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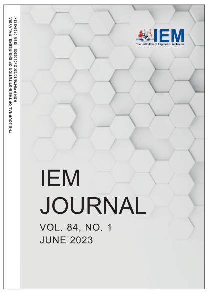

CONTENTS

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EFFECTIVE ENGINEERING NOISE CONTROL APPROACHES USING STOCHASTIC NOISE MAPPING SIMULATION TECHNIQUE: A CASE STUDY IN PALM OIL MILL

(Date received: 02.08.2023/Date accepted: 12.10.2023)

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ABSTRACT

Excessive sound levels pose a substantial risk to the hearing health of industrial workers. This study is to employ the RW-eNMS stochastic simulation method for occupational noise monitoring and mitigation planning at a palm oil mill. A case study was conducted at a Malaysian palm oil mill to predict noise mapping, evaluate personal noise exposure, and recommend an effective noise control strategy using the RW-eNMS method. Results showed that 29.6% of the area fell within the high-risk zone, with 28.1% in the extremely high-risk zone. Personal noise monitoring revealed that many workers were exposed to excessive noise, with a maximum time-weighted average sound level of 99.2 dBA among the worker groups. Despite the provision of protective equipment by management, regular usage of hearing protectors during work shifts was lacking. To reduce noise levels, two engineering control methods were proposed: erecting noise barriers around high noise emission sources and limiting the maximum sound power to 110 dBA for dynamic noise sources. Implementing these controls resulted in a 10.9% decrease in the extremely high-risk zone and a 17.8% decrease in the high-risk zone. These findings hold significance as they can guide the implementation of noise monitoring practices and engineering noise control in the industry.

Keywords: Noise Control, Noise Risk Zone, Occupational Noise Exposure, Stochastic Simulation, Strategic Noise Map

1.0 INTRODUCTION

Occupational noise exposure problems remain a significant disease in global industries. Previous studies had found that severe occupational noise exposure problems occurred in current industries (Hasson *et al.,* 2011; Hanidza *et al.,* 2013; Ali *et al.,* 2012). A noise exposure survey revealed that the noise levels from the industries still exceeded the permissible limits (Kock *et al.,* 2012). Many workers have suffered from hearing problems because they had been overexposed to noise in their workplace (Antônio, 2006; Rachiotis *et al.,* 2006; Azman *et al.,* 2022). During the years 2019 to 2022 in Italy, hearing loss accounted for 15% of all reported occupational diseases (De Sio *et al.,* 2023). In Japan, a study estimated that millions of workers were exposed to high noise levels in their workplaces with more than 40 dB hearing loss at 4 kHz (Miyakita and Ueda, 1997). Prolonged noise exposure has been associated with a range of adverse auditory and non-auditory effects, including noise-induced hearing loss, tinnitus, disorders of the endocrine systems and the nervous, mental distress, sleep disturbance, stress, annoyance, cognitive deficits, low performance, high blood pressure, and speech interruption (Thurston, 2012; Said *et al.,* 2014; Milerová *et al.,* 2013; Zeydabadi *et al.,* 2019; Hosseinabadi *et al.,* 2019; Alnabih *et al.,* 2021). Exposure to high noise levels may additionally increase the number of work-related accidents experienced by workers (Choi *et al.,* 2005). The workers would have a high occupational injury risk if the noise levels were greater than 85 dBA (Amjad-Sardrudi *et al.,* 2012). Furthermore, it was discovered that substantial noise exposure was closely linked to both workplace accidents and commuting accidents (Monteiro Ferreira *et al.,* 2020). Consequently, industries must take steps to ensure noise levels are adequately addressed to mitigate the ongoing negative impacts of noise exposure in the workplace.

According to Ganday (Ganday, 1982), good noise monitoring practice should include a noise map and personal noise exposure measurement. Recognising the rising concern of the European Union over the current noise issue, Directive 2002/49/EC was enforced to mandate the utilisation of strategic noise maps in evaluating the noise exposure problem (Directive 2002/49/EC, 2002). A strategic noise map provided information such as the location of noise sources, the pattern of noise distribution, and the noise circumstances (Bite *et al.,* 2005; Zannin *et al.,* 2013) , which could be utilised to examine permissible limits, decide on noise abatement strategies and design the optimal placement for new machines (Lee *et al.,* 2008; Tsai *et al.,* 2009). In addition, the strategic noise maps could indicate high noise exposure areas, thereby allowing noise practitioners to utilise the noise map as a reference to decide on areas for conducting personal noise exposure measurements (Han *et al.,* 2015). In Malaysia, compliance with the Factory and Machinery Act (Noise Exposure) Regulations is required for all industries as a guide to monitor noise levels in their workplaces (Factories and Machineries Act, 2019). Workers should not be exposed to a noise exceeding the equivalent sound level (L_{Aeq}) of 85 dBA. Moreover, the Occupational Safety and Health Administration mandates that hearing protectors such as earmuffs and earplugs must be provided in environments with an 8-hour-time weighted average (TWA) of 85 dBA or a 100% noise dose (Occupational Noise Exposure, 1983), to ensure the safety and health of workers. Despite this protective measure, numerous workers have been found to suffer from hearing problems and not regularly utilise hearing protection devices (Bedi, 2006; Bockstael *et al.,* 2012; Kim, 2010). Ali *et al*. reported that merely 24.5% of noise-exposed workers in the cement industry habitually used hearing protection devices. This may be attributable to unsatisfactory noise management and a lack of awareness amongst the workers concerning the potential risks related to noise.

Malaysia is the world's second-largest producer and exporter of palm oil products, comprising nearly half of the world's palm oil production share with an export value of over 44%. The expansion of the palm oil industry has been remarkable, with the total planted area reaching 4.85 hectares in 2010. Consequently, many workers were recruited to operate the palm oil mills, exposing them to occupational noise. Studies have been conducted regarding noise exposure and its influence on workers during oil production activities. Ohimain *et al*. (2013) found that activities during the digesting and oil extraction process involved high noise emission machinery. Naeini and Tamrin conducted a study on environmental noise monitoring and noise exposure on workers of two palm oil mills. They had concluded that the main working areas such as the engine room, nut plant, boiler house, thresher, pressing and digestion, clarification station, and sterilising areas were noisy and the workers might incur hearing problems as a result of prolonged exposure to noise in these areas (Naeini and Tamrin, 2014a; Naeini and Tamrin, 2014b; Naeini *et al.,* 2014). Furthermore, it was also found that about 66.7% of workers did not wear hearing protection devices in the investigation of five mills (Naeini *et al.,* 2014). A recent study revealed noise exposure as the main hazard in palm oil mills (Ruslan *et al.,* 2017; Azodo and Onyekwere, 2023). It is crucial to conduct further research on the noise exposure problem and noise control strategies in this industry. Current noise mapping practice still relies on unstandardised approaches for the development of noise maps for this industry (Han *et al.,* 2015). The latest noise mapping prediction technique (Han *et al.,* 2015) has confidentially demonstrated its high accuracy and reliability through its proposed stochastic simulation method. However, there is a lack of scientific rationale for incorporating this method into current noise control strategies. Therefore, the main objective of this study is to employ the RW-eNMS stochastic simulation technique to monitor occupational noise and recommend mitigation strategies at a palm oil mill. A case study was conducted on the selected palm oil mill and the activities included the sound power measurement, predictions of strategic noise map and noise risk zone, personal noise measurement, and engineering noise control simulation. The result from the study was used to conclude the effectiveness of the noise control strategy with the proposed method and the current noise circumstances in the palm oil industry. The following sections discuss the research methodology, results, engineering noise control, and discussion.

2.0 METHODOLOGY

A case study was conducted on a palm oil mill, which was located in the southern region of Peninsular Malaysia. The working period was divided into two shifts, namely the morning shift (8 am to 4 pm) and the evening shift (4 pm to 12 am). This study was conducted during the morning shift only with the presence of a total of 48 general workers and 7 management staffs. All workers were provided with hearing protectors to protect them from high noise exposure in this palm oil mill. The types of measurement equipment used were a sound level meter (3M SoundPro SE/DL Type 2) to measure the noise level and a dosimeter (3M the Edge) to measure the personal noise exposure level and a distometer to measure the distance from the source to the receiver. The sound level meter and dosimeter conformed to the requirements of the International Electrotechnical Commission (IEC), such as IEC 61672-1 (Sound Level Meters – Part 1, 2002). Both devices were calibrated at the start and end of measurements to ensure the accuracy of measurement results in the current environment and that the microphone was in good condition. Sequential activities of noise monitoring are shown in Figure 1. The first activity was a visit to the palm oil mill to observe the noise circumstances and noise sources in this workplace. The sound power measurement was conducted on the operating machinery. The measurement methods complied with the British Standards BS EN ISO 3744:2010 and BS ISO 6393:2008. Both methods were used to determine the sound power levels for static and dynamic machines, respectively. The duty cycles of machinery such as on, off, and idling modes were also recorded as the inputs were to be used in predicting a noise map for this workplace.

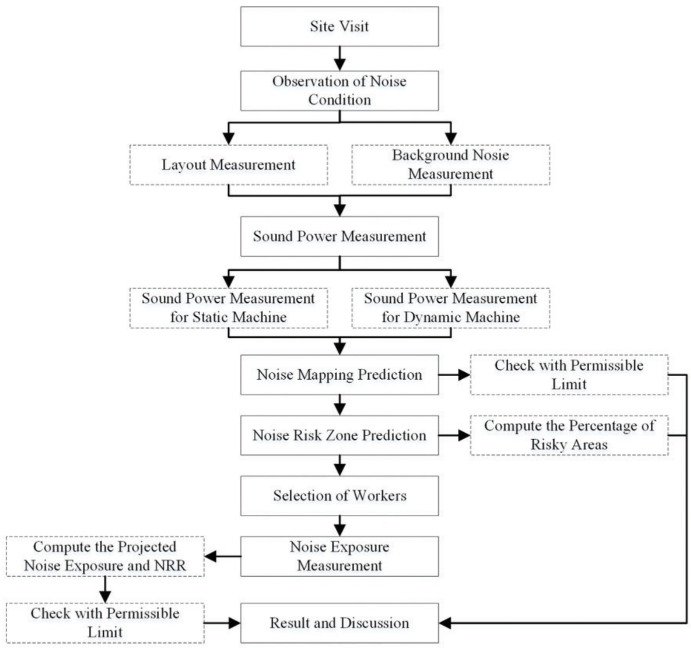

Figure 1: Framework of Noise Monitoring

This study utlised a stochastic simulation method, namely RW-eNMS, to predict a strategic noise map through the simulation of random movement and random noise emission from the machinery. This article explained the core concept and the development of the prediction method in detail (Han *et al.,* 2015). This method was established based on the theorem of stochastic modelling in a simulation process. It could effectively predict the noise levels by considering the dynamic noise circumstances from concurrent and non-concurrent activities. Han *et al*. proved that the accuracy of prediction results was mostly in the range of measurement, where most of the absolute difference from the prediction results was less than 2 dBA. Several inputs were required to be defined in this method, such as the site layout, background noise, locations of machinery, noise barriers, sound power levels, and duty cycles. This method also considered the barrier's effects, such as noise attenuation and noise reflection, and the computation method was referred to the British standard BS 5228:2009-1. The simulation process for this study was stopped at 1,500 steps since the prediction data had reached a steady absolute difference value, as mentioned in the previous study (Han *et al.,* 2015). All noise levels were predicted by assuming an equal height of 1.5 meters. After simulating 1,500 steps, the strategic noise map and the noise risk zone were generated from this method. A strategic noise map was used to study the noise circumstances by checking the permissible noise limit from Factory and Machinery Act and determining the percentage of noise that exceeded this limit. A noise risk zone was plotted by referring to the noise risk evaluation criteria (Han *et al.,* 2015). This evaluation was also implemented by previous studies to identify the sensitive spots of noise risk in the workplace (Al-Ghonamy, 2010; Armah, 2010).

Furthermore, the information obtained from the prediction significantly revealed the noise polluted areas and was used in the selection of noise-exposed workers for the personal noise exposure measurement. The selection was also based on the areas with critical noise risk and active working activities. Workers who were selected from the hazardous area were asked to wear the dosimeter and the duration of each measurement was 30 minutes. After that, the exposure result was normalised to 8 hours of full-shift noise exposure with the assumption that the workers were working in the same areas with constant noise exposure conditions. The projected noise dose and time-weighted average sound level were obtained through Eqn. 1 and Eqn. 2 (Occupational Noise Exposure, 1983). Likewise, the required noise reduction ratings (NRR) were also calculated to estimate the sufficient noise attenuation of hearing protectors protecting workers from hearing loss. The NRR calculation (Eqn. 3) followed the recommendation of the Occupational Safety and Health Administration (Occupational Noise Exposure, 1983).

Projected Dose =
Measured Dose x [(Shift Length/Sample Time)] (1)

where,
Projected Dose and Measured Dose are in units of percentage
Shift Length and Sample Time are in units of hours

$$TWA = 16.61\log_{10}\frac{D}{100} + 90dBA \quad (2)$$

where,
TWA is time-weighted average sound level for 8 hours, dBA
D is the percentage of noise dosage for the whole shift, %

Estimated exposure = TWA - [(NRR - 7) x 50%] (3)

where,
NRR is noise reduction rating, dBA

After analysing the results, this study proposed engineering control methods, such as utilisation of quieter machinery and the erection of noise barriers, to minimise noise exposure levels at this workplace. The decision of noise control was made after identifying the high noise exposure areas and the locations of high noise emission machines. As reported by Mok *et al*. (2019), the use of quieter machinery is an effective approach to further reduce noise at its source and achieve a quieter living environment. For proposing the noise barrier erection as control strategy, the RW-eNMS was developed in accordance with the noise attenuation and reflection approximation method, as specified in BS 5228-1:2009, as outlined in Table 1. This method serves as an initial approach for estimating the attenuation and reflection effects of noise barriers on ambient noise levels in the vicinity. Afterwards, once the approximation levels from this method have been validated and have successfully met the required noise level under the permissible limit, further engineering and comprehensive noise barrier design process will be required. This design process entails meticulous determination of dimensions, functionalities, and materials. Additionally, any specific design will depend on the condition of the noise source, taking into account factors such as ventilation, heat dissipation, and other relevant machinery-related considerations. However, it is important to note that this study is focused solely on the prediction process and does not encompass the detailed design stage. This study will employ the RW-eNMS to recommend noise barrier placement and evaluate their efficacy in attaining compliance with the permissible noise level limit.

Table 1: Noise Attenuation and Reflection Due to Barriers From BS 5228-1:2009 (B.S., 2009)

Condition	Approximation
Source is visible to the receiver	Attenuation -5 dB
Source is hidden from the receiver	Attenuation -10 dB
1 m from the façade of a building	Reflection +3 dB

3.0 RESULTS

3.1 Current Noise Management Practices and Machinery

Figure 2a shows the site layout of the palm oil mill with the dimension of the mapping area of 130 m x 78 m. A total of 12 machines were operating and emitting high noise to the surrounding environment during the measurement. About 8 static machines (S1 to S8) and 4 dynamic machines (D1 to D4) were labelled on the site layout (Figure 2a) to indicate the location of the machinery. The dotted sub-areas indicate the working areas for the dynamic machines. In sub-area 1, the working activity included a bulldozer (D1) which was dragging the ramping loader into the sterilizer for the cooking of palm oil brunches with live steam. Three dynamic machines (D2, D3, and D4) were working on the activities of palm oil waste clearance and excavation in sub-area 2. During the site visit, it was observed that many general workers were working in the ramp, workshop, kernel plant, engine room, and boiler room. The background noise was recorded as 51.9 dBA to represent the ambient noise level before the working activities start. Most of the workers were provided with an earmuff, but none of them used it regularly when working in this palm oil mill during the time of this sound measurement. For existing noise preventive action, the management posted a simple noise map (Figure 2b) at the entrance of the workplace to provide noise information for their workers. The map was plotted by using the current industrial noise mapping practice. Also, the engine room was the only area labelled with a warning sign to indicate high noise exposure and the required wearing of a hearing protector in this area.

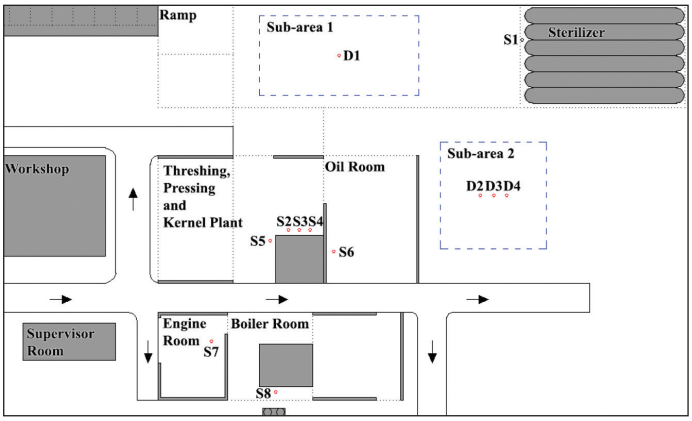

Figure 2(a): Site Layout of Palm Oil Mill

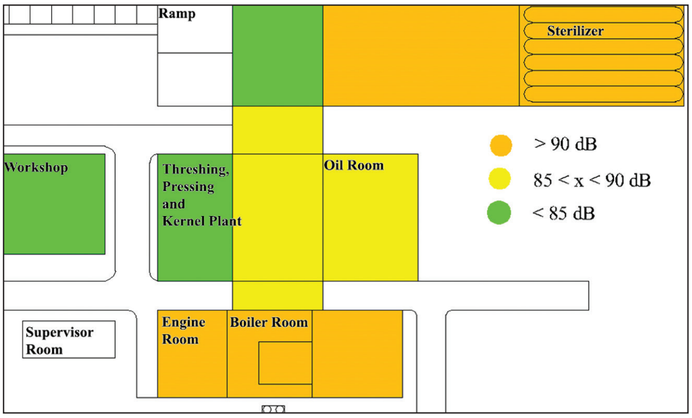

Figure 2(b): Existing Noise Map of Palm Oil Mill

Table 2 shows the properties of machinery including sound power level, dimension, and duty cycles. The dimension of machinery was important to be used in consideration of measurement as stated in BS standards and the percentage of duty cycles reflect the operating mode of machinery when the measurement was carried out. The turbine (S7) in the engine room was recorded as having the highest sound power level of 119.9 dBA and emitted a steady-continuous noise level to the environment; this machine was almost fully operating with a recorded 90% on mode during the measurement. This was followed by the bulldozer (D3) as the second-highest noise source, emitting fluctuating noise to the environment at 119.1 dBA. However, this dynamic machine was not fully operating at that time, and its duty cycles were recorded as 50% on and 50% idling modes, respectively.

3.2 Strategic Noise Mapping and Noise Risk Zone

A strategic noise map of this palm oil mill was predicted by simulating 1,500 steps from RW-eNMS as shown in Figure 3a. This map was plotted with different colours from blue to red, to represent the variation in noise levels in this workplace. The grey colour represents the existing buildings, walls, and structures which could bring the barrier effects on the attenuation and reflection of noise. According to the prediction results from the simulation software, it was estimated that about 28.1% of the mapping area exceeded the permissible limit of 85 dBA. Severe noise polluted areas were found in the engine room, kernel plant, boiler room, and sub-area 2. The workers might have a high risk of hearing loss and work-related accidents when working a full shift in these areas. Meanwhile, the working activities in sub-area 2 were temporarily in operation, and the noise levels were always changing, but still, the operators must always wear hearing protectors while working in this area. Moreover, a noise risk zone was plotted by using the noise mapping data to determine the category of risk zone from the noise risk evaluation criteria. Figure 3b shows a noise risk zone for this study and each risk zone was filled with colour to imply the risk

Table 2: The Properties of Machinery

Machine	Label	Sound Power level, dBA	Dimension	On, %	Off, %	Idle, %
Sterilizer	S1	109.3	1.0m x 1.0m	90	0	10
Crusher Silo 1	S2	117.2	3.0m x 2.0m	50	0	50
Crusher Silo 2	S3	117.2	3.0m x 2.0m	50	0	50
Crusher Silo 3	S4	117.2	3.0m x 2.0m	50	0	50
Siever	S5	111.3	8.5m x 1.5m	50	0	50
Oil Purifier	S6	103.2	0.8m x 0.8m	90	0	10
Turbine	S7	119.9	4.0m x 2.3m	90	0	10
Fan	S8	110.9	1.5m x 1.0m	90	0	10
Bulldozer 1	D1	106.5	4.8m x 2.5m	90	0	10
Bulldozer 2	D2	112.7	5.0m x 2.5m	50	0	50
Bulldozer 3	D3	119.1	6.0m x 2.5m	50	0	50
Excavator	D4	112.1	6.0m x 2.5m	50	0	50

circumstances in this workplace. For example, the red colour represents an extremely high-risk zone, where the noise levels in this area were above 85 dBA. Four risk zones were found at this workplace, such as extremely high-risk, high-risk, moderate risk, and low-risk zones. Based on the results, it had shown that more than half of the mapping area was categorized as a high-risk zone (29.6%) and an extremely high-risk zone (28.1%). About 29.2% and 13.1% of mapping areas were under the moderate and low noise risk zone.

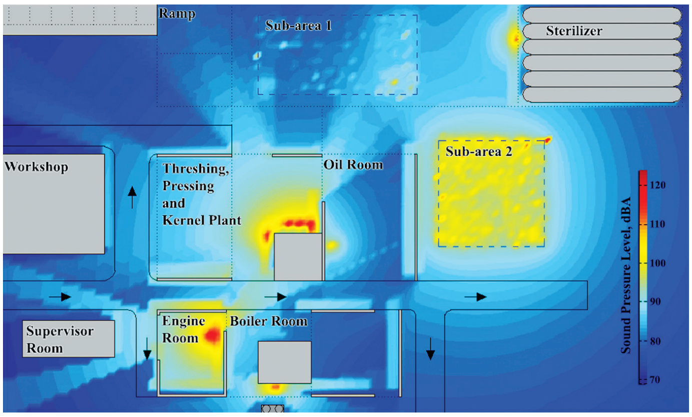

Figure 3(a): Strategic Noise Map

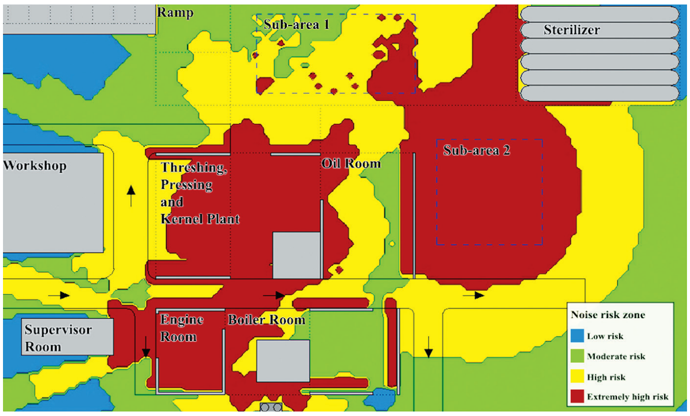

Figure 3(b): Noise Risk Zone

3.3 Personal Noise Exposure

In this study, a strategic noise map and a noise risk zone were used to determine the areas for personal noise exposure measurement. Three areas, such as the engine room, kernel room, and boiler room, were identified as having particularly high noise exposure and risk of noise-related problems and were consequently selected for the measurement. The sub-area 2 was not selected in this measurement because its activities were involved complex, dynamic, and not always in operation. Two workers from each of these selected areas were chosen to carry out personal noise exposure measurements. In total, six workers were involved as representatives of their respective areas to study the noise exposure problem. The measurement data were analyzed to produce noise dose projections over 8 hours, and the results were recorded in Table 3. All measurement results exceeded the TWA permissible exposure limit of 90 dBA as stated in OSHA regulation (Occupational Noise Exposure, 1983). The highest TWA was Worker 2 in the engine room, who had a 99.2 dBA exposure level. In the kernel plant, the TWA sound levels were 97.8 and 98.1 dBA, implying that the information from the strategic noise map and noise risk zone have accurately revealed high noise exposure and high risk in this area. Table 2 also shows the NRR of hearing protectors estimated to reduce the noise exposure level to 85 dBA. The proposed NRRs for the engine room, kernel plant, and boiler room areas are 35 dBA, 33 dBA, and 27 dBA, respectively. For adequate noise reduction in all independent working environments, it is recommended that workers wear hearing protectors with the proposed NRRs.

Table 3: Personal Noise Exposure

Worker	Dose$_{30mins}$, %	Dose$_{8hours}$, %	TWA, dBA	NRR, dBA	Location
1	19.9	318.4	98.4	34	Engine Room
2	22.3	357.0	99.2	35	Engine Room
3	18.4	294.7	97.8	33	Kernel Plant
4	19.2	307.4	98.1	33	Kernel Plant
5	12.8	204.3	95.2	27	Boiler Room
6	12.1	194.2	94.8	27	Boiler Room

3.4 Proposed Engineering Noise Control Methods in Palm Oil Mill

This study proposed engineering control measures for reducing noise levels from noise sources, including machinery enclosure design and the implementation of low-noise emission machinery. Enclosures or covers could be erected to house the machinery located in engine rooms, boiler rooms, and kernel plants, utilising sound insulation materials such as fiber cement board, brickwork, chipboard, fiberboard, and plywood. The efficacy of noise control at noise sources and machinery enclosure design with respect to BS5228-1:2009 was further discussed. This study proposed the erection of covers in noisy areas to attenuate and reduce noise, as well as the implementation of low-noise emission machinery to minimise noise exposure in the workplace. To accurately determine the cover effects, a simple approximation method from BS5228-1:2009 was employed.

Furthermore, to mitigate the noise exposure of the sub-area 2, the study proposed the implementation of earth-moving machines with a maximum sound power of 110 dBA, as the three earth-moving machines D2, D3 and D4 in this area had sound power levels exceeding this proposed level. In the control simulation, these machines were replaced with sound power levels of 110 dBA. However, the replacement of static machines with low-noise emission machines was not recommended due to the large amount of cost associated with purchasing new machines and modifying the existing working layout for machine installation. The effectiveness of noise control was then determined by comparing simulation results before and after the incorporation of engineering control into RW-eNMS. After the incorporation of engineering control in the pertinent areas, the noise exposure levels within the new simulation results were observed to decrease. A new strategic noise map and noise risk zones were predicted by simulating 1,500 steps from RW-eNMS, as depicted in Figures 4a and 4b, with the covers represented in black. By exhibiting sound insulation characteristics, the covers successfully reduced the propagation of noise to the adjacent environment. The overall noise mapping result predicted that 7.1% of the mapping area exceeded the permissible limit, a decrease of approximately 21.0% from the previous findings.

Meanwhile, this study selected fifteen control points to compare the L_{Aeq} before and after the implementation of engineering noise control. The locations of control points were plotted in Figure 4a with red circles and labels from C1 to C15. Most of the control points were located in the engine room, kernel plant, and sub-area 2. Table 4 shows the results and differences of LAeq before and after the engineering noise control at the selected control points. In the engine room, the noise was reduced by at least 9 dBA by referring to the control points C1 to C3. It implies that the erection of covers at turbine machines could significantly decrease the noise levels in this area. Similar to the noise circumstances in the kernel plant area as the noise levels had reduced in the range of 7.6 dBA to 9.5 dBA. For the control points near sub-area 2, the noise levels were also reduced by at least 5 dBA through the replacement of earth-moving machines for D2, D3, and D4 with a sound power level of 110 dBA. Besides, the noise risk zone indicated a reduction in the percentage of risky areas in this workplace. Table 5 reveals the results of the noise risk zone before and after the inclusion of engineering noise control. For example, the extremely high-risk zone and high-risk zone had decreased to 10.9% and 17.8% respectively, but contrarily the percentage of the low-risk zone had increased from 21.1% to 34.1% in the whole mapping area. Thus, the implementation of the proposed engineering noise control was shown to effectively reduce noise exposure levels and the risk of noise problems in this palm oil mill.

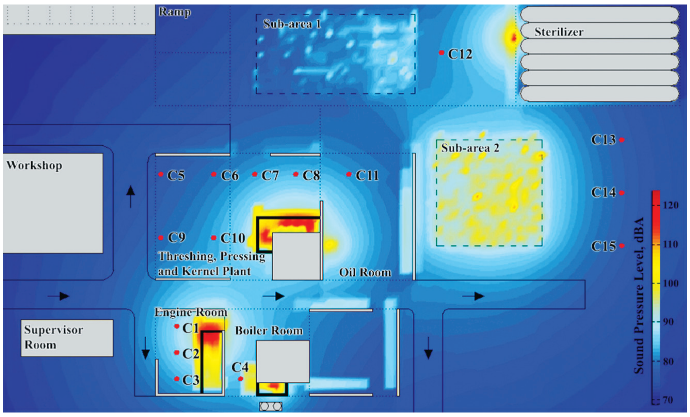

Figure 4(a): Strategic Noise Map and Noise Risk Zone

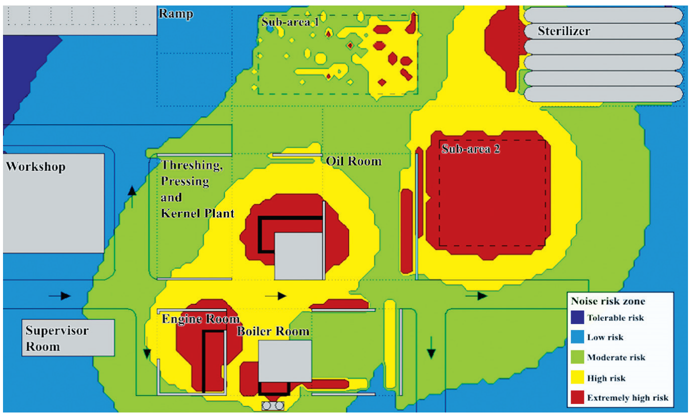

Figure 4(b): Strategic Noise Map After Engineering Noise Control

Table 4: Comparison of Equivalent Continuous Sound Pressure Level (L_{Aeq}) Before and After the Engineering Noise Control

Control Point	L_{Aeq} (Before), dBA	L_{Aeq} (After), dBA	Difference, dBA	Location
C1	95.0	85.4	9.6	Engine room
C2	94.7	85.0	9.7	Engine room
C3	91.5	82.1	9.4	Engine room
C4	87.9	83.3	4.6	Boiler room
C5	84.4	76.3	8.1	Kernel plant
C6	87.6	78.8	8.8	Kernel plant
C7	91.0	81.6	9.4	Kernel plant
C8	91.8	82.3	9.5	Kernel plant
C9	85.8	78.2	7.6	Kernel plant
C10	90.7	81.6	9.1	Kernel plant
C11	85.9	80.9	5.0	Oil room
C12	84.5	80.6	3.9	Near sterilizer
C13	82.3	77.3	5.0	Near sub-area 2
C14	82.8	77.4	5.4	Near sub-area 2
C15	82.1	76.8	5.3	Near sub-area 2

Table 5: Comparison of Noise Risk Zones Before and After the Engineering Noise Control

Category of Risk Zone	Percentage (Before), %	Percentage (After), %	Difference, %	Status
Safe	0.0	0.0	0.0	-
Tolerable	0.0	2.9	2.9	Increase
Low Risk	13.0	34.1	21.1	Increase
Moderate Risk	28.8	34.4	5.6	Increase
High Risk	30.6	17.8	-12.8	Decrease
Extremely High Risk	27.5	10.9	-16.6	Decrease

4.0 DISCUSSION

A strategic noise map was plotted using the RW-eNMS, a stochastic simulation method which can effectively predict the noise by taking into account the complexity and dynamism of operating activities (Han *et al*., 2015). Comparison of the generated map with the existing noise map (Figure 2b) in the palm oil mill demonstrated the inadequacy of conventional methods in considering the random duty cycles of machines and dynamic noises from earth-moving machines. This finding is in agreement with earlier studies which highlighted the neglect of randomness, uncertainty, and dynamics of work activities (Zhang *et al.,* 2014). Random duty cycles and machine movement have been identified as the main factors contributing to the spatial variation of equivalent noise levels (Haron *et al.,* 2009; Haron and Yahya, 2009). Analysis of the strategic noise map revealed that several manufacturing processes emitted superfluous noise into their surrounding environment, including sterilizing, stripping, pressing, threshing, digesting, boiling, and generating processes. These noisy processes have in turn been linked to numerous adverse effects on the workers (Naeini and Tamrin, 2014a; Naeini and Tamrin 2014b).

For current noise prevention practices, the management implemented the provision of hearing protectors to workers and a noise map to reflect the ambient sound levels in the workplace. However, many workers do not wear hearing protectors regularly, and some do not use them at all. The protective efficacy of a hearing protector is diminished if it is not used consistently (Hong, 2005). This situation is likely to cause both noise-induced hearing losses and work-related accidents. Various reasons have been identified to explain the intermittent use of hearing protectors, including bad attitudes and behaviours of workers, discomfort, interruption of communication, and reduced motivation (Arezes and Miguel, 2012; Tak *et al.,* 2009; Saleha and Hassim, 2006). Poor risk recognition on the part of the worker is also known to contribute to the reduced utilisation rate of hearing protectors (Arezes and Miguel, 2006). Thus, improvement of the quality of current noise maps to enhance the awareness of workers regarding the noise problem in their daily working area can be an effective alternative for management to consider. Management could use the findings from this study to disseminate information to their workers, who could self-perceive noise levels and risks through noise map information and risk zone information (Han *et al.,* 2015). Increased risk perception and self-efficacy levels could motivate workers to take preventive action more frequently [47, 48]. In addition, only one warning sign was found located in the engine room, when this study detected high noise exposure in other working areas, such as the kernel plant, boiler room, oil room, and sterilizing area. Therefore, warning signs should also be provided in these areas, to serve as a reminder to workers to use hearing protective equipment (Wogalter *et al.,* 2002).

Occupational noise exposure can be significantly reduced through the effective implementation of a noise control strategy, which is typically divided into two approaches: administrative or engineering control. The management can execute administrative control through the division of work shifts in a day. This strategy can be effective through the reduction of noise exposure time within the working period of 8 hours in their respective shifts. Hearing protection devices should be supplied adequately to workers as a common occupational hearing safeguard. A study by Saleha and Hassim found that Malaysian industries preferred to provide hearing protectors to their workers rather than implement the noise control method because it is a cheaper option compared to noise control. Still, the implementation of engineering controls on noise sources is the most effective way to reduce noise exposure levels in the workplace. Few strategic actions could be implemented to optimize engineering controls (Tuli *et al.,* 2020), including the replacement of low-noise emission machinery and the erection of enclosures at the noise source, as suggested in this study. This study has proven the efficacy of engineering noise control methods with the assistance of RW-eNMS to address the noise abatement strategy in the palm oil mill examined. Consequently, the management should consider implementing the proposed engineering control methods for optimal noise abatement.

5.0 CONCLUSION

In conclusion, it was found that the prevalence of severe noise exposure issues in the current palm oil industry was high. This study predicted that nearly 28.1% of the mapping area exceeded the permissible noise limit, which included areas such as the engine room, boiler room, kernel plant, and sub-area 2. Consequently, workers were exposed to a high risk of hearing problems in these areas. A strategic noise map and noise risk zone provided insight into the noise circumstances in the palm oil mill. The management should disseminate the relevant information of the noise map and risk zone to the workers to raise their awareness of the issue in their workplace and to encourage them to take preventive measures regularly. The proposed engineering noise control methods could be utilised by the management in devising the optimal sound abatement strategies. All in all, the palm oil industry needs to manage noise levels effectively to ensure a safe working environment and protect workers from hearing problems. This study has demonstrated that the stochastic noise mapping simulation method is capable of accurately predicting noise exposure levels while being suitable for use in designing a noise control strategy. It is recommended that future work includes the implementation of the proposed noise control methods outlined in this study, such as installing noise barriers around high noise emission sources and imposing limits on maximum sound power at the palm oil mill. Furthermore, future noise measurements should be conducted to validate the actual reduction achieved compared to the prediction results obtained in this study.

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PROFILES

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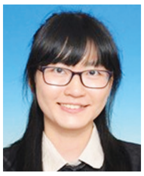

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ACTUAL SHEAR RATE PREDICTION ASSOCIATED WITH WALL SLIP PHENOMENON USING RADIAL BASIS FUNCTION NETWORK

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ABSTRACT

Wall slip can be defined as a phenomenon where the particles in a suspension move away from the wall boundary, leaving a thin liquid-rich layer adjacent to the boundary. Such a phenomenon may induce a significant impact on rheological measurements, particularly on viscosity, shear stress, and shear rate. Suspension has wide applications such as food processing, personal care products, pharmaceuticals, paints, medicine, and agrochemicals. The traditional technique for the actual shear rate prediction is challenging yet difficult and non-favourable from the perspective of time and cost-effectiveness. Therefore, the development of a mathematical computational model that can perform the prediction task with an acceptable level of accuracy is highly needed. Since radial basis function network (RBFN) can perform input-output mapping in a highly accurate manner, both approaches are employed to generate the actual shear rate prediction model. Through the model evaluation using a series of statistical analyses, it was found that RBFN model V is the best model as it shows the highest coefficient of determination (0.9998), lowest mean squared error (0.001058) and root mean squared error (0.001447), most negative Akaike information criterion (-18426.5) and Bayesian information criterion (-18415.5), and the smallest percentage error. The developed model can serve as an alternative tool to predict the actual shear rate of a suspension under an experimental-less condition.

Keywords: Actual Shear Rate, Radial Basis Function Network, Rheology, Suspension, Wall Slip

1.0 INTRODUCTION

Rheology can be defined as a branch of physics that deals with the flow of matter. There are several interesting rheology-related phenomena such as shear-induced migration, pattern formation, and wall slip. Among all, wall slip is the main focus of this research study.

Wall slip is a scenario that occurs in a two-phase or multiphase flow system where the suspended particles in the suspension migrate away from the solid wall boundaries, leaving a thin liquid-rich layer adjacent to the wall. Such a low-viscous layer induces a lubricant effect which enables fluid particles to flow over the boundaries easily (Alshahrani *et al.*, 2022; Barnes, 1995; Hatzikiriakos, 2015; Ponalagusamy, 2017). Under such circumstances, the rheological measurements, i.e. viscosity, shear rate, and shear stress, can be significantly affected. There may be several reasons behind the occurrence of wall slip, such as chemical, gravitational, steric, hydrodynamic, and viscoelastic forces (Ahuja and Singh, 2009; Barnes, 1995; Gudala, *et al.*, 2021).

As reported by Martin *et al*. (2008), slip as well as an apparent slip of suspension near solid surfaces is quite common in food products. In addition, the wall slip effect may be significant until dominating the perceived behaviour of a product. Under this condition, it becomes a challenging task to perform certain operations for industrial purposes, especially in manufacturing, transportation and designing of materials (Barnes, 2004; Raja *et al.,* 2021; Singh *et al.,* 2023; Wu *et al.,* 2022). For example, the operation of the pumping process for slippery materials cannot be optimised because the wall slip cannot be simply neglected in the selection of a suitable pump. Hence, it is essential to have a study on wall slip and develop an appropriate approach to ease the user while dealing with wall slip issues.

A series of laboratory experiments have been conducted to investigate the factors affecting wall slip. First of all, a range of previous research has proposed that the wall slip is appreciably affected by the size of suspended particles in suspension. As reported by Gulmus and Yilmazer (2005), wall slip velocity increases when the particle size increases due to the steric hindrance effect. The observation is in agreement with the comparison of findings between Jana *et al*. (1995) and Ahuja and Singh (2009). Concentration is another factor that influences wall slip. Several groups of researchers have carried out the research studies based on their preferences. Chen *et al*. (2008) claimed that in slurry flow, wall slip velocity shows an increasing trend with the decreases of volumetric concentration. A similar finding was also found in Chin *et al*. (2018a).

In addition, temperature has been identified as the third key element, playing a significant role in wall slip analysis. Wall slip can be originated from the thermal effects near the wall boundary (Barnes, 1995; Malkin *et al.,* 1993; Valdez *et al.,* 1995). Such a phenomenon can be explained by the Kinetic Theory. The fact was further supported by Soltani and Yilmazer (1998) who reported that the increasing temperature will lead to the increase of wall slip velocity values.

Currently, it is a challenging task to determine the actual shear rate for suspension that experienced wall slip as it requires several laboratory datasets. In terms of time and cost, it is non-effective. Therefore, a mathematical model which can mimic the rheological actual shear rate under wall slip condition with an acceptable level of accuracy is essential. In this digital era, the application of artificial intelligence (AI) has become the main trend in various fields and industries. Radial basis function network (RBFN) is one of the popular AI approaches that have been widely applied for problem-solving purposes (Du *et al.,* 2006; González-Camacho *et al.,* 2012; Hannan *et al.,* 2010; Khamis *et al.,* 2018; Venkatesan and Anitha, 2006). Since the approach has shown a relatively outstanding result while applied in different fields of study, it motivates the authors to develop the actual shear rate prediction model using the RBFN approach.

In this research study, the main target is to propose a computational mathematical model that can serve as an alternative to the rheological actual shear rate prediction. A series of RBFN models are developed and trained using all of the critical elements that affect the wall slip (Chin *et al.,* 2018a). The developed models are then evaluated and compared in terms of their appropriateness through statistical analyses. The novelty of the research study is the introduction of AI approaches into the rheological application which allows the users to predict the actual shear rate of a suspension under an experimental-less condition. The basic concept of this research study is shown in Figure 1.

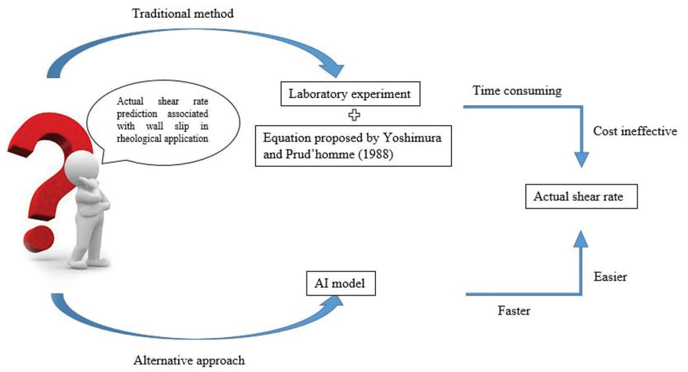

Figure 1: Overall Concept of the Research Study

2.0 MATERIALS AND METHODS

2.1 Data Collection

Laboratory rheological tests were carried out to collect a series of raw data as a preliminary preparation for the AI model development. The tested samples were mixed using poly (methyl) methacrylate (PMMA) and glycerine.

To ensure the credibility of the experiment data, the standard procedures were strictly followed (Ahuja and Singh, 2009; Chin *et al.,* 2018a; Yoshimura and Prud'homme, 1988). First of all, the density of both PMMA particles and glycerine was 1300 kg/m^3 (Chin *et al.,* 2018a; Shaliza *et al.,* 2015). The rationale behind this was to yield a neutrally buoyant suspension. In addition, the density differences might lead to a creaming effect, inducing an adverse impact on the result accuracy. Next, Ahuja and Singh (2009) and Buscall *et al.* (1993) stated that the impact on the viscosity might be significant even if there was only a small mismatch of particle fraction in suspension. Thus, it was important to ensure that the suspensions were mixed with an exact ratio according to the desired volumetric concentration.

The rheological tests were conducted using rheometer equipped with a parallel plate of diameter size 50 mm under two different gap heights of 0.75 mm and 1.0 mm respectively. Several experiment conditions were set, where the tests were run under six different volumetric concentrations (40%, 45%, 48%, 50%, 52%, and 55%), five different temperatures (15°C, 25°C, 35°C, 45°C and 55°C) and three different particle sizes (18 μm, 75.3 μm and 195.5 μm).

2.2 Radial Basis Function Network (RBFN)

A radial basis function network (RBFN) is a variant of the three-layer feedforward neural network. It consists of input layer, hidden layer and output layer where each layer has its role. The input layer, which corresponds to the inputs, is used to link the network to its environment, the hidden layer contains several RBF activation nodes which apply a nonlinear transformation to the input variables, while the output layer is mainly for the presentation of the final output.

The feature that distinguishes the RBFN from the traditional neural networks is its activation function. In RBFN, the activation function in the hidden layer is conventionally implemented as a Gaussian function (Eq. 1).

$$radbas(n) = e^{-n^2} \quad (1)$$

The raw experimental data were grouped into training and testing sets with a ratio of 80% to 20%. The RBFN models were constructed and trained by applying shear stress, volumetric concentration, temperature and particle size as inputs while the actual shear rate was kept as the output. The activation function was set as the Gaussian function. One of the challenges in constructing the architecture of RBFN is the determination of spread constant value. Therefore, a series of RBFN was developed using a wide range of spread constant from 0.0001 to 50 using the trial-and-error method. The performance of each model was then evaluated. The architecture design of RBFN is shown in Figure 2.

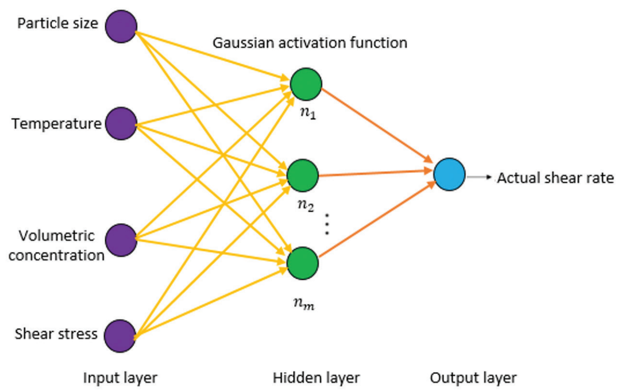

Figure 2: Architecture of RBFN

2.3 Statistical Analyses

The performance of all the developed AI models was examined using a series of statistical analyses, i.e. coefficient of determination (R^2), mean absolute error (MAE), root mean squared error (RMSE), percentage error (% error), Akaike information criterion (AIC) and Bayesian information criterion (BIC), to determine their appropriateness in predicting the actual shear rate for suspension under wall slip condition (Chin *et al.,* 2019).

$$R^2 = \left(\frac{n\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{n\sum x_i^2 - (\sum x_i)^2}\sqrt{n\sum y_i^2 - (\sum y_i)^2}}\right)^2 \quad (2)$$

$$\text{MAE} = \frac{\sum |y_i - x_i|}{n} \quad (3)$$

$$\text{RMSE} = \sqrt{\frac{1}{n}\sum (y_i - x_i)^2} \quad (4)$$

$$\text{Percentage error} = \frac{|True\ value - Predicted\ value|}{True\ value} \times 100\% \quad (5)$$

$$\text{AIC} = -2\log L + 2\text{K} \quad (6)$$

$$-2\log L = n(\log 2\pi + 1 + \log \frac{RSS}{n}) \quad (7)$$

$$\text{BIC} = -2\log L + \text{K}\log n \quad (8)$$

where n is the number of data pairs, x is the observed variable, y is the predicted variable, K is the number of model parameters (the number of variables in the model plus the intercept), L is maximised likelihood, and RSS is residual sum of squares.

3.0 RESULTS AND DISCUSSION

When designing the architecture of RBFN, a wide range of spread constant was applied. Due to the large number of developed models for each AI approach, only the selected models were presented and discussed in this section.

3.1 RBFN Models Evaluation

A total number of 9000 datasets were collected from rheological tests. Among the datasets, 7200 datasets (equivalent to 80% of total datasets) were used to train the RBFN model while the rest 1800 datasets were reserved for testing purposes. There is no concrete rule for data splitting, however, it is important to ensure the AI models were trained with a sufficient amount of data to enhance their reliability. As reported in previous studies, the most common percentage for training data is between 60% to 80% while for testing data the value should be 40% to 20% (Akter and Desai, 2018; Alimissis *et al.,* 2018; Zhang *et al.,* 2018). In this case, the upper limit was chosen to allow the models to learn the most possible input-output pattern.

The performance of each RBFN model was evaluated and tabulated in Table 1. Firstly, from the perspective of the coefficient of determination, the R^2 value for all of the examined models is considerably high (approximately 1) which indicates there is a strong correlation between the predicted and actual values. Secondly, in terms of error analyses, a low error value is always an indicator of good performance. In this case, from Table 1, it can be seen that both MAE and RMSE values show a fluctuating trend and generally perform better when the spread constant is an odd number.

Lastly, AIC and BIC measure how well the data fits into the model. Similar to the MAE and RMSE, lower AIC and BIC values are always favourable. As shown in Table 1, model V with a spread constant of 21 has the most negative AIC and BIC value which means that it achieves the best performance in terms of AIC and BIC.

All the statistical analysis outcomes in Table 1 point that model V emerges as the model with the best performance. The appropriateness of model V is further verified through the percentage error analysis. In this study, the percentage error range was fixed in between ± 15%. From Figure 3, around 96% of the total datasets in model V fall within the threshold error range, meaning that the prediction model has shown great potential to achieve at least 85% accuracy. Moreover, as shown in Figure 4, the maximum percentage error of model V is also the lowest among all the investigated models.

Overall, model V appears as the best-performed RBFN model where it produced the highest coefficient of determination (0.9998), lowest mean squared error (0.001058) and root mean squared error (0.001447), most negative Akaike information criterion (-18426.5) and Bayesian information criterion (-18415.5), and the smallest percentage error.

3.2 Models Comparison

The application of AI technique in rheological wall slip is still at the beginning stage. In the previous study, a multilayer perceptron neural network (MLP-NN) model was developed for the actual shear rate prediction (Chin *et al.* 2018b), however, there is still room for improvement to achieve a higher level of prediction accuracy.

Table 1: Statistical Performance for Each RBFN Model

Models	Spread Constant	R^2	MAE	RMSE	AIC	BIC
I	17	0.9998	0.001095	0.001461	-18391.8	-18380.8
II	18	0.9995	0.001346	0.002058	-17156.8	-17145.8
III	19	0.9996	0.001290	0.001962	-17329.4	-17318.4
IV	20	0.9985	0.002302	0.003692	-15053.2	-15042.2
V	21	0.9998	0.001058	0.001447	-18426.5	-18415.5
VI	22	0.9997	0.001207	0.001644	-17965.6	-17954.6
VII	23	0.9994	0.001727	0.002430	-16559.3	-16548.3
VIII	24	0.9994	0.001641	0.002337	-16698.9	-16687.9

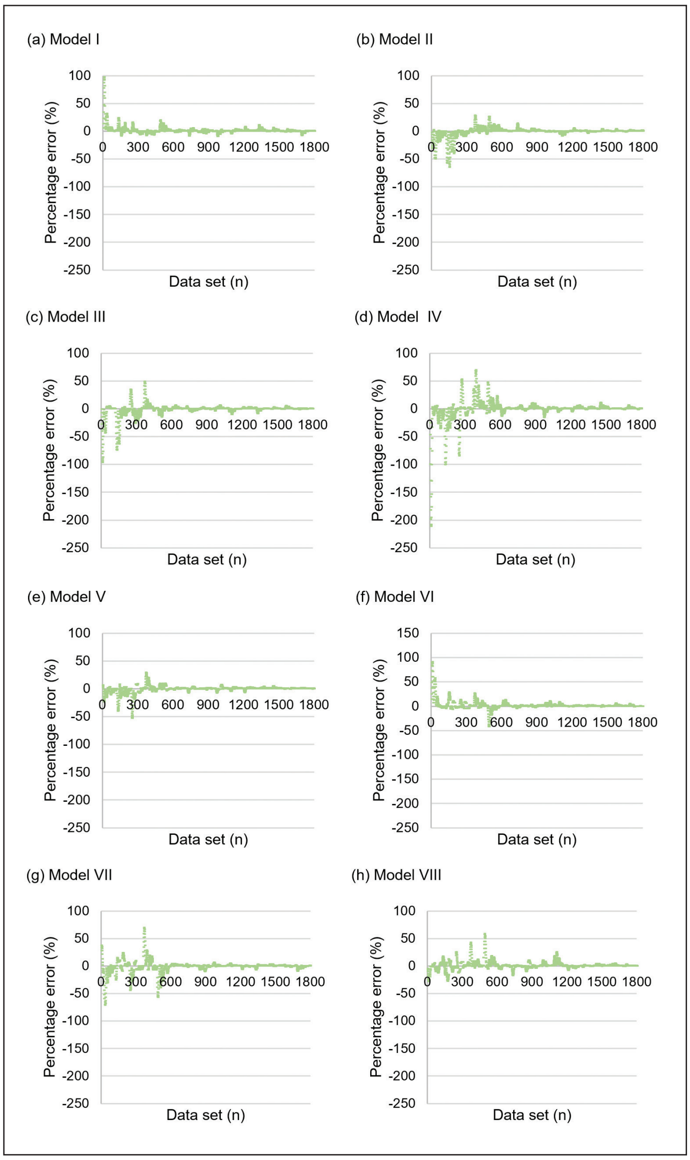

Figure 3: Percentage Error of the Respective Dataset Corresponding to Each RBFN Model

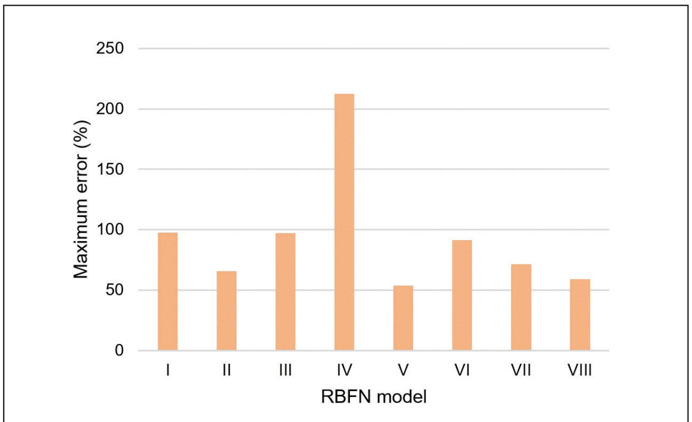

Figure 4: Maximum Percentage Error for Each RBFN Model

Under this section, the best-performed RBFN model will be compared with the MLP-NN model as developed by Chin *et al.* (2018b) using a series of statistical analyses, including coefficient of determination, mean absolute error, root mean squared error, Akaike information criterion, Bayesian information criterion and percentage error. As contained in Table 4, a significant improvement is clearly shown in terms of all the examined aspects while comparing the MLP-NN model to the RBFN model. At first, in the view of point of MAE and RMSE errors, the RBFN model produces a lower value than the MLP-NN model, meaning that the model RBFN model can produce more accurate output.

Next, a similar trend is also noticeable from the perspective of AIC and BIC. The most negative value is shown in the RBFN model, indicating that the predicted output fits better in the RBFN model than in the MLP-NN model.

Lastly, in terms of percentage error which is the most important indicator while developing an AI prediction model, the error is improved from the previously developed MLP-NN model (75%) to RBFN model (53%). In other words, the maximum percentage error has been greatly enhanced by the RBFN model.

Table 4: Comparison of the Best-Performed Model Corresponding to Each AI Technique

Model	MLP-NN (Chin *et al.* 2018)	RBFN
R^2	0.9967	0.9998
MAE	1.146804	0.001058
RMSE	1.652898	0.001447
AIC	-7657.3	-18426.5
BIC	-7646.4	-18415.5
Max. % Error	75	53

4.0 CONCLUSION

The main aim of this research study is to evaluate the appropriateness of the RBFN approach in generating the mathematical computational model which can perform a real-life output prediction within an acceptable level of accuracy.

During the development of RBFN, the determination of spread constant is a challenging task. Therefore, the trial-and-error method was applied to determine the best-suited parameters for the RBFN models which may lead to better prediction accuracy.

In this research study, several RBFN models were developed and their performance was evaluated under a series of statistical analyses. Based on the examined results, model V (with a spread constant of 21) emerges as the best-performed RBFN model where it has the highest R^2-value of 0.9998, lowest MAE and RMSE which recorded at 0.001058 and 0.001447 respectively, most negative AIC and BIC each with a value of -18426.5 and -18415.5, and the smallest maximum percentage error of 53%. Comparing the developed RBFN model with the MLP-NN model from previous literature, the improvement in terms of model performance is significantly noticed, where the maximum percentage error has been reduced from 75% to 53%, showing a significant enhancement.

This shows that the AI prediction model can be improved by implementing the other more advanced approaches where such approaches can make use of their special feature and enhance the overall performance.

5.0 ACKNOWLEDGMENT

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PROFILES

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INVESTIGATION ON THE ENGINEERING PROPERTIES OF PEAT SOIL STABILISED USING LIME STABILISATION AND ALKALINE ACTIVATION

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ABSTRACT

Peat soil is typically classified as a problematic soil due to its expansive behaviour that possesses geotechnical drawbacks. Thus, the condition of peat soil must be improved prior to any construction works. Stabilisation of peat soil can be done via chemical stabilisation and alkaline activation while incorporating industrial by-products or wastes as addictive. This study aims to investigate the effect of press mud as an additive in lime-stabilised and alkaline activator-stabilised peat soils. Press mud is a by-product of sugarcane juice filtering. The lime adopted is at 3% and 5.5% while the alkaline activator is used in cold and warm condition. A total of 5 percentages of press mud have been employed, namely 0%, 0.25%, 0.5%, 1% and 2%. The investigations revealed that regardless of the percentage of lime adopted, the optimum moisture content increases while the maximum dry density decreases when the percentage of press mud incorporated is increased. However, when the lime content is increased, the optimum moisture content increases significantly. The UCS of lime-stabilised peat soil sample achieved the greatest strength improvement when the lime and press mud is used at 5.5% and 0.25%, respectively. In contrast, the unconfined compressive strength (UCS) of 3% lime-stabilised peat soil samples with or without press mud shows comparable 28-day strength. On the other hand, the UCS of peat soil stabilised with alkaline activator shows significant improvement, while addition of press mud further improves the strength. Nonetheless, using warm alkaline activator improves the early strength development but cold alkaline activator results in higher 28-day UCS.

Keywords: Alkaline Activation, Lime Stabilisation, Peat Soil, Press Mud, Unconfined Compressive Strength

1.0 INTRODUCTION

Peat soil is a non-homogeneous or heterogeneous soil that is formed when organic matter such as plant remnants, foliage, leaves, and trunks putrefies (Ismail *et al.,* 2021). Peat soil can be found wherever in the world, except the arctic and arid areas, and it makes up around 5-8% of the planet's surface area (Mesri and Ajlouni, 2007). Untreated peat soil is usually high in moisture content, which is attributed to the high organic content of peat soil that increases the space between the peat soil particles and allows more water to be absorbed (Hauashdh *et al.,* 2020). Thus, peat soil usually has poor volume stability in the presence of water (James, 2020).

Peat soil typically possesses the following characteristics, namely high natural moisture content, high compressibility and water-holding capacity, low specific gravity, low bearing capacity, and medium-to-low permeability (Talif *et al.,* 2021). These characteristics are usually undesired in construction as they will increase the difficulty and complexity of works done on the peat land. The consequences are usually detrimental. For instance, in the worst scenario, a structure may collapse (Kolay and Taib, 2018). Considering the harmful risk, working on such soil is usually avoided. However, construction on peat land area has become or will become a necessity due to rapid industrialisation and population growth. To minimise the deleterious effect of peat soil, several soil improvement methods are employed, for instance, chemical stabilisation, alkali activation, soil replacement, prewetting, surcharge loading and usage of geosynthetics (Cristelo *et al.,* 2011; James and Pandian, 2016).

Besides stabilising problematic soils or peat soil using lime or cement as stabilisers, a combination of stabilisers with industrial by-products or wastes as additives in soil stabilisation technique has been explored (Dahale *et al.,* 2012), attributed to the solid waste management concerns developed from the huge number of industrial by-products or wastes that have been generated annually. Fly ash, phosphogypsum, rice husk ash, ceramic waste, silica fume, and paper sludge are some of the industrial by-products or wastes that have been employed in soil stabilisation (Choobbasti *et al.,* 2010; James and Pandian, 2016). Recently, the effect of press mud on lime-stabilised peat soil has been investigated. Press mud is the industrial waste of the sugar manufacturing industry. It is the leftover from the sugarcane juice filtration process. The sugarcane juice undergoes the clarification process to separate the juice and mud. The clear juice is sent for manufacturing and the mud sink in the bottom is collected and sent for filtration to filter out the suspended materials (Chittaranjan *et al.,* 2021).

In Malaysia, peat soil land represents 2.7 million hectares and this value is about 8 % of the total area of Malaysia (Rahman *et al.,* 2016). Thus, it is an unavoidable situation where the construction of peat land area is required, especially when the land becomes limited and higher in cost. Therefore, before construction, these soils should be stabilised and improved to ensure smooth and safe progress. In this work, locally available peat soil has been stabilised via lime stabilisation and alkali activation combined with the press mud. The optimum moisture content and maximum dry density of lime-stabilised peat soil incorporating press mud are investigated while the unconfined strength test (UCS) of the lime-stabilised and alkali activator-stabilised peat soil admixed with press mud is examined.

This study introduces an innovative approach to peat soil stabilisation by employing press mud, a by-product of the sugar industry, in combination with lime or an alkaline activator. While plenty of studies have explored soil stabilisation using either lime or alkaline activators, our research uniquely investigates the effects of integrating press mud into these methods. Unlike previous studies where stabilised soils often undergo additional chemical or physical treatments, we maintain the natural composition of our soil and press mud to preserve their inherent properties. We hope that this novel method could open new possibilities in the effective utilisation of organic waste materials like press mud for soil stabilisation.

2.0 MATERIALS AND METHOD

2.1 Materials

An essential natural resource, peat soil, was painstakingly collected from the scenic area of Sekinchan in Selangor, Malaysia. This area, renowned for its verdant vistas and distinct biological variety, offered the ideal setting for our soil collecting mission. With extreme care and precision, the peat soil known for its high organic matter content and remarkable water retention qualities was harvested with the least amount of disturbance to its fragile ecology. It is noted that this perfect peat soil was used exactly as it was, without being processed further to retain its natural qualities for our research.

Concurrently, in an attempt to utilise all available organic resources, press mud, a lucrative by-product of the sugar industry—was procured from Penang, a bustling city. This rich, dark residue was carefully harvested to preserve its purity and integrity. It is a by-product of processing sugar cane. As with the peat soil, the press mud was added to our study without being subjected to any chemical or physical treatments, so its natural composition and high nutritional content were preserved. These raw, organic materials served as the basis for our investigation, which was an honest and pure examination of their natural qualities and possible uses.

Table 1: Stabilisers and Press Mud

Stabilisers	Press mud (%)				
3 % Lime	0	0.25	0.5	1	2
5 % Lime	0	0.25	0.5	1	2
Cold alkaline activator (Room temperature)	0	0.25	0.5	1	2
Warm alkaline activator (50 °C)	0	0.25	0.5	1	2

2.2 Hydrated Lime

The alkaline activator is a mixture comprised of a 12.5M sodium hydroxide (NaOH) solution and sodium silicate (Na_2SiO_3) solution at a ratio of 1:2, by mass. Information regarding the chemicals. The alkali activator was stored in an oven at 50°C to serve as a warm alkali activator whereas for cold alkaline activator, it was cooled down to room temperature.

2.3 Mix Proportion

Table 1 presents the mixed proportion of stabilisers admixed with press mud to examine the engineering properties of the stabilised peat soil samples. Stabilisers adopted in this work were lime and alkaline activators; the former was added in two different percentages while the latter was employed at two different temperatures. A total of 4 types of stabilisers, i.e., 3 % lime, 5 % lime, cold alkaline activator and warm alkaline activator, were employed and admixed with various percentages of press mud, namely 0 %, 0.25%, 5%, 1% and 2%.

2.4 Testing Methods

Due to the heterogeneity of the peat soil samples, a minimum of three samples were tested with each percentage of stabilisers and the average result is reported.

2.4.1 Standard Proctor Test

The standard proctor test was carried out by the ASM D 698 to identify the optimum moisture content and the maximum dry density of the soil sing the following equations.

$$w = \frac{Mw + M_d}{M_w} \times 100 \tag{1}$$

where
W = Natural moisture content, %
M_w = Soil sample mass in wet condition, kg
M_d = Soil sample mass in dry condition, kg

$$\rho_m = \frac{M_{cs}}{v} \tag{2}$$

where
ρ_m = Soil sample moist density, kg/m^3
M_{cs} = Moist compacted soil mass, kg
v = Mould volume, m^3

$$\rho_d = \frac{\rho_m}{1 + \frac{w}{100}} \tag{3}$$

where
ρ_d = Compacted soil dry density, kg/m^3
ρ_m = Soil sample moist density, kg/m^3
w = Moisture content, %

2.4.2 Unconfined Compressive Strength

The UCS test was conducted in accordance with the ASTM D 2166 to examine the effect of press mud on the lime-stabilised and alkaline activator-stabilised peat soil samples. To determine the UCS, the sample was loaded between the upper and lower plates and in the UCS test's centre of the loading machine. The upper plate was adjusted to the height that was able to contact the peat soil sample and the deformation was set to zero. The test then began with a steady axial strain of between 0.5 and 2.0% per minute and the load and deformation readings were collected. The test was stopped when a decrease in load values happened or achieved 20% of the axial strain. The load and deformation values were recorded for calculations. The following equations were employed to determine the UCS of the samples.

$$e = \frac{\Delta L}{L_0} \tag{4}$$

where
e = Axial strain
ΔL = Change in soil sample length, m
L_0 = Initial soil sample length, m

$$A = \frac{A_0}{(1 - e)} \tag{5}$$

where
A = Average soil sample cross-sectional area, m^2
A_0 = Initial average soil sample cross-sectional area, m^2
e = Axial strain

$$\sigma_u = \frac{P}{A} \tag{6}$$

where
σ_u = Unconfined compressive strength, kN/m^2
P = Applied axial load at failure, kN
A = Average soil sample cross-sectional area, m^2

3.0 RESULTS AND DISCUSSION

3.1 Standard Proctor Test

Table 2 shows the results of the standard proctor test carried out on the lime stabilised-peat soil samples stabilised with 3% or 5.5% lime and admixed with various percentages of press mud, namely 0%, 0.25%, 0.5%, 1.0% and 2.0%. It is observed that regardless of the percentage of lime adopted, when the percentage of press mud incorporated is increased, the optimum moisture content increases while the maximum dry density decreases. A similar trend has been observed (Saini *et al.*, 2022). This is possibly due to the nature of press mud that possesses good water-holding capacity. On the other hand, it is also noticed that when the lime content is increased, the optimum moisture content increases significantly.

3.2 Unconfined Compressive Strength

3.2.1 Lime-Stabilised Peat Soil with Press Mud as an Additive

The UCS of 3 % or 5.5 % lime-stabilised peat soil samples with different percentages of press mud are illustrated in Figure 1.

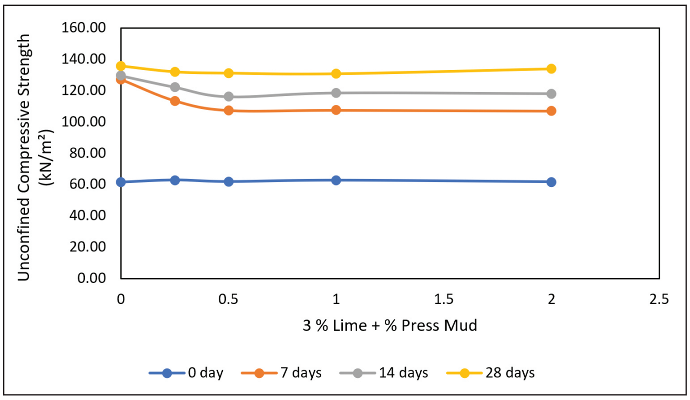

Figure 1(a): UCS of Lime-Stabilised Peat Soil with Different Percentages of Press Mud: 3% Lime

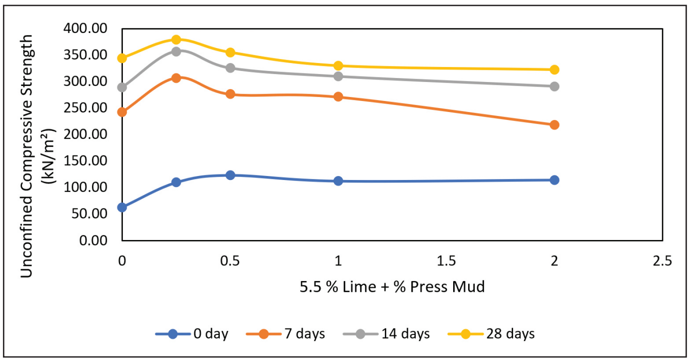

Figure 1(b): UCS of Lime-Stabilised Peat Soil with Different Percentages of Press Mud: 5.5% Lime

Generally, the UCS of lime-stabilised peat soil samples admixed with press mud increases with the curing period, indicating the pozzolanic reaction induced by the lime with the peat soil itself, and with the press mud. It can be seen from Figure 1(a) that when the content of press mud is increased, the UCS of 3% lime-stabilised peat soil samples were reduced significantly at an early age, especially at day 7. Nevertheless, the UCS of 3% lime-stabilised peat soil samples with or without the addition of press mud become comparable at day 28. The 28-day UCS of 3% lime-stabilised peat soil samples with 0%, 0.25%, 0.5%, 1% and 2% of press mud were 135.65 kN/m^2, 131.95 kN/m^2, 131.12 kN/m^2, 130.72 kN/m^2 and 130.80 kN/m^2, respectively. This indicates that the reaction between lime and the press mud happens at a slower rate, attributed to lower lime content.

On the other hand, incorporating press mud into 5.5% lime-stabilised peat soil samples showed significant strength improvement compared to the 3% lime-stabilised peat soil samples, implying 5.5% lime is sufficient to enhance the engineering properties of the peat soil samples. Among all the 5.5% lime-stabilised peat soil samples, the addition of 0.25% of press mud significantly improved the UCS of the peat soil

Table 2: Optimum Moisture Content and Maximum Dry Density of Lime-Stabilised Peat Soil

	3% lime + X % press mud					5.5 % lime + X % press mud				
	0	0.25	0.5	1	2	0	0.25	0.5	1	2
Optimum moisture content (%)	27.29	27.84	27.98	30.10	32.39	55.30	55.70	55.73	56.94	63.44
Maximum dry density (Mg/m^3)	0.59	0.57	0.56	0.49	0.42	0.67	0.67	0.66	0.66	0.65

samples, in which the highest 28-day UCS was achieved (378.92 kN/m^2). Further increment of press mud content does not show increment but decreases the UCS of 5.5% lime-stabilised peat soil samples, at all ages. Nonetheless, the UCS are still higher compared to the pure 5.5% lime-stabilized peat soil sample except when the press mud content is beyond 1%; The 28-day UCS of 5.5% lime-stabilised peat soil samples with 0%, 0.25%, 0.5%, 1% and 2% of press mud were 344.56 kN/m^2, 378.92 kN/m^2, 355.15 kN/m^2, 329.85 kN/m^2 and 322.38 kN/m^2, respectively This could be attributed to the presence of higher P_2O_5 that has known to influence the strength development. On top of that, the increment of press mud content also increased the organic content in the mixture due to high fibre content, which could be another potential factor in such observed trend (James, 2020; James and Pandian, 2016).

3.2.2 Alkaline Activator-Stabilised Peat Soil with Press Mud as an Additive

Figure 2 presents the UCS of alkali activator-stabilised peat soil samples admixed with different percentages of press mud, namely 0%, 0.25%, 0.5%, 1% and 2%. It is observed that the UCS of alkaline activator-stabilised peat soil samples is significantly enhanced regardless of the temperature of the alkaline activator. On top of that, the UCS of alkaline activator-stabilised peat soil samples gradually increase as the curing period increases, indicating the ongoing reaction between the alkaline activator with the peat soil and also the press mud. In addition, the UCS of alkaline activator-stabilised peat soil samples is found to increase with the press mud content, at all ages. The highest 28-day UCS is achieved when 2% of press mud is adopted into the alkaline activator stabilised peat soil, which is 423.85 kN/m^2

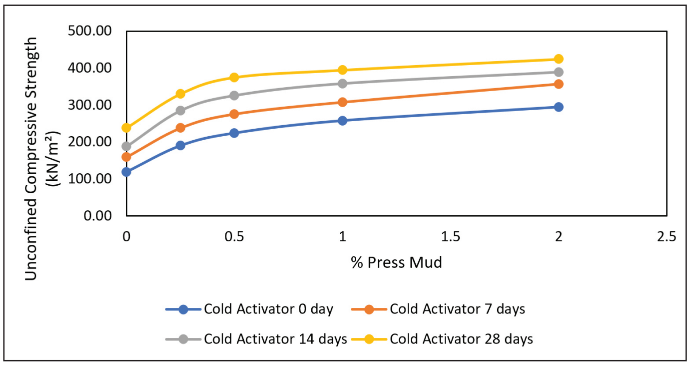

Figure 2(a): UCS of Alkaline Activator-Stabilised Peat Soil with Different Percentages of Press Mud: Cold Alkaline Activator

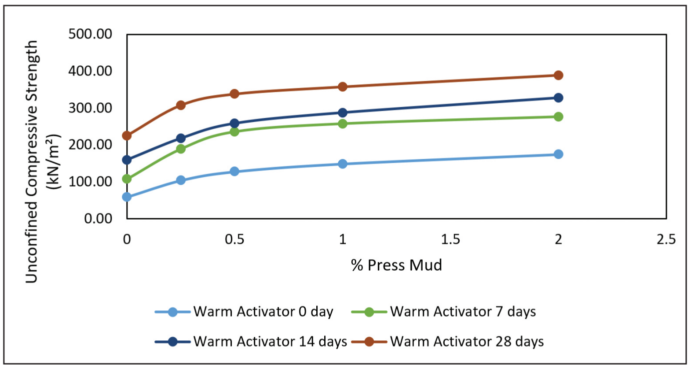

Figure 2(b): UCS of Alkaline Activator-Stabilised Peat Soil with Different Percentages of Press Mud: Warm Alkaline Activator

using a cold alkaline activator and 388.94 kN/m^2 using a warm alkaline activator. Although both alkaline activators successfully enhanced the UCS of the treated peat soils, the cold alkaline activator showed a much better soil stabilisation potential.

On the other hand, it is observed that the UCS improvement by percentage using warm alkaline activator decreases from time to time and has the least improvement at the 28-day curing period. Additionally, the peat soil samples stabilised with a cold alkaline activator showed smaller strength improvement compared to the peat soil samples stabilised using a warm alkaline activator at day 0 and day 7. This is possibly due to the increase in temperature helps in accelerating the chemical reaction thus improving the strength gain in the early stage. However, in the longer curing period, the peat soil structure will deteriorate (Cristelo *et al.,* 2011). Thus, this implies that increases in the temperature of alkaline activators can improve the strength development of peat soil at an early stage.

4.0 CONCLUSION

The study investigated the impact of press mud on peat soil stabilisation with lime or an alkaline activator. It was found that as press mud content increased, the optimum moisture content of lime-stabilised peat soil increased, but the maximum dry density decreased. Increasing lime content correspondingly led to an increase in optimum moisture content. A strength reduction was noted at the early stage in 3% lime-stabilised peat soil with added press mud, but this strength became comparable by day 28. For 5.5% lime stabilised peat soil, strength improved when press mud was less than 1%.

In terms of alkaline activation, peat soil's strength increased significantly irrespective of press mud addition when compared to lime stabilisation. However, the Unconfined Compressive Strength of warm alkaline activator-stabilised peat soil decreased over time, suggesting activation temperature can improve early strength gain of treated peat soil, but long-term enhancement was better with a cold alkaline activator.

Conclusively, this study demonstrated the potential of press mud as an effective additive in peat soil stabilisation. More research can further optimise these interactive effects for enhanced soil stabilisation.

5.0 ACKNOWLEDGEMENT

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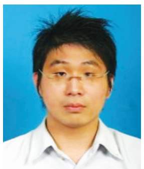

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AMMONIUM ADSORPTION BY SURFACE SEDIMENTS IN THE LOUGHOR ESTUARY, UK

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ABSTRACT

Ammonium is a form of nitrogen that can be present in natural water systems due to various sources, including agricultural runoff, wastewater discharge, and decomposition of organic matter. High concentrations of ammonium in seawater can have several significant consequences for marine ecosystems such as harmful algal blooms, oxygen depletion, acidification, and changes in nutrient ratios. Therefore, monitoring and regulating nutrient inputs are essential for protecting marine ecosystems and maintaining the health and productivity of coastal and open ocean environments. In this study, adsorption isotherm experiments were used to study ammonium adsorption by surface bed sediments in the Loughor Estuary, South Wales, UK. The findings indicated that the adsorption isotherm was linear and fitted the Freundlich adsorption isotherm. The adsorption coefficient of ammonium in the study area ranged from 9.3 to 18 ml/g and the dimensionless ammonium adsorption coefficient was found to be ranged between 23.0 and 36.5. These values correlated well with the organic carbon content, of the sediments and can be considered as the main factors controlling ammonium sorption. The results also showed that salinity affected the adsorption of ammonium and the distribution of ammonium between the sediments and the water column. The amount of ammonium adsorption on the sediments was found to decrease gradually with the increment of the salinity levels.

Keywords: Adsorption Coefficients, Ammonium, Estuaries, Salinity, Surface Sediments

1.0 INTRODUCTION

Over the centuries the sub-aerial processes of erosion and deposition have led to the formation of river valleys and estuaries [1]. An estuary conveys marine conditions into a river valley potentially up to the tidal limit to form a semi-enclosed coastal body of water connected to the open sea at one end and to an influx of fresh river water at the other [1], [2]. When the sea level rise exceeds the peak filling level, then the estuary is regarded as well-developed and persists. Marine environments and estuaries have acted as filters for a range of constituents, with large quantities of materials such as fertilisers and organic materials from the land being deposited in the receiving estuarine/marine basin [3]. This organic matter is decomposed by various heterotrophic organisms and produces large amounts of ammonium ions [4], [5].

Ammonium ions can accumulate in pore water and can be re-incorporated into organisms, adsorbed onto sediment particles, or diffused out of the sediments and into the overlying water column [6], [7]. The ammonium ions can be adsorbed onto the sediments due to adsorption at the cation exchange sites [8], [9]. These sites are present on the surface of clay minerals and organic matter [10], [11]. Organic matter controls the behaviour of ammonium sorption on sediments with low clay content [12], [13]. The amount of ammonium adsorption depends on the ion exchange capacity of the sediment which is usually related to organic matter and clay content of the sediments [14]. Therefore, the adsorption of ammonium by the sediments has an important influence on nitrogen cycling [15], which affects not only the diffusive flux of ammonium into the overlying water column but also the coupled nitrification/ denitrification occurring in the sediments.

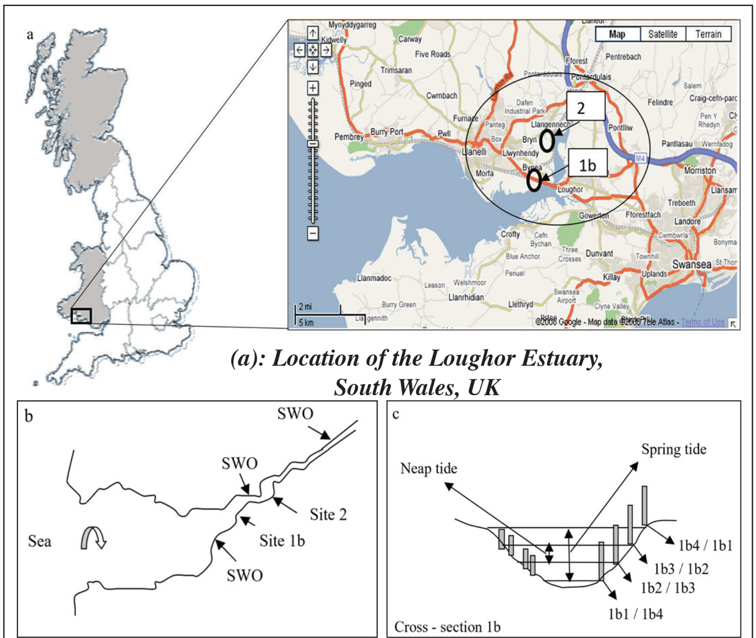
Fluctuating salinity in estuarine sediments plays a major role in controlling the ammonium ion adsorption of the sediments [16]. It was reported by Seitzinger *et al*. (1991) [17] that the amount of adsorbed ammonium was lower in estuarine sediments as compared to freshwater sediments. Salinity can influence the ammonium ion adsorption rate when freshwater mixes with seawater in estuaries. Sea water cations (e.g. Mg^{++}, Na^{+}, K^{+}) compete with the NH_4^+ ions on the surface of clay particles and the adsorption rate decreases with increasing salinity [17], [18], [19]. Increasing the ammonium ion desorption rate, as well as increasing the salinity in an estuarine system, can potentially affect the nitrification rate due to the decreasing residence time of ammonium on the surface of the clay [20], [21].

The Loughor Estuary, located in the Bristol Channel in the UK, has a land-sea transitional area which is a typical environmentally vulnerable zone. The changes in the environmental factors, particularly salinity, are very intense and can influence the ammonium adsorption rate as a result of the interaction between the fresh and seawater. The authors have measured the ammonium and nitrate concentrations in the Loughor Estuary waters and found that concentrations were between 0.08 to 4.12 mg/l for ammonia and 2.65 to 8.31 mg/l for nitrate. The ammonium adsorption rate by the sediments from the Loughor Estuary has not previously been reported in the literature. The objectives of the present study have therefore been to determine the adsorption coefficients for ammonium at the Loughor Estuary sediments and to establish the effect of salinity on this ammonium adsorption coefficient.

2.0 MATERIALS AND METHODS

2.1 Study Area and Sample Collection

Samples were obtained from two sites in the Loughor Estuary as shown in Figure 1. The Loughor Estuary is located in Southwest Wales and is one of the main tributaries discharging into Carmarthen Bay and the Bristol Channel. The Bristol Channel is located on the west coast of the UK, is a funnel-shaped estuary, and has the second-highest tidal range in the world (up to 14.5m). As for most macro tidal estuaries, the tides in the Bristol Channel and Carmarthen Bay play a major role in mixing fresh and saltwater and in re-suspending sediments from the bed and transporting the suspended sediments landward or seaward. During spring tides, the suspended sediments in the Loughor Estuary are transported into the outer bay and deposited in the near shore region just beyond the river mouth. Human activity, including agricultural practices, sewage treatment works, and disused mine discharges all arising along the Loughor River basin, generally have a negative influence on the receiving basin water quality.



(a): Location of the Loughor Estuary, South Wales, UK

(b): Location of the Two Sampling Sites where Sediments were Collected

(c): Cross-Section for Site 1b, with Grey Rectangles Indicating Sample Locations at Spring and Neap Tides Respectively

Figure 1: Sewage Treatment Station Outfall (SWO)

The Loughor Estuary is of particular interest in studying the transport pathways and the adsorption and desorption behaviour of nutrients associated with the sediments; eutrophication problems are not uncommon, and this has economic implications for the coastal waters in West Wales, particularly in connection with the fishing and tourism industries. A study by Abdulgawad *et al.* (2008) [22] indicated that high concentrations of all nutrients were found to occur in the Loughor Estuary and both the Loughor Estuary and the receiving coastal water body were affected regularly by algal blooms.

Bed sediment samples were taken close to the water's edge (at depths of 0-3 cm along the Loughor Estuary. These samples were taken as part of a project that was sponsored by the Environment Agency (EA) Wales and the samples were used for laboratory analysis. Three sediment samples were taken at each site and at hourly intervals. Samples $1b_1$, $1b_2$, $1b_3$, and 2_1, 2_2, 2_3 were collected at times of 1 pm, 2 pm, and 3 pm, respectively. The tidal predictions for 14th December show that the tide was above neap tide with tides ranging between 7.9 m at 8:48 am and 2.1 at 3:12 pm. Plastic bags were used for collecting the surface sediments, with the samples being stored in a refrigerator at 4 ºC for the next day (or night) for a series of adsorption experiments.

2.2 Determination of Sediment Physio-Chemical Parameters

The sediment-water content was measured by determining the weight loss of a known amount of wet sediment, dried at 105 ºC for 48 hr. The sediment particle density was measured as a mass of a known volume of the solid sediment. The sediment porosity was determined by use of the following formula [23]:

$$\phi = W / \{(100 - W) / \rho_s + W\} \qquad (1)$$

Where;

ϕ = sediment porosity; W (%) = sediment water content and ρ_s (g /cm^3) = sediment particle density.

The organic carbon (OC) content was determined after acidification with phosphoric acid and was obtained using a SHIMADZU analyser. The particle size distribution of the sediments was determined by using a laser particle size instrument, namely a Malvern Master sizer. Dry samples were measured and dispersed in distilled water and ultrasound was used to prevent flocculation. The corresponding results are given in table (1).

2.3 Fixed Ammonium on the Sediment

Measurement of the level of fixed ammonium on the sediments was obtained by KCl extraction. In this procedure, the slurry was made by adding 50 ml 2 M KCl solution to the centrifuge tubes containing a portion of the wet sediments. The slurries were shaken for 2 hr, centrifuged at 3,000 rpm for 20 min, and the supernatant was removed for analysis. The ammonium concentration in the supernatant was determined using a spectrophotometer, together with a HACH reagent. The spectrophotometer and the HACH meter (i.e., a colour meter) employed a similar concept of measurement which depends on the light wavelength absorbed by the sample. The wavelength of ammonium is 640 nm. The reagents used in both methods were identified as being roughly similar, which is used in the Phenate method [24]. All the measurements were made on wet sediments within 24 hours of collection.

2.4 Ammonium Adsorption Isotherm

Ammonium adsorption studies were undertaken using sediments again taken from the surface and between depths of 0 to 3 cm. Wet homogenised sediments were taken at each site, weighed, and placed in a centrifuge tube containing 40ml of NH_4^+Cl, at varying concentrations of NH_4^+. These sediment samples gave concentrations of 2, 6, and 10 mg/l NH_4^+. The centrifuge tube was placed on a shaker with continuous agitation for 24 hours, at a temperature of 20 ºC +/- 2 ºC. The samples were then centrifuged at 3000 rpm for 15 min. The supernatant was collected, filtered through a 0.45 µm cellulose filter paper, and then analysed for NH_4^+. The determination of ammonium concentration in the supernatant was undertaken using a Spectrophotometer Lambda EZ150, set at 640 nm [[24]. The ammonium concentration in the supernatant was considered to be the equilibrium concentration for the water. The adsorption isotherm experiments were followed by an adsorption procedure, in order to remove ammonium ions from the solids. 40ml of 2 M KCl solution was added to the sediments remaining in the centrifuge tubes and these sediments were then used to replace those on the shaker. After 2 hours of agitation, the solutions were centrifuged at 3000 rpm for 15 min. The supernatant was removed and analysed using the spectrophotometer. This procedure was repeated until all of the NH_4^+ was removed from the sediments.

2.5 Salinity Effect on Ammonium Adsorption

To study the effects of the salinity on ammonium adsorption, four different concentrations of artificial seawater were prepared including 1, 2, 3, and 4 parts per thousand (ppt). Artificial seawater was prepared according to the Scottish Association for Marine Science procedure [25](MASM, 2007), with the pH value of the artificial seawater being set to 8. The same methodology was used as that outlined for the above-mentioned isotherm adsorption experiments.

3.0 RESULTS

3.1 Sediment Characteristics

The sediments in the Loughor Estuary at the two sampling sites constituted fine sand with mean particle sizes (D_{50}) of 83 to 130 µm and 130 to 170 µm respectively (see Figure 2), samples were collected when the tidal range was greater than neap tide on 14th December. Sample 1b1 had the largest mean particle size of 130µm at site 1b. The mean particle diameter for site 1b samples (i.e., 1b1, 1b2, 1b3) decreased, declining gradually in cross-sectional area and with diameters of the order of 130, 100, and 83 µm, respectively. In addition, the mean grain diameter decreased during the outgoing tide. Sample 2_2 had the largest particle size among the samples for both sites (170 µm) and was collected in the middle of the cross-sectional area. At 2_3, i.e., the position furthest going down along the cross-section, sediment samples had the lowest mean particle size at 130 µm among the samples of site 2. Site 1b was located closer to the sea along the Loughor estuary, and was typically the area most affected by the interaction of seawater and freshwater along the estuary and further from the sea, as shown in Figure 1. The channel width at site 2 was larger than at site 1b, thus typically the water velocity at site 1b was generally higher than that at site 2. Samples collected from site 2 had a measured particle size higher than site 1b due to the water velocity being higher at site 2. The sediment porosity is ranged between 0.43 and 0.58. Sample 1b1 had the highest porosity value of 58% attributed to the amount of organic carbon contained in the sample. Sediments from site 1b were high in carbon content, constituting typically 1.53% – 3.74 % when compared to the sediment samples taken from site 2, which ranged from 1.29% to 4.81%. Sample 21 had the highest amount of organic carbon (4.81%), among the samples for both sites 1b and 2. This sample was collected at high tide. In contrast, sample 2_3 had the lowest amount of organic carbon at 1.29% which was collected at low tide compared to other samples from sites 1b and 2. The particle and the bulk density typically ranged from 1.0 to 1.6 mg/m^3 and 2.60 to 2.70 mg/m^3 respectively. The particle and bulk density are influenced by the mineralogy of the sediments and the organic matter content. The density of organic matter is much lower than the mineral solids density. Sediments high in organic matter and also some clay minerals have low bulk density. The particle density for sediments from both sites 1b and 2 ranged between, 2.63 to 2.69 mg/m^3, see Table 1. The Particle density for a quartz-dominated sediment is normally expected to

Table 1: Sediment Characteristics for Sites 1b and 2 of the Loughor Estuary

Sample	Sample Number	Porosity	Median Grain Size (µm)	Organic Carbon (%)	Particle Density (g cm^{-3})
$1b_1$	1	0.58	130	3.74	2.65
$1b_2$	2	0.51	100	2.82	2.67
$1b_3$	3	0.52	83	1.53	2.69
2_1	1	0.43	160	4.81	2.65
2_2	2	0.51	170	1.39	2.68
2_3	3	0.54	130	1.29	2.63

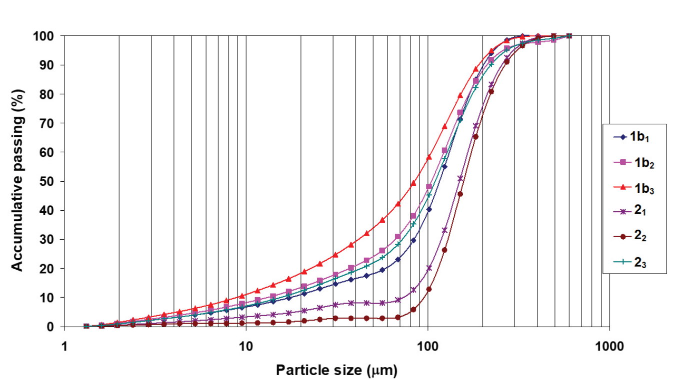


Figure 2: Particle Size Distribution of the Loughor Estuary Sediment Samples at Sites 1b and 2
(The subscript numbers refer to the Sampling Time)

be close to 2.65 mg/m^3 the slight variation of the particle density between the samples was believed to be due to the organic carbon and clay minerals content for both sites ranging from 2.63 to 2.69 g cm^{-3}. The sediment characteristics are summarised in Table (1). The results of X-ray diffraction (XRD) for the sediment samples collected at sites 1b and 2 indicated that the sediments from both sites mostly comprise quartz (66.1 to 88.3%), followed by calcite (9.9 to 17.5%), with minor amount of halloysite (0.1 to 8.4%), and Kaolinite (0.7 to 7.9%).

3.2 Adsorption Isotherm of Ammonium on Sediments

During out-going tides over a period of 3 hours at sites 1b and 2 samples were collected at regular intervals (i.e., samples $1b_1$, $1b_2$, $1b_3$, and 2_1, 2_2, 2_3), as shown in Figure (1). Figure (3) shows comparisons between the experimental or field data and the theoretical results, using Langmuir and Freundlich adsorption isotherm equations. In general, the results show good agreement between the experimental or field data and theoretical results. The Langmuir model fits the data particularly well for all the samples tested, according to the error analysis that was performed for all samples. The Langmuir adsorption equations have the following forms:

$$qe = x/m = \overline{Q}bC_e/(1+bC_e) \quad (2)$$

$$C/q_e = 1/\overline{Q}b + C/\overline{Q} \quad (3)$$

where, $\overline{Q}$ is Langmuir constants related to adsorption capacity, b is a constant related to; the energy of adsorption and the Langmuir adsorption coefficient (K_L), q_e is the ion adsorption amount (μg/g dry wt), C_e is the equilibrium concentration of the solute remaining in solute [26].

Freundlich equation has the following form [26], [27]:

$$q_e = x/m = K^* \ C^{1/n} \quad (4)$$

Where qe is the ion adsorption amount (μg/g dry wt), x is the amount of the adsorbate, m is the mass of the adsorbent, C is the ion equilibrium concentration in water (mg/l), K* and n are constants and n is almost equivalent to 1, i.e., the ion adsorption is linear [28]. In these experiments n 1. The equation is more useful in its logarithmic form, as expressed by Martin *et al.*, 1979.

Table 2 shows the error analysis for the Langmuir and Freundlich adsorption isotherms. The Chi-squared test (X^2) and nonlinear regression (R^2) were used to evaluate the fit of the theoretical data with the experimental data. The error analysis was applied to all of the samples using deionised water. The Chi-squared test for the Langmuir isotherm has lower values compared to the Freundlich isotherm for all sampling sites, showing that the Langmuir isotherm better fits the sample data. Sample $1b_1$ had the highest value of X^2 for all of the samples, with a value of 31.10. In contrast, sample $1b_2$ had the lowest X^2 of 8.93, in comparison with the other samples at both sites. The R^2 test also resulted in higher values for Langmuir isotherm data for all samples at both sites (1b and 2) in comparison with the Freundlich isotherm data. These results also illustrate that the Langumuir isotherm better fits the data of the ammonium adsorption for the Loughor Estuary samples.

Table 2: Error Analysis for Langmuir and Freundlich Adsorption Isotherms using Chi-squared Test (X^2) and Nonlinear Regression (R^2)

Samples	Langmuir Isotherm		Freundlich Isotherm	
	X^2	R^2	X^2	R^2
$1b_1$	9.30	0.94	31.10	0.75
$1b_2$	2.87	0.97	8.93	0.88
$1b_3$	4.99	0.94	13.17	0.81
2_1	7.86	0.95	15.65	0.80
2_2	6.30	0.95	14.15	0.86
2_3	7.80	0.94	15.65	0.84

The adsorption coefficient for ammonium is an important factor in calculating the concentration of nitrogen in the sediments. The formula of the ammonium adsorption coefficient of the sediment for the Loughor Estuary has the following form:

$$Q = K^*C + q \quad (5)$$

Where, Q (μg/g dry wt) is the amount of ammonium adsorbed on the sediment of the Loughor Estuary, K* is the slope of the regression line (adsorption coefficient), C (mg/l) is the ammonium ion equilibrium concentration in water, q is the fixed ammonium content in the sediments being zero.

The ammonium adsorption coefficient of the sediments for the Loughor Estuary was calculated according to the following formula.

$$K = [(1-\Phi)/\Phi]\ \rho K^* \quad (6)$$

Where K is the dimensionless ammonium adsorption coefficient; Φ is the porosity of the sediments; ρ is the density of the sediment (g cm^{-3}); and K* is the slope of the regression line or the Adsorption coefficient (ml g^{-1}).

Table 3: Ammonium Adsorption Coefficients of the Loughor Estuary, its Relative Parameters, and Total Organic Carbon Content (TOC)

Parameters	Sampling Sites					
	$1b^1$	$1b^2$	$1b^3$	2^1	2^2	2^3
K	34.5	26.2	23.0	36.5	25.7	23.0
Φ	0.58	0.51	0.52	0.43	0.51	0.54
K*(ml/ g)	18	10.20	9.3	10.4	10	10.3
ρ_s (g /cm^3)	2.65	2.67	2.69	2.65	2.68	2.63
TOC (%)	3.74	2.82	1.53	4.81	1.39	1.29

Table 3 summarises the relative parameters of the ammonium adsorption coefficient, such as the porosity, particle density total organic carbon, and the adsorption coefficient of ammonium. These parameters are important to calculate the dimensionless adsorption coefficient of ammonium (K) for the sediments of the Loughor Estuary. The table shows that the values of the dimensionless adsorption coefficient for ammonium ranged from 23.0 to 36.5. The highest dimensionless adsorption coefficient was found in the sediment containing the highest amount of total organic carbon, which was in sample 2_1 and with

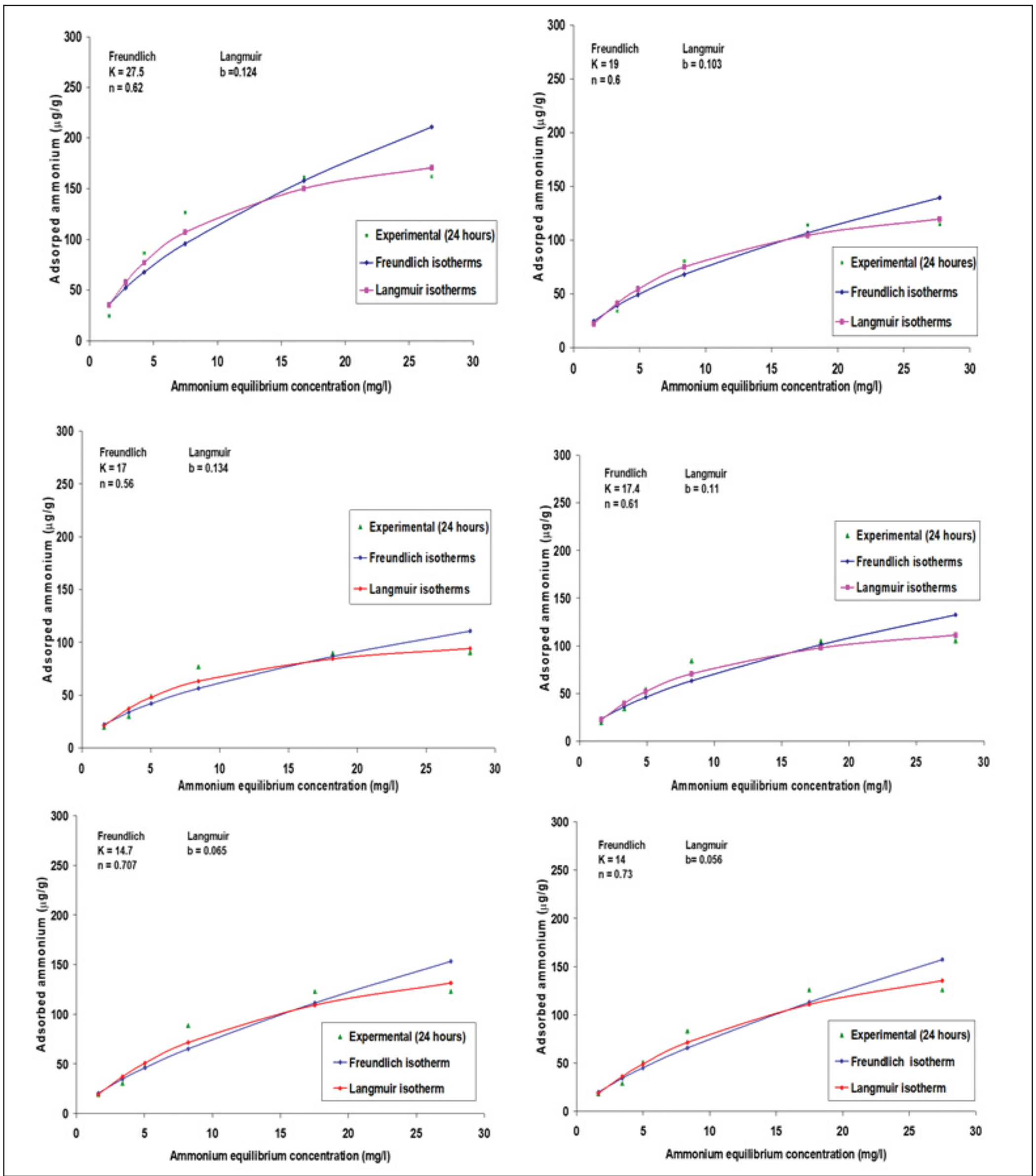


Figure 3: Experimental Results and Theoretical (Langmuir and Freundlich) Adsorption Isotherms of Ammonium for Samples in Distilled Water. b is the Langmuir Constant and Adsorption Coefficient, K is the Freundlich Adsorption Coefficient, and n is the Freundlich Constant

values of 36.5 and 4.81(%) respectively. In contrast, the lowest dimensionless adsorption coefficient was found in the sediment samples $1b_3$ and 2_3 which contained the smallest amounts of total organic carbon. The corresponding adsorption coefficient and TOC values were 23, 23, and 1.53 (%). 1.29 (%) respectively. These results indicate that total organic carbon is an important factor affecting the adsorption of ammonium onto the sediments in the Loughor Estuary. However, the results did not show any influence for other parameters namely Φ and ρ_s.

K is dimensionless adsorption; Φ is the sediment porosity; coefficient K*(ml g^{-1}) is the slope of the regression line (Adsorption coefficient); ρ_s (g cm^{-3}) is sediment density; TOC (%) is organic carbon.

3.3 Salinity Effects on Ammonium Adsorption

Site 1b was located in the mouth of the Loughor Estuary and in the region most affected by the interaction of seawater with riverine freshwater. Site 2 is located more towards the middle of the estuary. The salinity in the water column between low and high tides ranged from 0.02 to 26.90 ppt at site 1b and from 0.32 ppt to 17.21 ppt at site 2 (low to high tides) respectively. Sites 1b and 2 were therefore regarded as being ideal example sites for studying the salinity effects on the adsorption of ammonium by sediments for the Loughor Estuary. The results are shown in Figure 4, which indicates the salinity effect on the adsorption coefficient (K*) and the dimensionless adsorption coefficient for samples from sites 1b and 2. The results shown in the figure indicate that the adsorption coefficients (K* and K) for ammonium at both sites 1b and 2 were highest for zero salinity conditions and continuously dropped with increasing salinity up to 25 ppt. This result was as expected, caused by the sediment cation exchange sites being increasingly occupied by seawater cations and decreasingly by ammonium ions as salinity rose. The adsorption coefficients for ammonium were found to be higher for samples from site $1b_1$ compared to samples from site 2_1 for all salinity conditions. This was thought to be done in sample $1b_1$ containing a higher amount of organic matter than sample 2_1, which resulted in more exchange sites for ammonium being present. Thus, there was found to be a correlation between the level of organic matter in the bed sediments and the amount of ammonium adsorbed onto the sediments.

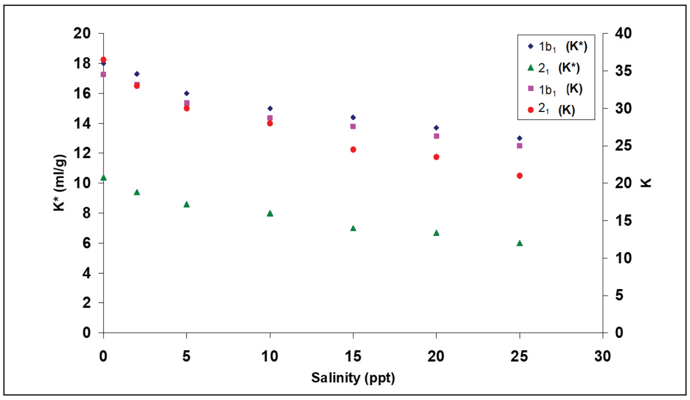


Figure 4: Ammonium Adsorption for Samples from Sites $1b_1$ and 2 under Varying Salinity Concentrations

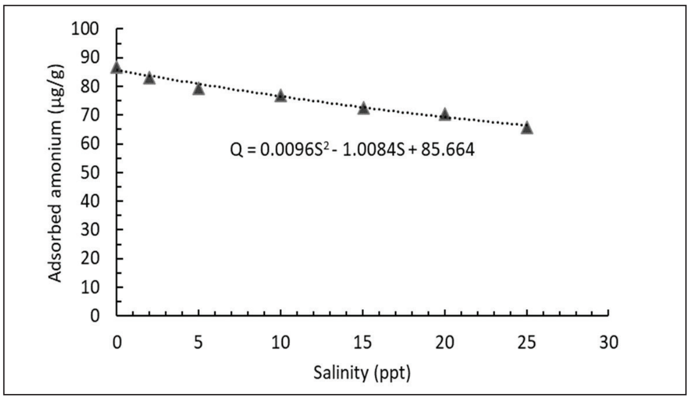


Figure 5: Salinity-Dependent Ammonium Adsorption in the Sediments for Sample $1b_1$, Q (µg/ g dry wt); S (ppt)

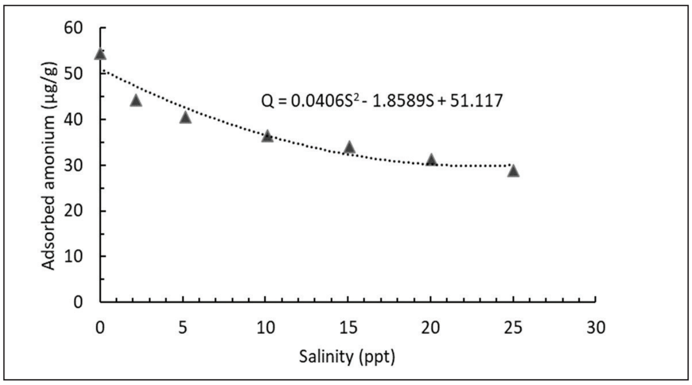


Figure 6: Salinity-Dependent Ammonium Adsorption in the Sediments for Sample 2_1, Q (µg/ G Dry Wt); S (Ppt)

Figures 5 and 6 show the difference in the ammonium adsorption under different salinity conditions and based on the same initial ammonium concentration (of 6 mg/l) in the water column for samples from sites 1b and 2. Equation 9 relates to site 1b for sample $1b_1$ and Equation 10 refers to site 2 for sample 2_1. The ammonium adsorption value in the sediments for samples $1b_1$ and 2_1 gradually decreased with increasing salinity levels, varying from 86.5 mg/g at 0 ppt to 64 mg/g at 25 ppt and 45.5 mg/g at 0 ppt to 28.5 mg/g at 25 ppt respectively, and was found to be best represented by the following equations:

Equation for sample $1b_1$:

$$Q = 0.0098\ S^2 - 1.0756\ S + 85.477 \quad (7)$$

The equation for sample 2_1:

$$Q = 0.0393\ S^2 - 1.8321\ S + 50.916 \quad (8)$$

Where, Q is the ion adsorption quantity (µg/ g dry wt); and S is salinity in the water column (ppt).

3.4 Organic Carbon and Grain Size Effect on Ammonium Adsorption

Sediments at Site 1b were found to be higher in carbon content when compared to the sediment samples taken from Site 2. It was found that the organic carbon content had a significant effect on the ammonium adsorption and this result agreed well with previous studies, such as those of de Lange, (1992); and Raaphorst and Malschaert, (1996) [29], [30]. The samples from Site 1b were found to have higher ammonium adsorption values than those at Site 2. It was also found that the samples taken from Site 1b, with a higher content of organic carbon, had a higher ammonium adsorption than those taken from the same site but with a lower organic carbon content. This finding was attributed to the fact that Site 1b was rich in organic carbon in comparison with Site 2. Studies published by other authors have indicated that sediments with a high ammonium adsorption rate also have a relatively large amount of organic matter, with this result being compatible with the studies of [12], [18]. The corresponding results are shown in Figure 7.

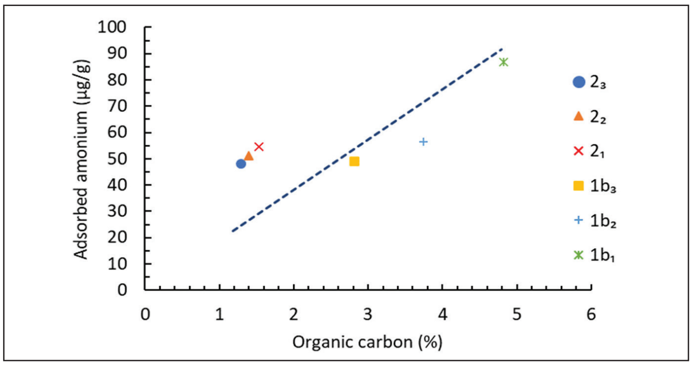


Figure 7: Correlation of Ammonium Adsorption with Organic Carbon Content for the Loughor Estuary Sediment Samples at Sites 1b and 2

4.0 DISCUSSION

The ammonium ion adsorption level in the sediments was found to obey the Langmuir isotherm equation, in particular, the study showed that the rate of adsorption by the sediments was found to be linear and fitted the Langmuir adsorption equation within the controlled range of ammonium concentrations in the water column. Figure 3 indicated that the experimental data fitted well with the theoretical data of adsorption (Langmuir isotherm) than (Freundlich isotherm) and there was found to be good agreement between the values for ammonium adsorption using both methods. The error analysis (Chi-squared and nonlinear regression) confirmed that ammonium adsorption data fits the Langmuir isotherm well. There was found to be good agreement between the values for ammonium adsorption using both error analysis methods.

The ammonium adsorption coefficient, defined as the ratio of the concentration of adsorbed ammonium and the equilibrium ammonium, was found to be important in highlighting the characteristics of ammonium adsorption on the sediments. K is the dimensionless equivalent of K*, with K being larger than K*, which is due to the sediment physio-chemical parameters. The sediment physio-chemical parameters are known to have a significant influence on the behaviour of ammonium adsorption [31]. The particle size of the sediments was also found to have a significant influence on the amount of ammonium adsorption. Samples with a small mean particle size have a larger overall surface area per unit diameter and therefore will have a high ammonium adsorption coefficient. The present study shows that samples with a 65 µm grain size, had the highest ammonium adsorption coefficient when compared to the other samples with a larger mean grain size; this result agrees with the findings of Raaphorst and Malschaert (1996) [29].

The present study showed that the ammonium adsorption coefficient did not appear to have any significant correlation with the sediment porosity. However, the adsorption coefficient was found to be highest in the sediments with comparatively higher amounts of organic carbon. Availability of organic matter was therefore considered to be one of the important factors controlling the degree of ammonium adsorption in the Loughor Estuary (see Figure 7); as can be seen, the adsorption coefficients were higher at Site1b when compared to the corresponding values measured at Site 2. This finding was attributed to the fact that Site 1b was rich in organic carbon in comparison with it 2. Studies published by other authors have indicated that sediments with a high ammonium adsorption rate also have a relatively large amount of organic matter, with this result being comparable with the studies of Hou *et al* (2003); Boatman and Murray (1982); and Mackin and Aller (1984) [12], [18], [28].

The difference in the adsorption isotherm of ammonium for the Loughor Estuary sediments, particularly at Sites 1b and 2, for different salinity concentrations showed that salinity affected the distribution of ammonium between the sediments and the water column. The ammonium adsorption coefficient was found to decrease with increasing salinity concentrations; meaning that lower salinity levels were found to be more favourable to ammonium adsorption by the sediments. The ammonium adsorption levels detected in the Loughor Estuary sediments, as taken from Site 1b and 2 when linked to the salinity levels were fitted to Equations 9 and 10, with the first derivative of this equation being given as:

$$dQ/dS = 0.0196\ S - 1.0756 \quad (9)$$

$$dQ/dS = 0.0786\ S - 1.8321 \quad (10)$$

Where, dQ/dS is the rate of change of the quantity of ammonium ($\mu g\ g^{-1}$ ppt); and S - the salinity -ranged from 0 to 25 ppt. From the above first-order derivative equations, it is possible to calculate the rate of change of ammonium adsorption in the sediments with respect to increasing salinity. The rate of change is higher within the lower range of salinity, thereby reflecting the fact that a small variation in the salinity at the start of the incoming tide has a relatively large effect on the rate of ammonium adsorption. One of the obvious challenges in analysing such processes in estuarine and coastal waters is the huge variation in the salinity levels during the mixing region between the freshwater and seawater flows.

Past studies by other authors of ammonium adsorption for Montmorillonite, Kaolinite, and fine and coarse sand, for different salinity concentrations, have indicated that the adsorption coefficient of ammonium was higher for distilled water and lower for artificial seawater conditions for Montmorilonite, Kaolinite and fine and coarse sand, respectively. For the current samples, Montmorilonite was found to have the highest adsorption coefficient, both for distilled water and artificial seawater [22]. This result led to further studies being undertaken to compare further the results between the field data and the modelled results, with both clay and sand being used. Figure 8 shows the adsorption coefficient for the field data, taken at both Sites 1b and 2 for clean clays (i.e., Montmorillonite and Kaolinite) and sand both (fine and coarse) under different salinity conditions. For all samples, it can be seen that the adsorption coefficients decreased gradually with increasing salinity concentrations. Also, the results indicated that Montmorillonite had much higher adsorption coefficients for all salinities than the field samples ($1b_1$ and 2_1), the clays, and the sand samples. The adsorption coefficients for Montmorillonite, at 0 and 25 ppt salinity ranged from 126 ml/g to 34 ml/g respectively. Kaolinite had the second highest adsorption coefficient ranging from 19.3 ml/g at 0 ppt salinity, to 8.5 ml/g at 25 ppt. Sample $1b_1$ at 25 ppt had a higher adsorption coefficient than Kaolinite with a value of 13 ml/g compared to 8.5 ml/g. Furthermore, the adsorption coefficients for sample $1b_1$ were higher than for fine sand, coarse sand, and sample 2_1 for all saline concentrations.

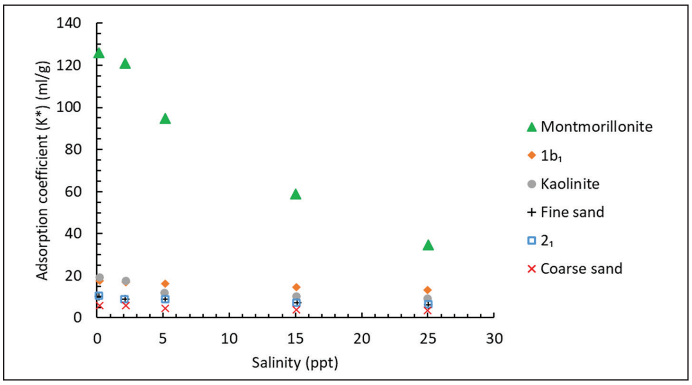


Figure 8: Comparison of Adsorption Coefficient of Field Samples $1b_1$ & 2_1 and Clean Clays (Montmorillonite and Kaolinite) and Sand (Fine and Coarse)

The fixed ammonium levels in the sediments for the Loughor Estuary were zero, as indicated earlier. This was attributed to the constant exchange of ammonium being adsorbed by the sediments, with large quantities of seawater cations such as Na^{+}, K^{+}, and Ca^{2+} from the area controlled by seawater (Sites 1b and 2). The salinity was found to have a significant influence on the fixed ammonium levels in the sediments. In addition, the ammonium levels were also thought to have been influenced by the nitrification process, which was relatively high in the estuary. This high of ammonium could be due to the agricultural activities along this section of the river (next to the farms) or due to a SWO outfall future upstream or have come with the river. This nitrification process is due to the level of inorganic carbon and dissolved oxygen, both of which are readily available as a result of the ammonium produced in the sediments and was rapidly converted to nitrate.

5.0 CONCLUSIONS

Ammonium adsorption isotherms for the sediments have been analysed for the Loughor Estuary, in the U.K. These analyses showed that the adsorption of ammonium by the sediments was almost linear and fitted to the Langmuir adsorption isotherm equation. The ammonium adsorption coefficient K* for the Loughor Estuary sediments ranged from 9.3 to 18 ml/g and the dimensionless ammonium adsorption coefficient, K, ranged from 23.0 to 36.5. These results showed a close affinity with the total organic carbon content and the types of sediments analysed indicated that the organic matter and mineralogy of the sediments were the main factors controlling the adsorption of ammonium. The main parameter found to affect the adsorption of ammonium by the sediments was salinity. Low salinity levels resulted in more ammonium adsorption on the sediments, in comparison with the levels of adsorption measured for higher levels. The fixed amount of ammonium measured on the Loughor sediments was zero, which was thought to be due to the competition of seawater cations to replace the ammonium on the surface of the sediment particles. Also, nitrification was anticipated to be higher in the estuary sediments as a result of the ammonium produced within the sediments being rapidly converted to nitrate. However, the adsorption of ammonium by surface bed sediments in aquatic environments is complex and influenced by several factors. Understanding these factors is essential for managing water quality and the fate of ammonium in natural systems. Future studies should in-depth investigate the effects of sediment composition, pH of the water, ionic strength, and sediment depth on the ammonium adsorption rate by the surface sediments.

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eLEAP AND END SEMESTER REPORT SYSTEM FOR TEACHING, LEARNING, AND ASSESSING PROGRAM OUTCOMES IN FACULTY OF ENGINEERING UNIMAS

(Date received: 03.01.23/Date accepted: 28.01.23)

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ABSTRACT

This paper critically examines the implementation of the e-Learning Enrichment and Advancement Platform (eLEAP) and the End Semester Report (ESR) system in the Faculty of Engineering at UNIMAS, Malaysia, as tools for promoting Outcome-Based Education (OBE), particularly during the COVID-19 pandemic. This paper consists of two (2) sections; firstly is the execution using an online T&L platform called eLEAP and secondly regarding the ESR system for assessing the achievement of Program Outcomes (POs) for the engineering courses in the Faculty of Engineering UNIMAS. By implementing these two systems, it was found that the eLEAP system provided many benefits during the COVID-19 pandemic in Malaysia. Therefore, the T&L process including evaluation was implemented during the tough period of the Movement Control Order (MCO) where students and course instructors were not allowed to come physically to the campus.

Keywords: e-Learning Enrichment, End-Semester Report, Engineering Education and Advancement Platform, Program Outcomes, Teaching and Learning

1.0 INTRODUCTION

The Faculty of Engineering at UNIMAS has embraced Outcome-Based Education (OBE) as a framework for curriculum design, teaching, and assessment. eLEAP and the ERS are two key technological tools introduced to support the implementation of OBE. OBE emphasizes the importance of clearly defined program and course learning outcomes (PLOs and CLOs) that guide the entire curriculum and assessment process. eLEAP and the ERS are designed to operationalise this approach by mapping the CLOs to PLOs and Program Educational Objectives (PEOs) to ensure alignment between course-level learning and broader program goals. Furthermore, these two tools are used to facilitate data-driven decision-making and improve transparency by providing centralised platforms for managing learning resources, assessments, and student performance data. Also, these systems promote active learning and continuous feedback by encouraging student engagement and personalised learning experiences.

The COVID-19 pandemic forced a global reckoning, prompting educational institutions to re-evaluate their pedagogical approaches. In this transformative period, the Faculty of Engineering at UNIMAS, Malaysia, embarked on a critical journey – transitioning from a traditional learning paradigm to a robust Outcome-Based Education (OBE) framework (Satri *et al.*, 2019), (Ismail *et al.*, 2010), (Pradhan, 2021), (Qadir *et al.*, 2020).

The main objective of this paper is to explore how these systems were utilised to navigate the unprecedented challenges of the pandemic, evaluate POs for engineering courses, and ultimately, contribute to a more robust and adaptable engineering education at UNIMAS. By examining the successes and challenges encountered during this pivotal period, we aim to shed light on the potential of eLEAP and ERS as not just pandemic solutions, but as cornerstones in the ongoing evolution of engineering education in Malaysia and beyond.

2.0 eLEAP SYSTEM

eLEAP stands for e-Learning Enrichment and Advancement Platform. eLEAP is the official online Learning Management System (LMS) used to complement the face-to-face T&L process for all academic programs in UNIMAS. It is designed to cater to the teaching, learning, and assessment processes by providing a platform for faculty members and students to access relevant information and resources. The system aims to enhance pedagogy by addressing the challenge of lack of knowledge and training on appropriate pedagogy for online learning. Furthermore, it seeks to ensure effective class management and prevent submission errors through its online interactive programs. This system is managed by the Centre for Applied Learning and Multimedia (CALM) UNIMAS which deals directly with the T&L function by actively promoting and cultivating excellence and innovation in university teaching through technological integration.

The COVID-19 pandemic forced universities to pivot towards online learning, demanding innovative solutions to bridge the educational gap. In this context, UNIMAS, Malaysia, turned to eLEAP (e-Learning Enrichment and Advancement Platform), its official Learning Management System (LMS). While eLEAP offered valuable support and demonstrated the potential of online learning, it also highlighted areas for improvement. eLEAP's primary strength lies in its ability to facilitate the transition to online learning. Its platform provided faculty and students with access to essential resources, including course materials, online lectures, and interactive activities. This ensured continuity of education despite physical classroom closures, mitigating the immediate disruption caused by the pandemic. Furthermore, eLEAP addressed the critical challenge of inadequate training in online pedagogy. Its user-friendly interface and readily available resources empowered faculty to adapt their teaching methods to the virtual environment. This, in turn, fostered a more engaging and interactive learning experience for students. Beyond content delivery, eLEAP offered features for effective class management and assessment. Online quizzes, assignments, and project submissions streamlined the evaluation process and minimized submission errors. This allowed faculty to provide timely feedback and maintain a sense of structure in the online learning environment.

Despite its strengths, eLEAP's implementation also revealed some limitations. The digital divide posed a significant challenge, with unequal access to technology and internet connectivity hindering equitable learning opportunities for some students. This exacerbated existing inequalities and highlighted the need for bridging technological gaps to ensure inclusive education. Furthermore, the shift towards online assessments raised concerns about the potential overemphasis on lower-order thinking skills, such as knowledge and comprehension. While eLEAP offered diverse assessment options, designing assessments that effectively evaluate higher-order skills, such as critical thinking and problem-solving, remained a challenge in the online context. Finally, the pandemic significantly increased faculty workload and stress levels. It was adapting to online teaching, mastering new technologies, and managing online assessments added to their existing responsibilities, potentially impacting their well-being and effectiveness. By addressing these challenges, eLEAP can evolve from a pandemic solution to a valuable tool for adaptable and inclusive learning in the digital age, contributing to UNIMAS's pursuit of excellence in education and training. Figure 1 presents the eLEAP dashboard for a course instructor.

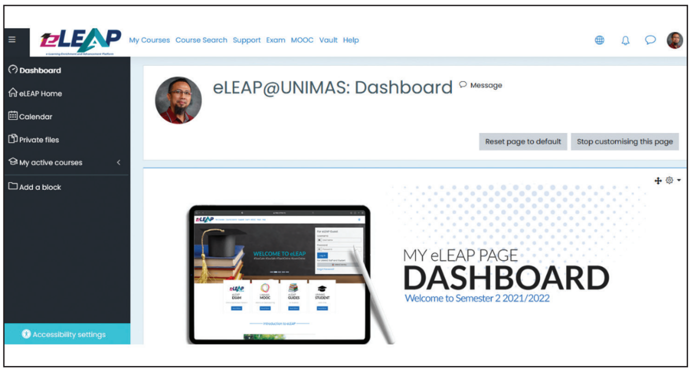


Figure 1: Display of eLEAP UNIMAS dashboard (CALM, 2022)

2.1 Setting Up Online Teaching and Learning Sessions

eLEAP has many features that course instructors can use to rapidly set up their online T&L sessions. The course instructor can also embed external tools as part of their online resources and activities into eLEAP. The four (4) main steps to perform the T&L in the eLEAP system are described as follows.

2.1.1 Step 1: Setup the Resources

Learning resources and materials can be uploaded on eLEAP to allow students to learn remotely. Figure 2 shows a list of resources available in eLEAP such as books, files, folders, labels, pages, etc. where the lecture slides, notes, teaching videos and webinars, and other resources like internet sources can be uploaded as resources. The example of resource features uploaded in the engineering courses is shown in Figure 3.

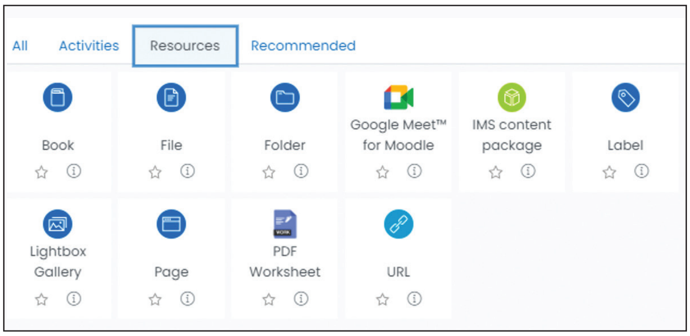


Figure 2: eLEAP UNIMAS Resources Features (CALM, 2022)

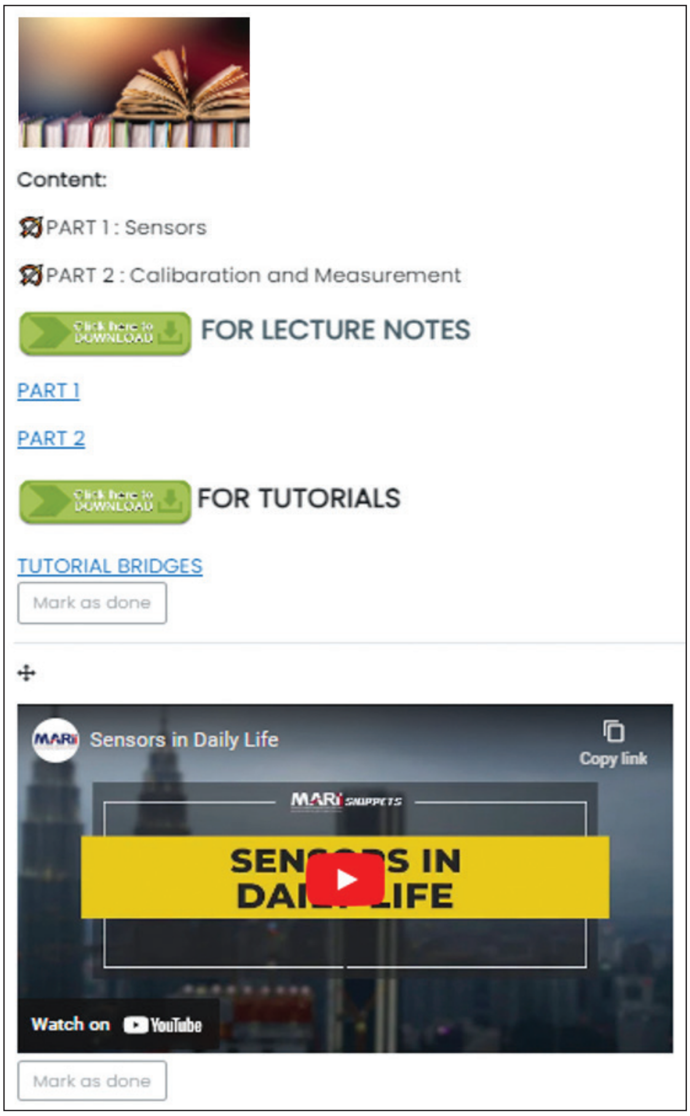


Figure 3: Example of Resources Features in eLEAP UNIMAS (CALM, 2022)

2.1.2 Step 2: Setup the Activities

Activities are important for the course instructor to check if students have understood the course content. It is highly recommended to create at least one activity per unit of content.

2.1.3 Step 3: Setup the Assessments

Integration of diversity, by adding the graded and ungraded formative assessments to enable a more comprehensive evaluation of student learning mastery.

2.1.4 Step 4: Communicate with Students

eLEAP offers promise for transparency and student engagement, but its effectiveness hinges on complementing it with other communication channels. While eLEAP facilitates prompt updates on course materials, schedules, and assessments, relying solely on this platform may not reach all students effectively.

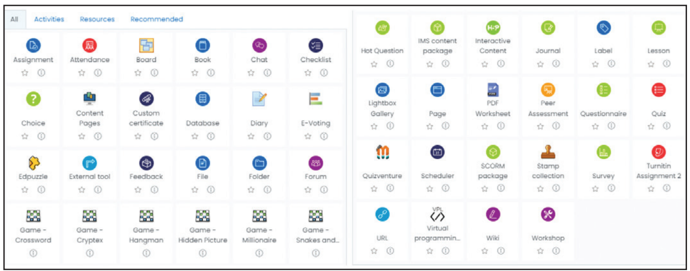


Figure 4: eLEAP UNIMAS Features (CALM, 2022)

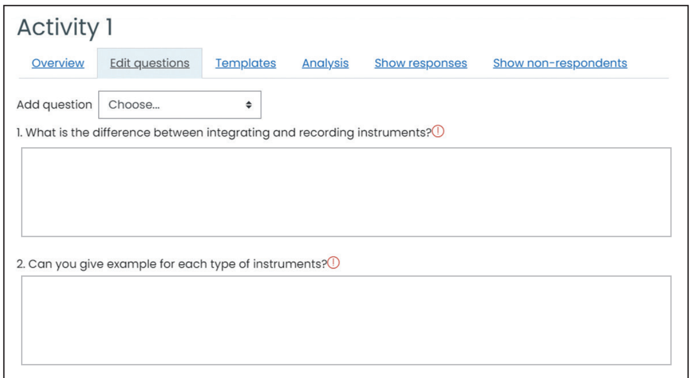
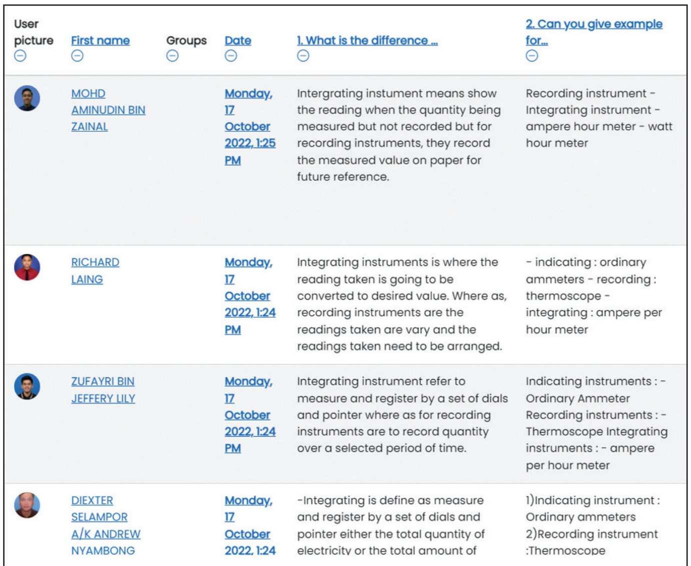


Figure 5: Example activites in eLEAP UNIMAS (CALM, 2022)



User picture	First name	Groups	Date	1. What is the difference ...	2. Can you give example for...
	MOHD AMINUDIN BIN ZAINAL		Monday, 17 October 2022, 1:25 PM	Intergrating instument means show the reading when the quantity being measured but not recorded but for recording instruments, they record the measured value on paper for future reference.	Recording instrument - Integrating instrument - ampere hour meter - watt hour meter
	RICHARD LAING		Monday, 17 October 2022, 1:24 PM	Integrating instruments is where the reading taken is going to be converted to desired value. Where as, recording instruments are the readings taken are vary and the readings taken need to be arranged.	- indicating : ordinary ammeters - recording : thermoscope - integrating : ampere per hour meter
	ZUFAYRI BIN JEFFERY LILY		Monday, 17 October 2022, 1:24 PM	Integrating instrument refer to measure and register by a set of dials and pointer where as for recording instruments are to record quantity over a selected period of time.	Indicating instruments : - Ordinary Ammeter Recording instruments : - Thermoscope Integrating instruments : - ampere per hour meter
	DIEXTER SELAMPOR A/K ANDREW NYAMBONG		Monday, 17 October 2022, 1:24	-Integrating is define as measure and register by a set of dials and pointer either the total quantity of electricity or the total amount of	1)Indicating instrument : Ordinary ammeters 2)Recording instrument :Thermoscope

Figure 6: Example responses for activities in eLEAP UNIMAS (CALM, 2022)

Consider exploring alternative methods like personalised emails or online forums to improve reach and foster deeper engagement. Furthermore, eLEAP's potential for immediate clarification and personalised assistance requires active course instructor participation to empower true student engagement. Figure 4 shows all the features provided in the eLEAP system for various resources and activities including assessments which can be utilised during the T&L of any course for a respective academic semester. The examples of activities and sample responses as shown in Figure 5 and Figure 6 respectively. Figure 7 and Figure 8 shows the example of assessments done using the assessment features in eLEAP and sample responses from the students respectively.

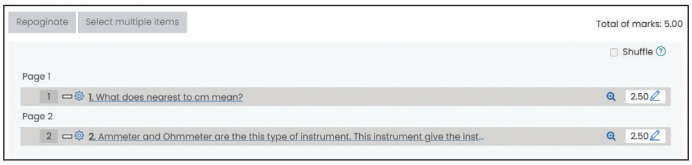
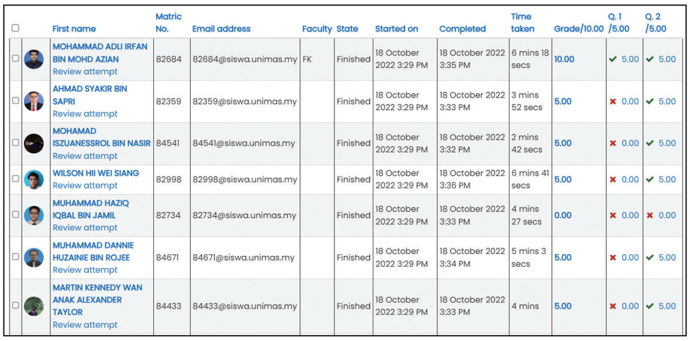


Figure 7: Example assessment in eLEAP UNIMAS (CALM, 2022)



First name	Matric No.	Email address	Faculty	State	Started on	Completed	Time taken	Grade/10.00	Q. 1 /5.00	Q. 2 /5.00
MOHAMMAD ADLI IRFAN BIN MOHD AZIAN Review attempt	82684	82684@siswa.unimas.my	FK	Finished	18 October 2022 3:29 PM	18 October 2022 3:35 PM	6 mins 18 secs	10.00	✔ 5.00	✔ 5.00
AHMAD SYAKIR BIN SAPRI Review attempt	82359	82359@siswa.unimas.my		Finished	18 October 2022 3:29 PM	18 October 2022 3:33 PM	3 mins 52 secs	5.00	✘ 0.00	✔ 5.00
MOHAMAD ISZUANESSROL BIN NASIR Review attempt	84541	84541@siswa.unimas.my		Finished	18 October 2022 3:29 PM	18 October 2022 3:32 PM	2 mins 42 secs	5.00	✘ 0.00	✔ 5.00
WILSON HII WEI SIANG Review attempt	82998	82998@siswa.unimas.my		Finished	18 October 2022 3:29 PM	18 October 2022 3:36 PM	6 mins 41 secs	5.00	✘ 0.00	✔ 5.00
MUHAMMAD HAZIQ IQBAL BIN JAMIL Review attempt	82734	82734@siswa.unimas.my		Finished	18 October 2022 3:29 PM	18 October 2022 3:33 PM	4 mins 27 secs	0.00	✘ 0.00	✘ 0.00
MUHAMMAD DANNIE HUZAINIE BIN ROJEE Review attempt	84671	84671@siswa.unimas.my		Finished	18 October 2022 3:29 PM	18 October 2022 3:34 PM	5 mins 3 secs	5.00	✘ 0.00	✔ 5.00
MARTIN KENNEDY WAN ANAK ALEXANDER TAYLOR Review attempt	84433	84433@siswa.unimas.my		Finished	18 October 2022 3:29 PM	18 October 2022 3:33 PM	4 mins	5.00	✘ 0.00	✔ 5.00

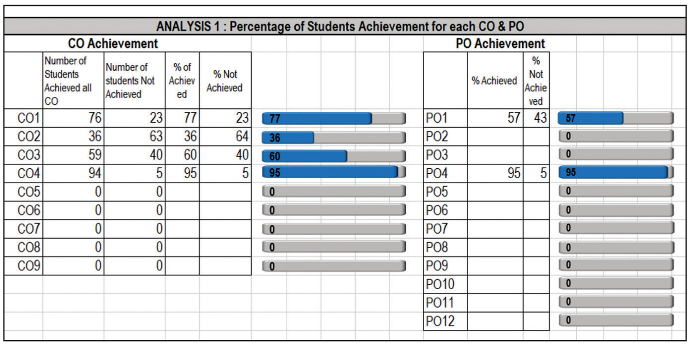
Figure 8: Example responses for quiz in eLEAP UNIMAS (CALM, 2022)

3.0 END SEMESTER REPORT (ESR) SYSTEM

The ESR System was developed and managed by the OBE Unit in the Faculty of Engineering UNIMAS. The ESR system was developed using Microsoft® Excel. Using this system, course instructors may assess their course marks by inserting all necessary marks for carry marks and the final exam, respectively. This system is capable of analysing student achievement including Course Outcomes (COs) and Program Outcomes (POs) achievements in detail including each student's performance. Feedback is encouraged, and regular briefings and training sessions for course instructors are provided to ensure effective system utilisation and OBE awareness.

Figure 9 shows percentages of student achievement for each CO and PO. There are four (4) COs and two POs covered for this course. The threshold for passing COs and POs is 50%. Therefore, the COs and POs for this course were achieved due to the mapping of COs and POs.

Figure 10 and Figure 11 show an example of Cos and POs achievement resulting from the ESR system, respectively. It is observed that the CO1, CO3, and CO4 pass the threshold and achieve meanwhile only 36 % of students did not achieve the CO2. The PO achievement enables the course instructor to evaluate the performance of the students for the respective course. Similarly, PO achievement highlighted that 54 % of students achieved all PO, 3 % did not achieve the PO, and the remaining achieved at least PO for this course.



ANALYSIS 1 : Percentage of Students Achievement for each CO & PO

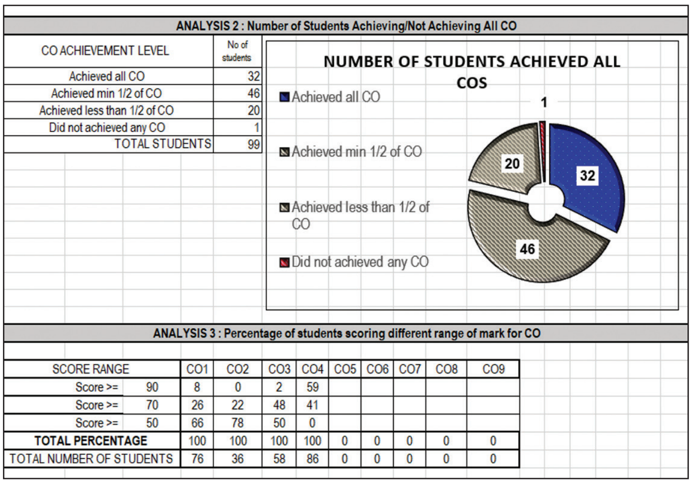
CO Achievement

	Number of Students Achieved all CO	Number of students Not Achieved	% of Achieved	% Not Achieved
CO1	76	23	77	23
CO2	36	63	36	64
CO3	59	40	60	40
CO4	94	5	95	5
CO5	0	0		
CO6	0	0		
CO7	0	0		
CO8	0	0		
CO9	0	0		

PO Achievement

	% Achieved	% Not Achieved
PO1	57	43
PO2		
PO3		
PO4	95	5
PO5		
PO6		
PO7		
PO8		
PO9		
PO10		
PO11		
PO12		

Figure 9: COs and POs students achievement results in ESR system



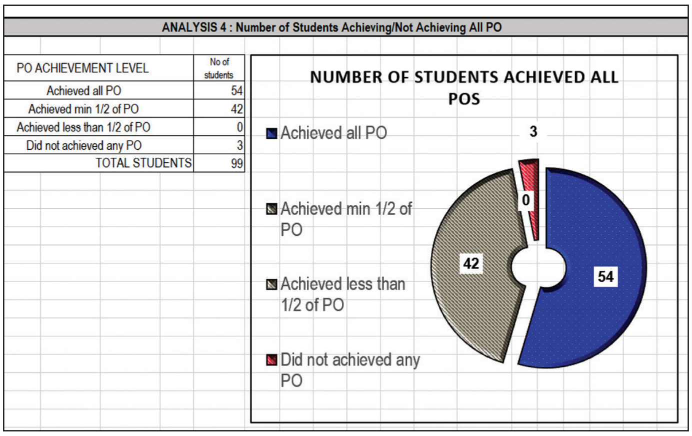
ANALYSIS 2 : Number of Students Achieving/Not Achieving All CO

CO ACHIEVEMENT LEVEL	No of students
Achieved all CO	32
Achieved min 1/2 of CO	46
Achieved less than 1/2 of CO	20
Did not achieved any CO	1
TOTAL STUDENTS	99

ANALYSIS 3 : Percentage of students scoring different range of mark for CO

SCORE RANGE		CO1	CO2	CO3	CO4	CO5	CO6	CO7	CO8	CO9
Score >=	90	8	0	2	59					
Score >=	70	26	22	48	41					
Score >=	50	66	78	50	0					
TOTAL PERCENTAGE		100	100	100	100	0	0	0	0	0
TOTAL NUMBER OF STUDENTS		76	36	58	86	0	0	0	0	0

Figure 10: COs achievement results in the ESR system



ANALYSIS 4 : Number of Students Achieving/Not Achieving All PO

PO ACHIEVEMENT LEVEL	No of students
Achieved all PO	54
Achieved min 1/2 of PO	42
Achieved less than 1/2 of PO	0
Did not achieved any PO	3
TOTAL STUDENTS	99

Figure 11: PO achievement results in the ESR system

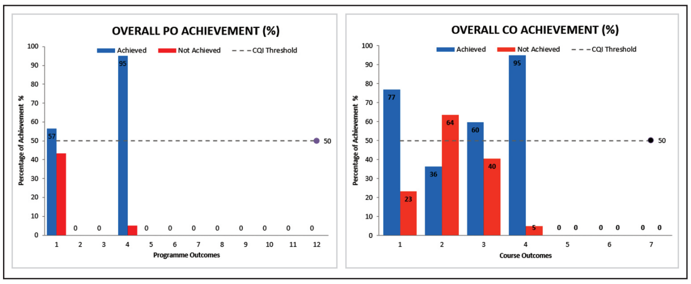


Figure 12: Overall analysis for CO and PO achievement results in the ESR system

The percentage of students scoring for different ranges of marks also have been calculated in the ESR system. The ESR system gives the summary of the course by giving the overall analysis of CO and PO as shown in Figure 12. This summary provides valuable insight and readily identifies areas requiring Continuous Quality Improvement (CQI) intervention for the next semester.

4.0 CONCLUSIONS

This paper has described the eLEAP and ESR systems, highlighting their impact on T&L and assessment of POs in the Faculty of Engineering, UNIMAS during the COVID-19 pandemic. eLEAP's diverse online learning tools empowered students to engage actively and fulfill learning tasks despite the shift to online classes. ESR, through its PO assessment functionalities, provided valuable insights for continuous improvement of the curriculum and teaching methods. While these systems facilitated adaptation during the pandemic, further research is needed to explore their long-term effectiveness in enhancing PO attainment and overall student learning outcomes. ■

LIST OF NOTATIONS

eLEAP	is an e-Learning Enrichment and Advancement Platform
CALM	is the Center for Applied Learning and Multimedia
COs	are the Course Outcomes of the subjects in the Faculty of Engineering UNIMAS
POs	are the Program Outcomes of the subjects in the Faculty of Engineering UNIMAS
CQI	is the Continuous Quality Improvement
ESR	is End Semester Report
LMS	is the Learning Management System
MCO	is the Movement Control Order
OBE	is the Outcome-Based Education

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