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Current Developments in Environmental risk Assessment and Management: A review

Syeda Iqra Basharat*, Amina Qadri, Javeria Kanwal, Maham Akram and Muhammad Usman

Department of Chemistry, University of Agriculture, Faisalabad-38040-Pakistan.

Abstract

Numerous environmental disasters and problems have impacted the world in recent years, highlighting the urgent need for preventative steps to address growing threats. Environmental risk assessment and management are undergoing a period of exciting development. Traditionally, these processes focused on understanding the impact of human activities on the environment. Today's advancements are broadening this scope. In risk identification, we only refer to those threats as risks and the risk level or value, which is the product of each threat's impact and likelihood. Determining the degree of each risk is a crucial matter that needs to be properly observed. It is common in risk assessment to set restrictions, especially safety-related ones, to expedite overall choices and ensure a minimum standard in some areas. Appropriate steps ought to be chosen to address the risks after they have been analyzed. Various RA strategies are frequently employed in industrial enterprises. Material flow analysis (MFA), environmental impact assessment (EIA), life cycle assessment (LCA), a strategic environmental assessment (SEA) are the methods used in environmental risk assessment. Life cycle assessment (LCA) is used to examine environmental impacts throughout a product's lifespan. Environmental impact assessment (EIA) to evaluate proposed projects' potential environmental effects. The development of control and precautionary methods requires the use of biochemical responses, such as biomarkers or genes, and sensing devices, such as sensors, biosensors, or nanosensors. As part of the environmental risk assessment process, data on the environmental destiny and behavior of chemicals in the air, water, and land are analyzed along with data on the impacts of the chemicals on people and ecological systems. Overall, the field of environmental risk assessment and management is on a promising path. By embracing innovation and addressing existing challenges, we can move towards a more comprehensive and effective approach to protecting our environment.

Keywords: Risk assessment, risk management, environmental risk assessment strategies

Full-length review article **Corresponding Author*, e-mail: syedaiqra970@gmail.com

1. **Introduction**

The process of finding, assessing, choosing, and putting into action steps to lessen the risk to ecosystems and public health is known as environmental risk assessment or risk management. Certain recently created national environmental risk assessment/risk management frameworks are impacted by the growing significance of environmental quality to the economy, human health, and ecosystems. This is particularly relevant given the ineffectiveness of command-and-control regulation in achieving desired outcomes. There are differences between the terms risk management and risk assessment when referring to the framework's phases of analysis and execution [1]. Climate change and other environmental challenges have garnered more attention in recent years. Businesses, individuals, public administrations, and legislators must all take the environment into account while making decisions to address these concerns. Because of this, information about the environmental effects of different systems is needed, and a variety of techniques and metricshave been created to evaluate and compare how various systems affect the environment. Examples of cost-benefit analyses (CBAs), material flow analyses (MFAs), ecological footprints, life cycle assessments (LCAs), and strategic environmental assessments (SEAs) [2].

To recognize, assess, distinguish, communicate, and (in a wide sense) manage/govern risk, the two main tasks of the risk field are (I) control general risk research and development about concepts, theories, frameworks, approaches, principles, methods, and models; and (II) using risk assessments and risk management to analyses and address the risk of particular activities (such as the operation of an offshore installation or an investment). The concepts, management techniques, and evaluation methods needed for the specific management and evaluation matters of (I) are found in the generic component (II).In short, risk management is the study of the world, including risk, and how we can and should evaluate, appraise, and manage it [3]. Risk assessments are analytical tools with a scientific foundation that adhere to a conceptual model that includes a step in the issue formulation process where policy protection objectives are taken into account. Since the legislatively declared policy protection aims are too vague and expressed in such wide terms to be instantly relevant in ERAs, risk assessors in the majority of countries encounter significant challenges. This means that risk assessors often lack clear guidance on what outcomes might be considered damaging when evaluating policy protection objectives [4].

Danger assessment emerged in the seventeenth century in England and the Netherlands with the insurance of merchant ships. Even now, the insurance and banking sectors employ the majority of risk assessors. Statistical study of historical event frequencies, trend analysis, mechanistic modeling, and expert judgment are some of the tools used in risk assessment in this context to estimate the future effects of proposed actions, isolated incidents, and ill-defined trends. Risk assessment has extended beyond the insurance sector to encompass risk evaluation for medical problems (drugs, devices, and chemicals), risk assessment for property and human safety, and risk assessment for engineering applications (such as reactor and aircraft safety) [5]. An activity that is gaining more attention is the assessment of risk and management. The European Union is also becoming more interested in risk management because of the revised Seveso directive's implementation. The Joint Research Centre has published a guidance document in which they address the question of whether a standardized strategy would be beneficial. While governmental regulations about nuclear power generation included some risk management principles, the majority of the development was brought about by several significant accidents that occurred in the chemical industry in the middle of the 1970s [6].

Exposures occur frequently; some are under control and some are not. The question of whether an exposure should be controlled or not is determined by how acceptable the results are. The federal government creates regulation exposure levels based on fairly conservative ideas and procedures to safeguard public health from the negative consequences of chemical exposure. The likelihood of injury or the kind of harm that should be expected if regulated exposure restrictions are exceeded are typically not reflected in these protective risk ratings. The exposure guideline values are not required by law and are not enforced. They aim to forecast what kinds and degrees of reactions will follow the exposure [7]. This paper's goal is to provide a summary of current advancements in environmental risk assessment and management. Growing worries about environmental degradation and its consequences on ecosystems and human health have made it imperative to continuously refine and improve methods for monitoring and controlling environmental threats. This review's objective is to examine the most current innovations in the industry, including new challenges and possibilities as well as techniques, technologies, and approaches.

2. Environmental Risk Assessment

2.1 Risk Identification

The definition of risk identification is "the process of finding, recognizing, and recording risks" (Iso, 2009). The practice of identifying risks aids in determining which ones might affect a particular firm. Thus, through the risk identification process, decision-makers are made aware of events that could potentially cause disruptions to the firm. It is significant to remember that several definitions of risk can be found in relevant academic works and global norms such as ISO 31000. Nonetheless, we concur with the description offered by the international BCM standard, ISO 22301, which reads, "Negative impacts of uncertainties and troublemaking warnings on the organization's goals [8].

Moreover, it should be mentioned that according to the mainstream literature on risk management, the phrases "operational risks" and "disruption risks" genuinely refer to threats or sources of hazards. But in this study, we directly talk about those threats as dangers and the degree of risk or value, which is the product of each threat's impact and likelihood. Supply chain risk management is a common context for these words. Put differently, "operational risks" refer to the causes of negative impacts that arise from decision-making and uncertainty related to business as usual. Similarly, situations that cause severe disruptions to a supply chain or organization are called "disruption risks." We have simply referred to threats or causes of risks resulting from uncertainty as "operational risks" and "disruption risks," respectively, to avoid misunderstanding [9].

It is of particular interest that operational and disruption risks are not the same. Natural disruptive occurrences like earthquakes, floods, terrorist attacks, or strikes provide a danger of disruption by employees. These hazards can also be technical in nature. Additionally, the inherent uncertainties in supply chain data, cost rate, and demand data (resulting from imprecise forecasting) are the source of operational hazards. In certain significant categories, the risks that have been discovered are further subcategorized (For instance, dangers of natural and environmental disruption). This can be used by managers to assess each risk category's importance and come to a consensus regarding those risks[10].

2.2 Risk Analysis

Each risk that is identified throughout the risk analysis process is assigned a numerical value that indicates its degree or value. This value is determined by multiplying the risk's chance by the risk's impact or consequences. This assessment may be either semi-quantitative, quantitative, or qualitative. Evaluating the degree of each danger is a crucial step that needs to be taken very seriously. As previously mentioned, the risk assessment will be carried out correctly if the quantity of each risk is accurately determined. To begin this process, identify the pertinent risk variables and their sub-factors [11]. The likelihood and impact of each risk are the two main elements that can be used to determine its permissible degree. A likelihood is the probability that a risk will materialize, regardless of whether the risk has an objective or subjective definition and may be expressed in terms of numbers or qualities. Thus, the probability could be evaluated based on past performance and/or the expert's judgment. Fitting a probability distribution function (PDF) is the ideal method if sufficient and trustworthy historical data about the risk's past occurrences are available. If not, computing the risk's past frequency can be used to estimate the possibility of it happening. According to a study, the number of risks or dangers in the industrial environment can be determined using the frequency factor f = N/t, where N is the number of similar events that have happened over time [12].

However, using possibility theory, which is an analogy of probability theory, one can use the expert opinions' subjective assessments to determine the possibility distribution of the risk occurring if it is not possible to determine the probability of a risk using the related PDF or frequency factor due to a lack of historical data. Here, it is fascinating to note that, in cases where historical data is not available, subjective probability could easily replace the possibility approach by integrating the subjective opinions of experts into subjective probability distributions [13].

As opposed to a risk that may be easily identified before to occurrence, one that is not detectable before it occurs may have a greater impact. The organization is better able to respond when each danger has a higher detectability level. It must so be regarded as an additional impact sub-factor. An additional risk factor taken into account by a research study is risk growth. Growth factors indicate potential directions in which a given danger could go. A low growth factor risk could quickly disappear. Conversely, a low-impact risk with a high growth factor would rise to a higher one. Therefore, one of the most important sub-factors to examine when assessing the impact of a risk is its rise [14].

2.3 Risk criteria

Finding a balance between many concerns, such as reputation, safety, profitability, and others, is the aim of risk management. Generally speaking, one weighs the advantages and disadvantages of a range of options before selecting the one that most closely aligns with the priorities and values of the decision-maker. It is usual in this process to impose boundaries, especially safety-related ones, to guarantee a minimum standard in some areas and streamline overall decision-making. This helps to prevent taking into account too many variables at once. These limitations are sometimes known as risk acceptance, risk criteria, and tolerance criteria [15].

For instance, according to Norway's petroleum rules, it is the operator's responsibility to develop risk acceptance criteria for significant incidents and environmental concerns. This strategy complies with the internal control principle, which says that the operator is the only one who can identify risks and ensure they are controlled. Nonetheless, there is disagreement over this technique, and recent research makes the case that it needs to be given another chance [16].

There are many reasons to oppose the application of such criteria; see, for example. First of all, key components of risk are overlooked when expressing tolerance or acceptance levels through probability. The probabilities that are used to compare these levels are significant since they do not accurately reflect the quality of knowledge that underlies the probability evaluations. Second, making decisions based solely on meeting requirements can easily be influenced by applying such criteria, rather than considering the best course of action, keeping in mind the analysis's limits, the uncertainty it overlooked, and other crucial aspects. It should be underlined that risk should inform a decision rather than being the exclusive factor. Evaluation and judgment by managers are constantly required [17].

2.4 Risk Evaluation

Appropriate steps ought to be chosen to address the risks after they have been analyzed. In an organization, resources to address risks are typically scarce. To allocate their limited resources effectively while responding to hazards, managers must ascertain which risks have the most potential to impact the organization's goals. To recognize the risks that could deviate from. The outcomes of the BIA and RA are combined into this step, which is about the organization's goals above the pre-established extreme variation (also called the risk appetite). The company can identify risks that could compromise its objectives and implement the necessary protections by connecting the identified hazards with the essential operations [18].

A risk may result in the loss of one or more resources. The loss of such resource(s) lowers the operational level of critical functions and may lead to some departures from the organization's objectives. The impact of the risks on resources is taken into account when calculating the degree of deviation from the goals. Danger could be highly probable and impactful, but it might not affect the particular resource at all (for example, an earthquake could result in the loss of facilities, apparatus, and human and financial assets, but a cyber-attack might only result in the loss of financial and material resources). Therefore, the impact of risks on the resources of the company is contingent upon the susceptibility of those resources[19].

3. Regulatory Framework of Risk Assessment

3.1 Risk assessment/management principles and strategies

It is helpful to go over two well-established risk management supports before diving into the most recent advancements in basic risk management concepts and methodologies: (a) the primary risk management techniques now in use, and (b) the process structure. When it comes to (a), the three main strategies that are frequently employed are risk-informed, cautious/precautionary, and discursive techniques. A robust and resilient strategy is another term for the precautionary/cautionary approach. Generally speaking, the optimum course of action should be created using these three strategies[20].

The application of risk assessments concerning risk management—transfer, avoidance, reduction, and retention—either absolutely or relatively is referred to as a "risk-informed strategy". The precautionary/precautionary strategy emphasizes features such as restriction, the growth of alternatives, safety factors, repetition in the design of safety devices, immune system strengthening, wide-ranging of approaches for accomplishing similar or similar goals, design of systems with moldable response options, improvement of emergency management, and conditions for system changing. In this case, it is critical to be able to identify signals and the early warning indicators of significant occurrences. All risk rules are based in part on these concepts to address the unknowns, threats, and potential for surprises. By reducing doubts and ambiguities, elucidating the facts, including those who will be impacted, engaging in discussion, and holding people accountable, the discursive approach employs techniques to foster confidence and loyalty [21].

The process for (b) can be broken down into the following steps: Provide background information, including standards, goals, and the rationale for risk management activities. Determine the events and situations (risks, opportunities, and hazards) that may have an impact on the proposed course of action and its objectives. To do this, numerous techniques have been created, including FMEA, HAZOP, and checklists. Examine the causes and effects of these occurrences using tools like fault trees, event trees, and Bayesian networks. Create a risk description or characterization and assess the occurrences' probability and impact. Assess risk to determine its importance. Managing risks [22].

Industrial enterprises often use a variety of RA techniques. Fault tree analysis (FTA), hazards and operability study (HAZOP), and failure mode and effect analysis (FMEA) are the most advantageous techniques[23].

3.2 Framework of Risk Assessment

Numerous frameworks and models have been put out to carry out the RA process in manufacturing companies. The author presents a framework for risk assessment in the context of operation cooperation[24]. This framework initially identifies several risks associated with the pre-creation, development, operation, and closing of enterprise collaboration. Then, ambiguous language words are used to determine each risk's probability and impact. An automaker tests the suggested structure as well. A risk management approach is presented in research to help a textile manufacturing company manage its hazards. The possible risks are initially noted in this framework. Next, the number of hazards, their likelihood, and their effect are determined [25].

Subsequently, the impact and likelihood of hazards are used to partition the four zones of the risk assessment matrix. Lastly, based on these four regions, four activities are recommended as risk response plans. Among these strategies are transfer (for low likelihood, high impact), reduce (for high likelihood, high impact), accept the risk (for low likelihood, low impact), and keep away from the risk (for high likelihood, low impact). A systematic framework for evaluating the risks associated with outsourcing information technology[26].

The four main steps of the methodology are outlined by the authors as follows: (1) recognizing the risks within the conditions of outsourcing information technology; (2) collecting language data on the likelihood and consequences of risks from the perspectives of specialists; and (3) multiplying the corresponding likelihood and outcome to determine the precise amount of risk. (4) Developing treatment plans appropriate for the risks. For offshore wind projects, an analysis offers a methodology for choosing the best risk-reduction tactics. The suggested method uses the fuzzy analytic network process (FANP) to select a mitigation strategy based on a set of criteria[27].

4. Methods and approaches used in environmental risk assessment

By systematically reducing uncertainty, risk assessment helps to solve problems. The degree of uncertainty surrounding its findings is carefully documented. While they collaborate, interact, and work together with risk managers, risk assessors carry out their tasks without regard to the values that risk managers take into account when making decisions. A rising number of professional communities are doing risk assessments, and many of them have created highly specialized risk assessment models specifically for their usage. Four generic steps are included in some form in the best of these models. To identify the risk's origin, the threat that must be avoided, or the opportunity that must be taken advantage of first. Next, consider the implications of the chance or risk. Third, ascertain the likelihood of the outcomes, possibly concurrently. In the fourth phase, provide a risk description that risk managers can understand by drawing on the science, evidence, and uncertainty identified in the preceding steps. A useful procedure that can be either qualitative or quantitative is risk assessment [28].

4.1 Life Cycle Assessment (LCA)

Using a life cycle assessment, you may examine the resources and possible environmental effects of a product at each point of its life cycle, from the addition of raw materials to waste management and production and usage. The processes of recycling and disposal are both part of waste management. Services and products are both included in the definition of "product." The Life Cycle Assessment (LCA) is an all-encompassing evaluation that takes into account the environment, human health, and the resources that are at hand. Goal and scope definition, life cycle inventory (LCI) analysis, life cycle impact assessment (LCIA), and interpretation are the four stages of an LCA study[29].

The target audience, intended use, and purpose of the study are explained in the Goal and Scope Definition. The functional unit's requirements and the study's system boundaries are described. A functional unit is a way to express the functions that a product (or service) provides numerically. A list of the resources and emissions that the product utilizes over the course of its life cycle around the functional unit is the outcome of the life cycle analysis (LCI). Understanding and evaluating the system under study's potential environmental effects, as well as their significance and magnitude, is the aim of the LCIA. The objectives and constraints for formulating conclusions and offering advice are evaluated in light of the results of the preceding phases of the interpretation [30].

It is highly advised to carry out an LCA in two steps: 1.The order of magnitude of each life cycle stage contribution is assessed in the preliminary evaluation, also known as screening, which is a brief and straightforward analysis. The objectives and constraints for formulating conclusions and offering advice are evaluated in light of the results of the preceding phases of the interpretation. 2. Secondly, a more thorough examination is carried out by thoroughly repeating the processes of inventory, impact assessment, and aim and scope definition. The emissions, processes, and stages with the biggest environmental impacts are identified using the data from the preliminary review and are given a priority ranking so that they can be investigated further. A thorough uncertainty analysis and sensitivity assessment are part of the last phase of interpretation. A comparison of environmental effects and socioeconomic performance could be the study's conclusion [31].

4.2 Environmental Impact Assessment (EIA)

An environmental impact assessment, or EIA, is the process of estimating an activity's potential effects on human welfare, the biogeophysical environment, and health. It then provides this information to the decision-makers who must approve the plans at a time when it could significantly impact their decision. Providing decision-makers with an understanding of the potential results of their actions is the ultimate goal of the Environmental Impact Assessment (EIA) process. Over time, it has become increasingly clear that judgments are made based on more than just ideas. A set of development proposals passes through multiple phases of decision-making, and most of them have an effect even before a formal project permission application is filed[32].

Even while EIA is typically associated with project management, it can be used at other stages of planning as well. However, there is not much experience using EIA to evaluate laws, policies, plans, projects, and other initiatives. EIA can be viewed as a data management procedure from a technical perspective. It is made up of three components. The right information must first be determined and, if necessary, gathered to make a certain decision. Secondly, the plan's implementation-related changes to the environment must be identified and contrasted with the circumstances that would probably arise in the absence of the proposal. Lastly, it's necessary to document and evaluate actual change. There is a risk that EIA will only be used for project appraisal because it has been incorporated into project planning so extensively [33].

4.3 Strategic Environmental Assessment (SEA)

An essential instrument for incorporating environmental considerations into strategic decision-making is the Strategic Environmental Assessment (SEA). Environmental Impact Assessments (EIAs) carried out at the project level are different from Strategic Environmental Assessments (SEAs), which assess the possible environmental effects of suggested plans, programmers, policies, or maneuvers. Early in the planning process, SEA takes into account a broad range of environmental, social, and economic aspects to help decision-makers make well-informed choices that promote sustainable development. This makes it easier to identify potential environmental hazards and possibilities[34].

Usually, the SEA procedure consists of multiple key steps. First, the assessment's objectives and scope are established, and the main environmental concerns and relevant parties are identified. This is known as scoping. Data on the current status of the environment and pertinent social and economic elements are gathered and analyzed as part of the baseline assessment process. The possible social, economic, and environmental effects of the suggested plan, program, or policy are evaluated along with any prospective alternatives in an impact forecast. Environmental factors are integrated into decision-making processes by identifying actions to reduce negative effects and increase favorable ones based on this assessment. To track the success of the policy, plan, or program and make required adjustments, monitoring and evaluation systems are lastly constructed [35].

The capacity of SEA to support integrated decision-making and guarantee that environmental factors are completely integrated into strategic planning processes is one of its main advantages. Before choices are made, SEA assists in identifying potential environmental hazards and opportunities by taking environmental considerations into account early in the decision-making process. Furthermore, by actively involving stakeholders throughout the evaluation process, SEA improves transparency and involvement while guaranteeing that the opinions of the general public and other stakeholders are taken into consideration. All things considered, SEA is a useful instrument for encouraging sustainable development, improving plans, policies, and programs, and raising their economic, social, and environmental performance [36].

4.4 Material Flow Analysis (MFA)

In the field of industrial ecology, material flow analysis (MFA) is one of the most extensively utilized and recognized methodologies. It quantifies the input-output material flow and looks at the flux and routes of each material flow across the complete system. In industrialized countries, material flow analysis (MFA) is an essential apparatus for managing complicated waste streams. Since its introduction by Greek philosophers more than 200 years ago, MFA has shown to be a useful decision-support tool when it comes to resource, waste, and environmental management [37].

Material flow analysis (MFA) measures the various ways that the resources that support contemporary society are utilized, recycled, and lost. is one of the primary methods of industrial ecology. A common tool used when presenting MFA results is Sankey diagrams, often known as the "visible language of industrial ecology." As environmental input-output assessments, life cycle assessments, and scenario development are now connected to MFA methodologies, these more thorough evaluations hold great potential as key instruments for future research on sustainable development and the circular economy. Additionally, the consequences of the MFA results for corporate and national policy are addressed, along with current inadequacies and future advances[38].

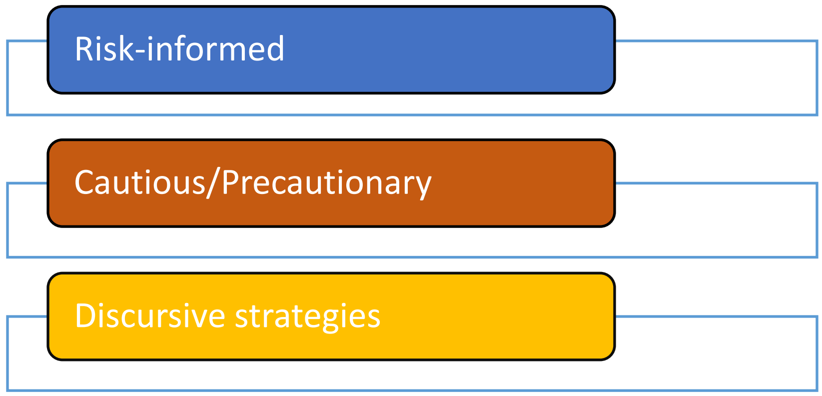

Figure 1. Primary risk management strategies

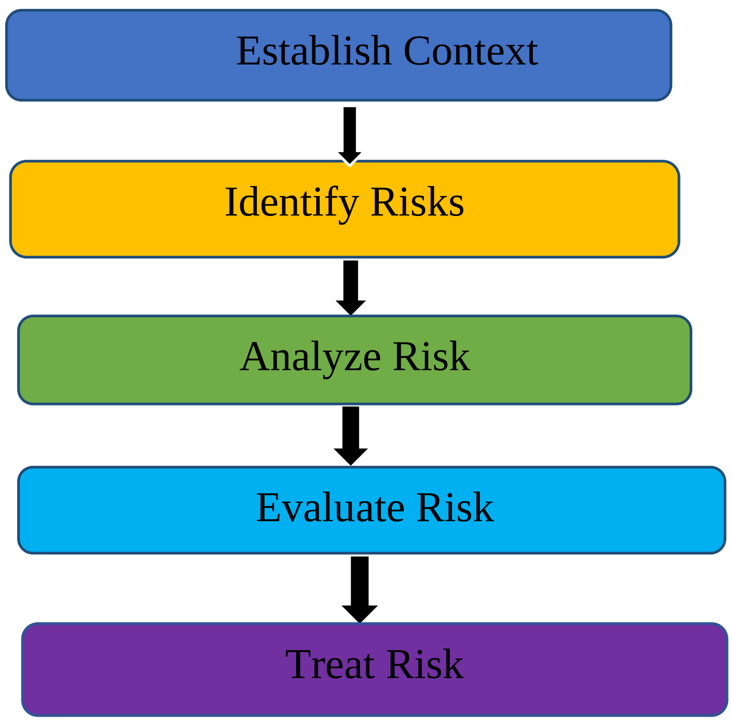

Figure 2. Process structure of risk assessment and management

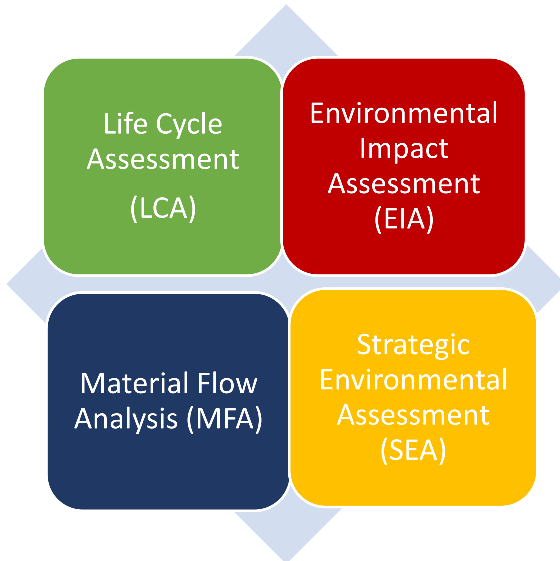

Figure 3. Methods and approaches used in environmental risk assessment

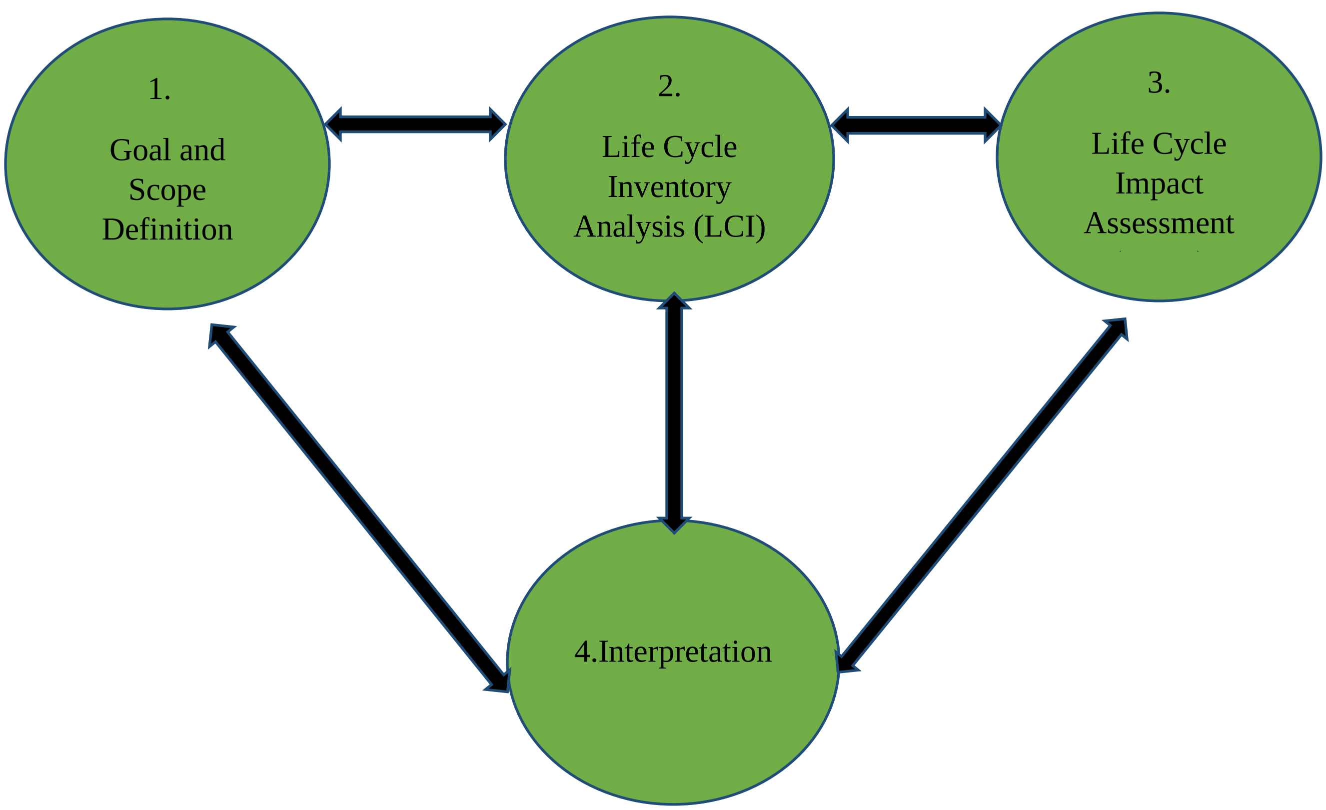

Figure 4.4 Phases of a Life Cycle Assessment

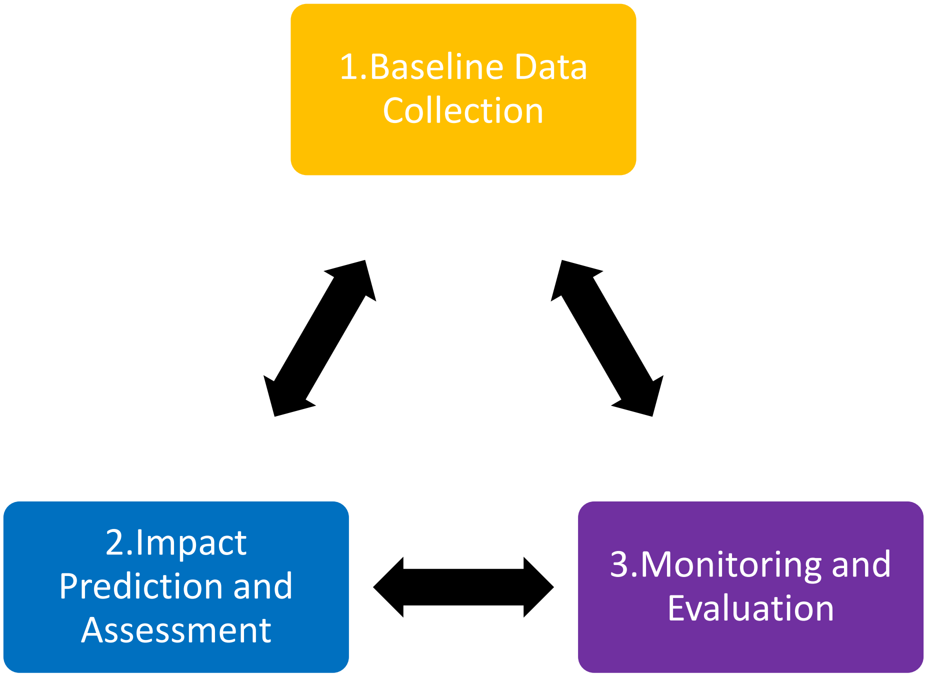

Figure 5.3 Components of EIA

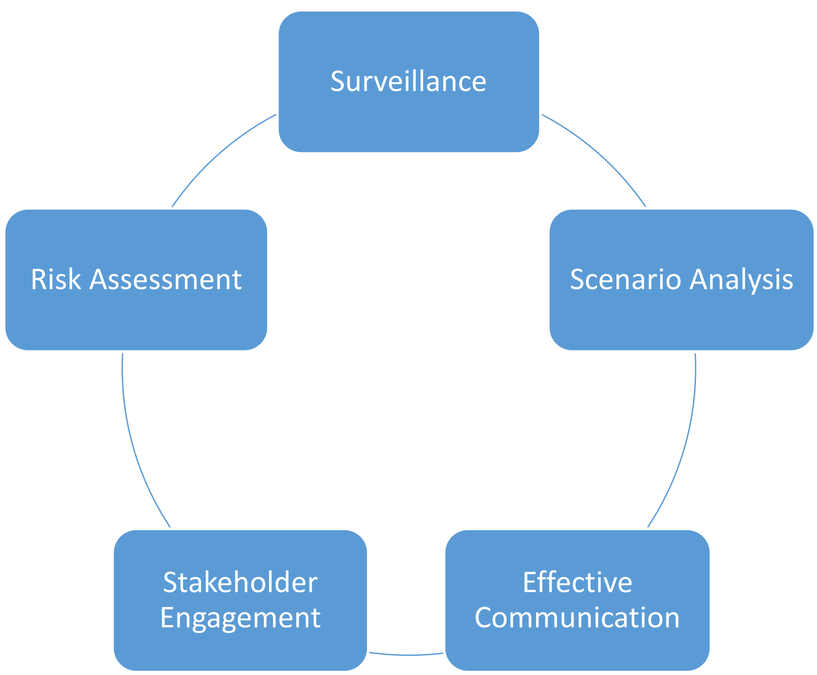

Figure 6. Multi-Faceted Approach Include

Environmental Uncertainty

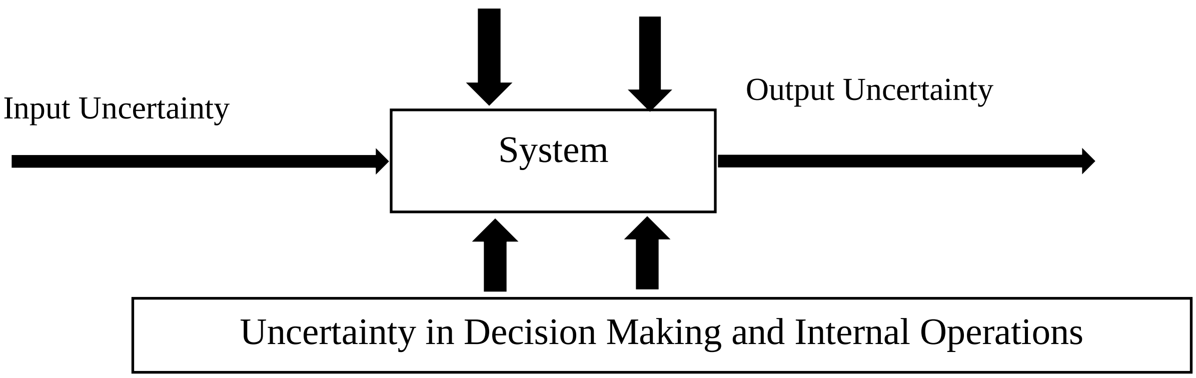

Figure 7. Sources of uncertainties in a system

Table 1. Risk Factors and Sub factors

Risk Factors	Risk sub-factors	Description of the sub-factor
Impact	Losses in terms of money and people (F1) Time and cost of recovery (F2) introducing additional hazards and creating a causal pathway (F3) Degree of non-detectability (F4)	The financial and human costs of taking a risk The financial and temporal requirements for resuming the halted activity The degree to which it presents further risks The failure to identify and investigate the risk before its manifestation
Likelihood	Growth rate (F5) Possibility (F6) Probability (F7)	The rate at which the risk's impact is growing or decreasing over time The likelihood of a risk event based on the expert's subjective assessment in cases where historical data is insufficient A probabilistic distribution function, the frequency of risk occurring based on past data that is available, or, in the absence of sufficient historical data, a subjective likelihood based on expert assessments

Table 2. An explanation of RA methods

RA Techniques	Description
FMEA	Component-driven FMEA methodology that facilitates hardware analysis of systems to identify possible failure modes, their causes, and their consequences.
FTA	FTA uses a fault tree to show potential faults, or occurrences, within a system that could have negative effects. It methodically displays the possible fault propagation, starting with low-risk occurrences and ending with high-risk ones.
HAZOP	HAZOP is a function-driven technique that looks at process activities to identify problems with the operability of the system.

5. Emerging Environmental Risks

The globe has suffered in recent decades due to the unbridled expansion of human efforts such as manufacturing, transportation, agriculture, and urbanization. The amount of pollution in the air, water, and soil has increased due to rising living standards and increased consumer demand. In addition, inappropriate waste disposal facilities have added to environmental contamination. The usage of throwaway goods, non-biodegradable materials, and pesticides are examples of soil pollution; water pollution includes a range of chemicals, nutrients, leachates, and oil spills; and air pollution includes CO2, other greenhouse gases, NOx, SO2, and particle matter [39].

Emerging pollutants, or EPs for short, are a broad category of artificially produced materials that are essential to modern living and are utilized extensively. Among these substances are medications, cosmetics, household and personal hygiene products, and insecticides. According to studies, the global annual production of anthropogenic chemicals rose from one million to four hundred million tons between 1930 and 2000. Environmentally hazardous substances accounted for more than half of all chemicals generated between 2002 and 2011, according to data released by EUROSTAT in 2013 (Table 3). Approximately 70% of these are chemicals, which have a major effect on the ecosystem[40].

5.1 Identification and Characterization of Emerging Environmental Risks

Ecosystem preservation and sustainable development now depend heavily on the identification and characterization of new environmental hazards. A multifaceted approach that includes stakeholder participation, risk assessment, scenario analysis, surveillance, and effective communication is necessary to understand these risks. For the identification of emerging environmental hazards, it is essential to continuously monitor environmental factors like biodiversity, land use changes, air and water quality, and climate patterns. To gather and evaluate pertinent data for this, satellite imaging, on-ground monitoring stations, and remote sensing technologies are used. Examples of rising environmental concerns that can be detected with the aid of remote sensing technology are changes in land use patterns, urban expansion, and trends in deforestation [41].

5.1.1. Risk Assessment

When relevant risks are identified, a comprehensive risk assessment is managed to ascertain the chances of an event and its potential effects on the economy, ecological systems, and public health. To do this, modeling studies, historical data analysis, and ecological and population vulnerability assessments are required. Risk assessments, for instance, can be used to forecast how vector-borne illnesses, like dengue fever and malaria, would spread in response to shifting climatic patterns. Controlling environmental risks effectively requires an understanding of the underlying causes of these risks. These factors could include the introduction of exotic species, deforestation, urbanization, industrialization, population growth, and climate change. Policymakers can create focused measures to reduce the related hazards by recognizing and comprehending these drivers [42].

5.1.2. Scenario Analysis:

It is defined as a description of a range of scenarios that could reasonably occur. Creating scenarios catalyzes to generation of ideas about potential outcomes, assumptions surrounding these outcomes, opportunities and hazards, and possible courses of action. Creating believable future scenarios is a key component of scenario analysis, which investigates how potentially emergent environmental threats might change in various scenarios. This aids in decision-makers' ability to identify problems and create flexible solutions. A helpful technique for projecting how extreme weather and sea level rise may affect coastal towns and infrastructure is scenario analysis [43].

5.1.3. Stakeholder Engagement

Stakeholder participation has gained popularity in business and social studies, as well as allied fields of study. The idea has gained popularity due to its great use in comprehending and elucidating the relationships that exist between businesses and stakeholders, including workers, clients, suppliers, rival businesses, local communities, and citizens, as well as the various outcomes that arise from these relationships.Stakeholders must effectively engage to identify and characterize new environmental hazards. This necessitates collaboration with enterprises, NGOs, government agencies, local communities, and other relevant parties. Incorporating diverse viewpoints from stakeholders can yield priceless knowledge and insights into the risk categorization process[44].

5.1.4. Risk Communication

To increase knowledge and facilitate well-informed decision-making, new environmental concerns must be communicated openly and efficiently openly and efficiently. This entails converting intricate scientific data into forms that the general public, media, and legislators can easily understand. Through disseminating information about the possible outcomes of newly identified environmental hazards, interested parties can garner backing for countermeasures and adjustments. Lastly, handling new environmental threats requires the development of mitigation and adaptation methods. This could involve expenditures in R&D and innovation, policy and behavior changes, technical advancements, and regulatory measures. Policymakers can lessen the probability and impact of new environmental hazards and increase their ability to withstand future setbacks by taking preemptive steps [45].

5.2. Recent Environmental Challenges and Crises

Numerous environmental disasters and problems have impacted the world in recent years, highlighting the urgent need for preventative steps to address growing threats. These problems threaten biodiversity and ecosystems, as well as human health, food security, and socioeconomic stability.One of the most significant environmental challenges of our day is Extreme weather events are happening more regularly and with considerable potency due to climate change. Heatwaves, droughts, floods, storms, and wildfires are happening more frequently and with greater intensity, causing massive havoc and casualties. The severe hurricanes like Harvey, Irma, and Maria in 2017 and the extraordinary wildfires that devastated Australia in 2019 and 2020, for example, serve as vivid reminders of the effects of climate change on our world[46].

5.2.1. Loss of biodiversity and habitat destruction:

Another grave environmental calamity is the destruction of habitats and the rapid decrease in biodiversity. A growing number of species are going extinct as a result of human activities like deforestation, urbanization, pollution, and climate change. Up to a million species could go extinct in the next several decades, according to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). A few examples of this issue's manifestations are the degradation of coral reefs due to ocean acidity and warming and the devastation of wildlife habitats caused by deforestation [47].

5.2.2. Air and water pollution:

Human health and the environment are still seriously threatened by pollution in the air and water. The main causes of air and water pollution, which in turn causes respiratory disorders, waterborne infections, and ecosystem damage, are urbanization, industrialization, and agricultural practices. According to the Lancet Planetary Health Commission, plastic pollution endangers ecosystems and marine life, while air pollution is thought to be a major cause of millions of preventable deaths globally each year[48].

5.2.3. Plastic Pollution:

A growing environmental concern is the pollution caused by plastics. Millions of tons of plastic waste enter our rivers, oceans, and terrestrial environments each year, posing a threat to human health, ecosystems, and marine life. The size of this issue is starkly illustrated by the Great Pacific Garbage Patch, a vast collection of floating plastic garbage in the Pacific Ocean. Small plastic particles known as microplastics, which are now found everywhere from the ocean floor to our lungs, are extremely dangerous to the environment and public health [49].

5.2.4Deforestation and Land Degradation:

Deforestation and land degradation are major causes of environmental change that result in habitat destruction, soil erosion, and biodiversity loss. Deforestation and land degradation are largely caused by the quick growth of agriculture, logging, mining, and infrastructure development. Because the rainforests in Southeast Asia, the Amazon, and the Congo Basin are some of the planet's most biodiversity and carbon-rich ecosystems, their demise is especially worrisome [47].

5.2.5. Water Scarcity and Drought:

Climate change, population increase, and inefficient water management techniques are making drought and water scarcity worse environmental problems. A problem with water scarcity exists in many places of the world which puts strain on freshwater supplies and agricultural output. The current drought in the western United States and the 2018 water crisis in Cape Town, South Africa, serve as sobering reminders of how delicate our water systems are [50].

5.2.6. Food Insecurity and Malnutrition:

Around the world, environmental issues like land degradation, water scarcity, and climate change are causing food insecurity and hunger, severe weather, agricultural failures, and interruptions in the supply of food chains are exacerbating hunger and malnutrition in many parts of the world. The Food and Agriculture Organization (FAO) estimates that millions more people experience food insecurity and micronutrient deficiencies and that over 800 million people are chronically malnourished. Around the world, environmental issues like land degradation, water scarcity, and climate change are causing food insecurity and hunger. In many regions of the world, the effects of extreme weather, crop failures, and interruptions to food supply networks are making hunger and malnutrition worse. The Food and Agriculture Organization (FAO) estimates that millions more people experience food insecurity and micronutrient deficiencies and that over 800 million people are chronically malnourished [51].

6. Challenges and Future Directions

6.1 Uncertainty in risk assessments

A crucial element in risk assessment and conceptualization is uncertainty. Since the early years of risk assessment in the 1970s and 1980s, there has been a great deal of conversation in the literature on understanding and managing uncertainty. Nevertheless, the subject is important. A study offers a contemporary viewpoint on issues, difficulties, and prospective paths for the representation and articulation of uncertainty in risk assessment. The most popular approach to managing uncertainty in risk analysis is probabilistic analysis, which encompasses both epistemic (originating from ignorance) and lavatory (expressing variance) problems. It is well accepted that possibilities with a confined relative frequency explanation can be used to express lavatory uncertainty. But it gets more complicated than that when it comes to pondering and articulating epistemic uncertainty. Although other approaches have been presented, such as interval possibilities, possibility calculations, and qualitative procedures, Bayesian subjective probability is still the most commonly used method [52].

One of the points brought up is the appropriateness of subjective probability.One typical argument is that It will be hard or impossible to give a subjective likelihood in which one can feel adequately sure if one has very little prior knowledge. On the other hand, one can always assign a subjective probability. The issue is in the fact that a given likelihood is taken to indicate a higher level of information than is warranted [53].

If the uncertainties are expressed as subjective probabilities, consideration must be given to the information underlying the probabilities. Imagine a scenario where a few risk analysts provide some probabilistic risk metrics in a decision-making setting. While the prior knowledge is different (stronger in one situation), the metrics and probability are the same in both cases. To get around this problem, other strategies like possibility theory and evidence theory can be looked into. Alternatively, you may adopt a different strategy and attempt to assist decision-makers by elucidating the quality of this information [54].

The examination of uncertainty importance is a key component of uncertainty in risk assessment. The difficulty lies in determining which factors contribute most significantly to production uncertainties and risk. Risk assessments heavily rely on models, and in the past few years, as well as throughout history, the problem of model uncertainty has received a lot of attention. However, there hasn't been much consensus in the risk community over the meaning of this concept [55].

6.2 Health impact assessment and health risk assessment

Plans often include components and actions that could lead to risks that could affect community health, therefore they should be carefully considered. An initial screening procedure is used in a project to determine whether a Health Impact Assessment (HIA) is required. An impact assessment (HIA) is usually required if the health consequences are considered significant, there is a chance of unknown health effects, or the impacts are challenging to control with well-established management strategies, according to the European Centre for Health Policy (1999).

The following phase, known as the Scoping Stage of HIA, is to identify the specific health hazards that need to be addressed if it has been determined that a plan may have potential effects on health. Scoping consists of Characterizing all possible health effects and ranking the most likely to be significant is the first step in addressing the potential health repercussions. Establish limits on the population, timeframe, and geographic region that may be impacted, while also indicating any vulnerable or particular concern sectors. Determining who the necessary parties to be involved are. Reaching a consensus between the proponent, the health authority, and other stakeholders over the specifics of the health risk assessment [56].

6.3 The future of risk assessment and management

These days, risk assessments are well-established in circumstances with copious amounts of data and precisely specified usage limitations. There are now tools for probability and statistics that provide useful decision assistance for a variety of applications. However, circumstances involving a great deal of ambiguity and emergence are increasingly influencing risk choices. Developing appropriate frameworks and tools to accomplish this goal is a major problem for the risk profession because diverse situations necessitate distinct methods and strategies. Rather than static or traditional risk assessment, the majority of research focuses on dynamic risk assessment and management[57].

In recent years, the idea of emergent risk has drawn more and more attention. The emergent risk idea is thoroughly examined, with a focus on how it relates to unknowns and black swan events. According to this work, when there are signs or believable beliefs that a novel event—novel in the context of the activity—may occur in the future and possibly have serious consequences for something that people value, we may be dealing with emerging risk-related to an activity when our past knowledge is limited. It is difficult to characterize scenarios due to a diversity of factors, including the inability to fully define the event and its implications [58].

We need to keep improving risk assessments that can recognize these challenges related to the knowledge dimension and the temporal dynamics. Strictly probabilistic methods, such as a Bayesian analysis, would not work because there wouldn't be enough background information to support the probability models and assignments. It's important to adaptively balance several risk management techniques, like exercising caution and paying attention to signals and warning indications.Much research and development are required to acquire appropriate modeling and analytical techniques—beyond the "traditional" ones—to "handle" new kinds of systems. Critical infrastructures, sometimes known as "systems of systems," are complex and frequently interconnected systems, such as electricity and transportation networks. Another example would be security-related applications, where evaluations of actors' intentions and capabilities are frequently made qualitatively without using a probability scale. Creating frameworks that combine conventional security techniques with methods for evaluating and managing uncertainty appears to offer a great deal of promise for major advancements in the way security is evaluated [59].

7. Nano biosensors for Environmental Risk Assessment and Management

In locations where there are hazardous chemicals and water pollution, environmental analysis has become more and more important. When there has been damage to the environment or public health, recovery attempts might not be possible or be too expensive. The development of control and preventative measures requires the use of biological processes, such as biomarkers or genes, and sensing devices, such as sensors, biosensors, or Nanosensors. An environmental risk assessment, often known as an ERA, looks at environmental problems and provides management recommendations. The ERA's components cover danger detection, communication and monitoring, risk assessment, risk management, and feedback [60]. All of these are thought to be foundational ideas in sustainability. Studies of possible and/or particular chemical, biological, and/or environmental contaminants are conducted using both quantitative and qualitative methods as part of risk assessment and management programs. It takes quick, accurate analysis techniques to find these environmental contaminants. Since biosensors are inexpensive, portable, and adaptable to individual requirements, they can be employed for the analysis of these compounds. Additionally, they can be used with nanomaterials to boost selectivity and specificity as well as surface area. They may be able to find analyses in a solution even at extremely low concentrations. The applications of these technological advancements include the detection of heavy metals, medications, diseases, and unknown pollutants. Therefore, environmental monitoring and danger detection are ideal applications for Nano biosensors [61].

8. Environmental Risk Assessment in Agriculture

Today's world is concerned about the contamination of agricultural soil and groundwater, which restricts their availability as resources for crop irrigation and as a supply of nutrients, respectively. When soil nutrients are scarce or unavailable, or when irrigation water resources are insufficient to sustain intensive agricultural practices, the related effects become increasingly apparent in regions experiencing desertification, salinization, soil erosion, or both.An alternative to toxicological research that is less expensive is the environmental risk assessment (ERA), which can be used to investigate how human activities like industry, agriculture, and urbanization cause risk to increase over time [62].

Data on the environmental destiny and conduct of chemicals in the air, water, and land as well as information on the chemicals' effects on people and ecological systems are analyzed as part of the environmental risk assessment process. The most latest ISO (International Standardization Organization) standards that apply to contaminated soils and sites contain a range of chemical, biological, and ecological measurements that can be utilized in situ or ex situ in the case of ERA.It is an essential tool for decision-making since it can identify contemporary environmental problems, prioritize agricultural management and regulatory initiatives, anticipate potential hazards related to planned actions, and then evaluate the effectiveness of those operations in the field. On the other hand, environmental risk assessment is a difficult process that typically calls for an interdisciplinary approach in the stages of design and development [63].

Target and intervention values, which are generic parameters used to categorize media as clean, slightly, moderately, or considerably contaminated, are used to evaluate the quality of the impacted medium. The intervention values show significant contamination, while the goal values are protective levels that represent the expected media quality. Much more computations on exposure rates over time and degrees of Ecotoxicological and human interventions are needed for the population risk assessment. The environment must be defined before any threats, hazards, or possible pollution sources that can negatively impact the nearby ecosystem can be evaluated in terms of both quality and quantity[64].

To date, the majority of agricultural environmental risk studies have either concentrated on the safe use of wastewater for irrigation or evaluated N/P/K leaching exclusively based on soil factors. When it comes to reducing adverse effects on agricultural development and long-term water conservation plans, irrigation water quality is by far the most important factor. The risks that irrigation water quality presents to crop yield and soil properties, on the other hand, are frequently intricate phenomena that rely on a wide range of interconnected factors. This is accomplished by using a water quality index, which gives a single value that characterizes the total water quality at a specific place and time depending on a variety of factors. The objective of an index is to translate complex data on water quality into information that can be used and understood by local government, farmers, and other relevant stakeholders[65].

9. Conclusions

Recent advances regarding environmental risk assessment and management (ERAM) techniques have been thoroughly examined in this paper. It has refined the fundamental concepts of risk assessment and management and highlighted their essential importance in preserving the health of our world. The framework of ERAM, which outlines the crucial phases of risk identification, analysis, evaluation, and criteria construction, has been examined in the review. It has also covered the legal frameworks and accepted practices used in ERAM, such as Environmental Impact Assessment (EIA) and Life Cycle Assessment (LCA), among others. The assessment highlighted the ongoing nature of environmental threats and the challenges related to identifying and describing them. It has highlighted the importance of ongoing research and development in this sector by giving instances of current environmental issues. In addition, the evaluation has looked into the future direction of ERAM techniques and handled the problems with uncertainty that come with risk assessment. This covers the possible applications of modern technologies such as the incorporation of health impact evaluations and nano biosensors. The overview concluded with a brief examination of how ERAM principles are applied in the agriculture industry, emphasizing how they might be used to reduce environmental hazards in this critical field. Improving our knowledge of ERAM developments and their prospects can help us work toward a more proactive environmental protection strategy. As a result, our planet will have a future that is more sustainable and healthier enabling us to more effectively prepare for and avoid risks.

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