Biomagnification**, also known as **bioamplification** or **biological magnification**, is the increase in concentration of a substance, e.g a pesticide, in the tissues of organisms at successively higher levels in a food chain

<ins>**Biodegradation**</ins> releases carbon dioxide and water as by-products into the environment. This process is typically limited in areas affected by environmental toxicants.

Harmful effects of such **chemical and biological agents** as toxicants from pollutants, insecticides, pesticides, and fertilizers can affect an organism and its community by reducing its species diversity and abundance.

Such changes in population dynamics affect the ecosystem by reducing its productivity and stability.

Although **legislation** implemented since the early 1970s had intended to minimize harmful effects of environmental toxicants upon all species, McCarty (2013) has warned that "longstanding limitations in the implementation of the simple conceptual model that is the basis of current aquatic toxicity testing protocols" may lead to an impending environmental toxicology "dark age".

Governing policies on environmental toxicity

U.S. policies

To protect the environment, the National Environmental Policy Act (NEPA) was written. The main point that NEPA brings to light is that it "assures that all branches of government give proper consideration to the environment prior to undertaking any major federal actions that significantly affect the environment." This law was passed in 1970 and also founded the Council on Environmental Quality (CEQ). The importance of CEQ was that it helped further push policy areas.

CEQ created environmental programs including the Federal Water Pollution Control Act (RCRA), Toxic Substance Control Act, Resources Conservation and Recovery Act (RCRA and the Safe). CEQ was essential in creating the foundation for most of the "current environmental legislation except for Superfund and asbestos control legislation."

Some initial impacts of NEPA pertain to the interpretation within Courts. Not only did Courts interpret NEPA to expand over direct environmental impacts from any projects, specifically federal, but also indirect actions from federal projects.

Toxic Substance Control Act

TSCA, also known as the Toxic Substance Control Act, is a federal law that regulates industrial chemicals that have the potential to be harmful to humans and the environment. TSCA specifically targets "themanufacture, importation, storage, use, disposal, and degradation of chemicals in commercial use."

The EPA allows the following to be done: "

1. Pre-manufacture testing of chemicals to determine health or environmental risk
2. Review of chemicals for significant risk prior to the start of commercial production
3. Restriction or prohibition on the production or disposal of certain chemicals
4. Import and export control of chemicals prior to their entering or leaving the USA."

The Clean Air Act

The Clean Air Act was aided by the signing of the 1990 amendments. These amendments protected reducing acid, the ozone layer, improving air quality and toxic pollutants.

The Clean Air Act was actually revised and with, support from President George H.W Bush, it was signed in.

The biggest major threats that this act targets are: urban air pollution, toxic air emissions, stratospheric ozone, acid rain etc.

Apart from targeting these specific areas, it also established a national operating that "permits program to make the law more workable, and strengthened enforcement to help ensure better compliance with the Act."

Regulations and enforcement actions on PCBs[*]

As mentioned above, though the United States did ban the use of PCBs, there is the possibility that they are present in products made before the PCB ban in 1979.

The Environmental Protection Agency (EPA) released its ban on PCBs on April 19, 1979. According to the EPA, "Although PCBs are no longer being produced in this country, we will now bring under control the vast majority of PCBs still in use," said EPA Administrator Douglas M. Castle. "This will help prevent further contamination of our air, water and food supplies from a toxic and very persistent man-made chemical."

Polychlorinated biphenyls

<u>***(PCBs)** are organic pollutants that are still present in our environment today</u>

PCBs has been tested on laboratory animals and have caused cancer and birth defects.

PCB is suspected of having certain effects on liver and skin of humans. They are also suspected of causing cancer as well.

EPA "estimates that 150 million pounds of PCBs are dispersed throughout the environment, including air and water supplies; an additional 290 million pounds are located in landfills in this country."

Again, even though they have been banned, there is still a large amount of PCBs are circulating within the environment and are possibly causing effects on the skin and liver of humans.

There were some cases in which people or companies that disposed of PCBs incorrectly. Up until now, there have been four cases in which EPA had to take legal actions against people/companies for their methods of disposal. The two cases involving the companies were fined $28,600 for improper disposal. It is unknown what fined was charged against the three people for "illegally dumping PCBs along 210 miles of roadway in North Carolina."

Though PCBs were banned, there are some exceptions where they are being used. The area in which it has been completely prohibited is "the manufacture, processing, distribution in commerce, and "non-enclosed" (open to the environment) uses of PCBs unless specifically authorized or exempted by EPA. "Totally enclosed" uses (contained, and therefore exposure to PCBs is unlikely) will be allowed to continue for the life of the equipment."

In terms of electrical equipment containing PCBs is allowed under specific controlled conditions. Out of the 750 million pounds of PCBs, electrical equipment represents 578 million pounds. Any new manufacture of PCB is prohibited.

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3rd, 4th,and 5th lectures **3rd Stage**

Sources of environmental toxicity

There are many sources of environmental toxicity that can lead to the presence of toxicants in our food, water and air. These sources include organic and inorganic pollutants, pesticides and biological agents, all of which can have harmful effects on living organisms. There can be so called point sources of pollution, for instance the drains from a specific factory, but also non-point sources (diffuse sources) like the rubber from car tires that contain numerous chemicals and heavy metals that are spread in the environment.

PCBs

Polychlorinated biphenyls (PCBs) are organic pollutants that are still present in our environment today, despite being banned in many countries, including the United States and Canada. Due to the persistent nature of PCBs in aquatic ecosystems, many aquatic species contain high levels of this chemical. For example, wild salmon (*Salmo salar*) in the Baltic Sea have been shown to have significantly higher PCB levels than farmed salmon as the wild fish live in a heavily contaminated environment.

PCBs pertains to a group of human-produced "organic chemicals known as Chlorinated hydrocarbons" The chemical and physical properties of a PCS determine the quantity and location chlorine and unlike other chemicals, they have no form of identification. The range of toxicity is not consistent and because PCBs have certain properties (chemical stability, non-flammability) they have been used in a colossal amount of commercial and industrial practices. Some of those include, "Electrical, heat transfer and hydraulic equipment, plasticizers in paints, plastics and rubber products and pigments, dyes and carbonless copy paper" to name a few.

Heavy metals

Heavy metals found in food sources, such as fish, can also have harmful effects. These metals can include mercury, lead and cadmium. It has been shown that fish (i.e. rainbow trout) exposed to higher cadmium levels and grow at a slower rate than fish exposed to lower levels or none. Moreover, cadmium can potentially alter the productivity and mating behaviours of these fish.

Heavy metals can also alter the genetic makeup in aquatic organisms

Radiation

Radiation is given off by matter as either rays or waves of pure energy or high-speed particles. Rays or waves of energy, also known as electromagnetic radiation, include sunlight, X-rays, radar, and radio waves. Particle radiation includes alpha and beta particles and neutrons. When humans and animals are exposed to high radiation levels, they can develop cancer, congenital disabilities, or skin burns. Plants also face problems when exposed to large levels of radiation. After the Chernobyl disaster in 1986, the nuclear radiation damaged the surrounding plants' reproductive tissues, and it took approximately three years for these plans to regain their reproductive abilities. The study of radiation and its effects on the environment is known as radioecology.

Metals toxicity

The most known or common types of heavy metals include zinc, arsenic, copper, lead, nickel, chromium and cadmium. All of these types cause certain risks on human and environment health.

Though certain amount of these metals can actually have an important role in, for example, maintaining certain biochemical and physiological, "functions in living organisms when in very low concentrations, however they become noxious when they exceed certain threshold concentrations." Heavy metal are a huge part of environmental pollutions and their toxicity "is a problem of increasing significance for ecological, evolutionary, nutritional and environmental reasons."

Arsenic

Arsenic, one of the most important heavy metals, causes ecological problems and health issues in humans. It is "semimetallic property, is prominently toxic and carcinogenic, and is extensively available in the form of oxides or sulfides or as a salt of iron, sodium, calcium, copper, *etc."* It is also one of the most abundant elements on earth and its specific inorganic forms are very dangerous to living creatures (animals, plants, and humans) and the environment.

In humans, arsenic can cause cancer in the bladder, skin, lungs and liver. One of the major sources of arsenic exposure in humans is contaminated water, which is a problem in more than 30 countries in the world.

Humans tend to encounter arsenic by "natural means, industrial source, or from unintended sources." Water can become contaminated by arsenical pesticides or natural arsenical chemicals. There are some cases in which arsenic has been used in suicide attempts and can result in acute poisoning. Arsenic "is a protoplastic poison since it affects primarily the sulphydryl group of cells causing malfunctioning of cell respiration, cell enzymes and mitosis."

Lead

Another extremely toxic metal, lead can and has been known to cause "extensive environmental contamination and health problems in many parts of the world." The physical appearance of lead is bright and silver colored metal. Some sources of lead pollution in the environment include Metal plating and fishing operations, soil waste, factory chimneys, smelting of ores, wastes from batter industries, fertilizers and pesticides and many more. Unlike, other metals such as copper, lead only plays a physiological aspect and no biological functions. In the US, "more than 100 to 200,000 tons of lead per year is being released from vehicle exhausts" and some can be brought in by plants, flow in water or fixation into the soil.

Humans come in contact with lead through mining, fossil fuel burning. In burning, lead and its compounds are exposed into air, soil, and water. Lead can have different effects on the body and effects the central nervous system. Someone who has come in contact with lead can have either acute or chronic lead poisoning. Those who experience acute poisoning have symptoms such as appetite, headache, hypertension, abdominal pain, renal dysfunction, fatigue, sleeplessness, arthritis, hallucinations and vertigo." Chronic exposure on the other hand, can cause more severe symptoms such as, "mental retardation, birth defects, psychosis, autism, allergies, dyslexia, weight loss, hyperactivity, paralysis, muscular weakness, brain damage, kidney damage and may even cause death."

Mercury

Mercury, a shiny silver-white, can transform into a colorless and odorless gas when heated up. Mercury highly affects the marine environment and there have been many studies conducted on the effects on the water environment. The biggest sources of mercury pollution include "agriculture, municipal wastewater discharges, mining, incineration, and discharges of industrial wastewater" all relatively connected to water.

Mercury exists in three different forms and all three possess different levels of bioavailability and toxicity. The three forms include organic compounds, metallic elements and inorganic salts. As stated above, they are present in water resources such as oceans, rivers and lakes. They are absorb by microorganism, and go through, "biomagnification causing significant disturbance to aquatic lives."

Mercury hurts marine life but can also be very hurtful towards humans' nervous system. Higher levels of mercury exposure can change many brain functions. It can "lead to shyness, tremors, memory problems, irritability, and changes in vision or hearing."

Cadmium

According to, ATSDR ranking, cadmium is the 7th most toxic heavy metal. Cadmium is interesting in that once it is exposed to humans (at work) or animals in their environment, it will accumulate inside the body throughout the life of the human/animal. Though cadmium was used as replacement for tin in WWI and pigment in paint industries back in the day, currently it is seen mostly in rechargeable batteries, tobacco smoke and some alloys production.

As stated by the Agency for Toxic Substance and Disease Registry, in " the US, more than 500,000 workers get exposed to toxic cadmium each year." It is also stated that the highest exposure to cadmium can be seen in China and Japan.

The effects of cadmium on the kidney and bones is huge. It can cause bone mineralization which "is the process of laying down minerals on a matrix of the bone". This can happen through renal dysfunction or bone damage.

Chromium

The 7th most abundant element, chromium, can occur naturally when one burns oil and coal and is released into the environment through sewage and fertilizers. Chromium usage can be seen in, "industries such as metallurgy, electroplating, production of paints and pigments, tanning, wood preservation, chemical production and pulp and paper production." Chromium toxicity affects the "biological processes in various plants such as maize, wheat, barley, cauliflower, citrullus and in vegetables. Chromium toxicity causes chlorosis and necrosis in plants."

Pesticides

Pesticides are a major source of environmental toxicity. These chemically synthesized agents have been known to persist in the environment long after their administration. The poor biodegradability of pesticides can result in bioaccumulation of chemicals in various organisms along with biomagnification within a food web. Pesticides can be categorized according to the pests they target. Insecticides are used to eliminate agricultural pests that attack various fruits and crops. Herbicides target herbal pests such as weeds and other unwanted plants that reduce crop production.

DDT

Dichlorodiphenyltrichloroethane (DDT) is an organochlorine insecticide that has been banned due to its adverse effects on both humans and wildlife. DDT's insecticidal properties were first discovered in 1939. Following this discovery, DDT was widely used by farmers in order to kill agricultural pests such as the potato beetle, codling moth and corn earworm. In 1962, the harmful effects of the widespread and uncontrolled use of DDT were detailed by Rachel Carson in her book The Silent Spring as we mention in second lecture.

DDT is not easily biodegradable and thus the chemical accumulates in soil and sediment runoff. Water systems become polluted and marine life such as fish and shellfish accumulate DDT in their tissues. Furthermore, this effect is amplified when animals who consume the fish also consume the chemical, demonstrating biomagnification within the food web. The process of biomagnification has detrimental effects on various bird species because DDT and DDE accumulate in their tissues inducing egg-shell thinning. Rapid declines in bird populations have been seen in Europe and North America as a result.]

Humans who consume animals or plants that are contaminated with DDT experience adverse health effects. Various studies have shown that DDT has damaging effects on the liver, nervous system and reproductive system of humans.

By 1972, the United States Environmental Protection Agency (EPA) banned the use of DDT in the United States. Despite the regulation of this pesticide in North America, it is still used in certain areas of the world. Traces of this chemical have been found in noticeable amounts in a tributary of the Yangtze River in China, suggesting the pesticide is still in use in this region.

Sulfuryl fluoride

Sulfuryl fluoride is an insecticide that is broken down into fluoride and sulfate when released into the environment. Fluoride has been known to negatively affect aquatic wildlife. Elevated levels of fluoride have been proven to impair the feeding efficiency and growth of the common carp (*Cyprinus carpio*). Exposure to fluoride alters ion balance, total protein and lipid levels within these fish, which changes their body composition and disrupts various biochemical processes.

PFAS chemicals

Per and poly fluoroalkyl substances, known as PFAS, are a group of approximately 15 000 chemicals. The common structure of these chemicals involves a functional group and a long carbon tail that is fully or partially fluorinated. The first PFAS chemical, polytetrafluoroethylene (PTFE), was accidentally synthesized in 1938 by DuPont researcher Roy J. Plunkett while making refrigerants. The chemical was found to have unique and useful properties such as resistance to water, oil, and extreme temperatures. In 1945 DuPont patented this chemical, along with other PFAS chemicals like PFOA with the now household name, Teflon. American multinational conglomerate 3M began mass producing Teflon in 1947. Then in the 1960's, the US navy and 3M created a new type of fire-fighting foam using PFAS chemicals, "aqueous film-forming foam" or AFFF, which was then shipped around the world and used at airports, military sites, and fire-fighting training centers. The chemicals are now used in many household products including nail polish, makeup, shampoos, soaps, toothpastes, menstrual products, clothes, contact lenses and toilet paper. The chemicals are also used in fracking, artificial grass, lubricants (mechanical, industrial and bicycle), food packaging, magazines, pesticides, refrigerants, and even surgically implanted medical devices.

These chemicals have been given the nickname "forever chemicals" due to their extreme stability and resistance to natural degradation in the environment. They also bioaccumulate in humans and animals, with many of the PFAS chemicals having half-lives of several years. The also "biomagnify", so animals higher in the food chain tend to have higher concentration of the chemicals in their blood. PFAS has been found in almost all human blood samples tested, one study found 97% of Americans has PFAS in their blood. PFAS chemicals have been linked to high cholesterol, altered kidney and thyroid function, ulcerative colitis, immunosuppression, decreased effectiveness of vaccines, low birth weight, reproductive issues, and cancers such as kidney, testicular and liver cancer. However, we are still uncovering the full health effects of these chemicals.

PFAS chemicals are now ubiquitous in the environment, recent research found PFAS chemicals in all rain water studied. DuPont and 3M had both done internal studies on the potential harmful effects of these chemicals, and had known for decades of their potential to cause cancers and low birth weight. Yet this research was not made public and the companies continued to make large profits off the harmful chemicals. In 2000 3M announced they will voluntarily halt production of PFOA and PFOS — technically known as “long-chain” chemicals — and will stop putting them in products by 2002. They replaced these chemicals with new “short-chain” PFAS formulations, but scientists have found these replacements to be possibly just as hazardous.

Cyanobacteria and cyanotoxins

Cyanobacteria, or blue-green algae, are photosynthetic bacteria. They grow in many types of water. Their rapid growth ("bloom") is related to high water temperature as well as eutrophication (resulting from enrichment with minerals and nutrients often due to runoff from the land that induces excessive growth of these algae). Many genera of cyanobacteria produce several toxins. Cyanotoxins can be dermatotoxic, neurotoxic, and hepatotoxic, though death related to their exposure is rare. Cyanotoxins and their non-toxic components can cause allergic reactions, but this is poorly understood. Despite their known toxicities, developing a specific biomarker of exposure has been difficult because of the complex mechanism of action these toxins possess.

Cyanotoxins in drinking water

The occurrence of this toxin in drinking water depends on a couple of factors. One, is the drinking water's level in raw source water and secondly, it depends on the effectiveness of removing these toxins from water when drinking water is actually being produced. Due to being no data on the absence/presence of these toxins in drinking water, it is very hard to actually monitor the amounts that are present in finished water. This is a result of the U.S not having state or federal programs in place that actually monitor the presence of this toxins in drinking water treatment plants.

Effects on humans

Though data on the effects of these two toxins are limited, from what is available it suggests the toxins attack the liver and kidney. There was an hepatoenteritis-like outbreak in Palm Island, Australia (1979), due to the consumption of water that contained, "*C. raciborskii*, a cyanobacteria that can produce cylindrospermopsin." Most cases (typically involving children) have required they be taken to a hospital. The results of hospitilation include: Vomiting, kidney damage (due to lose of water, protein and electrolytes) fever, bloody diarrhea, and headaches.

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Dr. Zaid .M. Joodi

6th,and 7th lectures **3rd Stage**

Environmental toxicology 6th,and 7th lectures 3rd Stage

Ecotoxicology

Ecotoxicology is the study of the effects of toxic chemicals on biological organisms, especially at the population, community, ecosystem, and biosphere levels. Ecotoxicology is a multidisciplinary field, which integrates toxicology and ecology.

The ultimate goal of ecotoxicology is to reveal and predict the effects of pollution within the context of all other environmental factors. Based on this knowledge the most efficient and effective action to prevent or remediate any detrimental effect can be identified. In those ecosystems that are already affected by pollution, ecotoxicological studies can inform the choice of action to restore ecosystem services, structures, and functions efficiently and effectively.

Ecotoxicology differs from environmental toxicology in that it integrates the effects of stressors across all levels of biological organisation from the molecular to whole communities and ecosystems, whereas environmental toxicology includes toxicity to humans and often focuses upon effects at the organism level and below.

History

Ecotoxicology is a relatively young discipline that made its debuts in the 1970s in the realm of the environmental sciences. Its methodological aspects, derived from toxicology, are widened to encompass the human environmental field and the biosphere at large. While conventional toxicology limits its investigations to the cellular, molecular and organismal scales, ecotoxicology strives to assess the impact of chemical, physicochemical and biological stressors, on populations and communities exhibiting the impacts on entire ecosystems. In this respect, ecotoxicology again takes into consideration dynamic balance under strain.

Ecotoxicology emerged after pollution events that occurred after World War II heightened awareness on the impact of toxic chemical and wastewater discharges towards humankind and the environment. The term "Ecotoxicology" was uttered for the first time in 1969 by René Truhaut, a toxicologist, during an environmental conference in Stockholm. As a result, he was de facto recognized as the originator of this discipline. In fact, the pioneering role of Jean-Michel Jouany, Truhaut's assistant, in conceptualising the discipline and in defining its objectives, is now fully recognized. In Jouany's mindset, ecotoxicology is primarily linked to ecology for its goal seeks to circumscribe the influence that stress factors can have on relationships existing between organisms and their habitat. Jean-Michel Jouany was indeed the young and brilliant mentor of René Truhaut who was at the time empowered to disseminate the emerging discipline proposed by his young assistant at the international level. Jean-Michel Jouany was promoted to the rank of full professor at the University of Nancy in 1969. He then laid out the teaching and research principles for ecotoxicology at the University of Metz with his colleague, Jean-Marie Pelt, as early as 1971.

In France, two universities (Metz and Paris-Sud) markedly contributed to expand this burgeoning discipline during the 1980s and 1990s. Several institutes followed suit in this respect. Indeed, CEMAGREF (now IRSTEA), INERIS, IFREMER and CNRS created research units in ecotoxicology, as did other French universities (in Rouen, Bordeaux, Le Havre, Lyon, Lille, Caen...). During the 1990s, a new offshoot of ecotoxicology casually appears known as Landscape ecotoxicology, whose objective seeks to take into account interactions between landscape ecological processes and environmental toxicants, in particular for species undergoing impediments linked to migratory passageways* (e.g., salmonids).

Common environmental toxicants

- PCBs (polychlorinated biphenyls) – found in coolant and insulating fluids, pesticide extenders, adhesives, and hydraulic fluids.
- Pesticides – used widely for preventing, destroying, or repelling any organism that may be considered harmful. Commonly found in commercially grown fruits, vegetables, and meats. Methyl parathion is a commonly used pesticide used for agricultural reasons. Methyl parathion causes the formation of toxic mediums for humans, soil and water, fresh water fish, and other hydrophilous organisms in the ecosystem. Methyl parathion proposes numerous health risk factors that are life-threatening.
- Mold and other mycotoxins.
- Phthalates are found in plastic wrap, plastic bottles, and plastic food storage containers, all of which make up a considerable part of household plastic waste.
- VOCs (volatile organic compounds) – such as formaldehyde; can be found in drinking water and sewage systems.
- Dioxins are a class of chemical compounds that are formed as a result of combustion processes such as waste incineration and from burning fuels like wood, coal, and oil.
- Asbestos is found in the insulation of flows, ceilings, water pipes, and heating ducts.
- Heavy metals include arsenic, mercury, lead, aluminum, and cadmium, which are found in fish, and pesticides.

- Chloroform is used to make other chemicals.
- Chlorine is commonly found in household cleaners.

Exposure to toxic chemicals

- Chemicals propose the risk of killing off another animal's food supply that changes the overall population of the prey
- Animals can go to the brink of extinction because of the food chain that exists through the different communities. For example, bald eagles, ospreys, and peregrine falcons were facing extinction because their food sources (fish and other birds) were contaminated with toxins.
- We are all connected between the communities of living things. Plants can absorb toxins through their roots and leaves. Animals and humans are always exposed to chemicals by the air we breathe, things we touch, and what we put in our mouth.
- Animals and humans can also eat other animals or plants that are already poisoned, which will continue the spread of chemicals, which is referred to as secondary poisoning

Effects on individuals and entire population

- Direct effects – direct consumption of a toxin or something that has been contaminated with a toxin by breathing, eating, or drinking.
- Developmental and reproductive problems
- Indirect effects – organisms directly affected by the loss of food, which has declined due to toxins.

- Sublethal effects – toxins or compounds that do not induce significant mortality but make the organism sick or make it change its behavior
- Increased sensitivity to toxicants when additional environmental stressors are present
- With chronic use of pesticides, this runs the risk of causing abnormalities in chromosome structure in humans, as well as affecting the reproduction, nervous and cardiovascular system of any animals exposed.
- The genetics can be affected by toxicant exposure, direct changes can occur to the DNA, and if not repaired, the changes can lead to the appearance mutations
- Contaminants can modify the distribution of individuals in a population, effective population size, mutation rate and migration rate

Effects of ecotoxicity on a community

- Predator-prey relationships – either the predator is affected by the toxin resulting in a decline of predator population and thus increasing the prey population; or the prey population is affected by the toxin resulting in a decline in the prey population that, in essence, will cause a decline in the predator population due to lack of food resources
- Community ecotoxicology studies the effects of all contaminants on patterns and species abundance, diversity, community composition, and species interactions. Communities that rely heavily on competition and predation will have a difficult time responding and thriving in disturbances from contaminants. A community that is species-rich will have a better chance

recovering from an exotoxin disturbance, rather than a community that is not species-rich. A species could be easily wiped out to the expense of a contamination from foreign chemicals. Protecting distinct community levels, such as species richness and diversity is essential for maintaining a healthy, well-balanced ecosystem

Overall effects

Chemicals are shown to prohibit the growth of seed germination of an arrangement of different plant species. Plants are what make up the most vital trophic level of the biomass pyramids, known as the primary producers. Because they are at the bottom of the pyramid, every other organism in an ecosystem relies on the health and abundance of the primary producers in order to survive. If plants are battling problems with diseases relating to exposure to chemicals, other organisms will either die because of starvation or obtain the disease by eating the plants or animals already infected. So ecotoxicology is an ongoing battle that stems from many sources and can affect everything and everyone in an ecosystem.

Ways of prevention

Regulation:

- In the United States, the Environmental Protection Agency (EPA) reviews all pesticides before the products are registered for sale to ensure that the benefits will outweigh the risks.
- Food Quality Protection Act and the Safe Drinking Water Act were passed in 1996, which required EPA to screen pesticide chemical for potential to produce harmful effects.

- Keep close track of the labeling when using a fertilizer, or pesticide. Try to look for products that will have less of an impact on the environment
- There are many federal and state laws protecting birds, animals, and rare plants. But the first order of protection comes from us taking steps to avoid harm since we are the main source of all the toxins.
- Proper waste disposal

Ecotoxicity testing

- Acute and chronic toxicity tests are performed terrestrial and aquatic organisms including fish, invertebrates, avians, mammalians, non-target arthropods, earthworms and rodents.
- The Organization for Economic Cooperation and Development (OECD) test guideline has developed specific tests to test toxicity level in organisms. Ecotoxicological studies are generally performed in compliance with international guidelines, including EPA, OECD, EPPO, OPPTTS, SETAC, IOBC, and JMAFF.
- LC50 is the acute toxicity, the lethal concentration at which 50% of the test organism dies within the test-specified time. The test may start with eggs, embryos, or juveniles and last from 24 hours to 96 hours.
- EC50 is the concentration that causes adverse effects in 50% of the test organisms (for a binary yes/no effect such as mortality or a specified sublethal effect) or causes a 50% (usually) reduction in a non-binary parameter such as growth.

- No observed effect concentration (NOEC) is the highest dose of stressor at which there is no statistically significant difference of effect ($p<0.05$) seen in the test organism.
- Endocrine Disruptor Screening Program (EDSP)
- Tier 1 screening battery
- Endangered species assessments.
- Persistent, Bioaccumulative, and Inherently Toxic (PBiT) assessments using the Quantitative Structure-Activity Relationships (QSARs) to categorize regulated substances.
- Bioaccumulation in fish using the Bioconcentration Factor (BCF) methods.

Classification of ecotoxicity

Total amount of acute toxicity is directly related to the classification of toxicity.

< 1 part per million → Class I

1–10 parts per million → Class II

10–100 parts per million → Class III