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SEMINAR

Futuristic Research of Energy & Environment (FREE) 2023

15th November 2023

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UiTM Shah Alam, Selangor

PROGRAMME BOOK

SEMINAR FUTURISTIC RESEARCH OF ENERGY & ENVIRONMENT (FREE) 2023

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Message from the

Deputy Director of Energy & Environment Research Nexus UiTM (ReNeU)

Assalamualaikum w.b.t. and Good Day.

On behalf of the organising committee, it is with pride and enthusiasm that I welcome all participants to the **Futuristic Research of Energy & Environment (FREE) 2023** seminar.

FREE 2023 bringing together brilliant minds to explore the futuristic endeavour in energy and the environment topics. This seminar is also a platform to establish cross-disciplinary research partnership between Research Group (RG) and Research Initiative Group (RIG) that are in line with the New Industrial Master Plan 2030 (NIMP 2030). We believe this seminar is a great platform for researchers to share and discuss the latest developments and findings in energy and environment topics. We hope that FREE not only empowers but also increase confidence and visibility of our researchers in an enjoyable, beneficial, entertaining, and memorable for all of us.

I would like to congratulate and express my heartfelt gratitude to all FREE committee members and all those who have helped in one way or another to ensure the success of this significant event. Last but not least, on behalf of the committee, I humbly welcome all of you to the Futuristic Research of Energy & Environment (FREE) 2023 seminar and look forward to listening to your thoughts and futuristic research ideas synergizing with all Energy & Environment ReNeU UiTM researchers.

Thank you.

Assoc. Prof. ChM. Dr. Zainiharyati Mohd Zain

Keynote Speaker 1

ChM. WAN MAZLINA WAN HUSSEIN

SIRIM BERHAD

ChM. Wan Mazlina Wan Hussein started her career as a Research Officer with SIRIM in March 1995. She has been actively involved in life cycle assessment-based environmental sustainability projects since 2000. Her first experience in LCA project was initiated by leading a research grant project under MOSTI (IRPA) in 2002. In 2010, she was entrusted to spearhead the development of a national life cycle inventory database (Malaysian Life Cycle Inventory Database - MYLCID), a mandate given to SIRIM under the RMk9 developmental initiative to support sustainable consumption and production in Malaysia. Over the years of service, she has been involved in negotiating, planning, leading, and implementing various environmental sustainability performance assessment projects with both international and national level governmental and industrial stakeholders. Her involvement in the LCA-based projects, LCA-based product carbon footprinting (CFP) & company-wide GHG emissions quantification consultancy and advisory and ecolabelling criteria developmental work (for ISO's Type-1 green criteria and product CFP category rules) covers multi-sectoral entities, enables her to have a wide spectrum of understanding and perspectives on the application of life cycle-based environmental performance assessment towards environmental sustainability strategies.

Keynote Speaker 2

MR. ZAREEN KHAN ABDUL JALIL KHAN

MALAYSIAN NUCLEAR AGENCY

Mr. Zareen Khan Abdul Jalil Khan is a dedicated Senior Research Officer at the Reactor Technology Centre, Technical Support Division, Malaysian Nuclear Agency. He holds a B.Sc (Hons) in Physics With Electronics from University Malaysia Sabah (2001) and an M.ENG (Hons) in Nuclear Engineering from Tokyo Institute of Technology, Japan (2012). With expertise in Reactor Physics, Reactor Detection System, and Reactor Instrumentation and Control Engineering, he has been a key contributor since his appointment in 2001. He has successfully led several impactful research projects, including the development of Power Controller Systems and Automated Controller Systems for nuclear reactors. His notable contributions have been recognized through projects funded by ScienceFund MOSTI and the Malaysian Nuclear Agency. His commitment to nuclear research and his exceptional skills in reactor technology make him an invaluable asset to any scientific endeavor.

Keynote Speaker 3

Ts. DR. ROSHASNORLYZA HAZAN

MALAYSIAN NUCLEAR AGENCY

Ts. Dr. Roshasnorlyza Hazan is a highly accomplished Research Officer at Malaysian Nuclear Agency with an impressive 14-year background in Materials Science and Engineering. Her expertise includes precious elements extraction, metal oxide synthesis, and data interpretation. She has a proven track record of successfully organizing and executing research projects, leading initiatives in Materials Science and Engineering. Notable projects she has overseen include the extractive recovery of yttrium, synthesis of graphite-doped nanotitania, and applications of uranium/thorium-fueled high-temperature gas-cooled reactors. She has received accolades for her work, including the Best Poster Award at R&D Seminar Nuclear Malaysia 2022, the Gold Medal at Malaysia Technology Expo 2018, and the Silver Medal (Paten Category) for Anugerah Harta Intelek Negara 2016, showcasing her outstanding contributions and achievements. Additionally, she has authored numerous articles in academic journals, demonstrating her expertise in areas like photocatalysis, materials characterization, and nanoparticle synthesis.

PROGRAM TENTATIVES

TIME	ACTIVITIES
8.00 – 9.00 am	Registration & Breakfast
9.00 – 9.15 am	**Opening Ceremony** Negaraku, Wawasan Setia Warga UiTM songs and Prayer Recital by Mr. Shaqayyum Nuraiman Hadis
9.15 – 9.30 am	**Welcoming Remarks** YBhg. Professor Ts. Dr. Mohd Rozi Ahmad Director of Research Nexus UiTM (ReNeU)
9.30 – 10.00 am	***Keynote Speaker 1*** ChM. Wan Mazlina Wan Hussein Head Environment Management Section SIRIM Industrial Research Title: **Championing Environmental Sustainability Performance Through Life Cycle Assessment (LCA)**
10.00– 10.30 am	***Keynote Speaker 2*** Mr. Zareen Khan Abdul Jalil Khan Research Officer Reactor Technology Division, Technical Support Division Malaysian Nuclear Agency Title: **Introduction to Nuclear Reactor Technology**
10.30 – 11.00 am	***Keynote Speaker 3*** Ts. Dr. Roshasnorlyza Hazan Research Officer MTEG Group Industrial Technology Division Malaysian Nuclear Agency Title: **Rare Earth Elements - Critical Materials for Green & Renewable Energy Applications**
11.00 – 11.15 am	Photography Session
11.15 – 11.35 am	FREE10: **Dr. Siti Nor Atika Baharin (Advanced Biomaterials & Carbon Development (ABCD))** Immobilised Photocatalyst Substrates: A Way Forward for Large Scale Wastewater Treatment
11.35 – 11.55 am	FREE01: **Hairi Ponichan (Efficient Energy Conversion Technology (EECT))** Assessment of CO_2 Concentrations in Office Environments Using Neural Network Prediction Method

11.55 am – 12.15 pm	FREE03: **Shazlynn Alia Saiful Shamizam (Synthesis & Application of Conducting Polymers)** Development of Biocompatible Blended Electrolyte System Comprising Epoxidized Natural Rubber (ENRs) and Chitosan (CTS) in the Presence of Lithium Perchlorate ($LiClO_4$) at Different Concentrations
12.15 – 12.35 pm	FREE05: **Dr. Kavirajaa Pandian A/L Sambasevam (Electrochemical Materials and Sensors Research Group)** Revolutionary Electrochemical Sensors: A Paradigm Shift in Sensing
12.35 – 2.00 pm	Lunch Break
2.00 – 2.20 pm	FREE06: **PM Is Ts Dr Baljit Singh (Energy Conservation for Automotive)** Solar Concentrator Power Generation Using Thermoelectric Generator
2.20 – 2.40 pm	FREE07: **Nor Intan Shafini Nasaruddin** Predictive Analytics of Rainfall and Water Level using Machine Learning-Driven for Smart Flood Preparedness in Sarawak
2.40 – 3.00 pm	FREE09: **Dr. Ir. Raden Maizatul Aimi Mohd Azam** Moisture Penetration Depth in Concrete Subjected to Wind-Driven Rain: Experimental and Numerical Simulation Approach
3.00 – 3.20 pm	FREE11: **Nur Shafieza Azizan (MyBiorec)** Future Development of Iron Oxide Nanoparticles as Microplastics Removal: Encapsulation and Porosity Enhancement
3.20 – 4.00 pm	**Closing Ceremony** Assoc. Prof. ChM. Dr. Zainiharyati Mohd Zain Deputy Director of Energy & Environment Research Nexus UiTM (ReNeU)

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Organized by

FREE01

Assessment of CO_2 Concentrations in Office Environments using Neural Network Prediction Method

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Abstract

Indoor air quality (IAQ) has emerged as a crucial concern for both researchers and occupants of enclosed spaces, given its significant impact on health and productivity. Carbon dioxide (CO_2) levels serve as vital indicators, assessing the efficacy of ventilation systems and ensuring a fresh air supply. This study synthesizes findings from various investigations examining the correlation between occupancy rates and CO_2 concentrations. Although CO_2 levels below 5,000 parts per million (ppm) are generally considered safe, higher concentrations can result in fatigue and decreased productivity. In response, the ASHRAE recommends maintaining CO_2 concentrations in office spaces at or below 800 ppm to support occupant well-being. This comprehensive study analyses 7,300 samples collected from five distinct floor locations, categorized into four time slots for CO_2 concentration measurements. The dataset reveals varying CO_2 concentrations throughout the day. The highest recorded value, 743.1 ppm, coincides with 46 individuals occupying the space at 1700 local time, emphasizing the influence of occupancy and time on CO_2 levels. In contrast, the lowest concentration of 432.6 ppm occurs at 0800 local time with zero occupancy, marking a 12.6% increase from the 380 ppm baseline. The study identifies inconsistencies in data points surpassing the established 800 ppm CO_2 concentration standard, suggesting sporadic events affecting CO_2 levels, requiring further investigation. This study highlights the dynamic nature of indoor CO_2 concentrations, shaped significantly by factors such as occupancy and time of day.

Keywords

Indoor air quality, carbon dioxide concentration, artificial neural network

Introduction

In the modern era of urbanization and the growing emphasis on sustainability, the complex interplay between the quality of indoor air and the well-being of occupants has emerged as a pivotal issue. Within this evolving backdrop, the concentration of carbon dioxide (CO_2) within confined environments,

particularly within office buildings, has gained remarkable prominence due to its possible ramifications for both human health and cognitive performance (Mishra et al., 2020). This research embarks on a nuanced and comprehensive journey, weaving together the domains of environmental science and cutting-edge neural network prediction techniques. The ultimate objective is to formulate an advanced occupancy model uniquely suited to the context of office buildings in Malaysia.

The topic of indoor air quality (IAQ) has gained substantial recognition, capturing the interest of researchers and building occupants alike, all driven by the pursuit of enhancing the air quality within enclosed spaces (Chithra & Nagendra, 2012). In this context, the heating, ventilation, and air conditioning systems (HVAC) play a pivotal role. Not only do they uphold indoor comfort, but they also strategically manage energy consumption by recirculating a significant portion of indoor air (Congradac & Kulic, 2009). CO_2 functions as a crucial indicator in this equation, aiding in the assurance that ventilation systems deliver an adequate supply of fresh outdoor air to the occupants (Lowther et al., 2021). For a more comprehensive understanding, Table 1 presents a compilation of various studies investigating the correlation between occupancy rates and the corresponding rise in CO_2 levels.

Table 1: Studies of occupancy impact to the elevation on CO_2

Source	Data Type*	No of Sample	Building Types	Research Location	Finding
Allen et al., 2016	EX	24 Persons 6 days	Office	Syracuse, New York	Cognitive scores were 61% higher on the green building day and 101% higher on the two Green+ building days than on the Conventional building day
Zhang et al., 2016	EX	2 Group of 5 people 153 mins	Laboratory	Denmark	Compared to CO_2 at 500 ppm, 2.5-hour exposures to artificially raised CO_2 close to 5,000 ppm did not cause any significant changes in perceived air quality, acute health symptoms or the performance of tasks resembling typical office work.
Vehviläinen et al., 2016	EX	4 Male in 3-4 hours change room	Office	Finland	High concentration of CO_2 in indoor air seems to be one parameter causing physiological effects, which can decrease the facility user's functional ability.
Kayili & Yetis, 2023	EX, SV	78 person in 2 rooms for 4 days	Academic Building	Safranbolu, Turkey	It was determined that female students were more disturbed by the low indoor quality than male students.
Ameen et al., 2023	A	-	Office	University of Gävle, Sweden	The results also show that the ventilation air supply rate is lower than the requirement for offices

				in two of the office rooms. The ACH rate is also low, at ≈ 1 h^{-1} for all the rooms, compared to the required levels of 2–4 h^{-1}. The CO_2 levels are within the recommended values; on average, the highest is in one of the south-facing rooms, with 768 ppm, and the maximum measured value is also in the same room, with 1273 ppm for a short period of time.

*Data Type: A= Actual, S = Simulation, SV=Survey, EX=Experiment
*Energy Types: H=Household, T=Transportation, C=Clothing & Hygiene F=Food & Beverage, B=Behavior
*NA=Not Available

While maintaining CO_2 levels below 5,000 parts per million (ppm) is generally deemed safe, elevated concentrations of CO_2 within office spaces can induce sensations of weariness, lethargy, and an overall perception of stagnant air [10]. A computational simulation showcased that within a confined room measuring 12 meters in length, 12 meters in width, and 10 meters in height, the exhalation of a resting individual (weighing 65 kg, with a height of 1.7 meters, and a basal respiratory quotient of 0.83) would necessitate approximately 4.37 hours to escalate indoor CO_2 levels to 2000 ppm, given an initial background indoor CO_2 level of 380 ppm (Majumdar & Chatterjee, 2020). Researchers are actively delving into the intricate relationship between heightened CO_2 concentrations and the subsequent decline in productivity. To serve as a guideline for preserving indoor air quality, the ASHRAE recommends maintaining CO_2 concentrations in office environments at or below 800 ppm (Prill, 2000).

More evidence is being gathered to support the idea that the features of a building and the resulting quality of the indoor environment have a significant impact on various aspects of health. These impacts encompass a range of health conditions such as symptoms associated with Sick Building Syndrome (SBS), allergic reactions, asthma symptoms, and respiratory ailments. Additionally, the quality of indoor air also seems to play a role in affecting the frequency of absences from work or school, the overall performance of individuals in their tasks, and even the costs incurred for healthcare (Fisk, 2000).

The indoor air quality within a building has the potential to impact larger-scale productivity and economic factors. Instances of absenteeism, whether in educational or professional settings, appear to be tied to the quality of the indoor environment. Suboptimal indoor air quality might lead to decreased work performance and academic achievement due to the discomfort and health issues it can cause. This, in turn, could contribute to increased healthcare costs, affecting both individuals and organizations.

In addition to unravelling the complex relationship between the saturation of CO_2 and patterns of occupancy, this study goes a step further by exploring the potential consequences of increased CO_2 levels on both human respiratory patterns and cognitive function. By shedding light on these critical elements, this research not only advances our understanding of the intricate dynamics within indoor environments but also emphasizes the importance of taking proactive steps toward sustainable design to promote the

well-being of occupants. This opening sets the groundwork for a comprehensive exploration of the methods, discoveries, and wider significance of this innovative research undertaking.

Methodology

This investigation delved into the impact of occupancy on CO_2 levels within office buildings. To address the complexity of analysing substantial datasets that prove challenging for conventional statistical approaches like correlation and regression analysis, the study explored the utility of neural networks. These advanced computational models possess the capability to effectively model and dissect extensive data. Ultimately, the research culminated in the application of a neural network employing backpropagation techniques, enabling the acquisition of precise predictions for both occupancy and CO_2 level patterns. This approach promises enhanced accuracy in modelling these interconnected variables.

Lonworks gateways are employed in conjunction with CO_2 sensors to facilitate data collection. The study involves five distinct sampling levels, each characterized by uniform attributes such as building functionality, meteorological conditions, and geological location. Notably, these sampling levels also share comparable active and passive design characteristics.

Data Collection Samples

The process of collecting data involved a systematic approach that focused on obtaining primary information from various sources. The sources for data collection consisted of five (5) office floors that share similarities in terms of size, design (both active and passive), architectural structure, and primary function.

In order to ensure a comprehensive monitoring of CO_2 levels, each level where data was sampled was equipped with three individual sensors. These sensors diligently recorded CO_2 measurements on a consistent schedule: four times a day, every day of the year, at 0800, 1100, 1400, and 1700 local time. To accurately represent the indoor environment, the sampling equipment was positioned at a height of 1.8 meters above the ground level. The total number of samples collected amounted to 7,300, thus providing a substantial and robust dataset for the analysis.

The occupant demographics are presented in Table 2, providing an overview of the occupants within the studied environment. The table highlights a total of 208 individuals in aggregate. Each specific sampling location maintains a relatively consistent maximum occupancy, with the exception of Level 12 – Office 5, where the occupant count is notably lower, comprising 29 individuals.

Furthermore, the table presents a concise breakdown of the occupant demographics in terms of age and gender. This inclusion provides insight into the distribution of occupants across different age groups and genders within the examined spaces. By detailing these demographic aspects, the study gains a more holistic understanding of the individuals inhabiting the environment under investigation. This comprehensive approach to occupant demographics adds depth to the overall analysis, enabling a more nuanced interpretation of the collected data.

Table 2: The demographic of the Occupant

Level and Sampling location	Social Demographic - Independent Variable						
	Age				Gender		Total (worker)
	Below 30	31~40	41~50	above 51	Male	Female	
	V1	V2	V3	V4	V5	V6	
Level 7 – Office 1	13	13	12	9	25	22	47
Level 9 – Office 2	12	18	11	5	16	30	46
Level 10 – Office 3	12	12	14	5	28	15	43
Level 11 – Office 4	10	11	14	8	9	34	43
Level 12 – Office 5	7	7	10	5	18	11	29
Total	**54**	**61**	**61**	**32**	**96**	**112**	**208**

Data Analysis

The process of data analysis and model development relies on the utilization of the MatLab Artificial Neural Network. The collected dataset is subjected to analysis, with a focus on employing an Artificial Neural Network (ANN) model. This model aims to uncover patterns and relationships within the data. To ensure robustness, the data is divided into subsets for training, testing, and validation, and this division adheres to the Neural Network Fitting MatLab methodology.

Specifically, the configuration for the Artificial Neural Network (ANN) Fitting involves allocating 70% (1277 samples) of the dataset for training, 15% (274 samples) for validation, and another 15% (274 samples) for each time testing model. The graphical representation of the Neural Network Diagram is illustrated in Figure 1, offering a visual depiction of the underlying neural architecture.

During the training process, the Levenberg-Marquardt algorithm is employed as the chosen Training Algorithm. This algorithm facilitates the optimization of the model's parameters to achieve accurate predictions. The ANN Fitting procedure is executed across four distinct time intervals, each corresponding to a recorded time (0800, 1100, 1400, and 1700 local time). As a result, four unique models are generated, each tailored to predicting CO_2 levels for the specified time points.

These models are designed to not only provide predictions within the range of observed occupant counts but also possess the ability to interpolate and extrapolate beyond these observed values. In essence, these models can predict CO_2 levels based on different occupant scenarios, enhancing the understanding of how occupant dynamics relate to indoor air quality. This approach amalgamates advanced mathematical

techniques with empirical data, contributing to a more informed comprehension of CO_2 concentration variations within the studied environment.

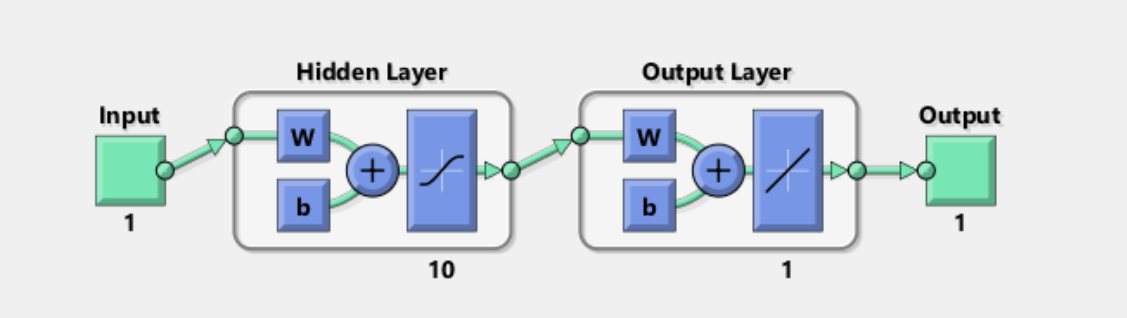


Figure 1: Neural Network Diagram

Result and discussion

The outcomes derived from the descriptive statistics of the collected samples reveal that a total of 7,300 samples have undergone analysis. The approach to sampling description involves segmenting the data into five distinct floor sampling locations, each linked to four distinct time categories designated for measuring CO_2 concentrations. The values gathered for overall and each of these parameters are presented in Tables 3 to 8.

Upon scrutinizing the values collected based on floor sampling locations, it becomes evident that the highest recorded CO_2 concentration is 1,411 parts per million (ppm), observed on level 11 – specifically, Office 4. This finding highlights a notable peak in CO_2 concentration within this specific environment. Furthermore, a noteworthy observation emerges from the results: all floor locations exhibit maximum CO_2 values that surpass the recommended threshold of 800 ppm, as established by the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) for acceptable CO_2 concentrations in office settings (Prill, 2000). This implies that the indoor air quality, as measured by CO_2 levels, tends to exceed the recommended standards in these office environments.

It's crucial to note that this excess of CO_2 concentration transcends different time measurements, suggesting a persistent issue. However, a closer examination of the data reveals that at the early morning measurement of 0800, the excessive CO_2 concentration occurs solely on floor 11 – specifically, in Office 4. This temporal variation suggests that specific locations, especially at certain times, might be contributing more significantly to elevated CO_2 levels.

These findings underscore the importance of addressing indoor air quality within these office spaces, particularly concerning CO_2 concentration. The results highlight a potential need for improvements in ventilation and circulation to ensure that indoor air remains within the recommended ranges for occupant health and comfort.

Table 3: Overall Sampling Description

		Occupancy	CO2_8am	CO2_11am	CO2_2pm	CO2_5pm
N	Valid	1825	1825	1825	1825	1825
	Missing	0	0	0	0	0
Mean		23.4658	469.4723	575.9825	573.9205	599.6384
Std. Error of Mean		.37427	1.19426	3.07258	3.33351	3.94382
Mode		.00	438.00	416.00[a]	409.00	404.00
Range		46.00	470.00	1031.00	1022.00	881.00
Minimum		.00	383.00	380.00	381.00	384.00
Maximum		46.00	853.00	1411.00	1403.00	1265.00

a. Multiple modes exist. The smallest value is shown

Table 4: Sampling Description on Level 7 – Office 1

		Occupancy	CO2_8am	CO2_11am	CO2_2pm	CO2_5pm
N	Valid	365	365	365	365	365
	Missing	1460	1460	1460	1460	1460
Mean		25.1068	457.1342	556.4932	540.5205	555.8000
Std. Error of Mean		.93449	1.95666	5.90142	5.49654	6.36299
Mode		.00	456.00	456.00	456.00	456.00
Range		46.00	261.00	509.00	370.00	500.00
Minimum		.00	386.00	388.00	394.00	390.00
Maximum		46.00	647.00	897.00	764.00	890.00

Table 5: Sampling Description on Level 9 – Office 2

		Occupancy	CO2_8am	CO2_11am	CO2_2pm	CO2_5pm
N	Valid	365	365	365	365	365
	Missing	1460	1460	1460	1460	1460
Mean		25.4603	465.8767	595.0658	579.2055	615.9068
Std. Error of Mean		.93194	2.17507	7.28616	6.87452	8.65603
Mode		.00	446.00	446.00	446.00	446.00
Range		45.00	356.00	547.00	674.00	615.00
Minimum		.00	389.00	394.00	387.00	387.00
Maximum		45.00	745.00	941.00	1061.00	1002.00

Table 6: Sampling Description on Level 10 – Office 3

		Occupancy	CO2_8am	CO2_11am	CO2_2pm	CO2_5pm
N	Valid	365	365	365	365	365
	Missing	1460	1460	1460	1460	1460
Mean		24.0795	457.4603	565.8192	557.5233	565.6658
Std. Error of Mean		.86169	2.24482	6.16947	6.17286	6.63539
Mode		.00	443.00	443.00	443.00	443.00
Range		42.00	363.00	571.00	447.00	525.00
Minimum		.00	390.00	395.00	387.00	385.00
Maximum		42.00	753.00	966.00	834.00	910.00

Table 7: Sampling Description on Level 11 – Office 4

		Occupancy	CO2_8am	CO2_11am	CO2_2pm	CO2_5pm
N	Valid	365	365	365	365	365
	Missing	1460	1460	1460	1460	1460
Mean		24.3945	488.9096	634.7973	683.3726	728.0877
Std. Error of Mean		.81909	3.69831	8.54345	9.95132	11.70386
Mode		36.00	438.00	438.00	438.00	438.00
Range		43.00	470.00	1031.00	1022.00	881.00
Minimum		.00	383.00	380.00	381.00	384.00
Maximum		43.00	853.00	1411.00	1403.00	1265.00

Table 8: Sampling Description on Level 12 – Office 5

		Occupancy	CO2_8am	CO2_11am	CO2_2pm	CO2_5pm
N	Valid	365	365	365	365	365
	Missing	1460	1460	1460	1460	1460
Mean		18.2877	477.9808	527.7370	508.9808	532.7315
Std. Error of Mean		.50901	2.52421	4.39820	3.92904	5.14494
Mode		27.00	549.00	549.00	549.00	549.00
Range		29.00	233.00	349.00	291.00	456.00
Minimum		.00	397.00	389.00	385.00	391.00
Maximum		29.00	630.00	738.00	676.00	847.00

Table 9: Sampling Occupancy Frequency

N	Frequency	Percent	Cumulative Percent	N	Frequency	Percent	Cumulative Percent	N	Frequency	Percent	Cumulative Percent
0	171	9.4	9.4	16	3	0.2	34.5	32	40	2.2	55.2
1	117	6.4	15.8	17	2	0.1	34.6	33	55	3	58.2
2	80	4.4	20.2	18	1	0.1	34.6	34	46	2.5	60.8
3	68	3.7	23.9	19	9	0.5	35.1	35	74	4.1	64.8
4	54	3	26.8	20	6	0.3	35.5	36	83	4.5	69.4
5	49	2.7	29.5	21	10	0.5	36	37	101	5.5	74.9
6	37	2	31.6	22	12	0.7	36.7	38	104	5.7	80.6
7	20	1.1	32.7	23	25	1.4	38	39	97	5.3	85.9
8	10	0.5	33.2	24	23	1.3	39.3	40	87	4.8	90.7
9	9	0.5	33.7	25	38	2.1	41.4	41	67	3.7	94.4
10	3	0.2	33.9	26	51	2.8	44.2	42	51	2.8	97.2
11	1	0.1	33.9	27	59	3.2	47.4	43	30	1.6	98.8
12	2	0.1	34	28	36	2	49.4	44	15	0.8	99.6
13	1	0.1	34.1	29	25	1.4	50.7	45	6	0.3	99.9
14	2	0.1	34.2	30	16	0.9	51.6	46	1	0.1	100
15	2	0.1	34.3	31	26	1.4	53	**Total**	**1825**	**100**	

*N = Occupancy

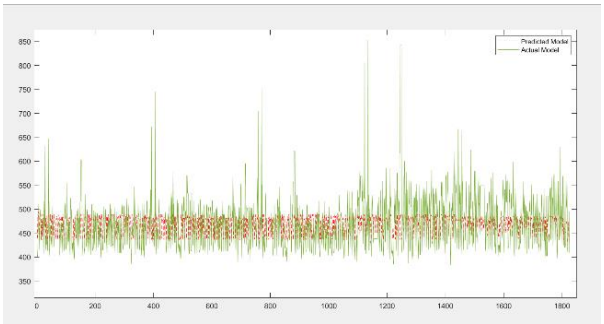
The distribution of occupancy frequencies has been organized into table format, specifically Table 9. The frequencies provided in this table reveal that the highest occurrence of occupancy numbers is associated with values 1, 37, and 38. Notably, even instances of complete absence (0 occupancy) have manifested over 100 times in the data set.

The central tendency of the occupancy distribution, as represented by the median value, is calculated to be 28 individuals. This median value signifies the midpoint of the distribution, indicating that roughly half of the observed occupancy instances fall below this value, and the other half fall above it which is slightly higher that the average value. This tabulated analysis of occupancy frequencies presents an overview of how often different levels of occupancy were observed within the studied environment. The occurrence of both high and low occupancy instances, as well as the notable presence of zero occupancy situations, provides insight into the fluctuating nature of the spaces being investigated. This understanding of occupancy patterns is crucial for comprehending the dynamics of indoor environments and their potential impact on factors like indoor air quality and comfort.

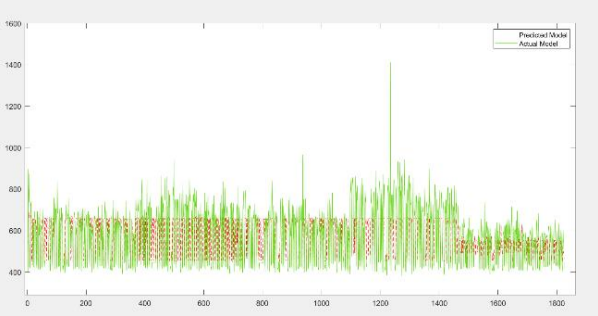
Utilizing the gathered dataset, an analysis employing Artificial Neural Networks (ANN) has been conducted. Leveraging the capabilities of ANN, a predictive model is developed, generating graphs that portray predicted CO_2 levels. These predicted graphs are then compared with the actual data recorded. The graphical representation of this comparison is displayed in Figure 2, offering a visual overview of the

disparities and similarities between predicted and actual CO_2 levels for four distinct time intervals: 0800, 1100, 1400, and 1700.

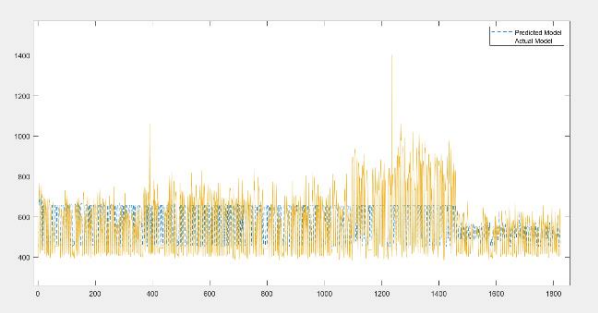
0800 Predict vs Actual Graph



1100 predict vs actual Graph



1400 predict vs actual Graph



1700 Predict vs Actual Graph

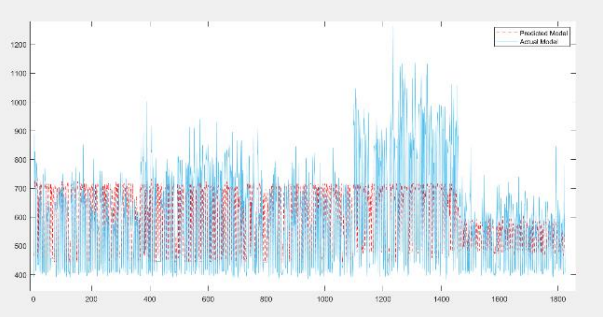


Figure 2: Visual Overview of Predicted and Actual Model

It becomes evident that a discernible trend aligns with the normalized pattern exhibited by the predicted data graph compared to actual data graph. This correspondence implies that the ANN model demonstrates a certain level of accuracy in approximating CO_2 levels based on the observed variables. However, it's important to consider the underlying complexities that impact CO_2 levels. Factors such as human behaviour, metabolic rates, and various other environmental variables can contribute to significant fluctuations in CO_2 concentration. These fluctuations make it challenging to rely solely on CO_2 values as a definitive guide for decision-making.

Considering that CO_2 plays a crucial role in this context, its concentrations can serve as a significant gauge for evaluating the effectiveness of ventilation systems in delivering an ample influx of fresh outdoor air to occupants, as highlighted in source (Lowther et al., 2021). However, the intricate interplay of various factors mentioned earlier introduces a degree of unpredictability, potentially resulting in substantial fluctuations in CO_2 levels. Consequently, basing decisions solely on CO_2 measurements might lead to misguided actions. Hence, it is of paramount importance to approach potential remedies or interventions with a degree of caution. To address this challenge, the utilization of techniques like Artificial Neural Networks (ANN) stands out as an effective approach. ANN provides a sophisticated method of analysing

and understanding complex relationships within the data, making it a valuable tool for generating reliable indicators of CO_2 levels.

By employing ANN to process the intricate web of variables impacting CO_2 concentrations, a more nuanced and accurate understanding of indoor air quality can be achieved. This approach enables a comprehensive assessment that considers not only CO_2 levels but also factors that contribute to their fluctuations. As a result, the use of ANN can serve as an exemplar of a viable methodology for establishing CO_2 level benchmarks that can effectively guide decision-making.

The ANN (Artificial Neural Network) model operates across four distinct time slots: 0800, 1100, 1400, and 1700 in the local time zone. One of the key strengths of this model is its ability to both interpolate and extrapolate data. This means it can effectively estimate values within the given time intervals as well as predict values beyond them. Leveraging this unique capability of the ANN model, it computes normalized occupancy and CO_2 predicted values. The outcomes of these calculations are organized and presented in detail in Table 10. This table encapsulates the model's predictions, showcasing its versatility in handling various time points and generating reliable estimates for occupancy and CO_2 levels.

Table 10: ANN Model Interpolate and Extrapolate Occupancy Data

N	800	1100	1400	1700	N	800	1100	1400	1700	N	800	1100	1400	1700
0	432.6	457.4	442.7	444.2	16	434.6	490.6	503.6	536.0	32	473.9	656.6	599.1	653.2
1	437.6	456.6	451.1	457.7	17	430.7	491.1	506.0	473.2	33	471.3	657.3	626.0	671.1
2	442.2	452.9	455.8	466.6	18	431.1	492.4	508.8	485.0	34	470.5	657.6	671.3	686.1
3	446.3	455.1	459.6	473.0	19	444.4	497.5	512.0	503.7	35	475.8	657.8	680.5	698.3
4	450.1	479.8	465.2	478.3	20	474.7	513.7	515.5	519.9	36	487.5	657.8	680.6	708.4
5	453.5	494.9	476.1	482.9	21	481.8	536.7	519.0	533.3	37	492.7	657.9	679.5	715.7
6	456.5	493.4	489.5	487.3	22	481.5	548.1	522.1	544.1	38	491.7	657.9	675.1	716.3
7	459.1	491.1	495.5	491.7	23	481.1	550.9	524.8	553.3	39	488.8	658.0	666.1	705.5
8	461.3	490.4	490.4	496.1	24	481.7	550.9	527.6	561.4	40	485.6	658.3	657.8	695.2
9	463.1	490.6	473.4	500.8	25	483.5	550.1	532.1	569.1	41	482.3	658.8	654.5	696.4
10	464.4	491.1	452.8	505.8	26	485.2	550.3	542.3	576.7	42	479.4	659.9	654.2	703.8
11	465.3	491.5	443.1	511.3	27	485.5	550.3	561.4	584.6	43	480.7	662.2	655.0	713.0
12	466.1	491.4	451.1	517.6	28	484.3	571.9	579.6	593.6	44	503.6	669.2	656.1	722.8
13	466.5	490.6	478.1	525.2	29	482.2	627.5	588.7	604.2	45	527.9	686.3	657.3	732.9
14	465.9	490.2	495.7	534.7	30	479.7	650.3	592.5	617.7	46	529.9	726.4	658.5	743.1
15	454.9	490.3	501.1	546.2	31	476.8	654.9	594.7	634.5					

*N = Occupancy

The ANN (Artificial Neural Network) model operates across four distinct time slots: 0800, 1100, 1400, and 1700 in the local time zone. One of the key strengths of this model is its ability to both interpolate and extrapolate data. This means it can effectively estimate values within the given time intervals as well as predict values beyond them. Leveraging this unique capability of the ANN model, it computes normalized occupancy and CO_2 predicted values. The outcomes of these calculations are organized and presented in detail in Table 10. This table encapsulates the model's predictions, showcasing its versatility in handling various time points and generating reliable estimates for occupancy and CO_2 levels.

The outcomes obtained from both interpolation and extrapolation highlight that the CO_2 levels remain consistently below the recommended threshold of 800 ppm. This threshold has been established by the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) as the acceptable concentration of CO_2 for office environments (Prill, 2000). The maximum recorded value within the dataset is 743.1 ppm, observed when there are 46 individuals occupying the space at 1700 local time. This particular peak occurs during the final hours of the workday, which is significant considering the time-based variations in CO_2 levels. In contrast, the lowest CO_2 concentration is recorded at 0800 local time when the occupancy is zero. This minimal value registers at 432.6 ppm, representing an increase of 12.6% compared to the baseline indoor CO_2 level of 380 ppm mentioned in reference (Majumdar & Chatterjee, 2020). The findings from the analysis reveal that there is inconsistency in the data points that surpass the established standard of 800 ppm for CO_2 concentration, as mentioned in the earlier collected results. This variability in values suggests that there could be sporadic instances or isolated events driving these fluctuations. It's essential to investigate these occurrences more deeply to understand their root causes.

A clear and significant trend in the model's behaviour is evident from Figure 3. This trend showcases a noticeable increase in CO_2 values, followed by a slight decline around 1400 local time. This particular drop could be attributed to a phenomenon such as an office recess, during which approximately 40% of the occupants take their lunch break outside of their office spaces. This temporary reduction in occupancy within the office area could contribute to the observed decrease in CO_2 concentration. However, post 1400 local time, there is an observable and sustained rise in CO_2 concentration levels. This rise could be attributed to several factors, including heightened metabolic activity among occupants, fluctuations in daily temperature patterns, or other relevant variables that warrant further investigation. Understanding these factors can provide valuable insights into the dynamics of CO_2 accumulation during the latter part of the day, aiding in the formulation of strategies to manage and maintain healthy indoor air quality.

Figure 4 presents the model's predictions at various time intervals. The observations from this figure indicate a consistent linear relationship across all these occurrences. Specifically, at 0800 local time, the graph exhibits a less steep slope, while the steepest graph is observed at 1700 local time.

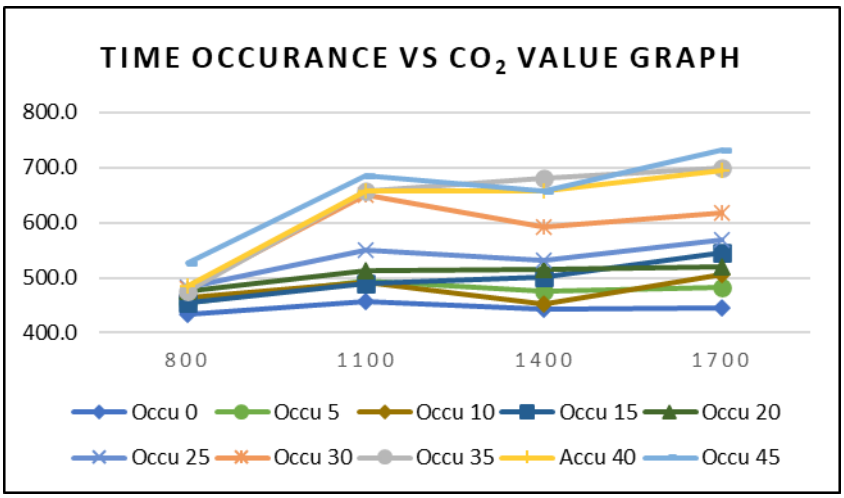


Figure 3: Visual Overview on Occurrence Time vs CO_2 Value

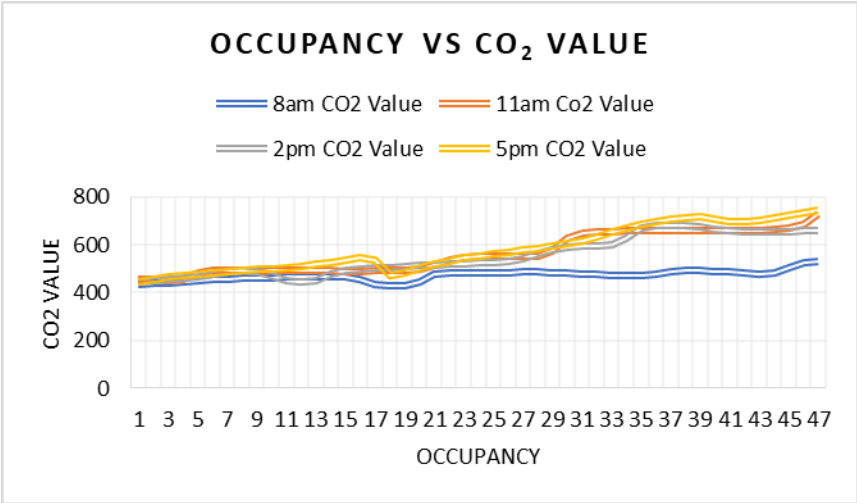


Figure 4: Visual Overview of Predicted Model

These findings are of considerable significance as they provide strong support for the notion that CO_2 levels within the environment are subject to dynamic changes influenced by several factors, with two prominent ones being occupancy and the time of day. The varying slopes in the graphs signify how CO_2 concentration tends to increase or decrease more rapidly during different periods. For instance, the shallower slope at 0800 local time suggests a slower rate of change, possibly reflecting lower occupancy or reduced CO_2 production during the early morning hours. Conversely, the steeper graph at 1700 local time indicates a faster rate of change, potentially linked to increased occupancy or activities in the late afternoon.

Conclusion

The findings from this study confirmed the dynamic nature of indoor CO_2 levels and underscores the importance of considering both time and occupancy when managing and optimizing indoor air quality to ensure it complies with established standards and promotes a healthy workplace environment. Overall, the analysis provides insights into the CO_2 concentration patterns, emphasizing the importance of maintaining levels within the recommended limits for optimal office air quality.

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FREE03

Development of Biocompatible Blended Electrolyte System Comprising Epoxidized Natural Rubber (ENRs) and Chitosan (CTS) in the Presence of Lithium Perchlorate (LiClO4) at Different Concentrations

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Abstract

The physical and chemical properties of Epoxidized Natural Rubber (ENR) with 25% and 50% epoxidized levels were used. The polymer was further used by blending ENRs separately with Chitosan (CTS) in the presence of lithium perchlorate ($LiClO_4$) at varying concentrations and a constant 50:50 polymer ratio using a solvent casting method. The ENR samples will undergo a mastication process to further enhance the rate of solubility before purification through a reprecipitation method. Fourier Transform Infrared Spectroscopy (FTIR) and Thermogravimetric Analysis (TGA) were employed to characterize the miscibility of these two polymers. The results revealed that the ENRs/CTS blend exhibited heterogenous miscibility behavior. ATR-FTIR was used to confirm the chemical structure of the ENRs/CTS blend and the impact of $LiClO_4$ addition. Furthermore, TGA analysis showed three distinct thermal decomposition stages for each blend, occurring at different temperatures. In the case of the ENRs/CTS blend, the stages were observed at 158°C, 231°C, and 345°C, while for the ENR50/CTS blend, the stages occurred at 157°C, 233°C, and 343°C, respectively. Regarding the conductivity of the ENRs/CTS/$LiClO_4$ blend system at ambient temperature, the values were found to be relatively low, ranging from 2.48 to 6.76 (10^{-8} S/cm) for ENR-25 and 2.10 to 7.42 (x 10^{-8} S/cm) for ENR-50 from a range of $LiClO_4$ concentrations. These conductivity values fall below the optimum acceptable range (< 10^{-5} S/cm) for a solid polymer electrolyte (SPE) system. Thus, further modifications and detailed studies needed to be carried out before further applications were made.

Keywords

ENR-25, ENR-50, chitosan, polymer blends, $LiClO_4$

Introduction

A potentially effective way to overcome environmental issues related to traditional battery technology is the use of biodegradable materials and inorganic salts in biodegradable rechargeable battery systems. Biodegradable materials can naturally decompose over time through biological processes, offering the potential to minimize the environmental impact related to battery disposal and waste management. Inorganic salts, on the other hand, provide essential electrolyte properties and contribute to the overall performance of biodegradable batteries (Lee et al., 2021).

To optimize rechargeable battery systems, researchers have been investigating polymer electrolyte (PE) as an efficient electrolyte system. Composed of polymer matrices and suitable ionic conductors, PE offers advantages such as high flexibility, enhanced stability, and resistance to leakage (Hallinan et al., 2013). There are three main types of electrolytes: liquid electrolyte (LE), gel PE (GPE), and solid PE (SPE) (Boaretto et al., 2020).

LPE is widely used in battery systems due to its high ionic conductivity value, about 10^{-3} to 10^{-2} S/cm, and the ease of preparation; however, the use of LPE carries the risk of poor mechanical properties, leakage, and electrolyte rusting (Liu et al., 2021; Zhang et al., 2019). As an alternative, the GPE system has been introduced to address the issue of LPE.

GPE improves the mechanical, thermal, and electrochemical stability of polymer electrolytes, but it also increases the possibility of flammability, which limits its applications in battery systems (Castillo et al., 2021; Zheng et al., 2021).

Moreover, SPE has excellent mechanical properties, is non-flammable, and does not promote corrosion like LPE, although authors reported that the SPE system still has relatively low ionic conductivity at room temperature, around 10^{-6} S/cm (Ramesh et al., 2011). Hence, researchers have been working to develop an optimal SPE system involving green energy resources with the addition of inorganic salts, which might improve the conductivity behavior of the system, and it has been proven that SPE is a viable option for creating eco-friendly, low-cost, and better mechanical properties in electrochemical devices (Tan et al., 2007).

Furthermore, Epoxidized Natural Rubber (ENR) and Chitosan (CTS), both hydrophilic biopolymers, have been combined through heterogeneous blends. The excellent mechanical strength, flexibility, and chemical stability of ENRs make it an ideal material for PE membrane fuel cells (Idris et al., 2001). CTS, derived from chitin, exhibits excellent film-forming capabilities, mechanical strength, flexibility, and thermal stability, contributing to the overall stability of the electrolyte system. CTS can also form complexes with metal salts, such as lithium perchlorate, enhancing the ionic conductivity of the electrolyte system (Wang et al., 2017).

Lithium perchlorate ($LiClO_4$), a commonly used salt in polymer electrolytes, dissociates into lithium cations and perchlorate anions, facilitating ion conduction within the electrolyte. Its high ionic conductivity, coupled with good solubility in various polymer matrices, including ENRs and CTS, further enhances the performance of the electrolyte (Dahham et al., 2018).

The involvement of $LiClO_4$ enhances the ionic conductivity of the electrolyte system, leading to better electrochemical reactions and overall battery performance. The improved ionic conductivity results in enhanced power output, faster charging or discharging rates, and increased energy efficiency of the battery

system (Aziz et al., 2018; Mahmood et al., 2018).

In addition, the presence of the epoxide group as an active site at the backbone of ENR may improve the ionic conductivity in the solid polymer electrolyte (SPE) system. Epoxide groups are advantageous in ENR structures due to the presence of lone pair electrons, polarity, hardness, compatibility, temperature resistance, and low air permeability. However, the low Tg, low molecular weight, and high gel content limit the solubility and processability in the SPE system (Whba et al., 2021). For ionic conductivity, inorganic salts like LiClO4 will be added into a polymer blend to improve the characteristics of the biodegradable rechargeable battery system. However, the full potential of the blended electrolyte system remains to be explored (Obino et al., 2021) This study aims to comprehensively understand the properties and potential of the ENR-25/CTS and ENR-50/CTS blended electrolyte system. The synthesis and characterization of the blend will provide valuable information on thermal stability, viscosity, and dielectric properties at different ENRs and CTS ratios. By doping LiClO4 at various ratios, the optimum conductivity value can be determined, leading to insights on improving the conductivity of the blended system. The development of an optimized blended system with improved biocompatibility, stability, and conductivity compared to existing electrolyte systems will be a significant contribution to the field of energy storage (Rayung et al., 2020; Vincent et al., 2020).

By addressing the environmental concerns associated with battery waste and reducing the reliance on non-renewable materials, this research contributes to the progress of green energy technologies. The implementation of the biodegradable blended electrolyte system in secondary batteries has the potential to revolutionize the energy storage landscape and pave the way towards a more sustainable and eco-friendly future.

Conclusion and recommendation

In conclusion, the development of a biodegradable blended electrolyte system based on ENRs, CTS, and LiClO4 offers a promising solution to the environmental issues related to traditional battery technology. The research in this area is crucial for advancing the field of energy storage and creating a greener and more sustainable future. It is advised that the blended electrolyte system be further enhanced and thoroughly characterized. The introduction of these environmentally friendly battery systems could pave the way for a greener and more sustainable energy storage future by lowering the negative environmental effects of battery waste and dependence on non-renewable resources.

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List of top universities/ research institutes in related field (local and international)

1. University of Malaya
2. Universiti Kebangsaan Malaysia
3. University of the Basque Country, Spain
4. University of California
5. Prince of Songkla University, Thailand

List of top industries in related field (local and international)

1. NextEra Energy, Inc. (International)
2. Pensonic Holdings Berhad (local)
3. Proton Holdings Berhad (local)

List of potential funders for future research grants (local and international)

1. Ministry of Higher Education
2. Ministry of Science Technology and Innovation
3. TORAY Foundation
4. Petronas-Academia Collaboration Dialogue (PACD)
5. Nagao Natural Environment Foundation
6. UK-Malaysia University Partnerships Catalyst Grant

FREE04

Effects of Nano Zero Valent (nZVI) Dosage, Temperature, and Time on Pure Hydrogen Production by Formic Acid Decomposition with NZVI

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Abstract

Formic acid decomposition with nZVI able to produce pure hydrogen without greenhouse gas as by-products. Formic acid decomposition reactions result in clean hydrogen production compared to other conventional fuels production method such as partial oxidation and steam-methane reforming. The main problem statement been identified which how clean hydrogen can be produced by formic acid decomposition with nZVI. It also lacks studies for nZVI and formic acid reaction as a new source for hydrogen energy production. NZVI is known as the most applied nanomaterials due to its efficiency while formic acid is as hydrogen sources in ambient liquid-phase because it is a non-toxic organic compound. Thus, the parameter in the production of pure hydrogen has been investigated which are the nZVI dosage, temperature, and time of the reaction for hydrogen yield. This project consists of some methodology which are synthesis of NZVI, decomposition of formic acid with NZVI and characterization of NZVI particles. The optimum results for NZVI dosage and temperature were 800 g/L and 25 °C, respectively which gives highest hydrogen yield. The hydrogen yield was increase with the reaction time until maximum period which is 30 minutes. The characterization has been determined by using BET and FTIR analysis methods. Surface area before reaction higher than after reaction, while pore size before reaction lower than after reaction. The functional group before reaction was primary amines and after reaction was alkenes. The project findings successfully been identified for the production of hydrogen from decomposition of formic acid with nZVI.

Keywords

Pure hydrogen production, nano zero valent iron (nZVI), decomposition of formic acid with nZVI, nanoparticles, characterization, energy

Introduction

Nowadays, the extraction of conventional fuels such as natural gas, coal and crude oil were used as the global energy demand. However, it has been found that this type of conventional fuels runs out very quickly (Tarhan & Çil, 2021). Hydrogen will replace fossil fuels as the new renewable energy sources that were more sustainable and greener compared to the conventional fuels, where it can reduce the pollution to the environment (Navlani-García et al., 2019). Hydrogen is known as the clean fuel and alternative energy feedstock with a various advantage of the production (Navlani-García et al., 2019). Most hydrogen produce from combustion process can be harmful to the atmosphere compared to the conventional combustion of fossil fuels (Ahmad et al., 2021). Hydrogen energy is qualified as the alternative fuel in order to replace the conventional fuels. Hydrogen can be used to powered fuel-cells for zero-emission vehicles since it can provide high efficiency of energy fuel to the vehicles which can contribute to the alternative transportation fuel. Besides, hydrogen also can be used for internal combustion engines purposes (Møller et al., 2017). The nZVI is known as the most applied nanomaterials due to its efficiency which in removes the contaminants (Turabik & Simsek, 2017). The simplest carboxylic acid which is formic acid that present in nature and can be used in the reaction with nZVI for hydrogen production (Chen et al., 2020). The formic acid also known as the less corrosive acid as well as less toxicity which can be handle for lab purpose in hydrogen production (Valentini et al., 2019). The decomposition of formic acid by nanoparticles provides an improvement in producing clean hydrogen at a room temperature and the reaction applied were formic acid reduction and iron oxidation (Wang et al., 2018).

The synthesis of NZVI used borohydride (BH_4^-) for the reduction of Fe (III) (Pasinszki & Krebsz, 2020). Below shows the redox reaction between $FeCl_2.6H_2O$ and $NaBH_4$:

$$4Fe^{3+} + 3BH^-_4 + 9H_2O \rightarrow 4Fe^0_{(s)} + 3H_2BO^-_{3(aq)} + 12H^+ + 6H_2$$

The reaction between formic acid and iron nanoparticles determined by investigating the effect of different parameters affecting the hydrogen gas yield during the reaction such as, nZVI dosage (200, 400, 600, 800, 1000 g/L), reaction temperature (25, 35, 45, 55, 60, 65, 70 and 75°C), and time (5, 10, 15, 20, 25 and 30 minutes) will be investigated. The experiment consists of a three-neck round bottom flask (reactor) immersed in a beaker and equipped with a connector. The connector was connected to a pneumatic trough by using rubber tube. All experiments been conducted in a fume hood (Eljamal et al., 2018).

First, 10 ml of formic acid will be added into the flask. Next, a specific amount of black iron nanoparticles was added to the flask. The hydrogen gas produced during the reaction been collected and displaced in an inverted burette initially filled with water. The volume of hydrogen gas generated is determined during constant time which is 30 minutes. For parameter of temperature study, a thermometer apparatus been added at one neck of three-neck round bottom flask and hotplate been used to increase the temperature of the mixture. The time observed was for 5, 10, 15, 20, 25 and 30 minutes. Hydrogen yield been generated at the inverted burette. Below shows the reaction equation between formic acid and nZVI in the formic acid decomposition reactions (A. K. Singh et al., 2018):

$$Fe_{(s)} + 2HCOOH_{(\ell)} + 2H_2O \rightarrow H_{2(g)} + Fe(HCOO)_2.2H_2O_{(s)}$$

The amounts of NZVI were reacted with 10ml of 50% (v/v) formic acid, was left for 30 minutes. The experiment observed that the volume of H_2 yields were increased for the dosage of 200 until 800 g/L which was 58.6 ml until 215.3ml, then was slightly decreased at dosage of 1000 g/L which was 209.4 ml. NZVI dosage of 800 g/L resulted to the highest yield in hydrogen production. It has been determined that adding

more nanoparticles might improve the production of hydrogen gas (Constantinou et al., 2023). NZVI dosage was determined to be an important parameter in the hydrogen yield (Pachakhan et al., 2023).

The volume of H_2 yields were observed based on the different temperature conditions used in the experiment. The temperature conditions used were 25, 35, 45, 55, 60, 65, 70 and 75°C, respectively. The temperature of 25 °C resulted in the higher values of hydrogen yield which is 250.2 ml compared to other range of temperatures. Then, the temperature of 25°C was taken as the optimum value for the next parameter. The experiment resulted in which the higher the temperature, the lower the H_2 yield. The optimum values of temperature been taken for 25°C as it produced in high H_2 gas (Duan et al., 2018).

The bubbles gas of H_2 were produced faster during the first 5 minutes which was 140.7ml since the reaction between NZVI and formic acid was faster. The production of H_2 gas was continuously increased until the minutes of 25, then it became constant until minutes of 30 and resulted to 215.6ml of H_2 gas collected. So that, the experiment shows that H_2 gas produced increased throughout the reaction time up to 30 minutes (V. V. Singh et al., 2015).

This hydrogen production methods contributes to a more sustainable hydrogen production process and expands the application of hydrogen as vehicles fuel, reducing dependency on petroleum – based fuels. Additionally, this research utilizes the abundant waste and by – product from Malaysia's biorefineries and processing industries, benefiting numerous sectors. Moreover, this research addresses the pressing need for high purity hydrogen gas crucial to chemical and food sectors, refineries and fuel cell applications. Furthermore, this research aligns with various strategic framework and initiatives, including the MySTIE 10-10 Framework of Energy, Shared Prosperity Vision 2030 of Industrial Revolution 4.0 (KEGA 3), Sustainable Development Goals of Affordable and Clean Energy (SDG 7), and the Twelfth Malaysia Plan of Economic Empowerment.

Graphical highlights of the future research direction

Conclusion and recommendation

The new study to produce hydrogen gas by the reaction between nanoparticles (nZVI) and formic acid been observed in the experiment. The effects of NZVI dosage, temperature and time on the hydrogen yield has been identified for the experiment to be run, where the optimum value of nZVI dosage, temperature and time for the hydrogen generation such as 800 g/L, 25°C and 30 minutes, respectively. The nZVI was also characterize by the specific surface area, pore size and elemental distribution of NZVI before and after reaction, BET and FTIR analysis been used (Turabik & Simsek, 2017). This reaction of formic acid decomposition and nZVI has the ability to be commercialize as hydrogen production method due to the abundantly and renewable raw materials and low cost (Valentini et al., 2019; Tang et al., 2021).

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List of top 5 universities/ research institutes in related field (local and international)

1. Universiti Sains Malaysia (USM)
2. Universiti Teknologi MARA (UiTM)
3. Universiti Teknologi Malaysia (UTM)
4. University California San Diego
5. Max Planck Institute for Intelligent Systems

List of top 3 industries in related field (local and international)

1. Sarawak Energy
2. Lotte Chemical
3. Petronas

List of 6 potential funders for future research grants (local and international)

1. Ministry of Higher Education (MOHE)
2. Ministry of Science, Technology and Innovation (MOSTI)
3. Petronas
4. Samsung Engineering
5. Sarawak Energy
6. Lotte Chemical

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Revolutionary Electrochemical Sensors: A Paradigm Shift in Sensing

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Abstract

The field of sensing has undergone a transformative change with the emergence of revolutionary electrochemical sensors. This conceptual review explores the impact of electrochemical methods on environmental pollutant detection, focusing on multianalyte detection, portable instrumentation, cloud-based storage, and synergistic applications. Electrochemical sensors revolutionize environmental pollutant detection with affordable tools and exceptional detection limits. Multianalyte detection is a remarkable capability, enabling simultaneous analysis of multiple organic and inorganic pollutants in a single measurement. With sensitivity to detect pollutants at parts per billion levels, electrochemical sensors outperform traditional methods like high-performance liquid chromatography. Portable potentiostats and screen-printed electrodes address challenges associated with conventional setups. These cost-effective alternatives enable on-the-spot sensing, suitable for multianalyte detection in environmental monitoring, biomedical diagnostics, and food quality control. Cloud-based storage enhances data management and accessibility in sensing, crucial in water quality monitoring. Remote storage and analysis of large volumes of data enable real-time monitoring and timely decision-making for effective pollution control strategies. Electrochemical sensors find synergistic applications in agriculture, food, oil industries, and environmental monitoring, highlighting their versatility. They detect and quantify pollutants in air, water, soil, and contribute to medical diagnostics for rapid and accurate biomarker detection. In the food industry, they monitor and determine contaminants, ensuring consumer safety. In conclusion, electrochemical sensors revolutionize sensing, particularly in multianalyte detection. Their sensitivity, affordability, and user-friendly nature make them invaluable for environmental pollutant analysis. Portable instrumentation, cloud-based storage, and synergistic applications enhance their capabilities. Continued research and technological advancements expand their applications in wearable health monitoring, smart cities, and beyond.

Keywords

Electrochemical sensors, portable potentiostats, IoT, cloud storage, wearable sensors, pollutant

Introduction

Multi-analyte detection holds greater significance compared to single analyte detection, particularly in the context of environmental pollutant detection. The monitoring of environmental pollutants is crucial for effective pollution control strategies and minimizing their impact on ecosystems and human societies. While electrochemical methods are widely employed for detecting environmental pollutants due to their affordability, user-friendliness, and favorable detection limits, their importance is further underscored in the realm of multi-analyte detection.

Traditional approaches, such as high-performance liquid chromatography coupled with expensive mass spectrometry detectors, are commonly used for detecting environmental pollutants. However, these methods are often required for trace level detection in the parts per billion (ppb) range. In contrast, electrochemical methods have demonstrated remarkable sensitivity for single pollutant detection, even at ppb levels. For instance, a study by Jimana et al. (2018) showcased the capability of a CoNPs/rGO exfoliated graphite electrode to detect arsenic in water below the World Health Organization's permissible limit.

What sets electrochemical methods apart is their ability to detect multiple pollutants simultaneously in a single analysis, offering both adequate sensitivity and excellent selectivity. This attribute makes them superior to traditional methods and opens up possibilities for comprehensive environmental monitoring in a more efficient and cost-effective manner. However, majority of reports in the scientific databases are still based on single analyte detection instead of multiple analyte detection which requires urgent attention from researchers around the world to diversify their electroactive materials with sufficient functionality for multi-analyte detection.

The advancement of electrochemical sensing applications can greatly benefit from the adoption of portable potentiostats, such as those offered by Palmsense or Zimmer Peacock. These portable devices allow for on-site measurements and analysis, enabling real-time monitoring and immediate decision-making in various fields, including environmental monitoring, healthcare diagnostics, and food safety (Mahato & Wang, 2021; Munawar et al., 2020).

Unlike traditional, bulky potentiostats commonly used in laboratory settings, portable potentiostats offer several advantages. Firstly, their compact size and lightweight nature make them highly portable, allowing researchers and field operators to conveniently carry them to the desired location for measurements. This portability eliminates the need for sample transportation to centralized laboratories, saving time and resources.

Additionally, portable potentiostats often boast user-friendly interfaces, intuitive operation, and simplified data analysis. These features enable non-experts to perform electrochemical measurements with ease, facilitating widespread adoption and democratization of the technology. Moreover, these portable devices are designed to be cost-effective, making them accessible to a broader range of users, including researchers in resource-limited settings and industries requiring point-of-care testing.

Despite the clear advantages of portable potentiostats, it is important to note that a significant portion of electrochemical sensing applications still relies on large potentiostats utilized in laboratory-scale experiments. This can be attributed to several factors, such as the availability of advanced features, higher

measurement precision, and compatibility with complex experimental setups (Suhaimi et al., 2023). Moreover, certain applications necessitate the use of large potentiostats to accommodate specific electrode configurations, multiple working electrodes, or custom experimental designs.

However, the growing interest and demand for portable potentiostats indicate a promising trend towards the development and deployment of electrochemical sensing applications at the point of need. As technology continues to evolve, it is anticipated that further improvements in portable potentiostats will bridge the gap between laboratory-scale research and real-world applications, leading to enhanced accessibility, efficiency, and widespread adoption of electrochemical sensing in various fields.

The increased exposure of water bodies to toxins from the expanding global population and industrialization has made water quality monitoring essential. Due to their sensitivity, selectivity, speed, low cost, and ease of operation-features that are not possible with conventional methods-detection strategies including electrochemical and optical analysis techniques have grown in popularity in environmental monitoring (Abels et al., 2021). However, the majority of these techniques' sensors are only useful in the laboratory and require specialised knowledge for signal and outcome analysis. This phenomenon makes on-site detection and off-site monitoring cumbersome (Mandal et al., 2019).

The emergence of cloud storage and the Internet of Things (IoT) has brought about significant advancements in the field of electrochemical sensors, enhancing their capabilities and expanding their applications. These technologies play a crucial role in enabling real-time data acquisition, remote monitoring, and seamless connectivity, revolutionizing the way electrochemical sensing is conducted.

The detection of biological and chemical (organic and inorganic) components in water has been greatly aided by electrochemical biosensing approaches (Liu et al., 2022). For instant, *E. coli* detection utilising an impedimetric approach and a smartphone-based MF sensor are two updated versions of the detection assays (Jiang et al., 2014). A smartphone is employed as a lightweight, inexpensive gadget with wireless connectivity, making it better suited for field applications and enabling remote water quality monitoring. An MF detection chamber (used in the preconcentration of bacteria in diluted samples) and detection electrodes make up the sensor section. The group of researchers created an Android application programme that allows for the simultaneous electrical operation of the sensor as well as the recording and presentation of EIS measurement and test results.

However, the integration of cloud storage and IoT with electrochemical sensors is of paramount importance, revolutionizing the field and unlocking a plethora of possibilities. These technologies provide seamless connectivity, real-time monitoring, and advanced analytics, empowering researchers and industries to make informed decisions, optimize processes, and achieve unprecedented levels of efficiency and accuracy in electrochemical sensing applications.

Electrochemical sensors have found wide-ranging applications across various fields including agriculture, food, and oil industries as well as in environmental and biomedical applications. For example, electrochemical sensors have been applied in environmental monitoring, where they are used to detect and quantify pollutants in air, water, and soil. These sensors also play a crucial role in medical diagnostics, enabling the rapid and accurate detection of biomarkers for diseases such as diabetes, cancer, and infectious diseases. Moreover, electrochemical sensors are employed in the food industry for the

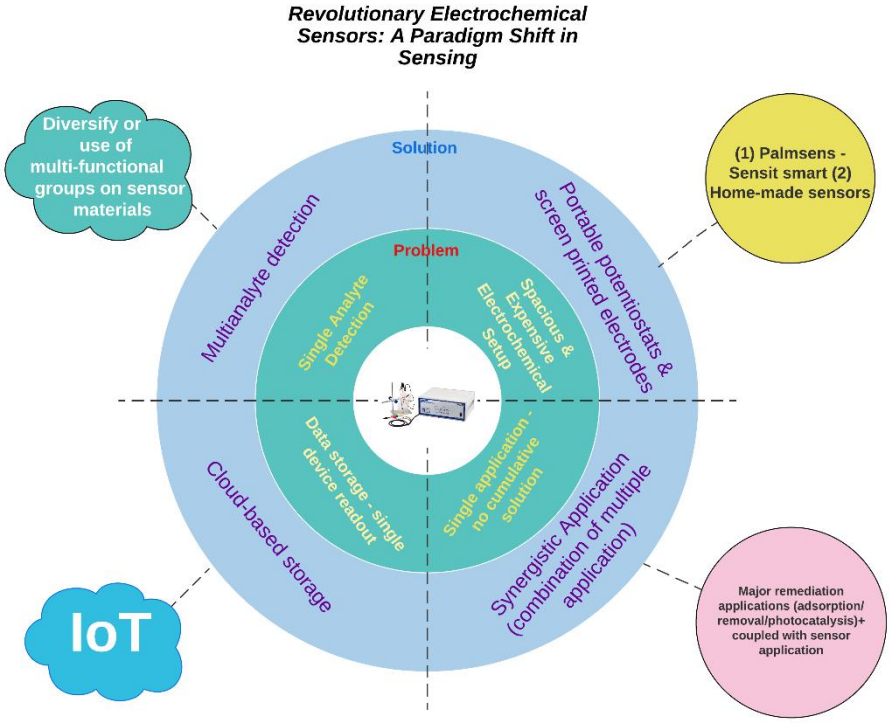
monitoring and determination of food contaminant. For instance, Gevaerd et al. have demonstrated a nanocomposite based screen-printed electrode. With a liner range of 0.03-15.6 ng/mL for aflatoxin B1 voltametric determination (Pérez-Fernández & de la Escosura-Muñiz, 2022).

Electrochemical sensors, despite their widespread use and effectiveness in various applications, have their limitations. One of the key problems with electrochemical sensors is their susceptibility to interference from other chemicals or environmental factors. The presence of substances with similar electrochemical properties can result in false readings or inaccurate measurements, jeopardising the reliability of the sensor. For instance, in glucose sensing for diabetes management, electrochemical glucose sensors rely on the enzymatic reaction between glucose and glucose oxidase to produce an electrical signal. However, certain substances such as uric acid or acetaminophen can exhibit electrochemical behavior similar to glucose and generate a signal that is indistinguishable from glucose (Teymourian et al., 2020).

Additionally, electrochemical sensors often require calibration to maintain their accuracy, which can be time-consuming and costly. Another issue is their limited selectivity, as certain sensor types may struggle to differentiate between closely related compounds, leading to potential misinterpretation of results. Furthermore, electrochemical sensors are typically limited in terms of their detection range and sensitivity, which can hinder their ability to detect low concentrations of target analytes. These challenges highlight the need for ongoing research to improve sensor selectivity through different strategies, such as modifying the sensor surface, utilizing specific enzyme coatings, or employing advanced signal processing algorithms, to minimize the impact of cross-reactivity and enhance the reliability of electrochemical measurements.

In the future, electrochemical sensors hold immense potential for advancements in wearable health monitoring devices, enabling continuous monitoring of vital signs and providing real-time feedback for personalized healthcare. Additionally, they could contribute to the development of smart cities by integrating into IoT systems for real-time monitoring of air and water quality and pollution levels. With ongoing research and technological advancements, the future prospects of electrochemical sensors involve increased sensitivity, selectivity, miniaturization, and cost-effectiveness, opening up new opportunities for applications in fields such as food safety, renewable energy, and security.

Graphical highlights of the future research direction



Conclusion and recommendation

In conclusion, the emergence of electrochemical sensors has revolutionized the field of sensing, particularly in the detection of environmental pollutants. These sensors offer affordability, user-friendliness, and good detection limits, making them popular for detecting organic and inorganic pollutants at low concentrations. They outperform traditional method in terms of sensitivity and selectivity, enabling the detection of pollutants at parts per billion levels. However, ongoing research is required to address issues like interference and limited selectivity. Nonetheless, electrochemical sensors are widely applied in environmental monitoring, biomedical diagnostics, and food quality control. Integration with wearable devices and IoT systems offers further potential. Continued research and technological advancements are essential to improve sensor performance, unlocking opportunities in food safety, renewable energy, and security. Overall, electrochemical sensors represent a paradigm shift in sensing and hold promise for the future.

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List of top 5 universities/ research institutes in related field (local and international)

1. University of Cambridge
2. Gordon Robert University
3. University of Chulalongkorn Thailand
4. National University of Singapore
5. Institut Teknologi Bandung

List of top 3 industries in related field (local and international)

1. Biosensors International Technologies (international)
2. Biogenes Sdn Bhd (local)
3. Ideria Sdn Bhd (Local) – start up UNIMAP
4. MIMOS Bhd

List of 6 potential funders for future research grants (local and international)

1. Ministry of Higher Education
2. Ministry of Science Technology and Innovation
3. TORAY Foundation
4. Horizon Europe
5. Innovate UK
6. MRANTI & CREST

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SOLAR CONCENTRATOR POWER GENERATION USING THERMOELECTRIC GENERATOR

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Abstract

Solar Thermoelectric Generator (STEG), a hybridization system of thermoelectric generator (TEG) with a heat exchanger, has been extensively studied due to its ability to simultaneously produce electricity and heat. STEG has been progressively enhanced to contend more effectively with rival technologies. However, STEG technology is not yet on par with CSP and PV systems in terms of effectiveness. Single TEG characterisation tests were performed for this study (indoor experiment). A theoretical modelling was developed based on the characterization test. To conduct the test, a single TEG was placed in the middle of a cooling system and an aluminium block. The study's goal is to determine the optimal power output of a single TEG under varying heating conditions using three distinct cooling strategies which is air, water and phase change material (PCM) cooling method. A water-cooled cooling approach (with water cooling jacket), an air-cooled cooling method (with finned heat sink and USB driven fan), and a PCM (phase change material)-cooled cooling method were used to test how well the TEG performed in each environment. The results demonstrated that compared to air and PCM cooling, water cooling improved STEG performance, resulting in more power output.

Keywords

Solar energy, temperature gradient, power generation, thermocouple

Introduction

Energy consumption is rising rapidly as a result of rising populations and increased industrialization. The role of developing countries, which will contribute considerably to the world's population increasing by two billion in a single generation, is crucial. Preventing an energy catastrophe is dependent on keeping up with this rising need for energy, which is inextricably related to the expanding human population around the globe.

Overusing nonrenewable energy sources is also dangerous, as it can accelerate climate change and cause ecological catastrophes. Consequently, switching to renewable energy is a must. Hygiene, affordability, stability, efficiency, and environmental impact are just few of the considerations that should go into selecting an energy source.

Pure, renewable, and plentiful, solar energy presents itself as an attractive option. The sun generates enough energy to power the world's economy for a full year in just 90 minutes. Although it has great promise, solar power still makes up a relatively small percentage of the world's energy supply. This situation is fast evolving as a result of worldwide measures to improve energy access, supply security, and climate change mitigation. Solar energy stands apart from other renewables due to its abundance and theoretical capacity to meet global energy demand.

Different methods, such as Concentrated Solar Power (CSP), Photovoltaic (PV), and the more contemporary Solar Thermoelectric Technology (STEG), have been developed to collect solar energy over the years. Concentrated solar power (CSP) makes use of mirrors to focus the sun's rays on a receiver, extracting heat that can be used either directly or indirectly in the production of electricity. Energy from the sun can be harnessed using photovoltaic cells. STEG is a no-moving-parts, solid-state technology that generates electricity through the Seebeck effect when one side is kept at a higher temperature.

STEG has promise, but it still can't compete with CSP and PV in terms of efficiency. The performance of STEG is the focus of current research. Although CSP is efficient, it requires extensive planning and lots of room to be put into action. However, PV technology can be pricey due to the time and materials required to build it. As a solid-state heat engine, STEG has benefits including running at greater temperatures with no moving parts or fluids.

The fundamental objective of this work is to evaluate STEG's performance, especially with regard to its thermal energy and electrical output capabilities. All other factors, including as cost, ease of installation, and impact on the environment, are ignored in favour of STEG's design and performance. Efficiency of the optical absorber and the thermoelectric subsystem are the primary focus of the assessment.

The findings of this study shed light on the promise of STEG as a means of harvesting solar power. Although it may not be as efficient as CSP or PV right now, researchers are working to improve it. The results can be used to fine-tune the system and make it more competitive with current solar energy collecting techniques. Advanced thermal interface materials, refined STEG module topologies, and novel cooling technologies can all be explored in future research to increase power output and meet the needs of specific applications.

Given the world's increasing energy needs and the need to switch to sustainable energy sources, STEG and other solar technologies hold great potential. One important step towards more efficient use of solar energy is to evaluate STEG's efficiency on its own. Researchers and engineers may help the world's efforts to optimise solar energy capture systems by taking into account the specific benefits and drawbacks of this technology, which is crucial for meeting the urgent energy and environmental concerns of the twenty-first century.

Figure 1 illustrates the P-V and I-V curves for the air-cooled (Forced Convection) cooling method for T_{hot} = 40°C to 120°C. Figure 2 represents the P-V and I-V curves for the water-cooled cooling method for T_{hot} = 40°C to 120°C, whereas Figure 3 displays the P-V and I-V curves for the PCM-cooled cooling method for T_{hot} = 40°C to 120°C. It can be deduced from these figures that as the temperature difference ΔT TEG between the two sides of the TEG increases, so do the output current V_{out} and output power P_{out}. In

addition, based on these data, the slope of I-V was nearly identical, indicating that the TEG internal resistance is constant regardless of the TEG hot side temperature and load resistance.

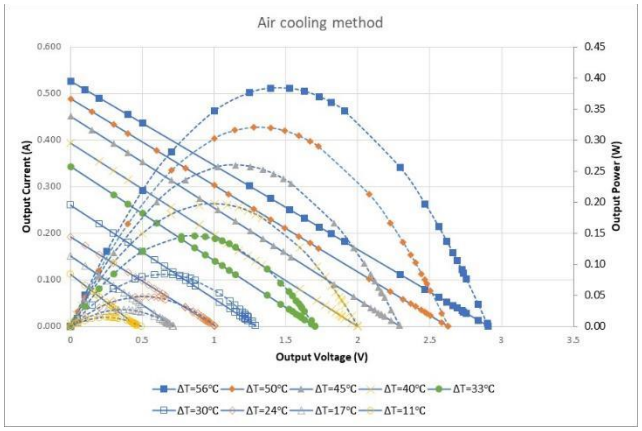


Figure 1: P-V and I-V curves for Air-Cooled Cooling Method (Characterization Test) for T_{hot} = 40°C to T_{hot} = 120°C.

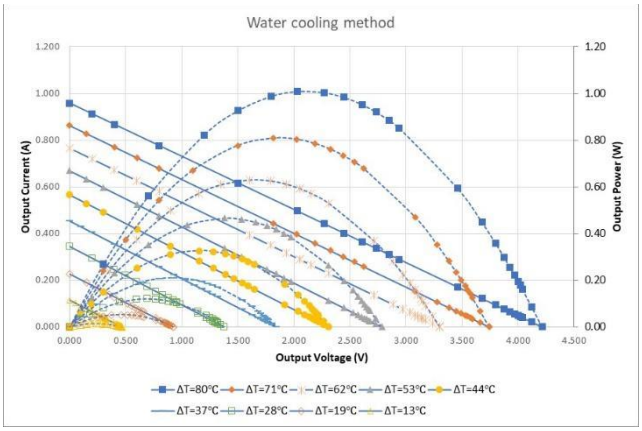


Figure 2: P-V and I-V curves for Water-Cooled Cooling Method (Characterization Test) for T_{hot} = 40°C to T_{hot} = 120°C.

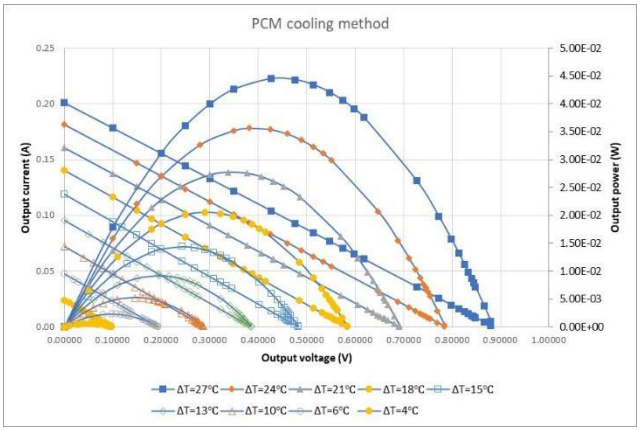


Figure 3: P-V and I-V curves for PCM-Cooled Cooling Method (Characterization Test) for T_{hot} = 40°C to T_{hot} = 120°C.

Using a heat sink and fan to cool the component with air yielded the second-highest power output (0.3808 Watts), but it was limited by the poorer thermal conductivity and heat capacity of air compared to water. The most efficient method was water cooling, which used water's greater heat transfer characteristics to keep temperatures down and produce the greatest electricity. The benefits of thermal energy storage and

controlled heat dissipation through phase change were established, making PCM cooling a practical passive cooling approach with a maximum output of 0.0443 Watts.

Figure 4 illustrates as the voltage output decreases, the graph will demonstrate a decreasing trend for the water cooling method. The maximum power output is relatively high at higher voltage outputs and progressively decreases as the voltage output decreases. This indicates that the TEG's optimal power output is achieved at higher voltage levels when water cooling is utilised. As the voltage output decreases, the power output also decreases, indicating a trend of decreasing power output. for air cooling method, the maximum power output values are substantially lower than for water cooling method. This indicates that the TEG produces less power when cooled with air as opposed to water. As the voltage output decreases, the graph will depict a steeper decline in power output. The maximal power output values for PCM cooling are even lower than those for air cooling and water cooling. As the voltage output decreases, the graph will show a relatively gradual decrease in power output.

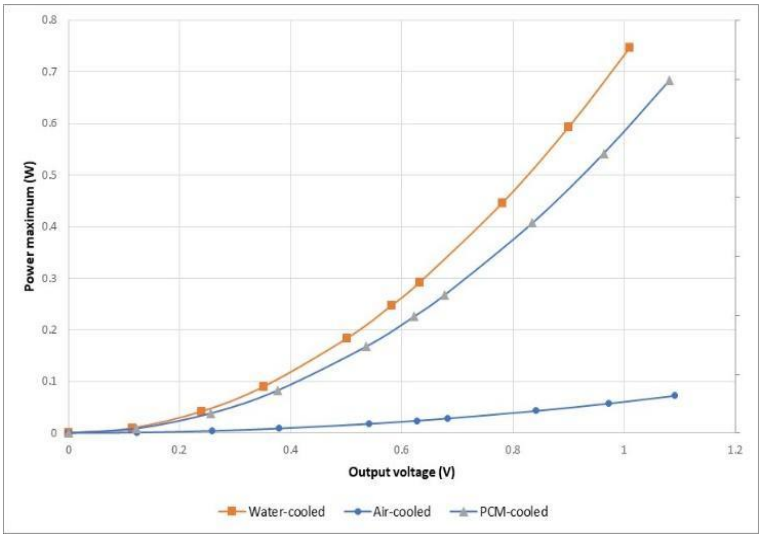
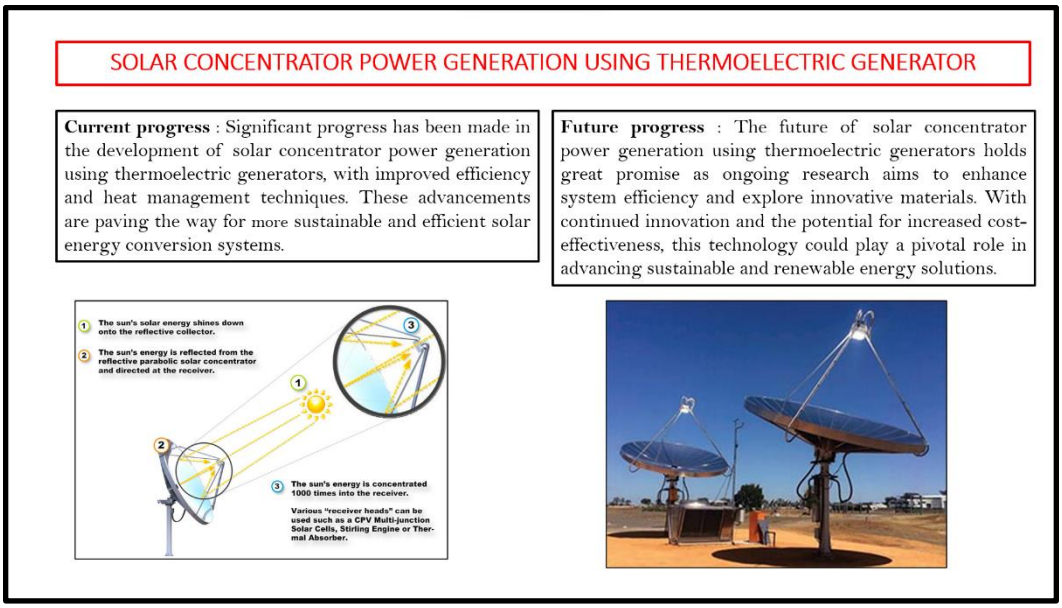


Figure 4: Power maximum output and voltage output for air-cooled, water-cooled and PCM-cooled cooling method

Graphical highlights of the future research direction



Conclusion and recommendation

As a result, the experiment revealed substantial differences in TEG performance depending on the cooling method used. With its 1.0051 watts, water cooling easily beat out the competition because to its efficient heat transmission and constant cooling. Using convective heat transfer and a heat sink, air cooling (producing 0.3808 watts) provided a viable option. With a power consumption of only 0.0443 watts, PCM cooling was a viable passive cooling solution. The results of the research stress the need of using an appropriate cooling strategy for TEG installations. While water cooling is the most effective method, air cooling is a respectable upgrade. Power-conserving modes of operation benefit from PCM cooling. This knowledge will inform future investigations into improving TEG system cooling methods.

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List of top 5 universities/ research institutes in related field (local and international)

1. University of Malaya
2. RMIT University
3. Universiti Tunku Abdul Rahman
4. National University of Malaysia
5. Jayabaya Universitas Indonesia

List of top 3 industries in related field (local and international)

1. FRH Energy Sdn Bhd (local)
2. Industrial System Supply & Engineering Services Sdn Bhd (**ISSES**) (local)
3. Solarvest Bhd (Local)

List of 6 potential funders for future research grants (local and international)

1. Ministry of Higher Education
2. Ministry of Science Technology and Innovation
3. TORAY Foundation
4. Horizon Europe
5. Innovate UK
6. MRANTI & CREST

FREE07

Predictive Analytics of Rainfall and Water Level using Machine Learning-Driven for Smart Flood Preparedness in Sarawak

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Abstract

Hydrology, climate science, water resource management, agriculture, and flood predictions all hinge on the critical analysis of water levels and rainfall patterns. This entails the examination of historical data, patterns, and trends to gain insights into the intricate dynamics of these hydrological phenomena. Accurate prediction of rainfall and water levels is paramount, as it forms the bedrock of flood forecasting and early warning systems. Such precision enables authorities and disaster management agencies to issue timely alerts, devise effective evacuation strategies, and mobilize resources to minimize the impact of floods, ultimately reducing the loss of life and property damage. In pursuit of this, our study aims to leverage cutting-edge machine learning-driven predictive analytics to classify and predict water levels and rainfall in the region of Sarawak. To facilitate this analysis, we harnessed a comprehensive dataset extracted from iHYDRO.sarawak. Our methodology encompasses feature selection preprocessing, classification, association, and data visualization through plot analysis. The efficacy of our predictive models was assessed using the WEKA tool on a dataset comprising 1000 instances, equally divided between water level and rainfall data. Root mean squared error (RMSE) was employed as a performance metric. In our evaluation, the "AddictiveRegression" algorithm demonstrated exceptional accuracy with an RMSE of 0.1386, establishing its superiority in water level prediction. For rainfall prediction, the "RandomForest" algorithm emerged as the topperforming model, boasting an RMSE of 3.6379. This research marks a significant stride toward enhancing flood preparedness in Sarawak, underpinned by the power of machine learning-driven predictive analytics for rainfall and water level forecasting.

Keywords

Predictive analytics, rainfall prediction, water level forecasting, climate science

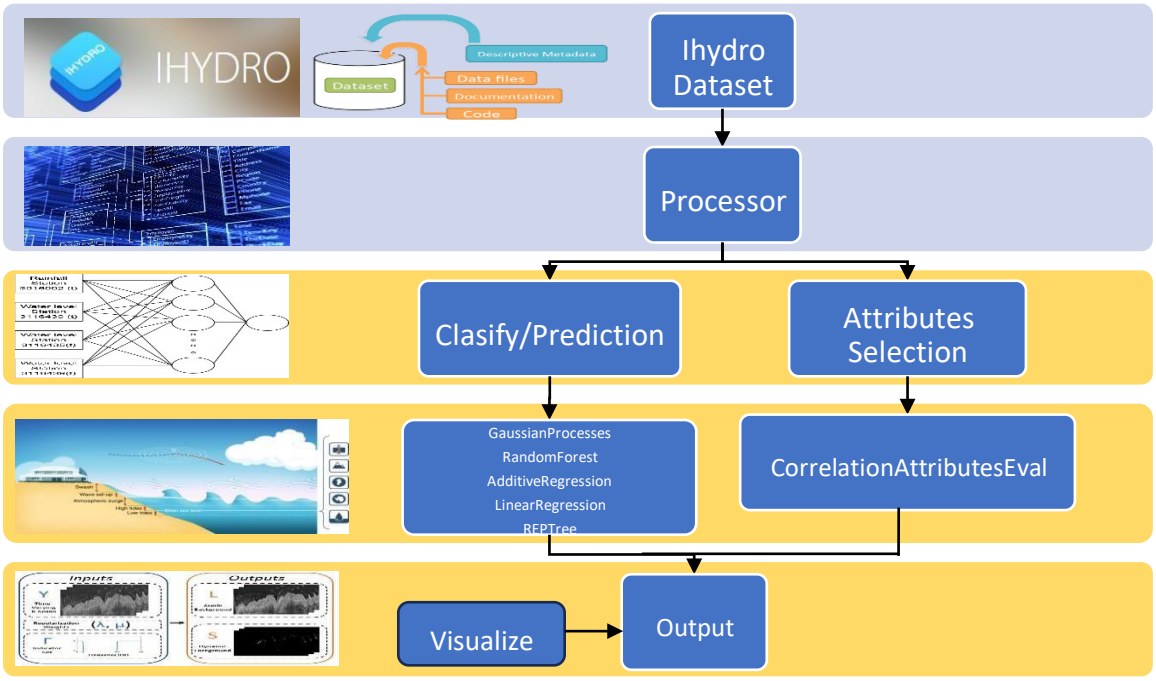
Introduction

In today's context, particularly during the rainy season, the accurate prediction of rainfall and water levels has become a matter of utmost importance. These forecasts play a pivotal role in safeguarding against various adverse consequences, including crop and farm losses, property damage, flooding, and numerous other potential disasters. Predictive measures allow us to proactively plan and mitigate these effects. When addressing forecasting strategies in the state of Sarawak, the utilization of IHYDRO Sarawak for predicting cumulative rainfall and water levels in its rivers becomes paramount. IHYDRO Sarawak, a website maintained by the Department of Irrigation and Drainage Sarawak, serves as an invaluable resource for accessing detailed information about rainfall and water levels. This user-friendly platform enhances data comprehension and facilitates informed decision-making. IHYDRO is, essentially, an online hydrological telemetry system created to provide real-time monitoring for droughts and floods. Operating under the Centralized Information Telemetry Networks (CITN), the Hydrological Telemetry System (HTS) is a public domain resource. It offers real-time data on rainfall and water levels, enabling the early monitoring and assessment of floods in Sarawak, ultimately reducing property damage and saving lives. The crux of the matter lies in the fact that without predictions, people remain uninformed about impending disasters, particularly in a region known for its vast and lengthy rivers like Sarawak. The predictive capacity for water levels is indispensable in ensuring the safety and efficiency of navigation and transportation along rivers, ports, and harbors. Water level forecasts enable ship operators to plan routes, factor in tidal variations, and steer clear of shallow areas or hazards resulting from high water levels. Accurate predictions underpin secure transportation of goods and passengers, contributing to economic activities. The significance of predictions extends further. Timely forecasting of water levels and rainfall empowers the government to issue timely alerts, coordinate evacuations in high-risk areas, and implement flood protection measures. This proactive approach significantly reduces the financial burden of flooding, saving lives and preventing property damage. Moreover, effective water resource planning and management hinge upon the ability to predict water levels and rainfall in reservoirs, rivers, and other water bodies. Such predictions aid in identifying available water resources, allocating them efficiently, and managing water supply systems, which is vital for industries encompassing agriculture, manufacturing, domestic water supply, and hydropower generation.

Conversely, failing to predict water levels and rainfall increases the risk of floods and hinders authorities from issuing timely warnings or implementing necessary precautions to mitigate flooding. This heightened risk can result in extensive property damage, loss of lives, and disruptions to critical infrastructure and services. Moreover, communities and decision-makers, lacking reliable predictions, may struggle to establish adequate safeguards for coastal areas, manage water resources, and address the challenges posed by climate change, including rising sea levels and altered precipitation patterns.

In light of these considerations, the prediction of water levels and rainfall in Sarawak emerges as a critical imperative for not only managing immediate risks but also for preparing for the broader impacts of climate change.

Graphical highlights of the future research direction



Conclusion and recommendation

This study has successfully harnessed data from Ihydro.sarawak.gov.my to construct forecasting models for rainfall and water levels along Sarawak's rivers in Malaysia. Through a meticulous analysis of historical data, this endeavor has shed light on the intricate patterns, trends, and interrelationships between rainfall and river water levels in the region. The resultant prediction models have exhibited an impressive degree of accuracy in foreseeing future rainfall and water levels. The implications of these findings are farreaching, significantly impacting Sarawak's water resource management and flood risk reduction strategies. Armed with precise estimates of rainfall and water levels, decision-makers can adeptly strategize and oversee the utilization of water resources.

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List of top 5 universities/ research institutes in related field (local and international)

1. Universiti Putra Malaysia(local)
2. Universiti Teknologi Mara(local)
3. University of Kuala Lumpur(local)
4. Harvard University (International)
5. Uniersity of Oxford (International)

List of top 3 industries in related field (local and international)

1. Department of Irrigation & Drainage Sarawak (local)
2. Sarawak Information System, SAINS (local)
3. Department of Meteorology Malaysia (local)

List of 6 potential funders for future research grants (local and international)

1. Ministry of Higher Education (local)
2. Ministry of Science Technology and Innovation (local)
3. Malaysia Toray Science Foundation (local)

FREE09

Moisture Penetration Depth in Concrete Subjected to Wind-Driven Rain: Experimental and Numerical Simulation Approach

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Abstract

Wind Driven Rain (WDR) has been one of the important factors that lead to problem in building configuration and durability performance of the building. To mention, the flooding issues on open spaces, penetration of WDR into the building material, soiling pattern on building wall and mould growth on building façade. However, there is still a small number on this study conducted for tropical country like Malaysia. Therefore, this study will mainly focus on quantification and distribution of moisture due to driven rain on the surface of concrete building. The main interest basically come from the idea that the estimation of moisture distribution in exposed concrete will lead to reliable prediction on its durability performance. And, the depth of moisture ingress in concrete under certain rain fall exposure and condition of physical concrete will be relate with the suitability design of cover thickness for reinforced concrete elements. This will be a major of interest for this study since the rational cover thickness is considered as the first protection barrier that significantly important in reinforced concrete to combat any undesirable fluid or gases to penetrate into concrete. The finding are expected to assist the prediction on potential expected area that could be affected and deteriorate in future under continues driven rain event exposure, thus lead for a rational inspection and maintenance program schedule.

Keywords

Wind-driven rain, moisture, concrete, durability

Introduction

Environmental factors play an important key towards the problem of durability faced by many structures where it comprises of moisture, temperature, solar radiation, air movement and pressure, precipitation, chemical and biochemical attack, and intrusion by micro- and macro-organisms (Moncmanova, 2007). Malaysia is one of the tropical climate countries that receive a lot of rainfall throughout the years. Strong winds frequently accompany the rainfall where the raindrops are impacted by the wind speed and their own gravitational pull when they fall. As a result, the raindrops fall at an angle rather than striking the building's roof and wall directly. A wind-driven rain effect is created, which typically increases the amount of rain and the pressure load of rain on the building's walls and roof (Sun et. al., 2021). When subjected

to the buildings, this oblique rain has an impact on the material durability of building facades, the water and heat exchange qualities, and is a substantial source of moisture for building facades. Its harmful effects can manifest in a variety of ways, such as moisture build up in porous materials, degradation of surface material, weathering and discoloration, and temperature and moisture gradients-induced cracking of structures (Gholamalipour et al., 2022).

Some previous studies have been conducted to look on the effect of normal rainfall and wind- driven rain on the structural building and materials. Study conducted by Sarkar & Bhattacharjee (2015) investigate the effect of tropical rainfall in India on the depth of moisture penetration in concrete through the numerical approach. Hadja & Kharchi (2017) looked on the action of rainwater that led to an erosion phenomenon particularly on the inclined reinforced concrete walls. Both studies did indicated some negative effect of normal rainfall on structural buildings but there is no particular discussions have been done on regards to wind-driven rain perspective.

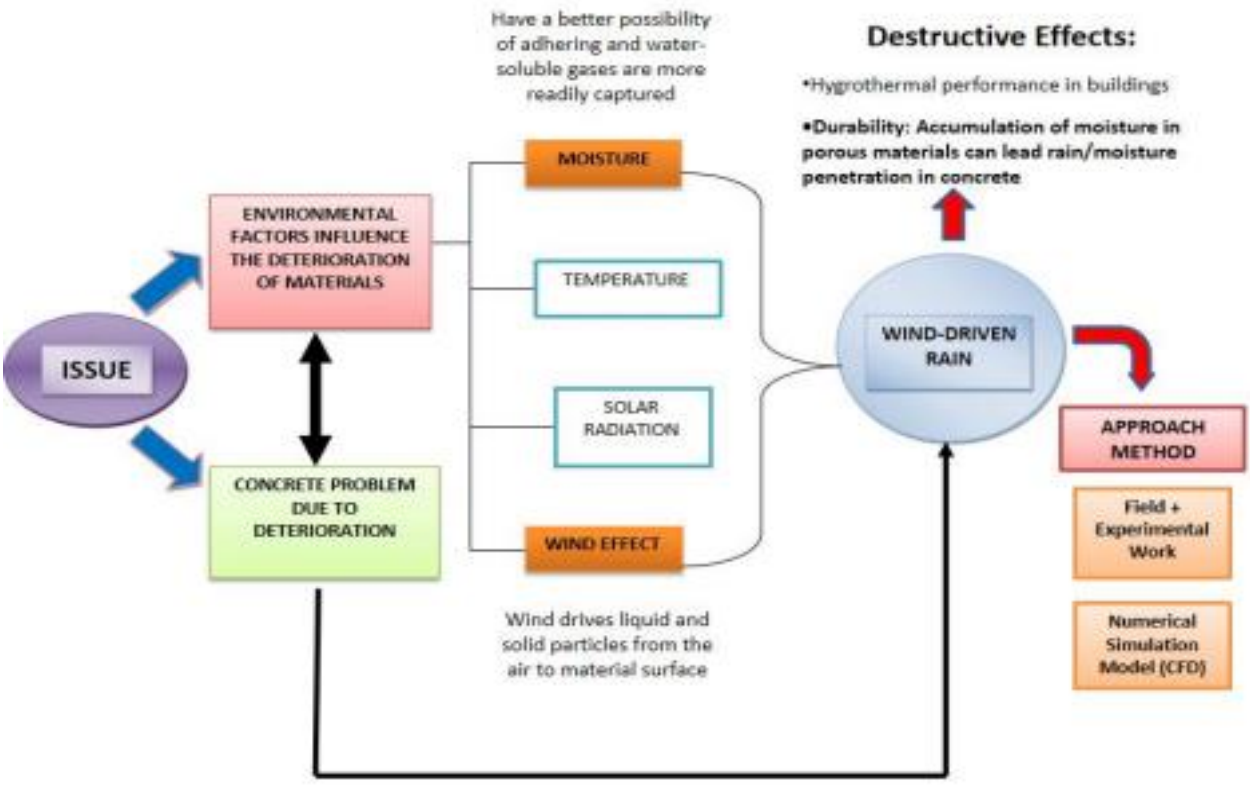
Meanwhile, on regards to wind-driven rain research subject, Choi (1997) have established the method for rain penetration testing under wind-driven rain event for the building envelope. Meanwhile, Krpan (2013) stressed on investigation of the rain penetration on the windows opening in building under the same test method proposed by Choi. Forghani et al. (2017) conducted the experimental to determine the leakage effect on masonry wall due to wind-driven rain exposure where the rain penetration test were developed using a standard test methodology. Orr & Cassar(2020) have proposed the indices to represent the exposure of cultural heritage in urban areas to extreme wind-driven rain events. In recent year, computational fluid dynamics (CFD) modelling become more advancing, and being more often used as a tool for wind-driven rain studies due to their data flexibility and cost optimization. Khalilzadeh et al. (2019) simulated the wind flow and wind-driven deposition around the six-storey building by using the computational fluids dynamics (CFD) numerical model. Kubilay et. al. (2021) on the other hand performed the (CFD) simulation of wind-driven rain to determine the part of the reference building envelope that prone to receive high intensity of rain in order to provide some data for the moisture-induced damage risk assessment. Fang et al. (2021) studied the effect of the wind- driven rain on hygrothermal performance of building wall by conducted the heat transfer simulation using CFD model analysis. Chen & Zhou (2022) looked on the behaviour of the wind-driven rain flow around the building by using the Eulerian multiphase solver of CFD numerical model.

In overall, findings from the previous research indicated that the wind driven rain have most significant contributor to moisture for a building and an inherent problem for large building and some cultural heritage where it can hamper the hydrothermal performance of structure and can cause major damage if left unchecked. However, most of these studies mainly pointed out the moisture penetration of driven rain on the building opening and envelope while only little discussion being done on the material properties consideration. To the knowledge of author, the research subjects on moisture penetration due to rainfall on concrete is still scarce particularly with the incorporation of wind-driven rain load. There is not much finding from the previous studies to verify the real potential of driven rains significant contribution on moisture penetrate in concrete as compared to the normal rain.

There is significant expectation that the characteristic of wind-driven rain could have potential contributed to the durability problem in concrete building materials due to ability of rain to accumulate and penetrate on the concrete surface. Therefore, to answer that research questions, this study will

looked on the effect of wind-driven rain on the moisture depth penetration on concrete material. At first phase, the parameter data for experimental testing will be design from the field measurement that will be conducted under the dominant weather conditions of the local environment, where in this study the environmental context is tropical climate in Shah Alam, Selangor in Malaysia. Data collected from the field measurement will be validating with the numerical method analysis. Numerical analysis will consist of simulation of WDR on respective building that will be conducted using Computational Fluid Dynamic (CFD) software namely as ANSYS: FLUENT. The expected output data from these approaches is it able to develop the wetting pattern distribution or catch ratio contour over the surface of building façade. Further, the series of experimental work will be conducted based on data from first phase where the sample of concrete specimen will be subjected to normal and wind-driven rain exposure and the comparison between both exposures will be discussed. In addition, to represent the actual physical condition of concrete under the course of service, the presence of service crack effect will also be investigate with their relation on moisture ingress in concrete in correlation to cover thickness depth. The mechanism and distribution of driven rain amount receive at particular area on reference building are expected to help us for better understand on potential deterioration process that will take place and thus lead to effective and rational inspection and maintenance works in the future.

Graphical highlights of the future research direction



Conclusion and recommendation

The focus of this study will be looked on how substantial wind-driven rain events can be as a factor that can contribute to moisture penetration in concrete materials. It was expected that excessive amount of moisture due rainfall event together with wind effect could lead to potential durability problem on concrete materials that come from the moisture penetration mechanism. The study's findings will be addressed in relation to the acceptability of cover thickness designs that could be used or avoided as a response to local environmental exposure. Knowledge on moisture sources and accumulation area on building surface can help to minimize the risk of moisture to penetrate into concrete and help to add some knowledge in rational design of cover thickness and maintenance program.

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2. Universiti Malaya (Local)
3. Eindhoven University of Technology,Netherlands (International)
4. Concordia University,Canada (International)
5. University of Zaragoza, Spain (International)

List of top 3 industries in related field (local and international)

1. The Malaysian Industry-Government Group for High Technology (MIGHT(Local)
2. NEAPOLI (Local)
3. Ecologically Sustainable Design Sdn.Bhd (Local)

List of 6 potential funders for future research grants (local and international)

1. Ministry of Higher Education (Local)
2. Ministry of Science Technology and Innovation (Local)
3. Malaysia Toray Science Foundation (Local)
4. MRANTI & CREST (Local)

FREE10

Immobilised Photocatalyst Substrates: A Way Forward for Large Scale Wastewater Treatment

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Abstract

Photocatalytic degradation emerges as one of the advanced methods for wastewater treatment especially for combating persistence organic pollutants (POP). The system utilizes photocatalyst that can be activated in the presence of light energy. The light causes the surface electrons (e-) of the photocatalyst to experience valence band excitation which later produce active radical species to degrade pollutant to safe and less harmful compound. Due to their high cost and ineffective post-treatment recovery, nano-sized photocatalysts frequently run into issues when use in a large-scale operation. Anchoring the nano-sized photocatalyst onto a support has gained interest recently. Some of the support that have been used to immobilize the photocatalyst including glass, carbonaceous compounds, clay, ceramics, zeolites, and polymers. The choice of the support significantly depends on chemical inertness, mechanical stability, low density, and ease of availability. It is worth to note that, the development of new immobilised photocatalysts that is efficient in photocatalytic activity under solar and/or visible light spectrums and can also be recycled over a number of runs without suffering a major loss in photocatalytic activity must get careful consideration. Contaminated effluents from businesses, dangerous organic compounds, and pharmaceuticals from home sewage, among other environmental stresses, can be greatly reduced with the widespread use of these types of immobilised catalysts.

Keywords

Photocatalyst, photodegradation, organic pollutant, immobilized catalyst, large-scale photorector

Introduction

Numerous inorganic and organic pollutants contaminate our groundwater and surface water, which raises serious concerns around the world (Ahuja, 2017). The main ways that hazardous substances are released into bodies of water are directly from residential, commercial, and industrial sources, over water overflow, and through the leaching of polluted soil. Given the endless negative effects of the pollutants has on the environment, it is necessary to develop technology that can effectively break down the contaminants to maintain a healthy and sustainable ecosystem for all living creatures. Water

resources have become scarce in recent years because of the shift in environmental imbalance. The limitations of both conventional and advanced water treatment techniques, such as adsorption, coagulation, flocculation, membrane desalination, and ion exchange, include high cost, difficulty removing slurry into the environment, difficulty operating, and a lengthy treatment time (Chen et al., 2020). As a result, there is a strong demand for water purification methods that are reliable, affordable, and environmentally friendly while also enhancing wastewater diversity, concentration, and characteristics.

The photocatalytic approach appears to be the most appropriate of the methods listed above for degrading the organic pollutant by photo-oxidative and photo-reductive degradation (Wang et al. 2020). Due to the active oxygen-containing species produced under UV-visible light as well as the simplicity of photocatalyst process. Heterogenous photocatalysts using hybrid semiconductor and other composite materials are frequently used as photocatalyst for contaminants degradation and in other variety of fields, such as electronics, catalysts, solar cells, and charge storage materials. The advantages of the heterogeneous photocatalyst are reduction of photo-generated electron hole recombination and enhancement of light absorption which later improve the photocatalytic activity. Translating low energy consumption into the research ideas has cornered two-dimensional (2D) nanostructures semiconductor-based materials as prospective photocatalytic materials in the heterogenous photocatalyst because of their visible light driven photocatalytic activity Example of 2D transition-metal oxides with semiconductive properties, such as ZnO, NiO, TiO_2, WO_3; sulphides, such as MoS_2, ZnS, In_2S_3, CdS (Saha et al., 2019).

However, most of the photocatalytic process used nano powder photocatalyst has their own disadvantages including the high cost and difficulty of removing nanoparticles, the strong tendency to aggregate, and the environmental effects of nanoparticle discharge into the biosphere (Bashir et al., 2019). It is highly challenging to recover and reuse these nanoparticles on an industrial scale from the majority of wastewater streams. In this regard, it is crucial to note that using the nanoparticles for the photochemical destruction of contaminants on an industrial scale is quite unrealistic. This is due to, nanoparticles can cause substantial genotoxicity and cytotoxicity to aquatic and human life if they are not removed from treated water streams after photocatalytic degradation Therefore, using techniques that make it easier to reuse used catalyst will go quite a way towards making the photocatalysis process more environmentally friendly in this context. Henceforth, employing of immobilised catalyst for the photodegradation of organic pollutant molecules emerge as the alternative for eco-friendly and sustainable solution for nano powder photocatalyst (Zakria et al., 2021).

In the literature, a variety of techniques have been utilised to immobilise or attach the photocatalyst to support material. It is provided a critical examination of the main photocatalyst immobilisation methods and how they relate to the removal of air pollution. A few immobilisation methods include sol-gel, solvent deposition, electrophoresis, thermal spraying, chemical and physical vapour deposition (Srikanth et al., 2017). Although a variety of materials are available for the photocatalyst support, it is imperative that the material have the qualities such as strong and permanently immobilised the catalyst, after immobilisation, the catalyst must have a large surface area, immobilising agent must also have the capacity to absorb contaminants on its surface and can withstand oxidative radicals produced during the photocatalytic process with great stability.

Immobilising agents made of carbon, particularly those based on carbon nanotube (CNT) and reduced graphene (rGO), are becoming increasingly popular. This can be explained by the reality that

these materials possess high specific areas, exceptional electronic, adsorption, thermal, and mechanical properties in addition to chemical inertness and stability, which make them capable of achieving high efficiency with semiconductor photocatalyst (Norsham et al., 2022, Zhu et. al., 2021). Microporous materials such as zeolites have attracted to become a support material for photocatalyst. This is because, zeolites have a large number of pores that enhance the surface adsorption of the pollutants to the photocatalyst. Besides cheap, safe, and environmentally friendly, zeolites also posses a selectivity quality whereby it can successfully target specific pollutants according to their molecular size (Torkian et al., 2022).

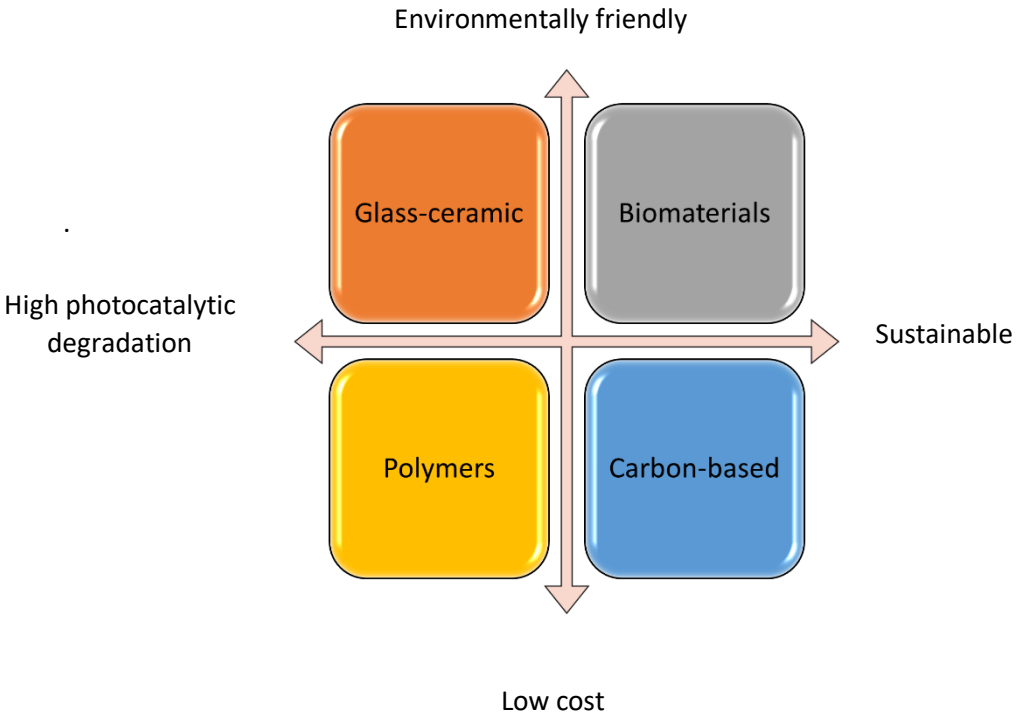
Glass-ceramic substrate in the form of beads or plate often used as the entrapping media for photocatalysts due to its inertness, resistance to high calcination temperatures, optical characteristics, and affordability. Zandona et al. (2021) successfully prepared glassy nanospheres with a SiO_2-TiO_2 composition using sol-gel spray-drying technique under controlled heat conditions. Moreover, lithium borate-bismuth tungstate glass-ceramics have found to have a band gap of 2.8 eV which positively degraded methylene blue dye with 65% degradation percentage in 240 minutes under visible light irradiation (Porwal et al., 2023).

It is relatively straightforward to prepare and produce polymeric materials. Because of this, they can be effectively used as a substrate for the immobilisation of the photocatalyst. Noteworthy that, it can allow for the possibility of recycling discarded polymers, which is a growing environmental concern. Numerous polymers have been used as the support, including polyvinyl chloride, polystyrene, polyaniline, poly(methyl methacrylate), poly(tetrafluoro ethane), poly(3-hexylthiophene, poly(styrene)-co poly(4-vinylpyridine) polyethylene, carbon nitride polymer, polycaprolactone and polycarbonate (Jangid et al., 2021). Yunus et al. (2020) degraded 2-chlorophenol from aqueous solution with 91.1% degradation percentage under direct sunlight using boron nitride doped polypyrrole photocatalyst. Polyethylene glycol (PEG)-modified $Ag/Ag_2O/Ag_3PO_4/Bi_2WO_6$ photocatalyst film exhibit enhanced efficiency and stability under solar light in the degradation of Rh B dye (Ma et al., 2020).

Recent years have seen a lot of interest in the combination of semiconductor and biomaterial as an effective photocatalyst in the degradation of pollutants. The bio-based polysaccharides cellulose, chitosan, and lignin are examples. Numerous benefits, such as ease of use, minimal energy requirements, and cost effectiveness, are provided by the combination. The improved electronic structure and charge transfer capabilities of chitosan-based N-doped carbon materials are responsible for their promising performance in electrocatalytic and photocatalytic reactions (Khan et al., 2020). Yin et al., (2021) prepared Fe_2O_3- stearic acid super hydrophobicity cellulose membrane which exhibited outstanding photocatalytic property that is sustainable after repeated separation for 6 cycles.

Graphical highlights of the future research direction

Immobilised Photocatalyst Substrates: A Way Forward for Large Scale Wastewater Treatment



Conclusion and Recommendations

In conclusion, for the degradation of dangerous organic pollutants that impair in our water resources, photocatalysis is a promising and environmentally friendly approach. The widespread use of photocatalysis for water treatment is hampered for a variety of reasons. The effectiveness of photocatalysts immobilised on supports in degrading various colours, pesticides, pharmaceuticals, and herbicides are among its key characteristics. The creation of new immobilised photocatalysts that can exhibit photocatalytic activity under solar and/or visible light spectrums and can also be recycled over a number of runs without suffering a major loss in photocatalytic activity must get careful attention. However, it is important to highlight that the widespread use of these immobilised catalysts can serve to significantly lessen environmental stress.

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List of top 5 universities/ research institutes in related field (local and international)

1) Rice University, Houston Texas
2) National Science University, Singapore
3) University of Malaya
4) King Saud University
5) Nanjing University

List of top 3 industries in related field (local and international)

1) Puralytics
2) Catalyst for World Water
3) Syzygy Plasmonics Inc

List of 6 potential funders for future research grants (local and international)

1) Ministry of Higher Education (FRGS and PRGS)
2) Ministry of Science Technology and Innovation (SRF)
3) MSTF TORAY Foundation
4) Kurita International Grant
5) Royal Society of Chemistry Grants
6) Organisation for the Prohibition of Chemical Weapons

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Future Development of Iron Oxide Nanoparticles as Microplastics Removal: Encapsulation and Porosity Enhancement

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Abstract

Plastic pollution is a major environmental problem caused by the widespread use of plastic products, inadequate recycling and improper plastic handling and disposal. Plastic is carried to bodies of water by wind and waves, where it fragments into micro and nanoplastics over time. Microplastics (MPs) derived from plastic waste have recently sparked widespread concern due to their widespread presence, posing a threat to natural ecosystems as well as human health and safety. Iron oxide nanoparticles could potentially be capable of removing microplastic pollutants from water. Recently, the use of iron oxide nanoparticles (Fe_3O_4-NPs) offers a promising approach for removing MPs pollutants from water via inducing its magnetic field and adsorption enzymatic immobilization. Due to their hydrophilic surfaces and the presence of charged sites, Fe_3O_4-NPs have a large surface area and can effectively adsorb microplastics. However, the stability of magnetic Fe_3O_4-NPs has interfered with their magnetic properties, which causes them to agglomerate, forming larger particles and reducing their magnetic field reactivity. As a result, a potential approach to consider in addressing this issue is encapsulating it with polyvinylidene difluoride (PVDF), the most used membrane forming polymer and increasing the mesoporous properties by using pore-forming agent. The encapsulated Fe_3O_4-NPs with PVDF modified by pore former will react as a nano-factory with high porosity and magnetic reaction, which will decrease the number of nanoparticles released into water bodies and improving MPs removal.

Keywords

Iron oxide nanoparticles, adsorption, microplastics removal, pore-forming agent, magnetite

Introduction

Plastic pollution is a major environmental concern that has become a threat to the natural environment and human health. The growth in the use of plastic will eventually lead to a rise in the generation of

plastic waste. Additionally, poor recycling rates and mismanagement of plastics adversely affect the waste generation situation. Because of mechanical force, biodegradation, and ultraviolet degradation, plastic wastes transform into spherical particles with varying grain sizes ranging from 0.1 to 5000 µm, eventually forming MPs (Zhao, Huang, et al., 2022). MPs are easily consumed by aquatic organisms such as aquatic organisms and fish, and can then be transferred from sea products to humans via the food chain, posing a risk to public health (Shi et al., 2022). Due to the difficulty in removing microplastics with diameters less than 1 m, they have been found to be abundant in water and wastewater treatment plants. To effectively remove microplastics from water, a reliable, simple, fast, and reusable method must be developed (Heo et al., 2022).

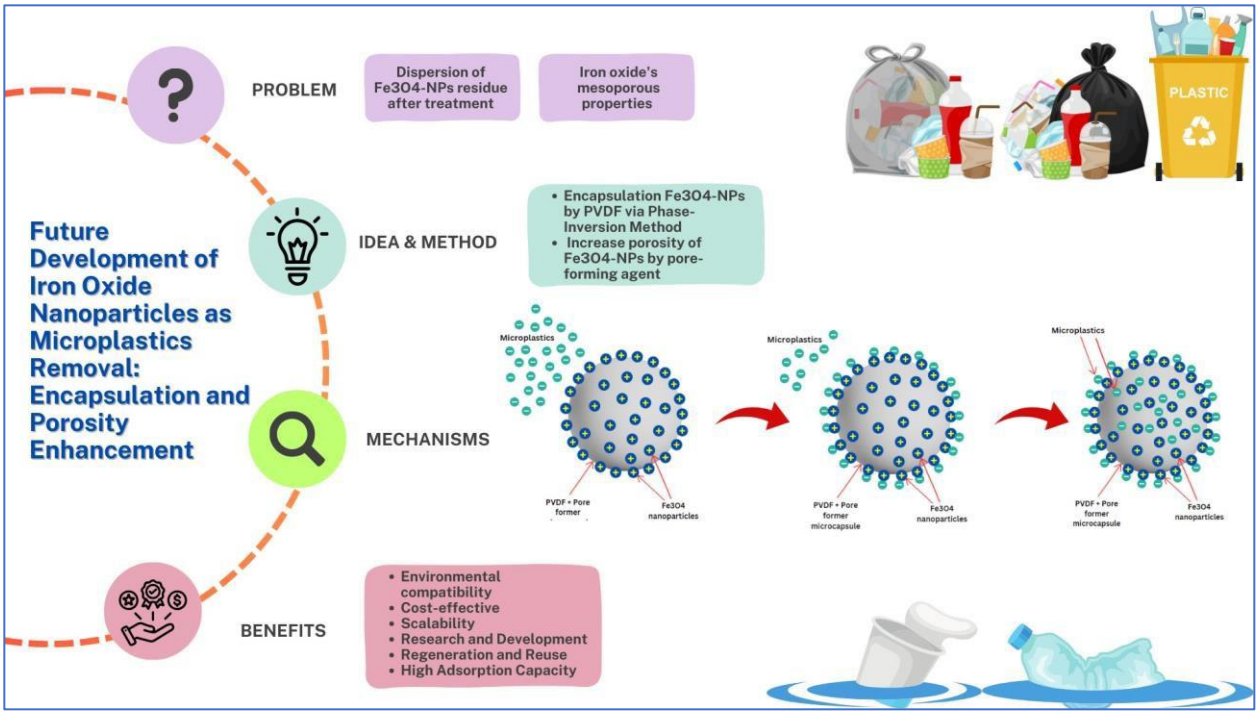
Physical, chemical, and biological methods are currently used to remove MPs from water. Recent studies have shown that coagulation-flocculation and adsorption methods can effectively remove MPs from water (Ma et al., 2019; Ramirez Arenas et al., 2021). Adsorbents with magnetic properties have recently piqued the interest of researchers due to their significant effect in accelerating separation and improving water treatment efficiency (Heo et al., 2022; Martin et al., 2022; Shi et al., 2022; Zhao, Yang, et al., 2022). The movement of magnetic nanoparticles (MNPs) in the direction of the magnetic field gradient is the basis for the magnetic separation of MNPs. Since the velocity of the magnetic field-induced motion is directly proportional to the magnetization value, MNPs with higher magnetization values are more appropriate to use in environmental remediation (Lim et al., 2014). Previous research (Ajinkya et al., 2020; Shi et al., 2022; Zhao, Huang, et al., 2022) has shown that some MPs can be bound on the surface of metal oxides. Magnetite, Fe_3O_4, for example, has a magnetization of 92–100 emu/g, which is higher than that of other iron oxides like maghemite, ɣFe_2O_3 (60–80 emu/g), and hematite, αFe_2O_3 (0.3 emu/g). As a result, it was discovered that Fe_3O_4-NPs responded to magnetic separation more quickly than αFe_2O_3 nanoparticles (L. P. Kong et al., 2017). Furthermore, after magnetic separation and regeneration, Fe_3O_4- NPs can be reused, making it a promising adsorber for removing environmental contaminants. Previous study (Shi et al., 2022; Tang et al., 2021) mentioned that Fe_3O_4-NPs is a good potential adsorbent, have a large surface area and a bunch of active sites for interacting with various pollutants.

However, researchers are concerned about the dispersion of Fe_3O_4-NPs residue after treatment. Due to their small size, these Fe_3O_4-NPs are challenging to recover from treated water (Park & Cho, 2020; Vargas- Ortiz et al., 2022; Xu et al., 2014). Another issue is the stability of magnetic nanoparticles in the liquid phase. This is due to the magnetic interaction between the nanoparticles, which increases the tendency for aggregation (L. P. Kong et al., 2017; Park & Cho, 2020). Reduced magnetic field reactivity is one of the problems that can arise when these nanoparticles clump together or aggregate. As a potential tool for removing microplastic from the environment, encapsulated Fe_3O_4-NPs in hydrophobic polymer have demonstrated promise. The incorporation of magnetic nanoparticles into polymeric materials is expected to have several advantages. The polymeric matrix acts as a regional barrier, locking the magnetic nanoparticles in place and ultimately sustaining their important nano-properties (Beyene, 2019; Gao et al., 2022). In this study, Fe_3O_4-NPs will be encapsulated with Polyvinylideneflouride (PVDF) by using phase inversion technique (Figoli & Duraikkannu, 2021; Osman & Hameed, 2017; Sakarkar et al., 2020). PVDF, on the other hand, is employed as the base polymer for the construction of microcapsules because of its advantages such as good radiation degradation

resistance, high homogeneity, outstanding mechanical strength, and high chemical, pH, and heat resistance(L. Kong et al., 2012; Nnaji et al., 2018).

Encapsulated Fe_3O_4-NPs with increased porosity can have several benefits. Basically, the adsorbent (Fe_3O_4-NPs) must generally have porosity, pore structure, and good adsorption position, which ensure an increased specific surface and uniform adsorption path, in order to achieve a higher adsorption removal rate (Hu et al., 2020). By using a pore-forming agent, iron oxide's mesoporous properties may be improved. Pore formers like Polyethylene glycol (PEG) (Osman & Hameed, 2017), can create channels or pores within the encapsulated structure, allowing for controlled release of Fe_3O_4-NPs after treatment. It is anticipated that the porosity factor will be crucial in the removal of MPs from water. There was no enhanced rate in the MPs' adsorption capacity because of the response time extension because the adsorption sites reached saturation and the pores were filled with Fe_3O_4-NPs (Zhao, Huang, et al., 2022). The encapsulated Fe_3O_4-NPs with PVDF modified by pore-forming agent microcapsules will react as a nano-factory with high porosity and magnetic response expected to improve water and wastewater treatment by lowering the number of nanoparticles released into water bodies.

Graphical highlights of the future research direction



Conclusion and recommendation

Encapsulated Fe_3O_4-NPs with hydrophobic polymer are a workable option for MPs removal via adsorption. In addition, pore-forming agents in encapsulated Fe_3O_4-NPs can provide several benefits, such as the ability to prevent the agglomeration of Fe_3O_4-NPs, environmentally friendly and cost-effective option. More research is required to characterize the interparticle interactions, compare laboratory simulations to environmental samples, optimize the types and intensities of magnetic fields, and come up with long- term solutions for handling MPs after they have been collected. Modern science must develop workable strategies to safeguard the environment from the effects of plastic pollution as we advance towards a sustainable future.

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List of top 5 universities/ research institutes in related field (local and international)

1. Universiti Sains Malaysia
2. Universiti Teknologi Mara
3. Northwest A&F University, Yangling, China
4. East China Normal University, China
5. Seoul National University, Korea

List of top 3 industries in related field (local and international)

1. Perbadanan Pengurusan Sisa Pepejal dan Pembersihan Awam (SWCorp)
2. Indah Water Konsortium Sdn Bhd
3. ERINCO Sdn. Bhd.

List of 6 potential funders for future research grants (local and international)

1. Ministry of Higher Education (FRGS and PRGS)
2. Ministry of Science Technology and Innovation (SRF)
3. MSTF TORAY Foundation
4. Kurita International Grant
5. Royal Society of Chemistry Grants
6. Organisation for the Prohibition of Chemical Weapons