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A Critical Review on Ecotoxicology, Environmental Safety and Possible Remediation

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ABSTRACT: Pesticides and other contaminants that get into the natural environment can affect wild plants and animals. The science of studying these effects is called ecotoxicology. Ecotoxicology is a mix of ecology, toxicology, physiology, analytical chemistry, molecular biology, and mathematics. Ecotoxicology looks at the impacts of contaminants including pesticides on individuals, populations, natural communities, and ecosystems. Communities of living things and the environments they live in form ecosystems. Ecosystems include ponds, rivers, deserts, grasslands, and forests, and they too can be affected by pesticides. Ecotoxicologists also study what happens to the pesticides themselves, where they go in the environment, how long they last, and how they finally break down. This detail will focus on pesticides in ecotoxicology. Environmental safety is defined by the guidance, policies, and practices enforced in order to ensure that the surrounding environment is free from hazards that will warrant the safety and well-being of workers and employees, residents near industrial operations, as well as the prevention of accidental environmental damage. The surrounding areas include industrial facilities, work areas, and laboratories. Environmental safety is a crucial issue for any industrial activity as negligence and non-compliance heighten the risk resulting in injuries, illnesses, and accidental environmental releases. Contaminated sites can pose a considerable threat to public health and the environment. Therefore, remediation techniques are implemented to reduce the concentrations of contaminants at the site and restore the ecosystem. Remediation technology involves physical, chemical, and biological techniques that are implemented either in situ or ex-situ after excavating the contaminated soil. Specifically, remediation of soil can be achieved by removal of contaminants, isolation of the contaminants for adequate time, removal of the contaminated soil and transformation of the contaminants to reduce their adverse effects on the environment. Knowledge about the contaminant distribution, soil and groundwater characteristics is necessary in order to design the best remediation mechanism or combination of them to meet the project's environmental expectations

KEYWORDS: remediation, environmental, safety, ecotoxicology, ecosystem, science, soil

I. INTRODUCTION

Ecotoxicology is the study of the toxic effects of chemicals on the aquatic and terrestrial environment. Ecotoxicologists study the immediate effect of a toxic substance on individual organisms and species in food webs, with the ultimate aims of predicting effects on wildlife populations, ecosystems and on human food resources such as fish and shellfish.[1,2]

Ecotoxicologists aim to understand (and ideally predict and prevent) undesirable events in the natural environment, by carrying out ecotoxicity testing and risk assessment on new chemicals that may be used, disposed, or otherwise reach the environment. They are often also involved in conducting detailed monitoring studies of invertebrates and fish in polluted rivers and estuaries, looking at species at many levels within a food chain. It may also be necessary to monitor the physiological and biochemical responses of organisms following exposure to a pollutant, which may reflect a toxic effect. In many cases, sub-lethal effects such as changes in behaviour, development or reproduction may be just as important for the survival of a species as a lethal effect.

Typically, ecotoxicologists are involved in tracing the metabolism, accumulation and movements of natural and synthetic chemicals through different food chains. They may identify population changes after exposure to pollutants, particularly genetic changes such as the development of resistance to pesticides in insects.

In seeking to predict and prevent pollution impacts, the ecotoxicologist's main task is increasingly to develop models which can be used to predict the fate and effects of chemicals within an ecosystem. Often, to do this successfully, there must be close co-operation with both ecologists working in the field and those in the laboratory, using the latest techniques of biochemical toxicology and chemistry. Fieldwork allows some ecotoxicologists to spend time outdoors, investigating the effects of chemicals in aquatic and terrestrial ecosystems. For the aquatic environment, this often involves working on research ships or possibly scuba diving; whilst for the terrestrial environment, ecotoxicologists may conduct surveys of farmland birds and mammals.[3,4]

Ecotoxicologists help to protect the environment and existing ecosystems for future generations, and they make important contributions to protecting food resources in agriculture, aquaculture and fishing around the world.

Many people are interested in an organization's approach to laboratory environmental health and safety (EHS) management including laboratory personnel; customers, clients, and students (if applicable); suppliers; the community; shareholders; contractors; insurers; and regulatory agencies. More and more organizations attach the same importance to high standards in EHS management as they do to other key aspects of their activities. High standards demand a structured approach to the identification of hazards and the evaluation and control of work-related risks. A comprehensive legal framework already exists for laboratory EHS management. This framework requires organizations to manage their activities in order to anticipate and prevent circumstances that might result in occupational injury, ill health, or adverse environmental impact. This article seeks to improve the EHS performance of organizations by providing guidance on EHS to integrate EHS management with other aspects of the organization.

Many features of effective EHS management are identical to management practices advocated by proponents of quality assurance and business excellence. The guidelines presented here are based on general principles of good management and are designed to integrate EHS management within an overall management system. By establishing an EHS management system, EHS risks are controlled in a systematic proactive manner.[5,6]

Within many organizations, some elements of EHS management are already in place, such as policy and risk assessment records, but other aspects need to be developed. It is important that all the elements described here are incorporated into the EHS management system. The manner and extent to which individual elements are applied, however, depend on factors such as the size of the organization, the nature of its activities, the hazards, and the conditions in which it operates.

Remediation Technology Types

Air Sparging involves the injection of air or oxygen through a contaminated aquifer to remove volatile and semivolatile organic contaminants by volatilization. The injected air helps to flush the contaminants into the unsaturated zone for treatment.

Bioreactor Landfills rapidly transform, degrade and stabilize organic waste through the addition of liquid and air enhance microbial processes.

Bioremediation uses microorganisms to degrade organic contaminants in soil, groundwater, sludge and solids. The microorganisms break down contaminants by using them as an energy source or cometabolizing them with an energy source.

Electrokinetics applies low-intensity direct current through the soil between ceramic electrodes that are divided into a cathode array and an anode array. This current mobilizes charged species, causing ions and water to move toward the electrodes, and removal of contaminants at the electrode may be accomplished by several methods.[7,8]

Evapotranspiration Covers utilize natural processes to manage water precipitating on municipal landfills, hazardous and industrial waste landfills to contain waste.

Environmental Fracturing technologies enhance or create openings in bedrock or soil with low effective porosity, such as clay, to help soil and groundwater cleanup methods work better.

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Ground-Water Circulating Wells create a three-dimensional groundwater circulation pattern that can provide subsurface remediation inside a well, in the aquifer or both. Groundwater is drawn into a well through one screened section and is pumped through the well to a second screened section where it is reintroduced to the aquifer.

In Situ Chemical Reduction places a reductant or reductant-generating material in the subsurface to degrade toxic organic compounds to potentially nontoxic or less toxic compounds. It immobilizes metals by adsorption or precipitation and degrades non-metallic oxyanions.

In Situ Flushing floods a zone of contamination with an appropriate solution to remove the contaminant from the soil. Contaminants are mobilized by solubilization, formation of emulsions or a chemical reaction with the flushing solutions and brought to the surface for disposal, recirculation or on-site treatment and reinjection.[9,10]

In Situ Oxidation typically involves reduction/oxidation (redox) reactions that chemically convert hazardous compounds to nonhazardous or less toxic compounds that are more stable, less mobile or inert.

Multi-Phase Extraction uses a vacuum system, sometimes combined with a downhole pump, to remove various combinations of contaminated groundwater, separate-phase petroleum product and vapors from the subsurface. The system lowers the water table around the well, exposing more of the formation for vapor extraction.

Nanoscale Materials for Environmental Site Remediation have been developed and used to remediate contaminated soil and groundwater, such as sites contaminated by chlorinated solvents or oil spills. Nanoscale materials can be highly reactive in part because of the large surface area to volume ratio and the presence of a larger number of reactive sites.

Natural Attenuation relies on natural processes to clean up or attenuate pollution in soil and groundwater. Natural attenuation occurs at most polluted sites. However, the right conditions must exist underground to clean sites properly.

Remediation Optimization uses defined approaches to improve the effectiveness and efficiency of an environmental remedy. Optimization approaches include site-wide optimization reviews, statistical evaluation tools, consideration of emerging technologies, review of operating system costs and the identification of cost reduction methods without loss of protectiveness.[11,12]

Permeable Reactive Barriers are subsurface emplacements of reactive materials through which a dissolved contaminant plume must move as it flows, typically under natural gradient. Treated water exits the other side of the permeable reactive barrier.

Phytotechnologies are broadly defined as the use of vegetation to address contaminants in soil, sediment, surface water and groundwater. Cleanup objectives for phytotechnologies can be contaminant removal and destruction, control and containment or both.

Soil Washing separates contaminants sorbed onto fine soil particles from bulk soil in a water-based system based on particle size. Soils and wash water are mixed in a tank or other treatment unit and usually separated using gravity settling.

Soil Vapor Extraction applies a vacuum to unsaturated zone soil to induce the controlled flow of air and remove volatile and some semi-volatile organic contaminants from the soil.

Solidification encapsulates waste to form a solid material, coat the waste with low-permeability materials to restrict contaminant migration or both. Solidification can be accomplished by mechanical processes or by a chemical reaction between a waste and binding reagents, such as cement, kiln dust, or lime/fly ash.[13,14]

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Solvent Extraction uses an organic solvent to separate organic and metal contaminants from soil. The solvent is mixed with contaminated soil in an extraction unit and then passed through a separator, where the contaminants and extractant are separated from the soil.

Ex Situ Thermal Treatment generally involves the destruction or removal of contaminants through exposure to high temperature in treatment cells, combustion chambers or other means. Contaminated media is contained during the remediation process.

In Situ Thermal Treatment includes many different methods and combinations of techniques to apply heat to polluted soil, groundwater or both. The heat can destroy or volatilize organic chemicals, and the gases can be extracted through collection wells for capture and cleanup in a treatment unit.

Impacted Media

Dense Nonaqueous Phase Liquids (DNAPLs) are chemicals or mixtures of chemicals that have two major characteristics: they are heavier than water, and they are only slightly soluble in water. When released into the environment, they can move through soils and groundwater until they encounter a resistant layer that impedes further vertical movement and allow the liquid to pool.

Fractured Rock zones display fundamentally different contaminant transport and fate behavior than in unconsolidated sand and gravel aquifers. Significantly more uncertainty exists as to the direction and rate of contaminant migration, as well as the processes and factors that control chemical and microbial transformations.[15,16]

Sediments at the bottom of a water body can become contaminated in a number of ways, including:

- Urban runoff of surface waters.
- Agricultural runoff of nutrients and pesticides
- Industrial spills and releases.
- Atmospheric deposition of substances.
- The discharge of contaminated groundwater through the sediments.

Contaminants

Exposure to higher than average levels of arsenic occur mostly in the workplace, near hazardous waste sites or in areas with high natural levels. At high levels, inorganic arsenic can cause death. Exposure to lower levels for a long time can cause a discoloration of the skin and the appearance of small corns or warts.

Exposure to chromium occurs from ingesting contaminated food or drinking water or breathing contaminated workplace air. Chromium VI at high levels can damage the nose and cause cancer. Ingesting high levels of chromium VI may result in anemia or damage to the stomach or intestines.

Exposure to 1,4-dioxane occurs from breathing contaminated air, ingestion of contaminated food and drinking water and dermal contact with products such as cosmetics that may contain small amounts of 1,4-dioxane. Exposure to high levels of 1,4-dioxane in the air can result in nasal cavity, liver and kidney damage. Ingestion or dermal contact with high levels of 1,4-dioxane can result in liver and kidney damage.

Exposure to dioxins occurs mainly from eating food that contains the chemicals. One chemical in this group, 2,3,7,8-tetrachlorodibenzo-p-dioxin or 2,3,7,8-TCDD, has been shown to be very toxic in animal studies. It causes effects on the skin and may cause cancer in people.

Exposure to mercury occurs from breathing contaminated air, ingesting contaminated water and food and having dental and medical treatments. Mercury, at high levels, may damage the brain, kidneys, and developing fetus.

Methyl tertiary butyl ether (MTBE) is a flammable liquid which is used as an additive in unleaded gasoline. Drinking or breathing MTBE may cause nausea, nose and throat irritation, and nervous system effects.[17,18]

Solid perchlorates can be very reactive chemicals that are used mainly in fireworks, explosives and rocket motors. Consumption of food and water containing perchlorates are the most relevant routes of exposure for the general population. High levels of perchlorates can affect the thyroid gland, which in turn can alter the function of many organs in the body. The fetus and young children can be especially susceptible.

Persistent organic pollutants (POPs) are toxic chemicals that originate from man-made sources associated with the production, use and disposal of certain organic chemicals. POPs are associated with serious human health problems, including cancer, neurological damage, birth defects, sterility, and immune system defects. Chronic exposure to low doses of certain POPs may affect the immune and reproductive systems. Exposure to high levels of certain POPs can cause serious health effects or death.

Polychlorinated biphenyls (PCBs) are a mixture of individual chemicals which are no longer produced in the United States, but are still found in the environment. Health effects that have been associated with exposure to PCBs include acne-like skin conditions in adults and neurobehavioral and immunological changes in children. PCBs are known to cause cancer in animals.

Trichloroethylene (TCE) is used as a solvent for cleaning metal parts. Exposure to very high concentrations of trichloroethylene can cause dizziness, headaches, sleepiness, incoordination, confusion, nausea, unconsciousness, and even death. The Environmental Protection Agency (EPA) and the International Agency for Research on Cancer (IARC) classify trichloroethylene as a human carcinogen.[19,20]

II. DISCUSSION AND RESULTS

Pesticide residues build up in organisms and in food webs. Bioaccumulation can occur if residues build up faster than the organism can break them down and excrete them. Bioaccumulation in aquatic animals where the pesticide is taken in from the water is called bioconcentration. If a predator eats many plants and/or animals that have pesticide residues in their tissues, the predator may suffer from even greater exposure than the prey. Bald eagles, ospreys and peregrine falcons were brought to the brink of extinction because their food sources (fish and other birds) were contaminated with DDE, the breakdown product of the insecticide DDT. The residues built up with each link in the food chain until very high concentrations were present in the eagles, falcons, and ospreys. When residues increase in the food web, the process is called biomagnification. No single exposure for either the prey or the predator is likely to cause injury, but the overall effects can be very harmful.

Top management should set in place procedures to define, document, and endorse a formal EHS policy for an organization. The policy should clearly outline the roles and expectations for the organization, faculty, EHS personnel, and individual employees or students. It should be developed in communication with laboratory personnel to ensure that all major concerns are adequately addressed.[21]

The EHS policy should state intent to

- prevent or mitigate both human and economic losses arising from accidents, adverse occupational exposures, and environmental events;
- build EHS considerations into all phases of the operations, including laboratory discovery and development environments;
- achieve and maintain compliance with laws and regulations; and
- continually improve EHS performance.

The EHS policy and policy statement should be reviewed, revalidated, and where necessary, revised by top management as often as necessary. It should be communicated and made readily accessible to all employees and made available to relevant interested parties, as appropriate.

With the increasing development of industry and urbanization, heavy metal contaminated sites have become progressively conspicuous, particularly by unreasonable emissions from electroplating, nonferrous metals smelting, mine tailing, etc. In recent years, soil remediation technologies for heavy metal contaminated sites have developed rapidly. Physical remediation (soil thermal desorption and soil replacement), bioremediation (phytoremediation and microbial remediation), chemical remediation (chemical leaching, chemical stabilization, electrokinetic remediation-permeable reactive barrier, and chemical oxidation/reduction), as well as various combined remediation are common.[22]

III. CONCLUSIONS

Thus, Ecotoxicology is a relatively new science that helps to protect the existing ecosystem from toxic environmental pollutants. The scientists are working towards prediction, observation, monitoring, risk assessment and prevention from these toxicants and their harmful effects on population, community and ecosystem. It is a multidisciplinary field, which integrates toxicology, chemistry and ecology. Presently the human interventions and chemical production without proper disposal are one of the most responsible factors for presence of harmful pollutants in the biosphere. The toxic chemical may cause detrimental effects like change in behavior pattern of population, reduced growth, physiological and molecular changes and developmental changes ultimately may change the whole exposed ecosystem. Although, ecotoxicologists are facing a lot of problems to predict the effect of a chemical on an individual living population, they are doing a great job to protect our ecosystem.[23]

The organization's EHS staff, the safety committee, or an equivalent group may also conduct laboratory inspections on a routine basis. These inspections may be comprehensive, targeted to certain operations or experiments, focused on a particular type of inspection such as safety equipment and systems, or audits to check the work of other inspectors.[24]

Safety staff are not the only nonlaboratory personnel who may conduct safety inspections. Facility engineers or maintenance personnel may add considerable value to safety inspection programs. They are also given the opportunity to gain a better perspective on laboratory work. It is advisable to have a representative from facilities engineering present during inspections so physical deficiencies can be appropriately and clearly noted and understood and priorities set for correction.[25]

Analysis of remedial technologies based on their use at multiple hazardous waste cleanup sites provides information useful to site managers and others involved in remedy selection and implementation.[26]

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