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Utilization of Treated Wastewater in Construction Activities for Sustainable Development Goal (SDGs) in Johor

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Abstract

This study investigates the utilization of treated wastewater in construction activities within Johor, Malaysia, as a strategic response to escalating freshwater demand and in alignment with Sustainable Development Goals (SDGs) 6 and 11. The construction industry's heavy reliance on potable water for processes like concrete mixing and dust suppression creates significant sustainability pressures, particularly in rapidly urbanizing regions facing water stress. The research aimed to identify specific non-potable applications for treated effluent, systematically examine the barriers to adoption faced by industry contractors, and propose actionable strategies for integration. A quantitative methodological approach was implemented, utilizing a structured questionnaire disseminated electronically to a targeted sample of 233 contractors registered with the Construction Industry Development Board (CIDB) under Grades G6 and G7, ensuring insights from key decision-makers in medium to large-scale projects. The results identified landscape irrigation, dust suppression, and equipment washing as the most promising applications, with high respondent agreement. However, critical challenges were also highlighted, primarily concerning the inconsistent quality and reliability of treated wastewater supply, high initial economic costs, ambiguous regulatory frameworks, and a prevalent lack of technical awareness among contractors. In conclusion, the study confirms the substantial potential of treated wastewater to enhance sustainable water management in Johor's construction sector. Realizing this potential requires a concerted effort to address the identified barriers through the development of clear standards, targeted financial or policy incentives, and comprehensive industry education programs.

1. Introduction

The construction sector is vital to Malaysia's socioeconomic development, contributing RM32 billion in Q4 2022, particularly in urbanizing regions like Johor (Nadzari, 2023). However, its high freshwater consumption for activities such as concrete mixing, curing, dust suppression, and site cleaning strains water resources, exacerbated by Johor's periodic water scarcity and rapid urbanization (Vaishali & Prashant, 2023). Treated wastewater, processed to remove contaminants, offers a sustainable alternative for non-potable construction uses, aligning with SDGs 6 (Clean Water and Sanitation) and 11 (Sustainable Cities and Communities) (United Nations, 2020). Despite its potential, adoption in Malaysia's construction industry is limited due to regulatory ambiguities, inconsistent water quality, and lack of contractor awareness (Rahim & Mohamed, 2022; Abu Zahra *et al.,* 2021).

This study focused on Johor, a hub of industrial and infrastructural growth, to explore treated wastewater utilization in construction. It addressed the research gap in localized implementation data and contractor perspectives and aimed to promote sustainable practices. Johor's construction sector drives economic growth but heavily relies on freshwater, intensifying water stress amid urbanization and projects like data centres said by Johor Bahru's mayor, Mohd Noorazam Osman (Rest of World, 2024). Treated wastewater, processed through physical, chemical, and biological treatments, is suitable for non-potable uses like concrete production and dust control, reducing environmental impact and costs (Kesari *et al*., 2021). Countries like Singapore demonstrate successful wastewater reuse, but Malaysia underutilizes this resource due to limited infrastructure and awareness (PUB Singapore, 2018; Husin *et al*., 2023).

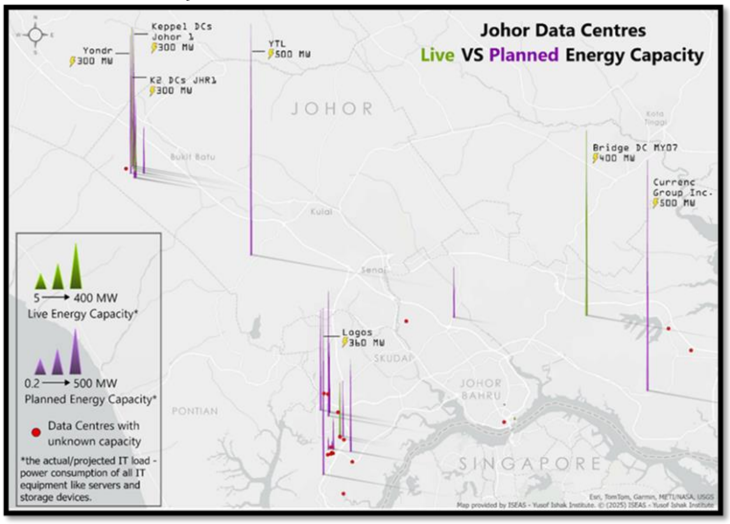

Fig 1. *Live and Planned Energy Capacities of Data Centres in Johor*

The construction industry is one of the world's greatest water users, relying on enormous amounts of freshwater for concrete mixing, curing, dust suppression, and site cleaning (Hamada *et al.,* 2023). In Malaysia, particularly in Johor, the continuous reliance on potable water supplies for such operations creates serious sustainability problems. Johor has undergone recurrent water stress, which has been compounded by increased urbanization, industrial activity, and climatic variability (Vaishali & Prashant, 2023). This makes it critical for the building industry to seek out alternate, more sustainable water sources.

One interesting solution is to use treated wastewater. Treated or reclaimed wastewater, whether derived from municipal facilities, plant wash water, or industrial effluents, has demonstrated promise for reuse in a variety of building applications. Certain forms of treated wastewater, such as tertiary treated or recycled wash water, have been demonstrated in studies to fulfil concrete performance criteria while maintaining material strength and durability (Elsayed *et al*., 2023; Azeem *et al*., 2021). For example, tertiary treated wastewater improved compressive strength in concrete compared to standard mixtures by up to 70% after 14 days of curing (Elsayed *et al*., 2023). Similarly, promotes the reuse of plant wash water to achieve zero-discharge compliance on building sites (CIDB, 2008.).

Despite the shown benefits, the use of treated wastewater in construction activities in Malaysia remains restricted due to several persisting challenges. These include confusion over regulations, a lack of defined reuse criteria, public and industry scepticism about safety and quality, and limited infrastructure for wastewater treatment and delivery (Vaishali & Prashant, 2023; Azeem *et al*., 2021). Furthermore, many contractors are ignorant of the performance variations between kinds of treated wastewater, with industrial and secondary effluents occasionally having insignificant or even negative effects on concrete qualities if not properly treated (Varshney *et al*., 2021).

Another important issue is that construction professionals lack expertise about how to implement wastewater reuse systems in practice. Most contractors and project managers still rely on old methods and are unaware of the

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possible environmental and economic benefits of using treated wastewater (Kristanti *et al.*, 2023). This underutilization not only diminishes the potential for water saving in construction but also impedes progress toward the Sustainable Development Goals (SDGs), notably SDG 6 (Clean Water and Sanitation) and SDG 11 (Sustainable Cities and Communities) (Abioye *et al.*, 2021).

Currently, research on wastewater reuse in construction has mostly concentrated on laboratory testing rather than real-world implementation in actual project situations. Furthermore, there is a shortage of data unique to Malaysia's construction sector, especially in Johor, on appropriate uses, stakeholder preparation, and regulatory adaptation for wastewater reuse. As a result, the purpose of this study is to identify construction activities where treated wastewater may be efficiently employed, to investigate the problems that contractors experience when adopting this strategy, and to make strategic recommendations to improve integration for sustainable development in Johor.

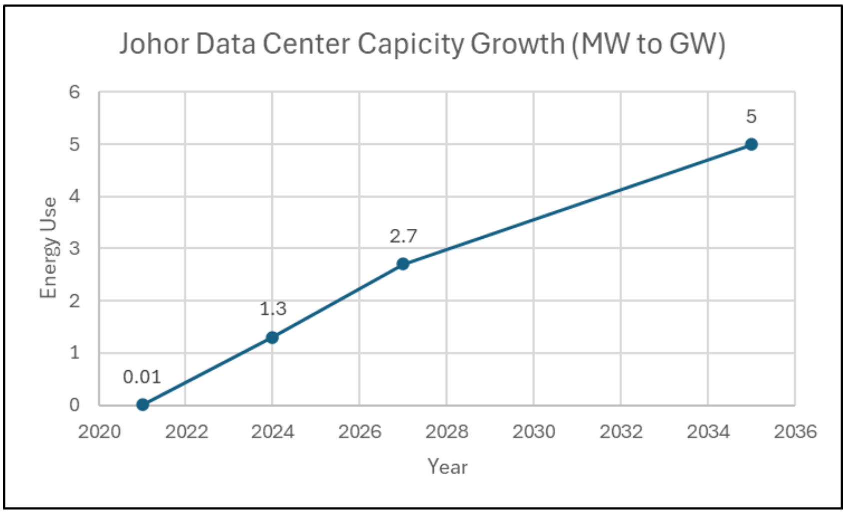

Fig 2. *Johor Data Center Capacity Growth (Loo, 2025)*

2. Literature Review

This section reviews existing studies on treated wastewater use in construction, focusing on applications, challenges, and strategies to support sustainable development in Johor.

2.1 Treated Wastewater and Its Applications

Treated wastewater, processed to remove pollutants, is suitable for non-potable construction uses like concrete mixing, dust suppression, and equipment cleaning (World Health Organization, 2020). Its reuse aligns with SDGs 6 and 11, reducing freshwater demand in water-stressed areas like Johor (United Nations, 2020). Types include domestic wastewater, industrial wastewater, greywater, blackwater, and reclaimed water, each requiring specific treatment levels for safe use (Hou *et al.,* 2025).

2.2 Potential Construction Activities that can Utilize Treated Wastewater Effectively

2.2.1 Concrete Mixing

Concrete production takes a lot of water, both for mixing and curing. Treated wastewater is a possible alternative to potable water in this procedure. Research has been done in urban India discovered that incorporating treated effluent into concrete manufacturing might save up to 30% of potable water consumption on-site while having no negative impacts on concrete structural integrity or setting time (Mohan *et al.*, 2020; Lim & Fauzi, 2023).

2.2.2 Dust Suppression

A field test in Johor was performed and discovered that using treated effluent from local sewage treatment facilities reduced airborne dust levels by more than 40%, resulting in dramatically improved on-site air quality (Zaini *et al.*, 2023). Furthermore, the Ministry of Health Malaysia has accepted that tertiary-treated water, when adequately disinfected, is safe for use in dust management applications (MOH, 2022).

2.2.3 Soil Compaction

The study concluded that factors such as chloride and sulphate concentrations should be kept below acceptable ranges to prevent corrosive effects on reinforcing steel in nearby structures (Aziz and Saeed, 2022). Furthermore, the pre-treated effluent might lower total water expenditures on big earthworks projects by 15-20% (Jamil et al., 2020).

2.2.4 Equipment and Vehicle Washing

Construction companies in Kuala Lumpur that used treated wastewater for equipment cleaning saved up to 25% on operating water expenditures over six months (Rahman et al., 2019). Furthermore, the World Bank recommends the reuse of reclaimed water in non-critical construction activities, claiming that secondary-treated water, when adequately screened and filtered, is acceptable for washing machines (World Bank, 2021).

2.2.5 Landscape Irrigation

A case study was conducted in Iskandar Puteri, Johor, and it was discovered that landscape areas watered with treated effluent had better plant health and development than those irrigated with potable water. The study also identified cost reductions in fertilizers because of the presence of nutrients such as nitrogen and phosphorus in the treated water (Chong *et al.,* 2022).

2.2.6 Concrete Curing

Concrete cubes cured with chlorinated effluent and discovered no significant variations in compressive strength and durability when compared to those cured with potable water (Lim and Fauzi, 2023). Additionally, it demonstrates that concrete cured using recycled water passed all ASTM curing criteria if turbidity and suspended particles were within prescribed limits (Harith *et al*., 2020).

2.3 Challenges Faced by Contractors in Utilizing Treated Wastewater

2.3.1 Quality and Reliability of Treated Wastewater Supply

For treated effluent to be utilized safely in applications such as concrete mixing, curing, or soil compaction, it must fulfil strict chemical and microbiological regulations. Many contractors are hesitant to take the risk because they are concerned about the structural quality being degraded owing to inadequate water (Abu Zahra *et al*., 2021).

2.3.2 Lack of Awareness and Technical Knowledge

Many experts are ignorant of the various applications of treated wastewater or the safety requirements that regulate its usage. More than 60% of surveyed Johor contractors had an inadequate understanding of treated wastewater's possible functions in non-potable building operations. This lack of information frequently leads to a reluctance to innovate and preserve status quo activities that rely on potable water (Ismail *et al.,* 2020).

2.3.3 Regulatory Ambiguities and Compliance Issues

This legislative uncertainty confuses contractors regarding the legality and liability of utilizing treated wastewater, leading to hesitation. Many contractors are concerned about the legal ramifications or contract conflicts that may arise from unorthodox water consumption techniques, especially if they are not specifically indicated in project paperwork (Rahim & Mohamed, 2022).

2.3.4 Infrastructure and Logistical Limitations

Many wastewater treatment plants are not located near active construction zones, necessitating expensive transportation networks. The substantial initial capital expenditure necessary to create such infrastructure frequently discourages small and medium-sized contractors from using treated wastewater systems (Goh & Lee., 2019).

2.3.5 Contractor Perception and Risk Aversion

There is a belief that clients and consultants would question the quality of work or refuse to accept constructions made of uncommon materials. Unless treated wastewater usage is specifically allowed in building rules and client requirements, it remains a professional risk for project managers and contractors (Ibrahim **et al.,** 2023).

2.3.6 Economic and Financial Constraints

Although treated wastewater might save long-term water expenditures, the initial costs of testing, transportation, infrastructure, and training can be prohibitively expensive. Furthermore, because there are no incentives or subsidies, contractors have no financial incentive to switch from traditional water sources. This research shows that 75% of respondents mentioned "lack of funding or incentives" as the primary reason for not integrating treated wastewater systems in their projects (Lee and Tan's, 2020).

2.4 Suggest the Potential Construction Activities that can Utilize Treated Wastewater

2.4.1 Concrete Mixing and Curing

Concrete constructed from tertiary-treated wastewater had compressive strength approximately equal to that of concrete mixed with potable water. Additionally, treated wastewater may be used for concrete curing, which requires a long-term moisture supply (Mohan *et al*., 2020). There is no detrimental effects on the compressive strength of concrete cured with disinfected effluent (Lim & Fauzi, 2023).

2.4.2 Soil Compaction and Grading

Soil compacted with treated effluent had equivalent density and bearing capacity to soil compacted with potable water, as long as the effluent satisfied salinity and chemical oxygen demand (COD) standards. This makes it a feasible alternative to site preparation, grading, and roadbed building activities (Aziz & Saeed, 2022).

2.4.3 Dust Suppression on Construction Sites

Spraying treated wastewater over unpaved roads and open spaces is an effective way to minimize airborne particulates. A case study in Johor found that using treated wastewater reduced dust levels by 40% on roadways under construction. This strategy not only conserves freshwater but also meets air quality criteria for public safety (Zaini *et al.,* 2023).

2.4.4 Equipment and Vehicle Washing

Treated wastewater can be used to wash equipment, hence lowering water use. Employing treated wastewater for car washing reduced overall water use by 18-25% in numerous projects across southern Malaysia while preventing equipment depreciation or corrosion (Rahman *et al*., 2019).

2.4.5 Landscape Irrigation and Green Area Development

It is discovered that in green-certified developments in Iskandar Malaysia, treated wastewater improved soil moisture and plant health while lowering total irrigation costs by 30%. Treated wastewater, which is high in nutrients like nitrogen and phosphorus, is ideal for irrigating post-construction landscapes like parks, green roofs, and buffer zones. It also helps conserve potable water and reduce fertilizer needs (Chong *et al.,* 2022).

2.4.6 Site Cleaning and General Maintenance

Treated wastewater is suitable for cleaning floors, scaffolding, and other non-sensitive surfaces. Using treated wastewater for general maintenance in public housing developments reduced municipal water expenses by 20% while maintaining cleanliness (Yusof *et al*., 2021).

3. Research Methodology

This study adopts a quantitative approach to assess treated wastewater use in Johor’s construction industry, targeting CIDB-registered G6–G7 contractors.

3.1 Research Design

A structured questionnaire, distributed via Google Forms to approximately 285 respondents, will collect data on wastewater applications, challenges, and strategies. Secondary data from journals and reports provide context. The methodology follows a flow chart (Fig 3), starting with objective setting, literature review, data collection, and analysis using SPSS.

3.2 Flow Chart of Research Methodology

The research design flow chart (Fig. 3) shows the steps of this study and offers an overview of the method. The research methodology for this study is quantitative, with the researcher creating a questionnaire to collect important information and data. The figure below shows the whole procedure for this study approach.

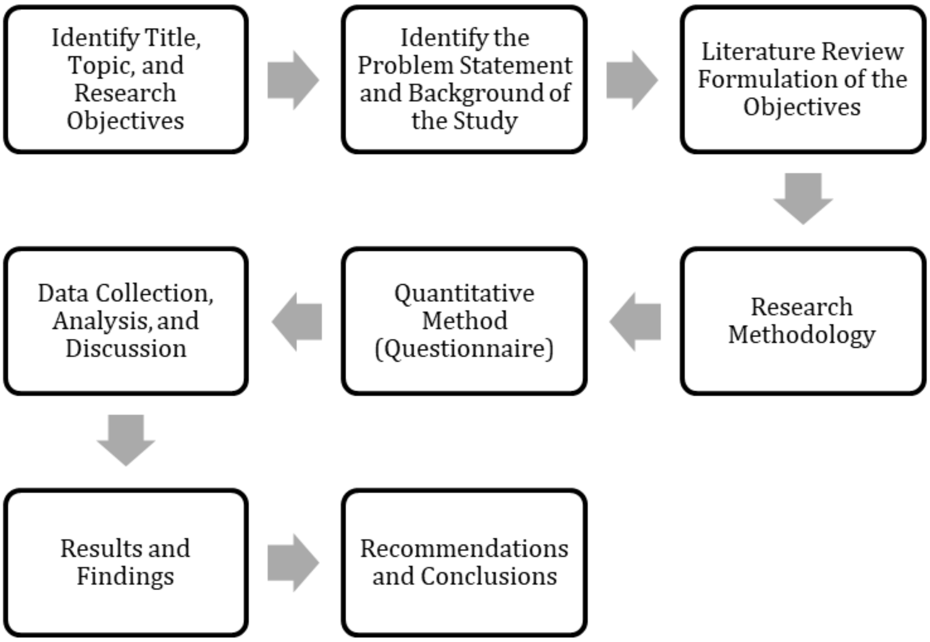

Fig. 3 *Research Design Flow Chart*

Based on Fig. 3, the first step is to choose the title and research objectives. Following this, the study focuses on developing the problem statement and the background for the research, which serve as the foundation for the whole research process. The following step entails performing a complete literature review to provide a theoretical framework and identify gaps in current research on the use of treated wastewater in construction operations for sustainable development in Johor, Malaysia.

Following that, the research method is developed to accomplish the research's objectives, which include the creation of a structured questionnaire for data collection. The data gathered from the questionnaire is then evaluated using statistical tools such as SPSS to create useful insights and answer research questions. Finally, the study presents its results, suggestions, and conclusions based on the data analysis.

3.3 Research Strategy

A research strategy is the systematic method taken to perform the research to answer a certain research topic or problem. It covers the overall research goal and direction, which guides the selection of data gathering and analysis methodologies and processes.

3.3.1 Quantitative Method

Quantitative research methods focus on objective measurement and statistical analysis of numerical data. These techniques are used to measure variables, establish connections, and test hypotheses. In this research, the method of quantification was chosen due to its capacity to produce accurate, quantifiable, and repeatable results. It allows the researcher to collect data from many respondents, creating a solid foundation for deriving statistically meaningful findings.

3.3.2 Research Tools

Research tools are critical components of research techniques, since they enable data collection, measurement, and analysis. In quantitative research, these instruments are used to gather organized and numerical data, assuring consistency and precision in the collecting process. The major research technique for this study would be a standardized questionnaire used to gather quantitative data from construction industry experts in Johor, such as construction manager, project manager, civil engineer, environmental engineer, site engineer, quantity surveyor, safety & health officer, and contractor.

3.3.2.1 Questionnaires

A questionnaire is a popular data gathering tool in quantitative research. It involves a series of structured questions designed to gather respondents' perspectives, perceptions, and experiences. In this study, the questionnaire will be conducted online via platforms such as Google Forms, allowing for efficient distribution and answer gathering. This strategy is especially useful for addressing an enormous and geographically scattered audience of construction industry experts in Johor.

3.3.2.2 Population

In research, a population is the total group of people or organizations who share specified characteristics important to a given study (Momoh *et al.,* 2021). The Construction Industry Development Board (CIDB) of Malaysia reports that the nation has around 137,279 registered local contractors and 1,429 registered foreign contractors, ranging from small-scale builders to large-scale infrastructure developers (CIDB, 2025). This study focuses exclusively on contractors' grades as G6, and G7. These contractor grades are chosen for their ability to complete large-scale, high-value projects that are more likely to include innovative methods such as treated wastewater utilization.

3.3.2.3 Sample Size

In a research project, the sample size is the number of participants or units required to accurately reflect the target population. According to Malaysia's Construction Industry Development Board (CIDB), Johor has 1,096 G6, and G7 contractors (CIDB, 2025). Given the population size, the sample size is computed using the Krejcie and Morgan (1970) formula, which is widely recognized for computing sample sizes for known populations. Using this formula, the minimum suggested sample size for this investigation is around 285. For this study, a sample size of 233 respondents was achieved, which was sufficient to facilitate effective data collection within the given timeframe.

3.3.2.4 Pilot Test

The primary goal of a pilot test is to ensure that the questionnaire properly gathers the necessary data and that respondents understand the questions. It also allows you to modify the structure, wording, and sequencing of survey items to reduce any biases and inaccuracies. Furthermore, it aids in identifying logistical concerns, such as the projected time required to complete the questionnaire and the clarity of response alternatives (Collier *et al.*, 2023). For this research, a small group of 32 contractors from the target demographic (G6 and G7 contractors in Johor) was participate in a pilot test to evaluate the questionnaire's clarity, relevance, and comprehensiveness. Exploratory studies, the sample size of 10 to 30 is commonly preferred since it is easy to collect and analyze data, permits easy hypothesis testing, and is commonly feasible, according to (Isaac and Michael, 1995). The feedback from this first group will be used to enhance the questionnaire before it is distributed widely, ensuring that it accurately represents the viewpoints and experiences of the larger target audience. This stage is critical for increasing the overall reliability and validity of the study findings while adhering to standard practices for quantitative research (Ismail *et al.,* 2023; Tan *et al.,* 2022).

3.4 Data Collection

Primary data came from a questionnaire with four sections:

- Demographic Profile.
- Identifying Potential Construction Activities that can Utilize Treated Wastewater (Likert scale).
- Challenges Faced by Contractors in Utilizing Treated Wastewater (Likert scale).

- Suggesting Potential Construction Activities that can Utilize Treated Wastewater (Likert scale).

Secondary data for this research comes from:
- Academic journals
- CIDB reports
- Industry reports
- Government publications
- Other relevant resources

3.5 Data Analysis Method

Data analysis is a crucial part of quantitative research because it enables researchers to extract relevant insights from acquired data and determine if the findings are consistent with the study's aims. This procedure entails converting raw data into a structured format for analysis and reporting. In this research, data will be analysed using the Statistical Package for the Social Sciences (SPSS), a popular statistical analysis program for social scientific research. SPSS is vital for successful data management, analysis, and presentation, giving researchers the tools they need to reach accurate and dependable findings (Abuela & Harwell, 2020).

The statistical software SPSS will be utilized to analyze the data acquired from 233 questionnaire replies from Johor construction industry experts. This program was chosen for its comprehensive statistical features, which include descriptive statistics, correlation analysis, reliability testing, and hypothesis testing, all of which are critical to accomplishing the study's research objectives. In addition to SPSS, Microsoft Excel will be utilized to organize the raw data and create graphs, tables, and charts to graphically represent the findings.

The Cronbach's Alpha test will be used to determine the questionnaire's reliability, which examines the internal consistency of the survey items. A Cronbach's Alpha score of 0.7 or above is typically regarded as sufficient to ensure questionnaire reliability (Abuela & Harwell, 2020). Table 1 presents the categorization of Cronbach's Alpha values.

Table 1: *Cronbach Alpha Classification (Permana & Suroso, 2018)*

Scale	Level of agreement
1	Strongly disagree
2	Disagree
3	Neutral
4	Agree
5	Strongly agree

3.5.1 Statistical Analysis

Statistical analysis is the process of collecting, analysing, interpreting, and presenting data to uncover patterns and trends. It is an important part of quantitative research since it allows researchers to synthesize complicated data and generate relevant conclusions (Simplilearn, 2021). In this research, statistical analysis will be carried out using SPSS, which will provide insights into the questionnaire replies. This technique assures that the results are correct, dependable, and statistically significant.

3.5.2 Descriptive Analysis

Descriptive analysis is a sort of data analysis that aims to summarize, organize, and display data in an understandable manner. It is frequently used to convey the main characteristics of data, such as frequencies, percentages, and averages, making it simpler to comprehend enormous amounts of information (Simplilearn, 2021). In this study, SPSS will be used for descriptive analysis to provide thorough summaries of the data obtained from G6 and G7 contractors in Johor, offering a complete picture of the results.

4. Results and Findings

This chapter presents and discusses the findings obtained from the questionnaire survey conducted among CIDB-registered G6 and G7 contractors in Johor. A total of 233 valid responses were collected, representing 81.75% of the targeted sample size of 285 respondents. The analysis focuses on addressing the three research objectives of the study.

Table 2: *Sample Size Adequacy*

Category	Population	Required Sample Size	Participated Respondents
G6 & G7 Contractors in Johor	1,096	285	233
Total	**1,096**	**285**	**233**

4.1 Descriptive Statistics Analysis

Descriptive statistical analysis was conducted to summarize and describe the data collected from G6 and G7 contractors in Johor regarding the utilization of treated wastewater in construction activities. Descriptive methods were employed to present the data in the form of frequency, percentage, mean, and standard deviation to provide a clear overview of respondents' backgrounds, perceptions, challenges, and views related to treated wastewater usage.

4.1.1 Potential Construction Activities That Can Utilize Treated Wastewater Effectively

Descriptive analysis was conducted to identify construction activities that have potential for treated wastewater utilization. The results indicate a high level of agreement among respondents regarding the suitability of treated wastewater for non-potable construction activities.

Activities such as dust suppression, concrete curing, equipment washing, site cleaning, soil compaction, and landscape irrigation recorded high mean values, indicating strong acceptance among contractors. This finding aligns with previous studies which highlighted that treated wastewater can safely replace potable water in non-structural and non-consumptive construction activities without affecting performance or quality.

The results demonstrate that contractors in Johor generally recognize the practicality of treated wastewater for reducing freshwater dependency, particularly for repetitive site operations.

Table 3: *Frequency of Level Potential Construction Activities That Can Utilize Treated Wastewater Effectively*

Level	Frequency	Percentage (%)
Low	0	0
Moderate	3	1.2
High	230	98.8
Total	**233**	**100%**

4.1.2 Challenges Faced by Contractors in Utilizing Treated Wastewater

The analysis identified several challenges that hinder the adoption of treated wastewater in construction activities. The most significant challenges include concerns regarding water quality and consistency, lack of clear regulatory guidelines, limited awareness and technical knowledge, infrastructure and logistical constraints, and financial constraints and lack of incentives.

Most respondents agreed that uncertainty surrounding water quality standards and legal compliance discourages contractors from adopting treated wastewater. The absence of incentives and high initial setup costs further limits implementation, especially for projects with tight budgets.

These findings are consistent with earlier studies which reported that regulatory doubt and risk aversion among contractors remain major barriers to sustainable water reuse practices in the construction industry.

Table 4: *Frequency of Level Challenges Faced by Contractors in Utilizing Treated Wastewater*

Level	Frequency	Percentage (%)
Low	1	0.4
Moderate	8	3.4
High	224	96.2
Total	**233**	**100%**

4.1.3 Suggest the Potential Construction Activities That Can Utilize Treated Wastewater

To address the third research objective, respondents were asked to suggest construction activities suitable for treated wastewater usage. The findings reveal a very high level of agreement, with 99.2% (231 respondents) indicating a high level of suitability.

The most recommended activities include dust suppression on construction sites, concrete curing, equipment and vehicle washing, site cleaning and maintenance, and landscape irrigation

These activities are non-structural and non-potable in nature, making them ideal for treated wastewater application. The results confirm that contractors are more willing to adopt treated wastewater when it does not directly affect structural integrity or client acceptance.

Table 5: *Frequency of Level Suggest the Potential Construction Activities That Can Utilize Treated Wastewater*

Level	Frequency	Percentage (%)
Low	0	0
Moderate	2	0.8
High	231	99.2
Total	**233**	**100%**

4.2 Standard Deviation and Mean Values

Table 5 presents the mean and standard deviation values for all variables in this study. Overall, the results show that all items recorded high mean values, indicating that most respondents agreed with the statements related to the use of treated wastewater in construction activities, the challenges faced by contractors, and the suggested potential applications.

Table 6: *Standard Deviation and Mean Score Level*

Sub-Variables	Items	Standard Deviation	Mean	Level of Mean
To Investigate the Potential Construction Activities That Can Utilize Treated Wastewater Effectively (IV1)	Treated wastewater is suitable for Concrete Mixing	0.364	4.10	High
	Treated wastewater is effective for Dust Suppression/Dust Control	0.541	4.76	High
	Treated wastewater can be used for Soil Compaction	0.557	4.09	High
	Treated wastewater is appropriate for Equipment and Vehicle Washing	0.569	4.76	High
	Treated wastewater is suitable for Landscape Irrigation	0.463	4.81	High
	Treated wastewater is suitable for Concrete Curing.	0.807	4.28	High
To Identify the Challenges Faced by Contractors in Utilizing Treated Wastewater (IV2)	The quality and reliability of treated wastewater supply are inconsistent	0.637	4.66	High
	There is a lack of awareness and technical knowledge among contractors	0.580	4.24	High
	There are no clear regulations or compliance guidelines for using treated wastewater	1.028	4.12	High
	Infrastructure and logistics (e.g., storage, transport) limit the adoption of treated wastewater	1.040	4.09	High
	Contractors are hesitant to use treated wastewater due to performance or reputation risks	0.814	4.33	High
	The economic cost of adoption (testing, infrastructure, training) is too high	0.661	4.43	High
To Suggest the Potential Construction Activities That Can Utilize	Treated wastewater is suitable for Concrete Mixing and Curing	0.582	4.58	High
	Treated wastewater is suitable for Soil Compaction and Grading	0.570	4.61	High
	Treated wastewater is suitable for Dust Suppression on Construction Sites	0.605	4.38	High

Treated Wastewater (IV3)	Treated wastewater is suitable for Equipment and Vehicle Washing	0.593	4.44	High
	Treated wastewater is suitable for Landscape Irrigation and Green Area Development	0.677	4.53	High
	Treated wastewater is suitable for Site Cleaning and General Maintenance.	0.647	4.43	High

4.3 Normality Test

The normality test was conducted using the coefficients of skewness, kurtosis, and the Kolmogorov–Smirnov test, as presented in Table 7. Skewness refers to the degree of asymmetry of a distribution around its mean, while kurtosis describes the peakedness or flatness of the distribution curve (Hair, Black, Babin, & Anderson, 2019).

Since the sample size in this study exceeds 50 respondents, the Kolmogorov–Smirnov test was applied to assess the normality of the data. Based on the results, the significance values ($p < 0.05$) indicate that the data are not normally distributed.

Table 7: *Normality Test*

	Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
	Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
IV1	.211	233	<.001	.838	233	<.001
IV2	.132	233	<.001	.849	233	<.001
IV3	.151	233	<.001	.940	233	<.001

4.3.1 Non-Parametric (NPar) Tests

According to Pallant (2020), non-parametric tests are commonly applied in social science and construction management research when the sample data are skewed or when responses are collected using Likert-scale questionnaires. These tests do not require strict assumptions regarding data distribution and are therefore more robust in handling real-world survey data. In this study, the NPar test allows for a more accurate interpretation of respondents' perceptions regarding the utilization of treated wastewater in construction activities and the challenges faced by contractors.

Furthermore, the application of non-parametric analysis helps to identify the strength and direction of relationships between variables without being affected by non-normal data distribution (Hair et al., 2019). Therefore, the NPar test supports the reliability and validity of the findings by ensuring that the statistical analysis is aligned with the characteristics of the collected data.

Table 8: *NPar Test*

			IV1	**IV2**	**IV3**
	N		233	233	233
Normal Paramenters[a,b]	**Mean**		4.4843	4.3126	4.4943
	Std. Deviation		.30831	.40433	.31290
	Absolute		.211	.132	.151
	Positive		.174	.100	.089
	Negative		-.211	-.132	-.151
Test Statistic			.211	.132	.151
Asymp. Sig. (2-tailed)[c]			<.001	<.001	<.001
Monte Carlo Sig.(2-tailed)[d]	**Sig.**		.000	.000	.000
	99% Confidence Interval	**Lower Bound**	.000	.000	.000
		Upper Bound	.000	.000	.000

5. Conclusion and Recommendation

5.1 Conclusion

This study investigated the utilization of treated wastewater in construction activities in Johor, Malaysia, with reference to Sustainable Development Goals (SDGs) 6 and 11. Based on the responses from 233 CIDB-registered contractors, the study concludes that treated wastewater has significant potential for use in non-potable construction activities. The findings confirm that contractors recognize the suitability of treated wastewater for activities such as dust suppression, concrete curing, equipment washing, and site cleaning. However, challenges related to water quality assurance, regulatory uncertainty, lack of awareness, and financial constraints continue to hinder widespread adoption. Despite these challenges, the high level of agreement among respondents indicates strong industry readiness, provided that appropriate support mechanisms are established.

5.2 Recommendations

Based on the findings of this study, the following recommendations are proposed:
(a) Development of Clear Guidelines
Relevant authorities should establish standardized guidelines and specifications for treated wastewater use in construction to reduce uncertainty and improve contractor confidence.
(b) Awareness and Training Programs
Training and awareness programs should be conducted by CIDB and related agencies to educate contractors on safe applications and benefits of treated wastewater.
(c) Infrastructure and Incentives Support
Government incentives, subsidies, or tax benefits should be introduced to offset initial setup costs and encourage contractors to adopt treated wastewater systems.
(d) Pilot Projects and Demonstration Sites
Pilot projects in Johor should be implemented to demonstrate the feasibility and effectiveness of treated wastewater in real construction environments.

5.3 Summary

This study investigated treated wastewater's potential to address water scarcity in Johor's construction sector, supporting sustainable development. By overcoming challenges through policy and education, the industry can achieve greater efficiency and SDG alignment. Future efforts should build on these findings for practical implementation.

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Conflict of Interest

Authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

*The authors confirm contribution to the paper as follows: **study conception and design:** Ganeswaran Magentharan and Hilyati Sabtu @ Othman; **data collection:** Ganeswaran Magentharan; **analysis and interpretation of results:** Ganeswaran Magentharan and Hilyati Sabtu @ Othman; **draft manuscript preparation:** Ganeswaran Magentharan, Hilyati Sabtu @ Othman, Norasmiha Mohd Nor, Aina Mardia Sallehuddin, Norliana Sarpin and Zailawati Khalid. All authors reviewed the results and approved the final version of the manuscript.*

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