Ecotoxicology and Environmental Toxicology

Refer lecturer for course updated notes.

Students are oblidged to follow the courses for evaluation process and presented notes are preliminary drafts for the whole evaluation process.

Introduction

- 1962 of Rachel Carson's seminal volume, Silent Spring catalysed the separation of environmental toxicology – and, subsequently, ecotoxicology – from classical toxicology.
- The term ecotoxicology, first introduced by Truhaut in 1969 =an area of science that brings together ecology and toxicology.
- the study of the harmful effects of chemicals upon ecosystems.
- study of the effects of toxic chemicals on biological organisms, especially at the population, community, ecosystem, and biosphere levels.
- But also as individual level

Introduction

- When do effects at the individual level become translated into changes at the population level?
- Changes at the population level may be in population density or in genetic composition
- anthropogenic toxicants
- ecological effects of diverse abiotic and biotic stresses, thereby integrating secondary effects of anthropogenic activities such as ocean acidification resulting from increased dissolution of carbon dioxide into the surface waters of the oceans

Ecotoxicology

- defined as the branch of science that deals with the nature, effects, and interactions of substances that are harmful to the environment.

What is the difference between ecotoxicology and environmental toxicology?

- Ecotoxicology differs from environmental toxicology in that it integrates the effects of stressors across all levels of biological organization from the molecular to whole communities and ecosystems, whereas environmental toxicology focuses upon effects at the level of the individual and below.

Environmental and ecotoxicology

PK Gupta, in Illustrated Toxicology, 2018

Environmental pollution

- Air pollution
- Water pollution
- Noise pollution
- Light pollution
- Thermal pollution
- Radioactive pollution
- Soil pollution
- Visual pollution
- Plastic pollution etc.

Air pollution

- Primary pollutants are substances that are released into the atmosphere directly from the polluting source, and are mostly derived from the combustion of fossil fuels.
- Petrol engines that ignite the fuel in an oxygen-restricted environment produce varying quantities of carbon monoxide, nitrogen oxides and hydrocarbons such as benzene and polycyclic aromatic compounds.
  - reduced by the use of a catalytic converter.
  - In contrast, diesel engines burn fuel with an excess of oxygen, producing little carbon monoxide but more nitrogen oxides and particulate matter.

Smoking and Air Pollution

Andrew B Lumb MB BS FRCA, in Nunn's Applied Respiratory Physiology (Eighth Edition), 2017

Air pollution

- Burning of coal and oil is now restricted almost entirely to power generation, and the pollutants produced depend on the type of fuel used and the amount of effort expended on ‘cleaning’ the emissions.
- particulates and nitrogen oxides are invariably produced, and this remains a source of sulphur dioxide.
- Secondary pollutants are formed in the atmosphere from chemical changes to primary pollutants.
- Nitric oxide (NO) produced from vehicle engines is quickly converted to nitrogen dioxide, and in doing so may react with ozone, reducing the atmospheric concentration of the latter.
- Alternatively, when exposed to sunlight in the lower atmosphere both NO and NO2 react with oxygen to produce ozone (O3).

Smoking and Air Pollution

Andrew B Lumb MB BS FRCA, in Nunn's Applied Respiratory Physiology (Eighth Edition), 2017

Air pollution

- Meteorological conditions influence
- strong wind, pollutants are quickly dispersed
- in cloudy weather the development of secondary pollutants is unlikely.
- Ground-level pollution in urban areas is exacerbated by clear, calm weather when ‘temperature inversion’ can occur.
- On a clear night, heat is lost from the ground to the atmosphere by radiation, and the ground level air cools dramatically
- At dawn the ground is quickly heated by the sun's radiation and warms the air, which lifts a blanket of cool air to approximately 50 to 100 m high. Because in still conditions mixing of air masses is slow to occur, the relatively cold air sits on top of the warm air below.
- In the meantime, the morning rush hour produces large amounts of pollutants that are unable to disperse and become trapped near the ground

Smoking and Air Pollution

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Particulate matter

- generic term to classify air pollutants comprising of suspended particles in air, varying in composition and size, resulting from various anthropogenic activities.
- Industrial facilities, Power plants, vehicles, incinerators, dust and fires are the major source of particulate matter.
- The particle size ranges between 2.5 mm (PM2.5) and 10 mm (PM10).
- The part of respiratory system affected by PM depends upon the size of particle.
- The upper respiratory tract is affected by PM10 while lung alveoli is affected by ultrafine particles (0.1 mm diameter).
- The size, surface, number and composition of particles play an important role in eliciting health effects.
- PM can absorb and transfer multitude of pollutants which results in its composition variation. However, PM mainly comprises of ions, reactive gases, organic compounds, metals, and particle carbon core.

Effects of Outdoor Air Pollution on Human Health

Rachida El Morabet, in Reference Module in Earth Systems and Environmental Sciences, 2018

Water pollution

- Waste product from factories, harmful chemicals from industries, dumping of household waste, dumping of medical and other hazardous waste directy into the water results in the deterioration of quality of water which ultimately leads to loss of drinking water and even deaths of various life forms.

- Aquatic life forms mainly suffer beacause of water pollution because of loss of enough amount of fresh dissolved oxygen in water bodies due to raised volume of toxicity in water. Toxicity which is a result of water pollution leads to death of aquatic life forms.

Acid rain

- Acid rain is a rain or any other form of precipitation that is unusually acidic, meaning that it has elevated levels of hydrogen ions (low pH). It can have harmful effects on plants, aquatic animals and infrastructure.

- Rainfall is a natural phenomenon by which earths water is circulated back to various water bodies in form of droplet. When water vapour rises up and gets condensed precipitation occurs which is called as rainfall.

- Rain water when mixed with smoke of burning coal and other fossil fuels which contains waste gases such as sulphur and nitrogen oxides, gives rise to acid which falls on earth in form acidic rainfall.
- Distilled water, once carbon dioxide is removed, has a neutral pH of 7. Liquids with a pH less than 7 are acidic, and those with a pH greater than 7 are alkaline. "Clean" or unpolluted rain has an acidic pH, but usually no lower than 5.7

omicsonline.org/environment-pollution-climate-change.php

Climate change

- adjustment in the normal or average weather of a region or city.
- adjustment in an area's normal yearly precipitation.
- adjustment in an area's normal temperature for a given month or season.
- Climate change is brought about by variables, for example, biotic procedures, variation in sunlight based radiation recieved by Earth, plate tectonics, and volcanic eruptions.
- Certain human activities have likewise been distinguished as critical reasons for recent climate change, often referred to as global warming.

Drought

- Drought is a deceptive risk of nature.
- insufficiency of precipitation over an expanded time frame - typically a season or more- - bringing about a water deficiency for some action, bunch, or natural segment.
- Its effects result from the transaction between the characteristic occasion (less precipitation than anticipated) and the interest individuals place on water supply, and human exercises can exacerbate the impacts of drought.
- Since dry season can't be seen exclusively as a physical marvel, it is generally characterized both conceptually and operationally.
- Drought is an extended time of lacking precipitation bringing about broad harm to crops, bringing about loss of yield

Disaster management/crisis management)

- production of arrangements through which groups diminish defenselessness to risks and adapt to disasters.
- does not deflect or take out the dangers; rather, it concentrates on making arrangements to diminish the impact of calamities.

Waste disposal

- is every one of the exercises and activities required to oversee waste from its beginning to its last disposal.
- This includes amongst different things, gathering, transport, treatment and transfer of waste together with checking and direction.
- It likewise envelops the lawful and administrative system that identifies with waste management including direction on reusing and so on.

- The term for the most part identifies with a wide range of waste, whether created during the extraction of crude materials, the preparing of crude materials into intermediate and final items, the utilization of definite items, or other human activities, including civil (private, institutional, business), farming, and social (medicinal services, family risky squanders, sewage sludge). Waste administration is proposed to diminish unfavorable impacts of waste on well being, nature or aesthetics.

Nanoparticle & Ecotoxicology

- Natural NPs have existed in the environment since the beginning of Earth's history, and natural sources can be found in volcanic dust, most natural waters, soils and sediments.
- Natural NPs are generated by a wide variety of geological and biological processes, and while there is evidence that some natural NPs can be toxic, organisms have also evolved in an environment containing natural NPs.
- There are concerns that natural nano-scale process could be influenced by the presence of pollution.
- Manufactured NPs show some complex colloid and aggregation chemistry, which is likely to be affected by particle shape, size, surface area and surface charge, as well as the adsorption properties of the material.
- Abiotic factors such as pH, ionic strength, water hardness and the presence of organic matter will alter aggregation chemistry; and are expected to influence toxicity.

Ecotoxicology. 2008 Jul;17(5):315-25. doi: 10.1007/s10646-008-0206-0. Epub 2008 Apr 12.

The ecotoxicology of nanoparticles and nanomaterials: current status, knowledge gaps, challenges, and future needs.

Handy RD[1], Owen R, Valsami-Jones E.

Nanoparticle & Ecotoxicology

- The physico-chemistry is essential to understanding of the fate and behaviour of NPs in the environment, as well as uptake and distribution within organisms, and the interactions of NPs with other pollutants.
- Data on biological effects show that NPs can be toxic to bacteria, algae, invertebrates and fish species, as well as mammals.
- However, much of the ecotoxicological data is limited to species used in regulatory testing and freshwater organism.
- Data on bacteria, terrestrial species, marine species and higher plants is particularly lacking. Detailed investigations of absorption, distribution, metabolism and excretion (ADME) remain to be performed on species from the major phyla, although there are some data on fish.

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Nanotoxicology

- Nanotoxicology is the study of the toxicity of nanomaterials.
- Because of quantum size effects and large surface area to volume ratio, nanomaterials have unique properties compared with their larger counterparts that affect their toxicity.
- Of the possible hazards, inhalation exposure appears to present the most concern, with animal studies showing pulmonary effects such as inflammation, fibrosis, and carcinogenicity for some nanomaterials. Skin contact and ingestion exposure are also a concern.

Gaseous pollutants (e.g., CO, SO2, NOx, VOCs, O3 etc.)

- Fossil fuel combustion produces gaseous pollutants, causing variation in atmospheric composition.
- Nitrogen Oxide (NO) reacts actively with ozone (O3) or radicals in atmosphere forming nitrogen dioxide (NO2).
- In lower atmospheric layers, sun light acts as catalyst in reactions between NO2 and VOC (Volatile Organic compounds) to produce Ozone.
- Carbon Monoxide (CO) produced from partial fossil fuel combustion.
- Nitrogen oxides and carbon monoxide produced from sulfur based fossil fuel (coal and heavy oils) combustion.

Persistent organic pollutants (POPs)

- group of organic compounds (pesticides, dioxins, furans, and PCBs).
- POPs bioaccumulate in food chain affecting environment and human health.
- Bioaccumulation is the result of the fact that POPs are resistant to natural/environmental degradation (biological, chemical and photolytic processes).
- Insolubility property of dioxins inhibits groundwater pollution. Air dust or pesticide deposit dioxins on plants which is their entry point in food chain by stably bounding with lipids.
- Dioxins half like in body is approximately 7–11 years. Their high toxicity lead to reproductive problems, immune system damage, hormone interference and cancer. short term exposure (high levels) in humans lead to skin lesions (chloracne), patched dark skin and liver function alteration.

Heavy metals

- lead, mercury, cadmium, nickel silver, chromium, manganese and vanadium.
- occur natural in earth's crust which neither can be degraded nor destroyed.
- Most common sources of heavy metals are lead acid batteries, fertilizers, paints, mining and industrial waste, vehicle emissions.
- transported by air and can enter water sources as well as human food supply.
- enter human tissue via, diet, inhalation or manual handling.
- Heavy metals are essential for normal metabolic reactions and maintenance.
- They are essential elements of many enzymes and play key role in oxidation reduction reactions.
- Even lower level of exposure can result in multiple organ damage.
- The bio-accumulating tendency of heavy metals render them dangerous.
- The increase of concentration of a certain chemical over time in biological organism as compared to natural environment concentration is termed as bio-accumulation.

- Pesticides and other biocides are used with the intention of causing damage to pest species and other organisms that threaten the health or well-being of humans.
- Which of the effects that pesticides may have on natural populations are to be seen as acceptable, and which as unacceptable?

Impacts of wastes in ecosystem

- Persistent organic pollutants and semivolatile chemicals, such as organochlorine insecticides, the fungicide hexachlorobenzene, and polychlorinated dibenzodioxins and polychlorinated dibenzofurans, which are toxic byproducts of organochlorine, synthesis, manufacturing processes, such as the Kraft paper, bleaching process can have serious effects on the immune, nervous, and reproductive systems, especially those of developing organisms.
- Such compounds can also reduce control of impulsive behaviors, impair learning, cause liver damage, and disrupt reproductive and thyroid hormone functions.
- Likewise leakage of acids from coal mines and drainage of hazardous substances, pollutants, or contaminants into the environment lead harm to fish and other aquatic life: If mine waste is acid-generating, the impacts to fish, animals, and plants can be severe

Bioindicator

- Bioindicator species are used in biomonitoring contaminant exposure.
- In order to evaluate how contamination exists spatially, sessile species are the best.
- In addition, a good bioindicator species is common and easily sampled, presenting some responses to toxicants (biomarker responses) that can be reliably measured and show concentration dependence.
- The suitability of bioindicator species varies markedly between aquatic bodies, as the sensitivities of organisms to different contaminants vary markedly.
- The commonly used model organisms are good bioindicator species only when they are common in the natural environment studied.

Bioindicators and Biomarkers

Mikko Nikinmaa, in An Introduction to Aquatic Toxicology, 2014

Biomarker

- Biomarkers of exposure indicate that the species has been exposed to a toxicant.
- Good examples are mRNAs, which show that exposure affects transcription, but do not give information on the effects of toxicants on the function of organisms.
- This is done by biomarkers of effect, which usually measure protein activities. T
- he biomarker responses can be markedly affected by the presence of other compounds in the environment, by natural environmental stresses, and by the length of exposure.
- Effect–biomarker responses translate to ecosystem effects if the measured parameter affects the fitness of the organism studied.

Bioindicators and Biomarkers

Mikko Nikinmaa, in An Introduction to Aquatic Toxicology, 2014

Climate Change and Pollution

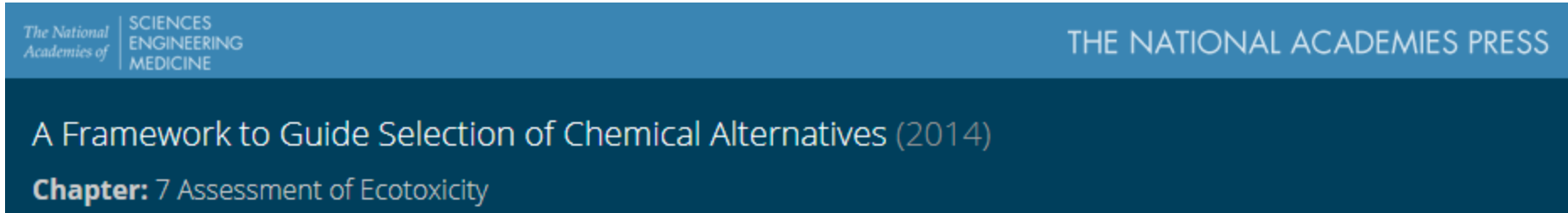
- climate change adds another level of complexity to predicting the toxic outcomes of pollutants, which is a challenge for the risk evaluation community.

ECOTOX

- The ECOTOXicology database (ECOTOX) is a source for locating single chemical toxicity data for aquatic life, terrestrial plants and wildlife.
- ECOTOX integrates three previously independent databases-AQUIRE, PHYTOTOX, and TERRETOX
- http://cfpub.epa.gov/ecotox/

Asessment of ecotoxicity

- Review physicochemical data to determine into which environmental compartments the chemicals will partition.
- Compile ecotoxicity data, paying particular attention to data for compartments identified in the first step. For missing data, estimate toxicity using read-across, QSAR, or other method.
- On the basis of all available data for each alternative, categorize toxicity as high, medium, and low for each end point and include the uncertainty associated with each categorization. Include a narrative description of the data.
- Create a visual display to show relative hazard in different environmental media (soil, water, sediment, air).



	Acute Toxicity			Chronic Toxicity		
Assessment Framework	**End Point**	**Threshold (mg/L)**	**Category**	**End Point**	**Threshold (mg/L)**	**Category**
DfE	EC_{50} or LC_{50}	< 1	Very High	NOEC or LOEC	< 0.1	Very High
		1-10	High		0.1-1	High
		10-100	Moderate		> 1-10	Moderate
		> 100	Low		> 10	Low
IC2	96 hr LC_{50} (fish)	< 1	Very High	Recommends GreenScreen® at Higher Levels of Assessment		
	48 hr EC_{50} (crustacean)	1-10	High			
		10-100	Moderate			
	72 hr or 96 hr EC_{50} (algae or aquatic plants)	> 100	Low			
TURI[a]	LC_{50} (animals)	< 0.1	10	NOAEC (fish)	< 0.00002	10
		0.1-1	8		0.0002	8
		1-50	6		0.002	6
		50-1000	4		0.02	4
		> 1000	2		< 0.2	2
	LC_{50} (plant)	< 0.1	10			
		0.1-1	8			
		1-10	6			
		10-100	4			
		> 100	2			
Guide on Sustainable Chemicals	NA			NOEC	< 0.01	Not Toxic

[a]Category values calculated from the Pollution Prevention Options Assessment System (P2OASys) worksheet, September 2014. The P2OASys worksheet returns numerical values based on a scale of 1 to 10 to represent relative hazard from low to high.

SOURCES: Rossi et al. 200

TABLE 7-2 DfE Ecotoxicity Categories for Terrestrial and Aquatic Organisms

Toxicity Category	Avian: Acute Oral Concentration (mg/kg)	Avian: Dietary Concentration (ppm)	Aquatic Organisms: Acute Concentration (ppm)	Wild Mammals: Acute Oral Concentration (mg/kg)	Non-Target Insects: Acute Concentration (µg/bee)
Very highly toxic	< 10	< 50	< 0.1	< 10	
Highly toxic	10-50	50-500	0.1-1	10-50	< 2
Moderately toxic	51-500	501-1000	>1-10	51-500	2-11
Slightly toxic	501-2000	1001-5000	> 10-100	501-2000	
Practically nontoxic	> 2000	> 5000	> 100	> 2000	> 11

SOURCE: EPA 2014f.

Standardized Aquatic Tests for Ecotoxicity Properties

ALGAE

- OECD 201: Freshwater Alga and Cyanobacteria, Growth Inhibition Test OPPTS OPPTS 850.4500 - Algal Toxicity
- OPPTS 850.4550 - Cyanobacteria (Anabaena flos-aquae) Toxicity

Standardized Aquatic Tests for Ecotoxicity Properties

FISH

- OECD 210: Fish, Early-life Stage Toxicity Test
- OPPTS 850.1400 Fish early-life stage toxicity test
- OECD 236: Fish Embryo Acute Toxicity (FET) Test
- OECD 212: Fish, Short-term Toxicity Test on Embryo and Sac-Fry Stages
- OECD 215: Fish, Juvenile Growth Test
- OPPTS 850.1075 Fish acute toxicity test, freshwater and marine
- OPPTS 850.1085 Fish acute toxicity mitigated by humic acid
- OECD 204: Fish, Prolonged Toxicity Test: 14-Day Study

Standardized Aquatic Tests for Ecotoxicity Properties

FRESHWATER

- OECD 230: 21-day Fish Assay
- OECD 229: Fish Short Term Reproduction Assay
- OECD 234: Fish Sexual Development Test
- OPPTS 850.1500 Fish life cycle toxicity
- OPPTS 850.1010 Aquatic invertebrate acute toxicity, test, freshwater daphnids

Standardized Aquatic Tests for Ecotoxicity Properties

Invertebrate

- OECD 211: Daphnia magna Reproduction Test
- OPPTS 850.1300 Daphnid chronic toxicity test
- OECD 221: Lemna sp. Growth Inhibition Test

Plants

- OPPTS 850.4400 - Aquatic Plant Toxicity Test Using Lemna spp
- OPPTS 850.4450 - Aquatic Plants Field Study

Standardized Aquatic Tests for Ecotoxicity Properties

Amphibians

- OPPTS 850.1800 Tadpole/sediment subchronic toxicity test
- OECD 231: Amphibian Metamorphosis Assay

Food web

- OPPTS 850.1900 Generic freshwater microcosm test, laboratory
- OECD 218: Sediment-Water Chironomid Toxicity Using Spiked Sediment
- OECD 219: Sediment-Water Chironomid Toxicity Using Spiked Water
- OECD 235: Chironomus sp., Acute Immobilisation Test
- OECD 225: Sediment-Water Lumbriculus Toxicity Test Using Spiked Sediment

Standardized Aquatic Tests for Ecotoxicity Properties

Freshwater invertebrate

- OECD 233: Sediment-Water Chironomid Life-Cycle Toxicity Test Using Spiked Water or Spiked Sediment
- OPPTS 850.1735 Whole sediment acute toxicity invertebrates
- OPPTS 850.1790 Chironomid sediment toxicity test
- OPPTS 850.1020 Gammarid acute toxicity test
- OPPTS 850.1025 Oyster acute toxicity test (shell deposition

Marine water Invertebrate

- OPPTS 850.1035 Mysid acute toxicity test
- OPPTS 850.1350 Mysid chronic toxicity test
- OPPTS 850.1045 Penaeid acute toxicity test
- OPPTS 850.1055 Bivalve acute toxicity test (embryo larval

MARINE SEDIMENT

- OPPTS 850.1740 Whole sediment acute toxicity invertebrates, marine

Standardized Terrestrial Tests for Ecotoxicity Properties

Birds

- OECD 223: Avian Acute Oral Toxicity Test
- OPPTS 850.2100 - Avian Acute Oral Toxicity Test
- OPPTS 850.2200 - Avian Dietary Toxicity Test
- OECD 205: Avian Dietary Toxicity Test
- OECD 206: Avian Reproduction Test

Plants

- OECD 208: Terrestrial Plant Test: Seedling Emergence and Seedling Growth Test
- OPPTS 850.4100 - Seedling Emergence and Seedling Growth
- OPPTS 850.4230 - Early Seedling Growth Toxicity Test
- OECD 227: Terrestrial Plant Test: Vegetative Vigour Test
- OPPTS 850.4150 - Vegetative Vigor
- OPPTS 850.4600 - Rhizobium-Legume Toxicity
- OPPTS 850.4300 - Terrestrial Plants Field Study

Standardized Terrestrial Tests for Ecotoxicity Properties

Honeybee

- OECD 213: Honeybees, Acute Oral Toxicity Test
- OECD 214: Honeybees, Acute Contact Toxicity Test
- OPPTS 850.3020 - Honey Bee Acute Contact Toxicity Test
- OECD 237: Honey Bee (Apis Mellifera) Larval Toxicity Test, Single Exposure
- OPPTS 850.3030 - Honey Bee Toxicity of Residues on Foliage
- OPPTS 850.3040 - Field Testing for Pollinators

Soil

Invertebrates

- OECD 207: Earthworm, Acute Toxicity Tests
- OPPTS 850.3100 - Earthworm Subchronic Toxicity Test

Microbes

- OPPTS 850.3200 - Soil Microbial Community Toxicity Test
- OPPTS 850.4900 - Terrestrial Soil-Core Microcosm Test

QSAR

- Toxicity Estimation Software Tool (TEST) (EPA 2014g).
- Ecological Structure–Activity Relationships (ECOSAR) (aquatic toxicity) (EPA 2014h)
- OECD QSAR Toolbox (OECD 2012b)

High throughput assays

- Caenorhabditis elegans - transparent nematode- high throughput toxicological screens, including screening for genetic and molecular targets of new chemicals
- zebrafish (*Danio rerio*)- embryo-larval bioassay was developed for use in preclinical screening of drugs because it is possible to visualize embryo development and there is a short time frame (4 days) from egg production to hatching