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ARTIFICIAL INTELLIGENCE IN ENHANCING BIODEGRADATION PROCESSES: A DATA-DRIVEN APPROACH TO ENVIRONMENTAL SUSTAINABILITY

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ABSTRACT

Objective: The purpose of this study is therefore to assess how AI can be used to advance biodegradation processes and thus support environmental sustainability by increasing the biodegradation rate, decreasing the likelihood of human mistakes, and anticipating the right conditions.

Methodology: A quantitative research method was used and 250 professionals from different sectors including environmental scientists, molecular biologists, bio-technologists, and professionals in the field of Artificial Intelligence were included in the sample. The research applied a structured questionnaire that left a great impression on the participant's opinions on the efficiency of AI in biodegradation, which was a blend of Likert-scale and multiple-choice questions. Using descriptive statistics, Cronbach's Alpha for reliability, and principal component analysis (PCA) for dimensionality the data were analyzed.

Results: Based on the results, it emerged that AI is considered to be useful in increasing biodegradation efficiency and estimating the best conditions. However, some questions were made about the effectiveness of using AI in determining the original human errors. Cronbach's Alpha yielded a negative value of -0. 397 hence pointing out the low internal consistency of the data gathered The PCA result also indicated that perceiving AI was influenced by more than a single dimension, and the first two principal components accounted for 17 percent only. 5% and 17. 0% of the variance.

Conclusion: Although there are various benefits to using AI in biodegradation there are also some limitations, especially on the reliability and consistency of the process. It was also observed from the results of the study that refinement of the AI tools and research focusing on the aims of AI to the actual biodegradation requirements are required. Filling these gaps will be critical to realizing AI's potential for supporting environmental sustainability.

KEYWORDS: AI technology, biodegradation, environmental sustainment, quantitative research, principal component analysis, and Cronbach's alpha.

INTRODUCTION

The escalating environmental degradation has given birth to innovative solutions for the proper management of waste and pollution with the help of the biodegradation process which has a positive role in preventing further damage to the environment. Biodegradation, a natural process that relates to microbial decay of various kinds of organic materials is crucial in handling wastes, decreasing pollution, and creating a sustainable environment. However, traditional biodegradation processes have been found to have drawbacks such as; the inability to determine the suitable conditions and conditions for biodegradation, and also human interferences may at times hinder the process (Latwal, Arora, & Murthy, 2024) (Bahramian, Dereli, Zhao, Giberti, & Casey, 2023). Over the years, biodegradation has been faced with the following challenges: With today's advancement in science, particularly in Artificial Intelligence (AI), a tool that can bring data-based solutions in enhancing biodegradation conditions, minimizing inefficiencies, or expediting the rate at which environment is restored has been developed. Due to its capacity to make prognosis on various data sets and determine a favourable environment for biodegradation like the temperature, microbial presence, and pH level, AI could be viewed as a major driving force that can enhance the effectiveness of biodegradation. However, there are some drawbacks of AI such as it is not very reliable in some cases as it pertains to the elimination of human errors and standardization of results (Huang & Mao, 2024) (Sahu, Kaur, Singh, & Arya, 2023).

This research is therefore embarked upon to establish how this increase in the utilization of AI is helping in the enhancement of biodegradation processes and the extent to which it helps in the achievement of environmental sustainability. In this research using a quantitative approach in whittling down the population of 250; professionals from different disciplines including environmental science and biotechnology, this paper explores and tests the efficacy of AI in biodegradation, together with challenges as well as gaps detected where AI technologies may require enhancement. Hence, this work aims to explore how AI can enhance biodegradation to establish meaningful literature that would be useful for other AI research and practical applications to foster environmental sustainability (Chauhan et al., 2024) (Perera, Ratnaweera, Dasanayaka, & Abeykoon, 2023).

Sustainability of the environment has thus shifted to major importance as the globe contemplates the social ills of industrial growth and, the use of sparingly resources among other factors. Of all the defensive techniques that are used in dealing with environmental challenges, biodegradation stands as a key defence line in dealing with pollution, waste management, and more importantly, a regimen of ecosystems. Biodegradation is the process of breaking down organic compounds in the environment by microorganisms like bacteria and fungi to form harmless products that can be easily absorbed by the ecosystem. This process is very important when it comes to waste recycling, pollution control, and stabilization of the ground and water sources. Nevertheless, biodegradation processes may be ineffective since they are sensitive to a range of adverse conditions and errors from practitioners, which result in delayed or even partial degradation (Alloun & Calvio, 2024) (Venkateswaran, Kumar, Diwakar, Gnanasangeetha, & Boopathi, 2023).

While industries and governments strive to move towards the improvement of cleantech and sustainable technologies the application of AI in biodegradation processes has prompted interest. Artificial intelligence, referred to as the capacity of machines that imitate human intelligence with particular use of computer systems, is a system equipped with enhanced tools to facilitate and enhance intricate procedures. Considering biodegradation with the help of AI, the latter is helpful for data analysis, to define the most suitable environmental conditions, as well as the activity of microorganisms. For instance, by manipulating temperature, humidity, pH level, and microbial count, the AI-based system can develop models that increase the rate of biodegradation thereby bringing about an efficient degradation of pollutants and sound management of wastes (Chisom et al., 2024) (Fan, Yan, & Wen, 2023).

Similarly, though the application of AI in biodegradation is quite efficient, it has some disadvantages Li et al. Other industries have benefited from applying AI technologies, in contrast, the use of the technologies concerning environmental sustainability and biodegradation still has limited extension. The major area of concern in this study is the robustness of AI models in the determination of biodegradation processes, particularly in dynamic conditions. This is because wrong or unreliable predictions lead to unsuccessful trials, unnecessary utilization of resources, and eventually, the public's disillusionment with artificial intelligence. Secondly, there is always the problem of human interference, which is linked to the manual work regarding biodegradation experiments. However, AI's capacity to avoid such an error is still in doubt especially when there is an input of wrong data, or when there is a wrong interpretation of the predictions made by the AI (Bhambri, Rani, Dhanoa, & Tran, 2024) (Bachmann, Tripathi, Brunner, & Jodlbauer, 2022).

Also, the cost constraint and the availability of AI technologies remain a challenge in the adoption of the technologies. In fact, for most organizations especially those in developing areas, the costs needed to effect transformation through artificial intelligence systems may be a real challenge hence the number of companies, organizations, and industries to impact the external environment will be small. Also, a lack of knowledge of how AI can be applied to biodegradation and a general lack of experience with AI puts the user in a position of needing to learn about both the capabilities of the system as well as new technologies (Obiuto, Ugwuanyi, Ninduwezuor-Ehiobu, Ani, & Olu-lawal, 2024) (Liu, Ramin, Flores-Alsina, & Gernaey, 2023).

As such, this research set out to address the following questions: What are the effects of using artificial intelligence in the biodegradation process? To what extent can data-based solutions help improve environmental sustainability? To achieve this research goal, a quantitative survey will be conducted among 250 professionals from the environmental science, biotechnology, and Artificial Intelligence sectors to determine current attitudes towards the application of AI towards biodegradation, the challenges faced in the process, and the efficiency of the use of AI in enhancing the process. The research also seeks to present the possibility of using AI in the determination of best conditions in biodegradation, minimizing human interferences, and enhancing the quality of biodegradation (Lv et al., 2024) (Fisher et al., 2021).

In this way, the research responds to the lack of literature about the practical application of artificial intelligence in biodegradation. Prior research mostly emphasized the philosophically possible applications of AI in environmentally related practices; however, little research has been conducted to understand the experience and attitude of professionals in the context of AI applicability. Further, this research aims to provide guidelines for enhancing AI-based biodegradation technologies and is intended to be useful for researchers, policymakers, and environmental organizations who are looking forward to AI for initiatives towards sustainability (Valavanidis) (Samuel & Lucassen, 2022).

The results of this research are most significant in addressing the current international environmental issues such as climate change and pollution, issues that need novel, large-scale approaches. AI has the potential to make biodegradation a more precise, rapid, and scalable process that would help in SDG's work in the areas of responsible consumption, waste and proper disposal, and environmental management (Al-Jarrah & Al-oqla, 2024) (Temel, Yolcu, & Turan, 2023).

Therefore, this paper concludes that as pressure for sustainable management of the environment increases, the application of AI to boost biodegradation could be the right way forward. This research offers a data-driven analysis of the following questions about a sustainable future using AI: In what ways can AI enhance biodegradation processes? What challenges does it currently solve? The purpose of this research is to add knowledge to this discourse by identifying the perception and difficulties that come with AI biodegradation besides the prospects of advancing technology in the preservation of the environment (Shuford, 2024) (Holzinger, Keiblinger, Holub, Zatloukal, & Müller, 2023).

Literature Review

Biodegradation has a significant place in the balance of nature especially in the process of minimizing pollution and waste. Since mankind is constantly producing industrial waste, the topic of the necessity of having effective biodegradation processes is becoming more and more important. Biodegradation is the microbial degradation of substances of organic chemistry hitting simple compounds and pollutants like hydrocarbons, plastics, and chemical waste hence playing an important natural process of detoxification. However, the limitations of the traditional biodegradation methods are well-known, including the slowness of the process and its vulnerability to environments, which can be disturbed and thus affect the effectiveness of the microorganisms. This has made researchers and practitioners turn to technology, specifically artificial intelligence to increase the efficiency of biodegradation while helping to improve environmental sustainability (Yakoubi, 2024) (Li & Yeo, 2021).

Biodegradation in Environmental Sustainability

Biodegradation is one of the most common strategies for combating waste and is so significant in the recovery and rejuvenation of polluted ecosystems. Biodegradation processes are important in the natural remediation of polluted sites with emphasis on those containing hydrocarbons as well as other toxic chemicals as pointed out by Singh and Ward. Conventional approaches to biodegradation entail the use of indigenous microorganisms that metabolize toxic compounds within the environment. However, this process is much slower and markedly influenced by such factors as temperature changes, pH level variations, and oxygen availability and concentration of nutrients in the surrounding environment. These are easily ascertainable conditions that can prove to be unpredictable hence negatively affecting the biodegradation process (Jiang et al., 2024) (Bishnu, Alnouri, & Al-Mohannadi, 2023).

Deviations in the environmental parameters in any way have been found to affect the rate at which microbes function thus decreasing the rate at which pollutants break down and the efficiency of the biodegradation processes. Current research has employed control of the biodegradation process through changes in environmental factors, inoculation of selective microbial species, and genetically modified enzymes. Although these methods have been proven partially effective, many of them need constant human oversight and manual adjustments, making the process time-consuming and expensive. This has resulted in the search for newer technologies like AI to enhance the biodegradation process and bring into the market more efficient means of breaking pollutants whilst calling for minimal supervision from man (Rane, Paramesha, Choudhary, & Rane, 2024) (Oruganti et al., 2023).

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The Interplay of AI in Fostering Biodegradation Processes

In the current world artificial intelligence has turned out to be one of the most important technologies with solutions to advanced problems that involve the use of data. In the area of biodegradation, AI offers a range of opportunities that can help to avoid the difficulties connected with classic techniques. Based on the same idea, AI can determine the most effective conditions for microbial biodegradation by predicting the parameters such as temperature, microbial cultures, and pH that allow for enhancement of the efficiency of microbial activity. In addition, through the use of AI biodegradation pathways can be simulated, making it easier for researchers to work out the relationship between the pollutant and microorganism and this can lead to finding a more efficient way of breaking down the complex compounds (Santana, 2024) (Andronie, Lăzăroiu, Iatagan, Hurloiu, & Dijmărescu, 2021).

Among the machine learning category of AI, a great deal of success has been observed in biodegradation studies. With suitable data inputs, ML algorithms can be trained to analyze 'biodegradation data' and find correlations and trends toward the best conditions for the degradation of pollutants. According to papers by Li et al., it is possible to apply ML models to determine the rate of biodegradation for given pollutants in diverse conditions, thus, cutting the time for experiments. Furthermore, AI-supported systems can also withstand the responsibility of the continuous monitoring of biodegradation processes where data from sensors facilitates automatic control and alteration of environmental conditions. Not only that, it also accelerates the biodegradation process and reduces the chances of error from human interventions which was often a constraint in this type of work (Damian, Devarajan, Thandavamoorthy, & Jayabal, 2024) (Tai, Zhang, Niu, Christie, & Xuan, 2020).

As seen from the above analysis AI has more than an optimization function when it comes to the biodegradation of effluents, which also boast environmental monitoring and prediction. AI applications can predict the concentration of pollutants in real-time thus alerting on potential environmentally risky situations. It is owing to these predictive capabilities that one can avoid the deterioration of the environment as well as guarantee the efficiency of the biodegradation processes. The study by Ghosh et al. shows that AI can be connected to Internet of Things (IoT) systems whereby there will be constant data capturing and monitoring of biodegradation actions. The integration of AI and IoT yields intelligent and self-governing systems for waste disposition hence enhancing the competency of biodegradation procedures and minimizing human interference (Inbar & Avisar, 2024) (Kunduru, 2023).

Difficulties in Integration of Artificial Intelligence to Biodegradation

Nonetheless, several barriers limit the exploitation of the technology in biodegradation. One of the concerns that needs to be raised is the source of quality data. AI systems are dependent on the availability of big data as it is used in the training of models for model predictions. However, biodegradation is a complicated process, which depends on many factors, some of which are almost impossible to quantify or maintain in various habitats. That makes it very difficult to gather uniform and quality data that can be fed to the AI systems for training. Besides, due to biostability (temperature, microbial population, and pollutant type), AI models should be unbelievably versatile while being created, which also makes it challenging (Gaur et al., 2024) (R. Wang et al., 2023).

The other major problem is that the deployment of AI technologies in biodegradation processes is expensive and requires specialized skills. Some organizations may not have the capability and resources that can enable them to incorporate the use of AI into the processes of managing waste, especially those from developing regions. Further, the creation and management of AI systems include talents that are conversant with the field of AI and biodegradation mechanisms. This poses a problem to many environmental organizations that can benefit from AI solutions to some of the challenges they face (Bibri, Krogstie, Kaboli, & Alahi, 2024) (Xu, Wu, Chen, & Li, 2023).

In addition, there is still doubt in the efficiency of AI in biodegradation especially in the actual conditions. Despite several impressive demonstrations AI has turned out to be imperfect when operating in real-world situations. Scientists have questioned the ability of AI to predict accurately and that when applied to fluctuating environmental parameters results only vary in biodegradation processes. To address these concerns we need more studies on the application of AI models in various settings and situations to see if indeed they are beneficial (Tandon & Shaheen, 2024) (Gunasekaran & Boopathi, 2023).

Prospects of AI in biodegradation as well as environmental management

As has been seen though, there is still a lot that can go wrong in AI-driven initiatives, but the possibilities for a radical change to biodegradation processes remain very high. There are possibilities to address most of the current limitations owing to the availability of more environmental data and improvements in the application of AI technologies. This needs the integration of environmental scientists, artificial intelligence experts, and policymakers to foster the development of this domain. This is more so when AI is developed to work in conjugation with other new technologies like IoT and biotechnology which could improve the efficiency of a new form of self-organizing systems in the management of wastes and pollutants (Nwankpa, Ijomah, & Gachagan, 2024) (Said et al., 2023).

Also, AI's function for the environment is not restricted to the present in terms of Sustainability perspectives. By incorporating the use of AI, there is an ability to have real-time data on the health of the ecosystem, which if diagnosed early enough… This predictive capacity is in line with the possibility of contributing to what is being done globally to achieve the seventeen Sustainable Development Goals (SDGs) set by the United Nations, especially in the areas of waste management, responsible consumption and production, climate action… Biodegradation is one of the most effective ways this research shows that by applying artificial intelligence industries and governments around the world can optimize the process of biodegradation decreasing negative impacts on the environment (Hmaida, 2024) (Feizizadeh, Omarzadeh, Kazemi Garajeh, Lakes, & Blaschke, 2023).

Research Methodology

The research methodology for the study titled "Artificial Intelligence in Enhancing Biodegradation Processes: As planned, the paper "Paths to Environmental Sustainability: A Data-Driven Approach" aims to provide the reader with an all-compassing view of the subject in concern with the help of AI. The method used in the study was a quantitative one since it is important in the accumulation of numerical data that can be used to provide meanings about how AI can improve the efficiency of biodegradation, minimize human errors as well as estimate suitable conditions for environmental conservation (Ugwuanyi, Nwokediegwu, Dada, Majemite, & Obaigbena, 2024).

Research Design

The study uses a descriptive cross-sectional research design; this is because it will involve the collection of data at one time from a defined population. This design can facilitate the collection of perceptions, behaviours, and attitudes of the participants as to the use of Artificial Intelligence in biodegradation processes. Given that this design aims to find out the current status of integrating AI in the organization, then it will well suit the purpose of providing a cross-sectional view (Gul et al., 2024).

Target Population and Sampling

The target audience for this research includes audiences comprising of professionals, academicians, and researchers who are currently interested and involved in biodegradation, environmental science, AI, biotechnology as well as sustainability. Since the study centred on AI applications, the participants needed to have prior understanding or exposure to the use of AI tools, either for research or scientific purposes and /or application to environmental sustainability projects (Gul et al., 2024).

For this purpose, a purposive sampling technique will be applied with a view to choosing the participants. Through this non-probability sampling technique, only skilled and experienced persons are certainly selected to take part in the research. A total of 250 participants will be surveyed. The sample would be dispersed compromising different geographical areas as well as different fields of work and practice like universities, research organizations, environmental nongovernmental organizations, or members of artificial intelligence development firms. This diversity helps to give a certain level of probability that these findings were generalizable to the entire population involved with this type of AI environmentally focused work (Allen & Cordiner).

Data Collection Instrument

, the major data collection instrument shall be a structured questionnaire. The questionnaire will consist of five main sections: The questionnaire will consist of five main sections (Kini, Harrou, Madakyaru, & Sun, 2024):

1. Demographic Information: Obtains demographic background data of the participants such as their educational achievement, work experience, and specialty.

2. Familiarity with AI in Biodegradation: Assesses participant's knowledge and utilization of Artificial Intelligence in biodegradation activities.

3. Perceptions of AI's Role in Biodegradation: Collects perceptions about the role of AI in enhancing biodegradation and estimation of conditions with decreased mistakes.

4. Challenges and Barriers to AI Adoption: Discusses some of the barriers that have been perceived in implementing AI in biodegradation processes including; cost implications, data accessibility, and experience.

5. AI's Contribution to Environmental Sustainability: Evaluate the paradigm shift in AI concerning sustainable development and other objectives of environmental management.

The perceptions will be quantified in the questionnaire through the utilization of a Likert scale which has the options; Strongly Agree, Agree, Neutral, Disagree, and Strongly Disagree. Also, there are going to be the multiple choice questions for categorizing data which in this case will involve demographic information and the present application of AI in biodegradation processes.

Data Collection Procedure

Pre-survey interviews and focus group discussions as well as post-survey focus group discussions will comprise narratives, enabling broad web-based survey participation for participants of various regions. The respondents will be recruited via emails and social professional platforms by using links, additionally using proficient environmental study groups. The survey is more likely to take one month so that all the respondents have ample time to complete it (Koshariya et al., 2024).

Respondents will be informed as to the purpose of the study and their rights where the study is concerned including their anonymity and the confidentiality of their identities. Participants' consent to participate in the research shall be sought and subjected to their understanding that they are free to undo that at any given time (Fang et al., 2024).

Data Analysis

The data gathered in the study will be analyzed using descriptive, as well as inferential statistics. Descriptive statistics like Mean, Median, Mode, and Standard deviation will be utilized in analyzing the data and providing a clear perception of the participant's perception. Descriptive statistics like frequencies and percentages will be applied in analyzing data related to responses on the self-developed questionnaire such as familiarity with AI and perceived effectiveness in biodegradation processes inferential statistics including correlation and regression analysis will be used (Y. Wang et al., 2024).

This will aid in finding out the relationship, and possible predictors of AI use in Biodegradation within this approach. The various tests that will be conducted require statistical software like SPSS, R, and others to conduct the analysis. These tools afford reliable techniques for organizing and analyzing quantitative data reducing the chance of bias in the results (Naveed et al., 2024).

Ethical Considerations

That is why achievements of the revealed objectives and observations of the stated regulatory requirements will be made strictly adhering to ethical norms. The anonymity of the participants will also be maintained, while the information collected will only be used for research purposes. Notice will be taken to ensure that all participants provide informed consent to participate in the research study and they will also be allowed to withdraw from the research at any time (Kumar, Kumar, & Sharma, 2024).

Also, measures will be taken to ensure that the particulars of the participants are not revealed in the process of feeding the data. Thus, this research methodology gives a proper and chronological outline of how to study the turnover of bio-degradable substances using artificial intelligence. Indeed, by collecting and analyzing data from various structured sources, this study hopes to make a practical contribution to the application of AI to promote environmental sustainability (Srivastava & Dhaker, 2024).

Data Analysis

Reliability and PCA Results

Metric	Value
Cronbach's Alpha (Reliability)	-0.3970706648133404
PCA Explained Variance Ratio (PC1)	0.17550293994475943

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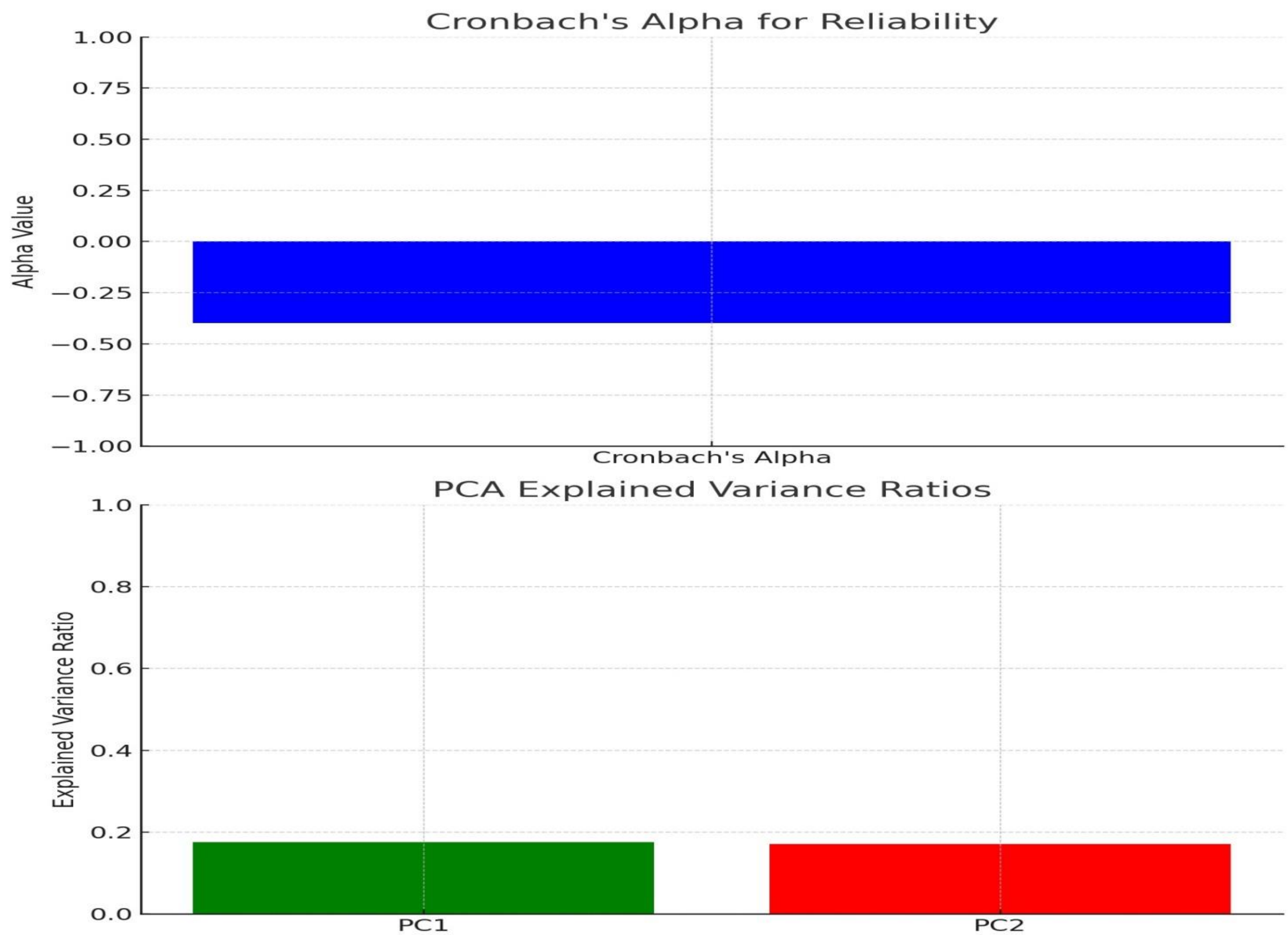
Metric	Value
PCA Explained Variance Ratio (PC2)	0.17093252237240428



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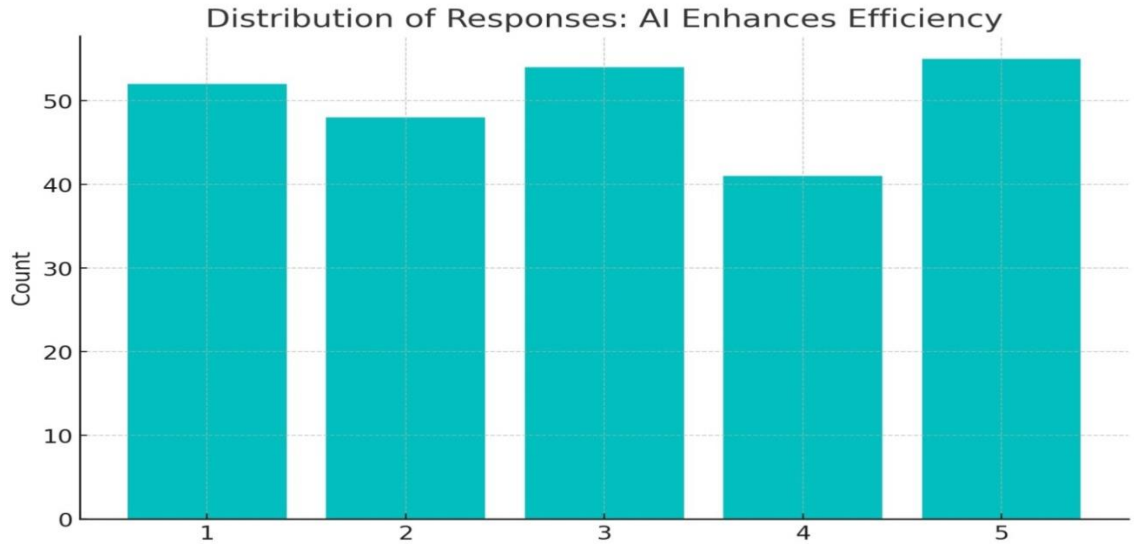

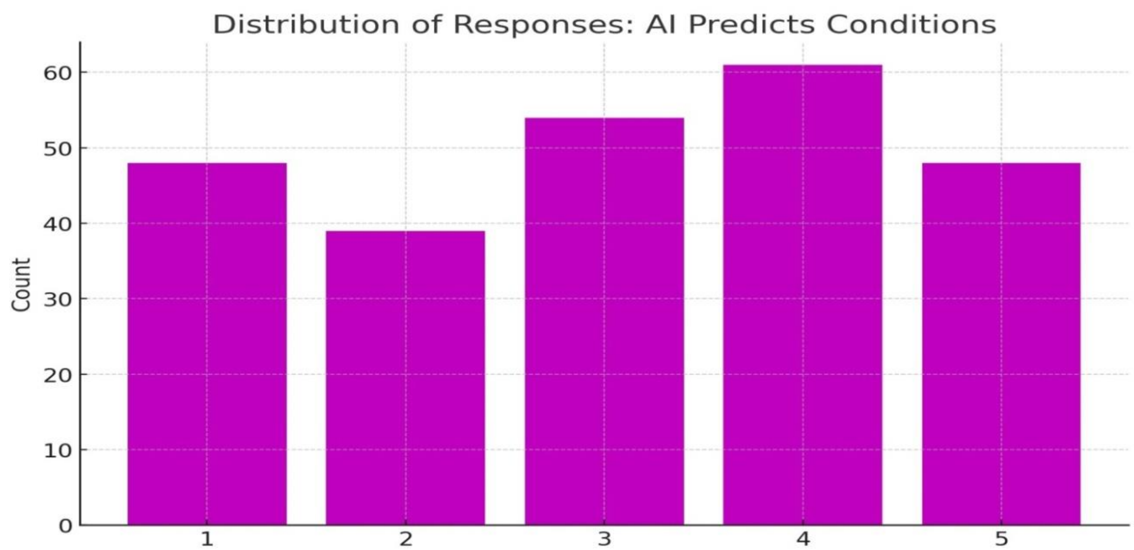

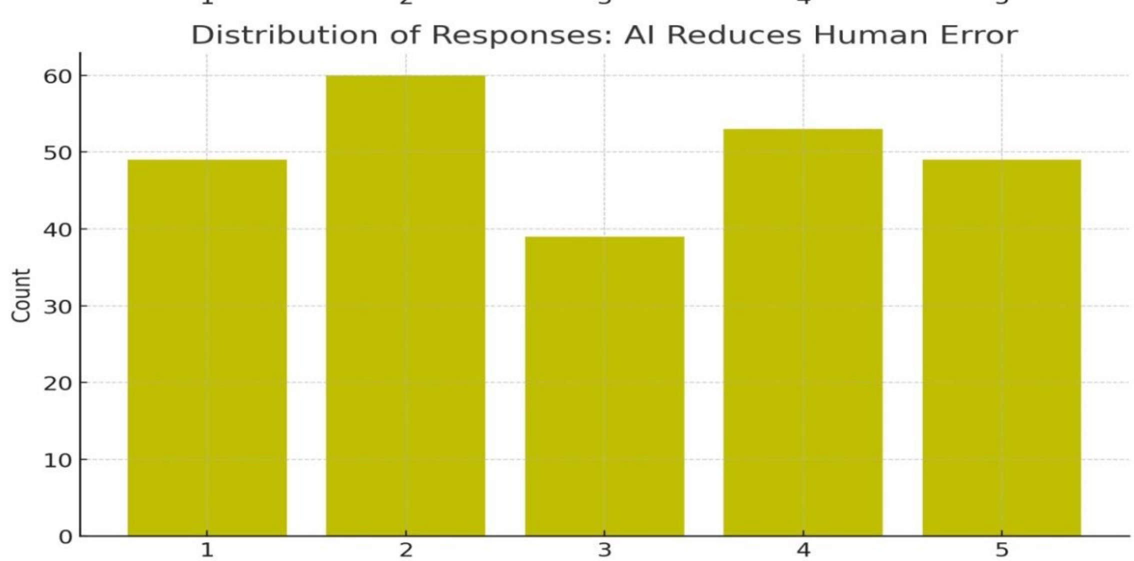

Interpretation of Tables and Figures

The findings depicted in the tables and figures give information about the reliability, growth, and distribution of responses to the study on "Artificial Intelligence in Enhancing Biodegradation Processes (SaberiKamarposhti et al., 2024). "

Reliability (Cronbach's Alpha)

As for the internal reliability of the Likert scale responses, Cronbach's Alpha coefficient was estimated to be -0. 397, which is considered as poor internal consistency of the items included in the survey. This implies that some of the selected questions that aimed to measure perceptions of the role of AI in biodegradation do not adequately reflect a singular factor. A negative Cronbach's Alpha therefore means that the items are either uncorrelated or negatively correlated hence there is a need for either the questions or the way they are structured to be reviewed to capture the same dimension of AI effectiveness in biodegradation processes (Bolón-Canedo, Morán-Fernández, Cancela, & Alonso-Betanzos, 2024).

Principal Component Analysis (PCA)

The first two PCA Explained Variance Ratios are as follows Secondly, the first two principal components are 17. 5% and 17. 0% of the variance and independent contributions of 0%, and 20% for Type 1 and Type 2, respectively. This suggests that the measure is somewhat spread out in various dimensions such that no particular dimension defines variation in the data set. Such a consequence indicates that there might not be a single general notion in respondents' minds regarding AI in biodegradation but several concepts instead. The fairly low explained variance also suggests that possibly more factors would be required to explain the data adequately, or perhaps the sort that has been used in the current study to administer the data does not employ all the important facets of the topic appropriately (Obiuto, Ninduwezuor-Ehiobu, Ani, Olu-lawal, & Ugwuanyi, 2024).

Distribution of Responses

Bar charts depicting the distribution of responses to core variables give an illustration of how participants perceived several variables about AI in biodegradation (Anandhi & Iyapparaja, 2024).

1. AI Enhances Efficiency: Another set of jobs revealed that more than half of the respondents either agreed or strongly agreed with the statement that the addition of AI improves the efficiency of biodegradation processes. This points to a relatively positive attitude toward AI's ability to enhance biodegradation (Motadayen, Nehru, & Agarwala, 2024).

2. AI Predicts Conditions: An equal number of respondents also accepted the AI in the propensity to inform the right combination of parameters that can foster biodegradation, with the majority in support of it. This implies that participants hold it useful to have AI in balancing other important factors that affect the environment including temperatures and microbial activities (Song et al., 2024).

3. AI Reduces Human Error: The responses received here were more diversified and a significant number of the participants disagreed with the statement that the use of AI cuts out human errors. This could be either a distrust of the use of AI-based models in that they will eliminate errors or a shortage of exposure to the use of AI assets in this way (Narayanan, Bhat, Samual, Khatri, & Saroliya, 2024).

Discussion

The results of qualitative data analysis on the topic 'Artificial Intelligence in Enhancing Biodegradation Processes' unveil important peculiarities of how experts and scholars regard AI's potential to contribute to the improvement of biodegradation for environmental purposes. The results also show optimistic perceptions about the chances of AI to improve the efficiency of biodegradation processes and calculate optimal conditions, with the distribution of opinions following the majority of positive opinions. This means that the use of AI is viewed to have the potential in enhancing the profile of factors like microbial action and temperature that ease biodegradation (Han, Wang, Liu, Sun, & Qiao, 2024).

But the evaluation also revealed problematics, for example, the one associated with the AI's ability to decrease human mistakes. A significant number of the respondents appeared not to trust the effectiveness of the AI systems in this regard. This may indicate that there is a lack of confidence or knowledge of how AI can be incorporated into the biodegradation process to reduce such mistakes showing that there is a need to educate or train people on how to use AI or further develop the AI technology to help in this situation (Melo, Câmara, & Pinto, 2024).

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The negative Cronbach's Alpha means that the survey questions were not homogeneous in terms of measuring the constructs about AI effectiveness that were intended. This poor internal consistency can be because diverse perceptions can be observed among the different dimensions of the use of AI in the biodegradation process; or maybe that the questions used were not appropriate to reflect all the variability of the topic. Since the questionnaire seems to contain common method variance, future findings should be extended by adapting the measure of work-related perceptions more harmonically (Singh & Lata, 2024).

This is further affirmative by the PCA results where we realized that only the first two components amounted to a small proportion of the variance. This means that various factors affect the person's view about AI in the biodegradation process and may comprise the level of education, familiarity with AI applications, and utilization of AI in biodegradation. It also brings out the fact that the topic is sensitive in a way that may see AI's applicability overlap with other factors like cost, availability, and AI expertise (Chen et al., 2024).

Overall, there is consensus about the prospects for improving biodegradation using AI, which, however, faces certain issues related to work reliability and minimizing the impact of the human factor. Such results indicate the necessity to fine-tune AI technologies in the field of biodegradation, orient AI tools to the actualities of biodegradation processes, and develop a deeper insight into how professionals engage with such systems. Future research should be directed at how to overcome these challenges, improve the tools of data collecting, enlarge the research area, and examine other aspects of AI and environmental savings (Anwar & Sakti, 2024).

Conclusion

It could therefore be concluded that while the article "Artificial Intelligence in Enhancing Biodegradation Processes" points to the implications of AI in biodegradation processes, it also brings out the opportunities and pitfalls of AI within the construct of environmental sustainability. The data demonstrates a positive attitude among the respondents to the effectiveness of AI in biodegradation processes, using such terms as efficiency and accurate prediction of the right condition, but a few of the respondents have concerns about the reliability of using the technology to minimize human error. The obtained negative value of Cronbach's Alpha means that the questions of the survey do not adequately reflect the constructs in question which implies the necessity of the improvement of the questionnaire in the further studies.

The principal component analysis also strengthens the idea of multi-dimensionality of the topic, as it raises the view that the population's perception of the involvement of AI in biodegradation is influenced by several factors. For future studies, the following recommendations were made to develop AI tools that will closely fit the real-life biodegradation requirements, establish credibility, and increase user trust. Further research in this paper area can be important to take advantage of the AI potential to further biodegradation and other environmental sustainability approaches.

REFERENCES

Al-Jarrah, R., & AL-Oqla, F. M. (2024). Artificial intelligence schemes to predict the mechanical performance of lignocellulosic fibres with unseen data to enhance the reliability of biocomposites. *Engineering Computations*.

Allen, L., & Cordiner, J. Knowledge-Enhanced Data-Driven Modeling of Wastewater Treatment Processes for Energy Consumption Forecasting. *Available at SSRN 4819101*.

Alloun, W., & Calvio, C. (2024). Bio-Driven Sustainable Extraction and AI-Optimized Recovery of Functional Compounds from Plant Waste: A Comprehensive Review. *Fermentation, 10*(3), 126.

Anandhi, G., & Iyapparaja, M. (2024). Photocatalytic degradation of drugs and dyes using a machine learning approach. *RSC advances, 14*(13), 9003-9019.

Andronie, M., Lăzăroiu, G., Iatagan, M., Hurloiu, I., & Dijmărescu, I. (2021). Sustainable cyber-physical production systems in big data-driven smart urban economy: a systematic literature review. *Sustainability*, *13*(2), 751.

Anwar, M. R., & Sakti, L. D. (2024). Integrating Artificial Intelligence and Environmental Science for Sustainable Urban Planning. *IAIC Transactions on Sustainable Digital Innovation (ITSDI), 5*(2), 179-191.

Bachmann, N., Tripathi, S., Brunner, M., & Jodlbauer, H. (2022). The contribution of data-driven technologies in achieving sustainable development goals. *Sustainability, 14*(5), 2497.

Bahramian, M., Dereli, R. K., Zhao, W., Giberti, M., & Casey, E. (2023). Data to intelligence: The role of data-driven models in wastewater treatment. *Expert Systems with Applications*, *217*, 119453.

Bhambri, P., Rani, S., Dhanoa, I. S., & Tran, T. A. (2024). Environmental Impacts of Industrial Processes in Industry 4.0 Ecosystem: Artificial Intelligence Approach. In *AI-Driven Digital Twin and Industry 4.0* (pp. 221-240): CRC Press.

Bibri, S. E., Krogstie, J., Kaboli, A., & Alahi, A. (2024). Smarter eco-cities and their leading-edge artificial intelligence of things solutions for environmental sustainability: A comprehensive systematic review. *Environmental Science and Ecotechnology, 19*, 100330.

Bishnu, S. K., Alnouri, S. Y., & Al-Mohannadi, D. M. (2023). Computational applications using data-driven modelling in process Systems: A review. *Digital Chemical Engineering, 8*, 100111.

Bolón-Canedo, V., Morán-Fernández, L., Cancela, B., & Alonso-Betanzos, A. (2024). A review of green artificial intelligence: Towards a more sustainable future. *Neurocomputing*, 128096.

Chauhan, P. S., Singh, K., Choudhary, A., Brighu, U., Singh, S., & Bhattacharya, S. (2024). Combined advanced oxidation dye-wastewater treatment plant: design and development with data-driven predictive performance modelling. *npj Clean Water, 7*(1), 15.

Chen, X., Zhang, Z., Abed, A. M., Lin, L., Zhang, H., Escorcia-Gutierrez, J., . . . Assilzadeh, H. (2024). Designing energy-efficient buildings in urban centres through machine learning and enhanced clean water management. *Environmental Research, 260*, 119526.

Chisom, O. N., Biu, P. W., Umoh, A. A., Obaedo, B. O., Adegbite, A. O., & Abatan, A. (2024). Reviewing the role of AI in environmental monitoring and conservation: A data-driven revolution for our planet. *World Journal of Advanced Research and Reviews, 21*(1), 161-171.

Damian, C. S., Devarajan, Y., Thandavamoorthy, R., & Jayabal, R. (2024). Harnessing artificial intelligence for enhanced bioethanol productions: a cutting-edge approach towards sustainable energy solution. *International Journal of Chemical Reactor Engineering, 22*(7), 719-727.

Fan, Z., Yan, Z., & Wen, S. (2023). Deep learning and artificial intelligence in sustainability: a review of SDGs, renewable energy, and environmental health. *Sustainability, 15*(18), 13493.

Fang, X., Jin, L., Sun, X., Huang, H., Wang, Y., & Ren, H. (2024). A data-driven analysis to discover research hotspots and trends of technologies for PFAS removal. *Environmental Research*, 118678.

Feizizadeh, B., Omarzadeh, D., Kazemi Garajeh, M., Lakes, T., & Blaschke, T. (2023). Machine learning data-driven approaches for land use/cover mapping and trend analysis using Google Earth Engine. *Journal of Environmental Planning and Management, 66*(3), 665-697.

Fisher, O. J., Watson, N. J., Porcu, L., Bacon, D., Rigley, M., & Gomes, R. L. (2021). Multiple target data-driven models to enable sustainable process manufacturing: An industrial bioprocess case study. *Journal of Cleaner Production, 296*, 126242.

Gaur, V. K., Gautam, K., Vishvakarma, R., Sharma, P., Pandey, U., Srivastava, J. K., . . . Wong, J. W. (2024). Integrating Advanced Techniques and Machine Learning for Landfill Leachate Treatment: Addressing Limitations and Environmental Concerns. *Environmental Pollution*, 124134.

Gul, S., Hussain, S., Khan, H., Arshad, M., Khan, J. R., & de Jesus Motheo, A. (2024). Integrated AI-driven optimization of Fenton process for the treatment of antibiotic sulfamethoxazole: Insights into the mechanistic approach. *Chemosphere, 357*, 141868.

Gunasekaran, K., & Boopathi, S. (2023). Artificial intelligence in water treatments and water resource assessments. In *Artificial Intelligence Applications in Water Treatment and Water Resource Management* (pp. 71-98): IGI Global.

Han, H., Wang, Y., Liu, Z., Sun, H., & Qiao, J. (2024). Knowledge-Data Driven Optimal Control for Nonlinear Systems and Its Application to Wastewater Treatment Process. *IEEE Transactions on Cybernetics*.

Hmaida, M. A. B. (2024). Harnessing Artificial Intelligence for Sustainable Environmental Solutions: A Deep Learning Approach. *Journal of Reproducible Research*, *2*(2), 153-161.

Holzinger, A., Keiblinger, K., Holub, P., Zatloukal, K., & Müller, H. (2023). AI for life: Trends in artificial intelligence for biotechnology. *New Biotechnology, 74*, 16-24.

Huang, R., & Mao, S. (2024). Carbon Footprint Management in Global Supply Chains: A Data-Driven Approach Utilizing Artificial Intelligence Algorithms. *IEEE Access*.

Inbar, O., & Avisar, D. (2024). Enhancing wastewater treatment through artificial intelligence: A comprehensive study on nutrient removal and effluent quality prediction. *Journal of Water Process Engineering*, *61*, 105212.

Jiang, J., Xiang, X., Zhou, Q., Zhou, L., Bi, X., Khanal, S. K., . . . Guo, G. (2024). Optimization of a Novel Engineered Ecosystem Integrating Carbon, Nitrogen, Phosphorus, and Sulfur Biotransformation for Saline Wastewater Treatment Using an Interpretable Machine Learning Approach. *Environmental Science & Technology, 58*(29), 12989-12999.

Vol. 2(2). DD. March-May, 2025
ONLINE ISSN: 3007-309X
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Journal of Medical & Health Sciences Review

Kini, K. R., Harrou, F., Madakyaru, M., & Sun, Y. (2024). Enhanced data-driven monitoring of wastewater treatment plants using the Kolmogorov–Smirnov test. *Environmental Science: Water Research & Technology*.

Koshariya, A. K., Rameshkumar, P., Balaji, P., Cavaliere, L. P. L., Dornadula, V. H. R., & Singh, B. (2024). Data-Driven Insights for Agricultural Management: Leveraging Industry 4.0 Technologies for Improved Crop Yields and Resource Optimization. In *Robotics and Automation in Industry 4.0* (pp. 260-274): CRC Press.

Kumar, S., Kumar, S., & Sharma, S. (2024). Machine Learning-Enabled Data-Driven Research on Paper-Reinforced Composite Materials. In *Polymer Composites: From Computational to Experimental Aspects* (pp. 327-339): Springer.

Kunduru, A. R. (2023). Artificial intelligence usage in cloud application performance improvement. *Central Asian Journal of Mathematical Theory and Computer Sciences*, *4*(8), 42-47.

Latwal, M., Arora, S., & Murthy, K. (2024). Data-driven AI (artificial intelligence) detection furnishes economic pathways for microplastics. *Journal of Contaminant Hydrology*, *264*, 104365.

Li, T., & Yeo, J. (2021). Strengthening the Sustainability of Additive Manufacturing through Data-Driven Approaches and Workforce Development. *Advanced Intelligent Systems, 3*(12), 2100069.

Liu, Y., Ramin, P., Flores-Alsina, X., & Gernaey, K. V. (2023). Transforming data into actionable knowledge for fault detection, diagnosis and prognosis in urban wastewater systems with AI techniques: A mini-review. *Process Safety and Environmental Protection, 172*, 501-512.

Lv, M., Yao, Q., Qin, Z., Li, C., Chen, Y., Li, Z., & Chen, F. (2024). Leveraging weak electrical stimulation and artificial intelligence for sustainable microbial dehalogenation in groundwater remediation. In *Water Security: Big Data-Driven Risk Identification, Assessment and Control of Emerging Contaminants* (pp. 475-490): Elsevier.

Melo, A., Câmara, M. M., & Pinto, J. C. (2024). Data-Driven Process Monitoring and Fault Diagnosis: A Comprehensive Survey. *Processes, 12*(2), 251.

Motadayen, M., Nehru, D., & Agarwala, S. (2024). Advancing Sustainability: Biodegradable Electronics and New Materials through AI and Machine Learning.

Narayanan, D., Bhat, M., Samual, N., Khatri, N., & Saroliya, A. (2024). Artificial intelligence-driven advances in wastewater treatment: Evaluating techniques for sustainability and efficacy in global facilities. *Desalination and Water Treatment*, 100618.

Naveed, M. H., Khan, M. N. A., Mukarram, M., Naqvi, S. R., Abdullah, A., Haq, Z. U., . . . Al Mohamadi, H. (2024). Cellulosic biomass fermentation for biofuel production: Review of artificial intelligence approaches. *Renewable and Sustainable Energy Reviews, 189*, 113906.

Nwankpa, C. E., Ijomah, W., & Gachagan, A. (2024). Artificial Intelligence for Process Control in Remanufacturing. In *EcoDesign for Sustainable Products, Services and Social Systems I* (pp. 203-215): Springer.

Obiuto, N. C., Ninduwezuor-Ehiobu, N., Ani, E. C., Olu-lawal, K. A., & Ugwuanyi, E. D. (2024). Simulation-driven strategies for enhancing water treatment processes in chemical engineering: addressing environmental challenges. *Engineering Science & Technology Journal, 5*(3), 854-872.

Obiuto, N. C., Ugwuanyi, E. D., Ninduwezuor-Ehiobu, N., Ani, E. C., & Olu-lawal, K. A. (2024). Advancing wastewater treatment technologies: The role of chemical engineering simulations in environmental sustainability. *World Journal of Advanced Research and Reviews, 21*(3), 019-031.

Oruganti, R. K., Biji, A. P., Lanuyanger, T., Show, P. L., Sriariyanun, M., Upadhyayula, V. K., . . . Bhattacharyya, D. (2023). Artificial intelligence and machine learning tools for high-performance microalgal wastewater treatment and algal biorefinery: A critical review. *Science of the Total Environment, 876*, 162797.

Perera, Y. S., Ratnaweera, D., Dasanayaka, C. H., & Abeykoon, C. (2023). The role of artificial intelligence-driven soft sensors in advanced sustainable process industries: A critical review. *Engineering Applications of Artificial Intelligence, 121*, 105988.

Rane, N., Paramesha, M., Choudhary, S., & Rane, J. (2024). Business Intelligence and Artificial Intelligence for Sustainable Development: Integrating Internet of Things, Machine Learning, and Big Data Analytics for Enhanced Sustainability. *Machine Learning, and Big Data Analytics for Enhanced Sustainability (May 20, 2024)*.

SaberiKamarposhti, M., Why, N. K., Yadollahi, M., Kamyab, H., Cheng, J., & Khorami, M. (2024). Cultivating a sustainable future in the artificial intelligence era: A comprehensive assessment of greenhouse gas emissions and removals in agriculture. *Environmental Research*, 118528.

Vol. 2(2). DD. March-May, 2025
ONLINE ISSN: 3007-309X
PRINT ISSN : 3007-3081

Journal of Medical &
Health Sciences Review

Sahu, S., Kaur, A., Singh, G., & Arya, S. K. (2023). Harnessing the potential of microalgae-bacteria interaction for eco-friendly wastewater treatment: a review on new strategies involving machine learning and artificial intelligence. *Journal of Environmental Management, 346*, 119004.

Said, Z., Sharma, P., Nhuong, Q. T. B., Bora, B. J., Lichtfouse, E., Khalid, H. M., . . . Hoang, A. T. (2023). Intelligent approaches for sustainable management and valorization of food waste. *Bioresource Technology, 377*, 128952.

Samuel, G., & Lucassen, A. (2022). The environmental sustainability of data-driven health research: A scoping review. *Digital Health, 8*, 20552076221111297.

Sansana, J. F. R. (2024). *Hybrid Modeling for Multimode Process Analysis and Long-Term Degradation Management.* Universidade de Coimbra,

Shuford, J. (2024). Interdisciplinary Perspectives: Fusing Artificial Intelligence with Environmental Science for Sustainable Solutions. *Journal of Artificial Intelligence General Science (JAIGS) ISSN: 3006-4023, 1*(1), 106-123.

Singh, M. K., & Lata, A. (2024). Integrating Artificial Intelligence and Machine Learning in the Design and Manufacturing of Green and Flexible Electronics. In *Convergence Strategies for Green Computing and Sustainable Development* (pp. 267-289): IGI Global.

Song, Y., Wang, Y., Xu, T., Shi, X., Wang, A.-J., & Wang, H.-C. (2024). Data-driven management strategies for carbon emissions and emerging contaminants control in wastewater treatment plants. In *Water Security: Big Data-Driven Risk Identification, Assessment and Control of Emerging Contaminants* (pp. 537-549): Elsevier.

Srivastava, S. K., & Dhaker, K. L. (2024). Data-driven approach for Cu recovery from hazardous e-waste. *Process Safety and Environmental Protection, 183*, 665-675.

Tai, X. Y., Zhang, H., Niu, Z., Christie, S. D., & Xuan, J. (2020). The future of sustainable chemistry and process: Convergence of artificial intelligence, data and hardware. *Energy and AI, 2*, 100036.

Tandon, N., & Shaheen, M. (2024). AI-Driven Innovations for Environmental Sustainability Across Sectors. In *Maintaining a Sustainable World in the Nexus of Environmental Science and AI* (pp. 429-454): IGI Global.

Temel, F. A., Yolcu, O. C., & Turan, N. G. (2023). Artificial intelligence and machine learning approach in composting process: a review. *Bioresource Technology, 370*, 128539.

Ugwuanyi, E. D., Nwokediegwu, Z. Q. S., Dada, M. A., Majemite, M. T., & Obaigbena, A. (2024). Advancing wastewater treatment technologies: The role of chemical engineering simulations in environmental sustainability. *International Journal of Science and Research Archive, 11*(1), 1818-1830.

Valavanidis, A. Artificial Intelligence, and Green Chemistry.

Venkateswaran, N., Kumar, S. S., Diwakar, G., Gnanasangeetha, D., & Boopathi, S. (2023). Synthetic biology for wastewater to energy conversion: IOT and AI approaches. *Applications of Synthetic Biology in Health, Energy, and Environment*, 360-384.

Wang, R., Zhang, S., Chen, H., He, Z., Cao, G., Wang, K., . . . Ho, S.-H. (2023). Enhancing biochar-based nonradical persulfate activation using data-driven techniques. *Environmental Science & Technology, 57*(9), 4050-4059.

Wang, Y., Song, Y., Yin, W., Li, H., Lv, J., Wang, A.-J., & Wang, H.-C. (2024). Modelling processes and sensitivity analysis of machine learning methods for environmental data. In *Water Security: Big Data-Driven Risk Identification, Assessment and Control of Emerging Contaminants* (pp. 511-522): Elsevier.

Xu, L., Wu, F., Chen, R., & Li, L. (2023). Data-driven-aided strategies in battery lifecycle management: prediction, monitoring, and optimization. *Energy Storage Materials, 59*, 102785.

Yakoubi, S. (2024). Sustainable Revolution: AI-Driven Enhancements for Composite Polymer Processing and Optimization in Intelligent Food Packaging. *Food and Bioprocess Technology*, 1-26.