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Fuzzy Logic Techniques For Environmental Impact Assessment: A Way Forward Towards A World Where Health Is Valued

Ms. Anurita Yadav [1],Dr. Bhumika Sharma [2]
[1] Ph.D. Research Scholar, Sharda School of Law, Sharda University, India
[2] Assistant Professor, Sharda School of Law, Sharda University, India

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Abstract

The road to development is the advancement of technology and innovation. Fuzzy Logic plays a very crucial role in the advancement of intelligent systems as it focuses on and appreciates that reality is not precise but rather not certain. It represents a logical and accurate system, unlike its usual misunderstanding that it is fuzzy; unlike binary which dwells with either and or. Fuzzy logic deals with uncertainty. It presents a qualitative computation method with a way to arrive at a concrete conclusion based on ambiguous inputs. Fuzzy logic presents propositions with levels of false and truth. The use of Fuzzy Logic techniques for Environmental Impact Assessment has been increasing with time. Policies and regulations are highly focused on the implementation of measures to mitigate the adverse impact of development projects on the human health, well-being, economics socio-cultural areas. The main motive of impact assessment is to identify the gravity of the impact on humans and the environment, predicting the prospects of solutions to mitigate the challenges about the developmental or economic activity in question along with the overall impact on the environment. Screening, scoping, public consultation, and finally the appraisal or assessment are the steps involved primarily in the impact assessment process. This phenomenon is only possible once the overall impact of a project/developmental activity on social, health, economic, or overall environmental factors, etc is properly assessed. The paper highlights the use of fuzzy logic as a tool for decision-making and undertaking the environmental impact evaluation for a healthy and sustainable tomorrow.

Keywords: *Decision making, Environment Impact Assessment, Future, Fuzzy impact, Fuzzy logic, Health.*

Objectives: The rapidly increasingly development processes lead to urbanization influencing constantly the social, economic and cultural and environmental phenomena. Assessment of these impacts focusing on the ways of identifying potential effects of a project and mitigating the possible measures of mitigation shall remain the main focus area of impact assessment; aiming to make the adverse impact of any development activity reversible.

Methods: We reviewed a collective list of policies, programmes, legislations, SDGs and targets, EIA notifications working towards a collective well-being of environment inclusive of all species. We aim to identify the ways of conducting environment impact assessment via fuzzy logic techniques in the best and effective manner.

Results: Fuzzy logic techniques inculcation in conducting EIA can be beneficial while dealing with humongous data generated from diverse sources as it proves to be better at dealing with ambiguous and distinct inputs. Fuzzy logic can be highly beneficial in managing multiple stakeholders helping in decision matrices facilitating further communication; this can help in providing a holistic overview of the environmental impact along with this inculcation of traditional validation techniques with fuzzy logic can be beneficial to ensure the reliability of results.

Conclusion: Countries around the world are developing such processes which can help in assessing the cumulative impact of the economic activity/projects on social, economic, cultural, and health factors. The flexibility of the fuzzy logic allows the modelling of the numerous complex interacting variables relating to human health, well-being, socio-economic, cultural variables. It offers new potentials for the integration of complex information via a

systematic and precise mathematical approach which can ensure transparent assessment, which can be of great help in the evaluation of vague and ambiguous or unstructured data. The use of fuzzy logic can help in incorporating qualitative inputs taken from the experts and stakeholders and further translating them into quantitative assessment, which helps in bridging the gap between the distinct perspectives in the process of evaluation.

1.INTRODUCTION

Fuzzy logic represents a specific logic of impressions, it is not fuzzy. The concept of fuzzy logic was created by Lotfi Zadeh in 1965 as an extension of a concept of classical logic or Boolean logic.The concept of Fuzzy logic is meant essentially for dealing with the vagueness and unclear aspects. This concept was introduced to showcase the functioning of human reasoning on a day-to-day basis. Fuzzy logic is a degree of truth, unlike a binary logic which lies between either and or; fuzzy logic ranges between 0 to 1; whereas a binary logic is 0 or 1. As the decisions we make are based upon logical rules. What we are going to experience due to bad service or behavior of the server, the chances of tipping the server low would be higher based upon one's experience.

The concept of fuzzy logic represents the ways of dealing with uncertainty. Merriam Webster dictionary defines fuzzy as not clear or uncertain; logic as a science dealing with principles of logic and techniques as a method of completion of a desired aim or result.

With the recognition of the right to a clean, healthy & sustainable environment as a universal human right, the United Nations General Assembly has made a landmark move, furthering the objective of sustainable development for all. One of the most significant developments at the Rio De Janeiro (Earth Summit), 1992 was the adoption of the Rio Declaration on Development and Environment introduced an instrument to assess the potential impact on the environment of the economic activity via Principle 17.[i] The Earth Summit of 1992 led to the reaffirmation of the Stockholm Declaration which was adopted on June 16, 1972, which established the goal of building and establishing a global partnership for the first time at the international level for the human environment and created various levels of cooperation amongst nation-states. This opened the door for international agreements for the establishment of a global system of protection of environmental development system, while keeping in view the multifaceted interest of all; focusing on the protection of Earth, our home.

The concept of assessment under environmental protection is considered to be one of the most important factors in ascertaining the balance between environment conservation and need for the economic development. When we speak of the concept of environmental Impact Assessment (EIA), it acts as a tool of sustainable development along with other measures like Social Impact Assessment (SIA) to identify the implications of economic activity on humans and the environment.[2] The use of fuzzy logic has been incremental in terms of dealing with and managing uncertainty in terms of unclear data about the assessment of the environment and its interdependent components.[3] The use of fuzzy logic has made the assessment of uncertain data to be done more effectively as it allows the movement beyond the stagnant outcomes of yes and no, while dealing with the diverse and volatile nature of data collected about the environmental condition; fuzzy logic proves to be more beneficial when it comes to moving beyond the rigidity and shaping the uncertain data effectively.[4]

When it comes to the impact of any economic activities it is essential to be open to the possibility of all kinds of impacts which can be short-term and long-term. Data related to environmental aspects are always considered to be uncertain as there can be conditions that can limit or restrict the data collection process; also with the data collection, there is the possibility of insufficient data collected. In situations like these, the use of fuzzy logic may prove helpful in terms of dealing with uncertainty by integrating various degrees of outcomes instead of just yes (positives) or no (negatives). Another aspect that creates humungous differences is its role in the decision-making process, fuzzy logic system would help in the integration of the multi-dimensional aspects for example impact on ecology, water quality, and air quality; which will eventually help in the assessment of quantitative data in a subjective manner, which in turn will help in making informed decisions.

3.FUZZY LOGIC TECHNIQUES FOR THE ENVIRONMENT

The use of fuzzy logic has increasingly been used for Environment Impact Assessment (EIA) to handle the ambiguous/uncertain/imprecision that is often inherent in the assessment of the environmental effects. Environment Impact Assessment is widely been used as a tool to anticipate the adverse impact of economic activity on the environment. It is an integrated process which is playing a very important role in ascertaining the effect on the economic, social, and biophysical ambit; helping in preparing measures to mitigate the challenges posed by the developmental activities. It is a tool that helps in dealing with crucial concerns like pollution and health challenges by presenting a holistic perspective of the environmental impact.[5] The origin of concerns towards the environment took a more concrete picture with Rachel Carson's Book titled 'Silent Spring' published in the year 1962. [6] The work highlights the adverse impact of pesticides on human health and the environment, further focusing on the harmful effects of the development and technology on environmental sustainability. The period 1960s marks the beginning of the focus on environmental assessment and mitigating the challenges.[7]

The concept of Environmental Impact Assessment can be traced back to the first ever statutory mention in 1969 with the National Environment Policy Act (NEPA), which laid down the foundation for creating practices to accelerate environmental awareness in activities by taking into consideration and assessing the environmental impact of the proposed project/s. This concept of laying focus on the quality of the environment was primarily fixed by making the protection of the environment a part of procedures, which made it imperative for the federal agencies in the U.S. to incorporate the concerns of the environment while making decisions and taking action. The federal agencies are required to assess and prepare a statement on the environmental impact of the projects. For execution, monitoring, and coordinating all federal environmental efforts; a Council of Environmental Quality(CEQ) was set up under the executive office of the President. In 1972, the Stockholm Conference on Human Environment changed the course of and perspective of humankind towards the importance and role of environment in our lives.

One of the important turning points came when the World Council on Environment and Development presented and through Brundtland Report " Our Common Future". [8] the concept of sustainable development saw the light of the day. The ability to fulfill our needs, without compromising the ability of our future generation to fulfil their needs. It introduced the norm of sustainability at the World level, talking about the strategies, policies, and perspectives of attaining sustainable development for all.

During the period of 1978-79 in India, an Impact Assessment was conducted for the very first time for the river valley projects, later other projects were also covered like thermal power, mining, industries, infrastructure, developmental projects, etc. In 1992, at Rio in Earth Summit (A Conference for Environment and Development along Agenda 21(closing document) emphasized the need for a social, technical, and ecological system leading to the fulfillment of our goal of sustainability and finding strategies and tools to ensure environmental protection. Principle 17 of the Rio Declaration introduced EIA as a tool a national instrument in the hands of the government to ensure the assessment and identification of the adverse impact of proposed projects and to mitigate the same.to make it happen, it became imperative to establish some concrete guidelines and goals that are attainable both nationally and internationally.[9] In India, through the Environment Protection Act of 1986, EIA notifications were issued to ensure compliance in 1994, 2006 .

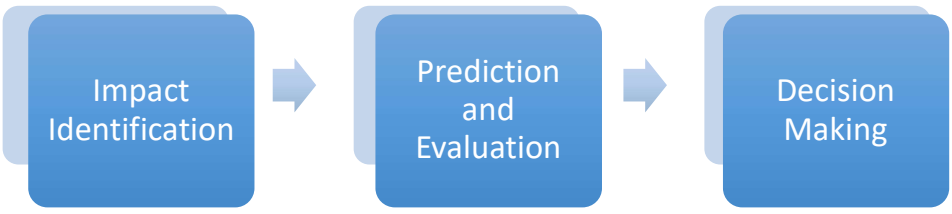

Fig.1: Model of EIA

The system of impact management focuses on the significance of identifying, predicting, evaluating, and forming

decisions in a process of Environmental Impact Assessment (EIA). The State Level Committee established under the EIA notification, is composed of experts of various fields working to identify and anticipate the possible impact of the proposed projects and to mitigate the adverse impacts.

In the assessment process of real-world situations, certainly, the conditions are not binary in nature as the truth can be expressed in varied forms and categories. For instance, when categorizing the temperature of a drink as cold or hot; people can also categorize them as warm or Luke warm or moderately hot. Looking at the core concepts of fuzzy logic involve sets that have degrees of membership. For example, a strict cutoff in sets of the category of young people may have varying degrees of membership falling under the category of young people based on their different age groups. Furthermore, the membership functions express how each point in the input space is particularly mapped to a degree of membership varying from 0 to 1. Similarly, in terms of linguistic variables also, fuzzy logic takes into consideration linguistic terms like low, medium, and high to describe variables that allow for more human-like aspects of reasoning along with decision-making. Also, the system of fuzzy logic is dependent often upon the system which focuses on if and then rules to make decisions.[10] For example, if the temperature is high, then the Ac temperature also needs to be high, this phenomenon can be interpreted with varying degrees which are essentially based upon fuzzy set definitions. The application of fuzzy logic creates a channel to handle partial truths and further imprecision is something which gives it a highly adaptable character for real-world issues; especially where data or information along with conditions are not clear in nature. Another aspect that one must take note of fuzzy logic is that it can be used in different domains like automotive systems, control systems, and decision-making processes. Further, it has human-like reasoning under which the fuzzy logic makes systems intuitive and enables them to situations which are not clear or vague and complex situations in an effective manner.[11]

Environmental data is imprecise or incomplete often; the usage of fuzzy logic enables the modelling and interpretation of this kind of uncertain data by using degrees of membership along with fuzzy sets, hence can better represent the data that is vague or uncertain. This eventually helps in the decision-making processes through the use of fuzzy rules along with the membership functions to evaluate and assess various environmental factors. For example, the assessment of the impact of the infrastructure project on the quality of the air can be done by taking into consideration fuzzy variables like impact which can be moderate or high. It helps in the assessment of environmental risks by the integration of various factors like level of pollutants, impact on health, time of exposure, etc which is easily quantifiable. This process helps in the development of the comprehensive model of risk assessment.

As we know the system of environment is very complex and involves various interacting variables. In this situation, the use of fuzzy logic creates flexibility and allows the modelling of these complex interactions which a binary system of logic might not be able to do. Furthermore, it leads to the incorporation of the qualitative inputs of the experts along with various stakeholders in translating the subjective judgment of the assessment into a quantitative form of assessment; this enables bridging the gaps that persist between different perspectives of the process of evaluation. Thus, the leveraging of the fuzzy logic in the environmental impact assessment can make the whole process of assessment more robust and allow the accommodation of the nuanced and subjective nature of environmental data and impact assessment.Furthermore, it is essential for the assessment of the potential or probable impact (adverse) on the environment which is actually not concrete but rather vague; the application of the fuzzy logic can be significantly useful as the very understanding of what we are taken under the category of environmental degradation; interpreting and understanding what actually would constitute or add up to be known as environmental degradation, itself is subjective; it is vague.[1[ii]] Hence, the usage of fuzzy logic in the techniques of assessment of environmental impact can be useful in terms of quantification of subjective judgment, most significantly dealing with environmental degradation as it would be proved helpful in providing a significantly comprehensive and flexible assessment. The sole objective of imposing certain limitations and restrictions while any project is being undertaken, solely to ascertain the adverse impact of the same economic activity or the project along with the modernization or modification of the ongoing project on the environment with the help of the environment impact assessment tool.

Another significant factor that plays an important role is the use of fuzzy logic as a technique of assessing the environmental impact of any project would be helpful in risk analysis in a comprehensive manner; as the possibility of evaluation of several ambiguous risks attached to or associated with the environmental sphere will help in

evaluation or appraisal of the imprecise or vague data and contradictory particulars. The use of fuzzy logic will help in channelizing and modelling frameworks to assess the potential impacts on the environment in a significantly stabilized fashion or balanced way. Furthermore, it is imperative and beneficial to include all stakeholders in the process of environmental impact assessment, often so this process involves engagement with the variegated opinions and perceptions of the people. The application of fuzzy logic can be supportive and help in the incorporation of these varied types of diversified inputs or sundry perceptions into the process of environmental impact assessment by making it a comprehensive process of impact assessment. Moreover, the use of fuzzy logic can lead to adaptive management which can help in the development of adaptive management techniques which in turn will help in the adjustment of changing conditions of the environment along with ever-changing information which will help in the improvisation of flexibility.[1[iii]] Overall, fuzzy logic enhances the robustness and flexibility of Environmental Impact Assessments by addressing the complexities and uncertainties of environmental data and decision-making processes. Amongst many measures, the use of fuzzy logic in the techniques of Environment Impact Assessment can be incremental in the attainment of the objective of balancing environmental and economic development together; finding the state of equilibrium for sustainable development.

3. ENVIRONMENTAL IMPACT ASSESSMENT: A KEY TO A HEALTHY AND SUSTANABLE FUTURE

The core objective of conducting an Environmental Impact Assessment is to predict the potential adverse effect of the proposed developmental projects on the human and environment. This identification tool is to be applied proactively, as it has the potential of not just identifying the possible impact of a project (even before the project has been implemented or carried out) but also has an objective of finding such measures to mitigate the effects of the project on the surrounding environmental and to ensure that the impact of adverse is reversible and to identify the irreversible implications. Thus, if the projects are found to be leading to adverse effects of an irreversible nature, then such projects have to be dropped or no grant/clearance shall be given. The main focus of EIA is to act as a tool that enables a balance the development and environmental protection. The EIA process helps in identifying the potent impact of a project on the environment which includes socioeconomic, cultural, and environmental components; leading to a healthy environment. Human health is one such aspect that is inherently related to environmental health.

It is a well-recognized fact that environmental health is directly proportional to human health. According to WHO, about 12 million people lose their lives due to health hazards every year around the world. Excessive deterioration of the environment in terms of pollution, land or soil degradation, and all types of contamination of essential elements of life like water, air, soil, etc are all leading humanity towards graver health hazards.[1[iv]] Health and EIA go hand in hand as the projects whether mining, construction, agricultural activities, etc shall have an impact on its surroundings, these impacts can be long-term or short-term, reversible or non-reversible, especially on the health of the people and ecology; it is imperative to conduct EIA to assess and identify the potent factors and potential threats and develop policy measures while estimating the assessed impact and take effective steps to protect the health and well-being of the targeted population or affected population.it is necessary to build such policies and programs which strictly allow only those projects to be implemented, which will be benign to the environment and human health.

Screening, scoping, assessment, recommendation, reporting, monitoring, and evaluation of the proposed projects are to be thoroughly done to identify the potential impact on health. Every economic activity whether industrial or agricultural can create an adverse impact on human health and the overall health of the environment; right from the community's access to nutritious food, water, and air to climate change is causing humungous human and environmental health hazards. Thus, it is important to protect the ecosystem through biodiversity conservation and sustainable uses of resources; in this, EIA plays a crucial role in identifying the critical areas where the proposed economic activity can impact. And, also helps in identifying, planning, and implementing the measures to mitigate the identified challenges, EIA can play an essential role in protecting and maintaining the good quality of air, water, soil which are essential for human and environmental health and well-being. However, the only way of ensuring this predictive assessment of potent impact/s on human health and the environment is through an Effective implementation of Environment Impact Assessment.

4. CHALLENGES AND SOLUTIONS

One of the prominent challenges in terms of collecting data is inaccurate or incorrect or inadequate baseline data leading to incorrect EIA Reports, lack of monitoring and compliance being done by proponents, and ineffective public participation leading to lack of coordination and ineffective decision making. To understand the challenges in the applicability of fuzzy logic in environmental assessment; it is essential to determine the effectiveness of fuzzy logic in conducting environmental impact assessment. Although, Fuzzy logic helps in the integration the of the qualitative entities belonging to the mathematical models; it further helps in the representation of methodology of a transparent nature. However, in the presence of several environmental indicators like water, quality of soil, air, etc; it is imperative to characterize these indicators with the help of an analytical system but the characteristics of the environment are such that they vary locally, regionally, nationally; in situation like this the biggest challenge is to calculate the dynamic behavior of these indicators though the analytical system. Hence, the fuzzy logic-based mathematical system has to be used. Amid the varied types of data available; the use of fuzzy logic which doesn't focus on fixed and precise information, will give space for the dynamic interpretation of the data along with the linguistic variables and use of mathematical precision. Another challenge can be the collection of information can be inaccurate; however, it can be used in times dealing with inaccurate inputs. Other challenges can be the rules being predetermined, in such a situation if the rules are turned out to be faulty then it affects all processes. Further, to create a fuzzy logic system, it is imperative to create more accurate membership functions that can define fuzzy rules and adjust the system to handle different types of environmental factors. However, this can make the whole system more complex and thus, difficult in terms of designing and implementing efficiently, mainly in terms of large-scale environmental impact assessment along with the diverse environmental factors. This can be resolved with the help of technological tools (software tools) or make use of pre-built fuzzy logic libraries, which can be useful in assisting with defining membership functions along with the automating rule creation.

Along with this, the inculcation of a multi-disciplinary approach in terms of deriving help from ecology, environmental science, and computer science for the creation of more accurate models can be beneficial and effective. To do the proper estimation of the impact of proposed projects, it is imperative to evaluate environmental factors and impacts caused due to economic activity. With the help of the mathematical model, a high degree of objectivity can be attained as it carries the possibility of addition and deletion of parameters and can easily redefine patterns used, range, along rules implemented.

Another challenge in the realm of using fuzzy logic in the conduction of EIA is due to the inherent complexity of the Environmental systems poses difficulty with the different interconnected factors like socio-economic, technological, ecological, and cultural; as the interaction between these factors happens at the linear level, it often becomes difficult to predict the outcomes. In situations like this, the usage of fuzzy logic can allow the modeling of multi-dimensional relationships by acknowledging a distinct range of all possible outcomes rather than just looking at a single deterministic answer. Also, the multi-dimensional phenomena allow the appreciation of the interaction between the multi-dimensional domains. Furthermore, one of the challenges can be the lack of a clean-cut threshold to determine the relevance of the environmental impact; as the different stakeholders may carry different opinions about what will be acceptable or not acceptable in terms of impact. In such a case, the use of fuzzy logic can provide qualitative judgments and a more nuanced flexible approach to the assessment of environmental impacts, most importantly in a scenario, where precise thresholds are not there. When the integration of fuzzy logic seems difficult then the inclusion of the hybrid methods can prove to be beneficial for the improvement of the precise quality of data. Traditionally, the use quantitative methods like cost-benefit analysis, multi-criteria decision analysis(MCDA) along expert judgement have been used in conducting EIA. [15] In situations like these, integration of fuzzy logic can be difficult in a technical sense. However, through hybridization integration can be done in prevailing techniques of Environment Impact Assessment. The use of Fuzzy logic can be induced in areas of multi-criteria decision analysis framework to deal with the uncertain evaluation process. This mechanism can further prove the effectiveness of the traditional quantitative methods by improving the precision in terms of qualitative assessments.

It is a well-known challenging fact that to conduct EIA, a humungous amount of data is to be collected that to be from diverse sources; many times such sources can not be comparable or are not standardized. Introducing Fuzzy logic techniques can be beneficial while considering different types of inputs coming from different sources. With the help of fuzzy sets and the use of fuzzy inference systems, the translation of data into a common fuzzy framework

enables comparison and helps in the aggregation of the diverse nature of data.
Another important aspect is the engagement of multiple stakeholders with different perspectives, coming with distinct types of values and concerns. In such a scenario, reaching a consensus on the question of environmental impacts can be challenging, especially when dealing with subjective types of judgments. In this situation, the use of fuzzy logic can help in designing models for stakeholder preferences with the help of fuzzy rules and help in decision matrices facilitating further communication; this can help in providing a holistic overview of the environmental impact. The Fuzzy logic technique is based on computation, especially when dealing with large amounts of data involving complex systems of Variables, which makes the process of EIA a lot time-consuming and resource-intensive (heavy).To deal with this challenge, simplifying the model of fuzzy logic can help in reducing the number of variables.[16] Along with this advanced computational tools like machine learning algorithms can be used for more efficient processing. Thus, it is prevalent that the application of fuzzy logic demands a high degree of technical proficiency and technical expertise, which can help in understanding the theoretical aspects involved in the fuzzy system and its implementation in practice. Oftentimes, one of the biggest challenges is that the experts may lack the required skills to use the technique of fuzzy logic effectively. This gap can be bridged with the help of the training programs and, the use of user-friendly software; helping in learning and application of the technique of fuzzy logic efficiently. Furthermore, the validation or verification of the results can be a task or limitation of the techniques of fuzzy logic, which can be overcome by the use of sensitivity analysis and can be integrated into the process to test the validity of the fuzzy models in the light of data inputs; along with this inculcation of traditional validation techniques with fuzzy logic can be beneficial to ensure the reliability of results.

4. CONCLUSIONS

With the growing environmental challenges, the impact of urbanization and industrialization is felt with greater intensity. Although the need to improvise and develop remains constant the possibility of dealing with the potential adverse impact of these economic activities remains a potent struggle. Countries around the World are developing such processes which can help in assessing the cumulative impact of the economic projects on social, economic, cultural, and health factors. A right to a healthy and wholesome environment also entails the phenomena of Human health; however, it is still very vague in terms of its assessment. The SDGs along with the environmental impact assessment allow identifying and addressing the human concerns regarding health, sanitation, clean air, water, livelihood, community, etc. Environment Impact Assessment is a way of finding alternatives and adopting the one that helps in striking the balance between environmental and economic harmony; it helps in comparing the alternatives and acts as a tool for mitigating adverse impacts by anticipating the effect of the proposed project and finding the mitigating measures.
Environmental Impact Assessment is a result of not only environmental data but also social and economic impact caused by the developmental activity. It is an anticipatory tool to manage the adverse impact on the environment by finding measures to mitigate the probable challenges to limit the possibility of irreversible damage.[v] Environmental impact assessment cannot be done without assessing the impact of the economic and social factors. Fuzzy logic allows the handling of uncertain data; often imprecise and incomplete for the assessment process by utilizing the degree of membership and using fuzzy sets, which can be used in representing vague and ambiguous information. Further, it can be helpful in the process of decision-making, evaluation, and weighing the different types of environmental factors like the high pollution or the kind of impact whether low, moderate, or high which can be essential aspects of assessment when it comes to the assessment of the environmental impact of any construction project. Fuzzy logic can play an incremental role in evaluating the risks associated with environmental factors by determining the health impact, pollutant levels, times of exposure, and such factors that are not easily quantifiable, hence this method of assessment helps conduct a comprehensive risk assessment.
The flexibility of the fuzzy logic allows the modelling of the numerous complex interacting variables. It offers new potential for the integration of complex information via a systematic and precise mathematical approach which can ensure transparent assessment, which can be of great help in the evaluation of vague and ambiguous or unstructured data. The use of fuzzy logic can help in incorporating qualitative inputs taken from the experts and stakeholders and further translating them into quantitative assessment, which helps in bridging the gap between the distinct perspectives in the process of evaluation. Hence, by leveraging the method of fuzzy logic in the assessment of the environmental impact, the whole process can become more robust and can accommodate the subjective nature of

the environmental data and its impacts; finding effective measures to mitigate challenge; leading us towards a healthy and sustainable tomorrow.

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