International Journal of Environmental Impacts
Vol. 8, No. 4, August, 2025, pp. 667-673
Journal homepage: http://iieta.org/journals/ijei

Knowledge and Perception of Brine Waste Management Policies in the Desalination Industry, Malaysia

Cynthia Mahadi[1], Norhafezah Kasmuri[1*], Zakaria Mat Diah[2], Mohd Fuad Miskon[3], Satoto Endar Nayono[4], Amin Mojiri[5]

[1] Faculty of Civil Engineering, Universiti Teknologi MARA, Shah Alam 40450, Malaysia
[2] Umbak Baru Sdn. Bhd, Bandar Baru Tunjong, Kota Bahru 16010, Malaysia
[3] Institute of Oceanography and Maritime Studies (INOCEM), Kulliyyah of Science, International Islamic University Malaysia, Bandar Indera Mahkota, Kuantan 25200, Malaysia
[4] Department of Civil Engineering and Planning, Faculty of Engineering, Universitas Negeri Yogyakarta, Yogyakarta 55281, Indonesia
[5] Nanosystems Engineering Research Center for Nanotechnology-Enabled Water Treatment, School of Sustainable Engineering and the Built Environment, Arizona State University, Tempe AZ 85287, USA

Corresponding Author Email: norhafezahkasmuri@uitm.edu.my

https://doi.org/10.18280/ijei.080404

Received: 19 March 2025
Revised: 30 April 2025
Accepted: 3 June 2025
Available online: 31 August 2025

Keywords:
brine waste, environmental impact assessment, fuzzy Delphi study, seawater desalination, sustainability

ABSTRACT

Desalination can be implemented to ensure sufficient water supply for agricultural and economic sectors, as well as daily population demand. This detailed study explores various methods for handling brine discharge in Malaysia by analyzing environmental regulations and practices from other countries. A survey of 20 expert engineers from the Department of Environment Malaysia (DOE) and community leaders has been conducted in the study. Later, a Fuzzy Delphi Method (FDM) was used to evaluate the key parameters of temperature limit (P1), pH limit (P2), salinity impact zone (P3), and salinity limit (P4) from the output of the questionnaire. The assessment indicated that P1, P2, P3, and P4 obtained fuzzy scores of 0.770, 0.790, 0.792, and 0.803, respectively. Moreover, factors such as the construction of a desalination plant need to be included in the prescribed activities of Schedule 1 (S1) or Schedule 2 (S2) under the Guidelines of Environmental Impact Assessment (EIA), which are also being evaluated. The regulations on brine waste disposal in the Environmental Quality Act 1974 (S3) must be imposed and considered to be embedded in this regulation. From the survey, it has been indicated that S1, S2, and S3 had fuzzy scores of 0.803, 0.743, and 0.725, respectively. The expert chose the approach with the highest fuzzy score as the most acceptable option. This comprehensive analysis provides insight knowledge for Malaysia to have clear understanding and later develop sustainable approach in managing brine waste from desalination process and updating the current environmental regulations.

1. INTRODUCTION

The global scarcity of fresh water has led to the increased implementation of desalination plants to meet the rising demand for water in human consumption, industrial processes, and agriculture [1]. Seawater desalination involves removing salt and contaminants from seawater to produce freshwater, though it has some disadvantages. One primary by-product of this process is hypersaline effluent, also known as brine, which contains high concentrations of salts, nutrients, heavy metals, organic pollutants, and microbial contaminants [2].

Desalination plants typically produce about 1.5 litres of brine per litre of freshwater, affecting ocean chemistry and health due to altered physicochemical properties [3, 4]. Brine disposal harms marine ecosystems and biodiversity, increasing salinity, temperature, and harmful chemicals [5]. The presence of toxic substances like metals and pesticides in brine makes its disposal an environmental threat [6].

Improper brine disposal affects both marine and land environments. It can contaminate aquifers, degrade soil quality, and pose health risks due to high salinity levels. Even minor salinity shifts (1–2 ppt) can harm communities. Better understanding and management of brine are crucial for environmental sustainability [7].

It can be presumed that seawater desalination is gaining attraction in Malaysia, with many plants proposed or in the planning stage [8]. Desalination plants are planned for Johor, Pulau Pinang, and Labuan, and one existing plant has been constructed in Bachok, Kelantan, Malaysia. Additionally, MPDT Capital Berhad, under a joint venture with Johor Special Water (JSW), has established the largest desalination plant in this part of the region. The seawater desalination plant, with a capacity of 250 MLD, will supply demineralized water to the Pengerang Integrated Petroleum Complex (PIPC) located in Pengerang [9]. MPDT also plans to build a seawater desalination plant in Pulau Pinang, supplying 250 MLD of water to state utility Penang Water Supply Corporation (PBAPP) [10-12].

The proposed desalination plant project aims to address water shortages, but the environmental impact of brine byproduct requires further investigation. Limited studies in Malaysia highlight gaps and opportunities during pre and post-construction stages. Previous research did not clearly address the environmental impact of brine effluent in Malaysian policies. This study examines awareness and perception of desalination plant policies before and after construction and the environmental impact of brine waste on ecosystems. Findings will address gaps in Malaysia's regulatory framework and propose new policy recommendations, comparing practices from other countries. According to Abdul Ghani et al. [13], the increasing public awareness about desalination plants may pose challenges for stakeholders. Nonetheless, it is possible to mitigate the adverse environmental impacts of desalination through the promotion of environmental consciousness and comprehensive preliminary planning. Enhanced awareness among the public and policymakers regarding the environmental issues associated with brine disposal could lead to the development of new environmental regulations in Malaysia.

2. MATERIALS AND METHODS

This study utilized an exploratory mixed-method approach, combining qualitative and quantitative research in a descriptive survey [14]. The review included previous studies from various sources such as journal papers, environmental regulations, government reports, research papers, conference proceedings, academic theses, dissertations, and digital publications [15].

This study used the Fuzzy Delphi Method (FDM) for clear data interpretation. Implementing FDM requires achieving a threshold value d and expert consensus with over 75% agreement. FDM relies on expert agreement via questionnaires [16]. The survey used a seven-point scale from 'very strongly disagree' to 'very strongly agree' [17]. Responses were later converted to the Fuzzy scale, where higher rankings indicate greater data accuracy [18].

2.1 Selection of experts

Khalli et al. [19] recommends a minimum of 10 experts for uniformity in Fuzzy Delphi studies. In this study, 20 experts with over 15 years of experience in environmental and waste management were selected through purposive sampling. They included representatives from the Department of Environment Malaysia (DOE) and community leaders, chosen for their expertise in evaluating the environmental threats of brine waste from a proposed desalination plant. Beiderbeck et al. [20] noted that selecting these experts ensures accurate insights relevant to the study. Each professional has significant knowledge and experience in the field. Subsidy policies aimed at improving environmental quality are being promoted through community development, which advances local policies effectively [21].

2.2 Designing and plotting the questionnaire

Criteria for the questionnaire were established based on a review of existing literature, a pilot study [22], and practical experiences. The objective is to collect comprehensive data to develop items suitable for the survey form. The questionnaire has undergone validation for content validity, with any inconsistencies or irregularities addressed before final approval. Upon approval, the questionnaire will be distributed to experts [23]. Distribution was executed using a Google Form questionnaire accessible via an internet link or a poster featuring a QR code. Table 1 displays the seven-point linguistic scale employed in this study, utilizing fuzzy triangular numbers (TFNs). In this context, n_1 represents the minimum values, n_2 denotes the most plausible value, and n_3 indicates the maximum value for each linguistic variable.

Table 1. Seven-point linguistic scale [18]

	Linguistic Variables	Scale Fuzzy		
1	Extremely Strongly Disagree	0.9	1	1
2	Strongly Disagree	0.7	0.9	1
3	Disagree	0.5	0.7	0.9
4	Not sure	0.3	0.5	0.7
5	Agree	0.1	0.3	0.5
6	Strongly Agree	0	0.1	0.3
7	Extremely strongly agree	0	0	0.1

2.3 Getting the average value

The average values were determined for each questionnaire: m_1 is the average minimum, m_2 is the average most plausible, and m_3 is the average maximum.

2.4 Determining the value of 'd'

The value of 'd' (threshold value) must be determined in the research study according to Eq. (1).

$$d(\bar{m},\bar{n})\sqrt{[\tfrac{1}{3}(m_1 - n_1)^2 + (m_2 - n_2)^2} \tag{1}$$

where,

$d(\bar{m}, \bar{n})$: Average threshold

value n_1, n_2, n_3: Fuzzy value

m_1, m_2, m_3: Average Fuzzy value

It is denoted that if the value of d is d<0.2, all the experts have agreed. If the value of d is d>0.2, the researchers had to repeat the procedure. Moreover, if the average expert assessment data is less than or equal to the threshold value, all experts are considered to have reached a consensus. Even if d is more than 0.2 but does not reach 0.3, the value is still considered lesser or equal to 0.2.

2.5 Getting a 75% consensus

The results obtained for the threshold value (d), the survey with more than 0.3, will be discarded. The number of respondents who acquired threshold value, d < 0.3, with the respondent's total, was calculated in percentage value. The conditions in FDM must be complied with by getting 75% consensus from the experts (percentage of the threshold value, d for each participant, does not exceed 0.3) for each item in the questionnaire. It was agreed that a 75% consensus would be required to display an agreement between the experts. Suppose an item does not reach an agreement percentage by an expert exceeding 75%. In that case, the item will be rejected, reviewed, and improved before the response process is repeated to the same respondent.

2.6 Get a fuzzy evaluation

Defuzzification is also known as a Fuzzy score. It aims to obtain the Fuzzy score (A) value. It must be greater than or equal to the median value (α-cut) 0.5. This process indicates that the element is accepted by expert consensus. According to the experts, another function, the Fuzzy score (A) value, can determine the ranking and priority. The formula involved in obtaining the Fuzzy score value (A) is as in Eqs. (2)-(4):

$$Amax = \frac{1}{3} * (m^1 + m^2 + m^3) \tag{2}$$

$$Amax = \frac{1}{4} * (m^1 + 2m^2 + m^3) \tag{3}$$

$$Amax = \frac{1}{6} * (m^1 + 4m^2 + m^3) \tag{4}$$

where,
Amax: Average Fuzzy score.
m_1, m_2, m_3: Average Fuzzy value.

3. RESULT AND DISCUSSION

Based on expert feedback, seven questions were modified, and two were removed from the revised questionnaire. Questions that appeared unclear or confusing were omitted. Part A of the distributed questionnaire includes the respondent's name, years of experience, education level, and organization.

Table 2 shows demographics of 100 respondents: 60 from government agencies like DOE and SPAN, 28 from private companies such as Dubai desalination firms and CarbonWorks, and the rest from universities including Universiti Teknologi Malaysia and Universiti Malaysia Terengganu.

Table 2. Demographic data of respondent

Age	No	Years of Experience	No.	Education Level	No.	Organization	No.
<30	27	<5	28	Certificate	2	Government Authority	60
31-40	46	6-10	28	Diploma	25	Private Companies	28
41-50	23	11-15	19	Bachelor	56	Environment NGO	1
>50	4	>15	25	Master	15	Government Linked Company (GLC)	2
				PhD	2	Semi-Government	1
						University	8
Total	100		100		100		100

In this study, twenty (20) experts were selected from a pool of 100 respondents, representing diverse fields of expertise and varying years of experience. These experts, chosen for the next phase of analysis, possess over 15 years of experience in critical areas such as the desalination process, environmental impact assessment (EIA), environmental engineering, chemical engineering, mechanical engineering, civil engineering, and waste management. The careful selection of these experts is crucial for the Fuzzy Delphi study, as the study's validity hinges on the panel members' expertise. This selection process ensures that the study's findings are grounded in the knowledge and experience of seasoned professionals in their respective fields.

3.1 Fuzzy Delphi Method (FDM) for parameter's limit for brine disposal

The symbols P1, P2, P3, and P4 denote the temperature limit, pH limit, salinity impact zone, and salinity limit, respectively. Table 3 shows the threshold value, d, for regulation and guidelines for brine disposal.

According to Table 3, the 'd' value for P1 is 0.263, P2 is 0.227, P3 is 0.223, and P4 is 0.199. All the threshold values are less than 0.3, indicating that all experts accept the suggested solutions. The panel's agreement indicates that the chosen parameters are linked to the theoretical framework, as these factors impact environmental ecosystems when considering brine effluent.

Table 4 presents the percentage of parameters for the limit of brine disposal. For P1, 15 experts achieved d values less than or equal to 0.2, resulting in a 75% agreement among experts. For P2, 16 experts had d values below 0.2, amounting to 80% expert unanimity. Similarly, P3 also saw 16 experts with d values under 0.2, leading to an 80% consensus. In the case of P4, 17 experts reported d values smaller than 0.2, indicating 85% expert agreement. Consequently, all parameter limits are accepted by the experts as the consensus exceeds 75%.

Table 3. The threshold value, d, for regulation and guidelines for brine disposal

Expert	Regulation and Guideline for Brine Disposal			
	P1	**P2**	**P3**	**P4**
1	0.700	0.428	0.142	0.449
2	0.156	0.125	0.122	0.103
3	0.398	0.428	0.431	0.236
4	0.283	0.255	0.251	0.236
5	0.114	0.138	0.734	0.156
6	0.283	0.255	0.251	0.236
7	0.398	0.138	0.122	0.156
8	0.398	0.428	0.431	0.449
9	0.156	0.125	0.122	0.103
10	0.283	0.225	0.122	0.103
11	0.283	0.428	0.431	0.449
12	0.283	0.255	0.251	0.156
13	0.283	0.255	0.251	0.236
14	0.156	0.125	0.122	0.103
15	0.398	0.255	0.251	0.236
16	0.156	0.125	0.122	0.103
17	0.114	0.138	0.122	0.103
18	0.114	0.138	0.142	0.1563
19	0.156	0.125	0.122	0.103
20	0.156	0.125	0.122	0.103
'd' value for each item	**0.263**	**0.227**	**0.223**	**0.199**

Table 5 presents a defuzzified process for determining the fuzzy score. As indicated by the table, the fuzzy scores are as follows: P1 is 0.770, P2 is 0.790, P3 is 0.792, and P4 is 0.803. P4 achieves the highest score, suggesting that the most effective actions recommended within these four proposals should be implemented to enhance the Environmental Quality Act 1974 (Act 127) and mitigate the environmental impact of brine effluent disposal on marine ecosystems.

Table 4. Percentage (%) of parameters limit of brine disposal

	Regulation and Guideline for Brine Disposal			
	P1	**P2**	**P3**	**P4**
No of Item d ≤ 0.2	15	16	16	17
% No of Item d ≤ 0.2	75.0%	80.0%	80.0%	85.0%

Tables 4 and 5 explain the correlation between the consensus of 75% and the fuzzy scores for different parameters (P1, P2, P3, and P4), which reflect the complexity and uncertainty associated with brine waste management. These fuzzy scores indicate the importance of incorporating these factors into policies or guidelines for both the pre-construction and post-construction phases of desalination plants due to brine waste management considerations [24].

Table 6 provides summaries of the parameter's limit of brine disposal regulations and guidelines. Here, all the solutions offered adhere to the criterion provided by the FDM. This result also revealed that P4 received the top rating based on the fuzzy score. P2 and P3 have the same rank, and P1 has the fourth-ranking score. Undoubtedly, all the proposed guidelines are acceptable to all the experts who participated. However, P4 is the most efficient after considering the proposed guidelines in the questionnaire form. In agreement with Khan and Al-Ghouti [25], the expert acknowledges that the salinity limits (P4) play a crucial role in brine disposal management. The high saline content in brine poses severe threats to aquatic organisms. Furthermore, elevated salinity levels in land application can harm groundwater, potentially leading to aquifer pollution.

Table 5. Defuzzified process for determining the fuzzy score

Experts	**Regulation and Guideline for Brine Disposal**											
		P1			**P2**			**P3**			**P4**	
1	0.1	0.3	0.5	0.3	0.5	0.7	0.5	0.7	0.9	0.3	0.5	0.7
2	0.7	0.9	1	0.7	0.9	0.7	0.7	0.9	1	0.7	0.9	1
3	0.3	0.5	0.7	0.3	0.5	1	0.3	0.5	0.7	0.9	1	1
4	0.9	1	1	0.9	1	0.7	0.9	1	1	0.9	1	1
5	0.5	0.7	0.9	0.5	0.7	1	0.1	0.3	0.5	0.5	0.7	0.9
6	0.9	1	1	0.9	1	0.9	0.9	1	1	0.9	1	1
7	0.3	0.5	0.7	0.5	0.7	1	0.7	0.9	1	0.5	0.7	0.9
8	0.3	0.5	0.7	0.3	0.5	0.9	0.3	0.5	0.7	0.3	0.5	0.7
9	0.7	0.9	1	0.7	0.9	0.7	0.7	0.9	1	0.7	0.9	1
10	0.9	1	1	0.9	1	1	0.7	0.9	1	0.7	0.9	1
11	0.9	1	1	0.3	0.5	1	0.3	0.5	0.7	0.3	0.5	0.7
12	0.9	1	1	0.9	1	0.7	0.9	1	1	0.5	0.7	0.9
13	0.9	1	1	0.9	1	1	0.9	1	1	0.9	1	1
14	0.7	0.9	1	0.7	0.9	1	0.7	0.9	1	0.7	0.9	1
15	0.3	0.5	0.7	0.9	1	1	0.9	1	1	0.9	1	1
16	0.7	0.9	1	0.7	0.9	1	0.7	0.9	1	0.7	0.9	1
17	0.5	0.7	0.9	0.5	0.7	0.9	0.7	0.9	1	0.7	0.9	1
18	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.1	0.9
19	0.7	0.9	1	0.7	0.9	1	0.7	0.9	1	0.7	0.9	1
20	0.7	0.9	1	0.7	0.9	1	0.7	0.9	1	0.7	0.9	1
	Defuzzification Process											
Average of each element	0.620	0.790	0.900	0.640	0.810	0.920	0.640	0.815	0.920	0.650	0.825	0.935
	m1	m2	m3	m1	m2	m3	m1	m2	m3	m1	m2	m3
Fuzzy Score		0.770			0.790			0.792			0.803	

Table 6. Summaries of the FDM for parameter's limit of brine disposal

Proposed Guideline	**Triangular *Fuzzy* Numbers Conditions**		***Defuzzification Process***				**Consensus Within Expert**	**Ranking**
	***Threshold* Value, d**	**Consensus Within Expert, %**	**m1**	**m2**	**m3**	***Fuzzy* Score *(A)***		
P1	0.263	75.0%	0.620	0.790	0.900	0.770	Accept	4
P2	0.227	80.0%	0.640	0.810	0.920	0.790	Accept	2
P3	0.233	80.0%	0.640	0.815	0.920	0.792	Accept	2
P4	0.199	85.0%	0.650	0.825	0.935	0.803	Accept	1

3.2 Fuzzy Delphi Method (FDM) for brine management practice

There are three brine management practices for this section: (1) The construction of a desalination plant should be included in the prescribed activities of Schedule 1 (S1) or Schedule 2 (S2) under the Guidelines of Environmental Impact Assessment (EIA); (2) Regulations on brine waste disposal under the Environmental Quality Act of 1974 (S3) should be implemented. Table 7 shows the threshold value for brine management practices.

Table 7. The threshold value 'd' for brine management practice

Experts	Brine Management Strategies and Technologies		
	S1	S2	S3
1	0.153	0.072	0.215
2	0.153	0.072	0.052
3	0.448	0.363	0.336
4	0.238	0.322	0.349
5	0.153	0.072	0.052
6	0.153	0.072	0.052
7	0.153	0.188	0.336
8	0.238	0.363	0.336
9	0.104	0.363	0.215
10	0.238	0.188	0.215
11	0.153	0.363	0.336
12	0.104	0.188	0.336
13	0.238	0.322	0.349
14	0.104	0.188	0.215
15	0.238	0.363	0.036
16	0.104	0.188	0.052
17	0.153	0.188	0.215
18	0.153	0.072	0.052
19	0.153	0.188	0.215
20	0.238	0.188	0.215
'd' value for each item	**0.184**	**0.216**	**0.224**

Table 7 showed that all of the threshold values are less than 0.3, suggesting that all experts agree upon all of the assertions in this section. The table showed the expert consensus of questions relating to brine management practice. The average d value for the statement that the construction of a desalination plant should be listed in the prescribed activities of Schedule 1 (S1) is 0.184. In contrast, the idea of the construction of a desalination plant should be listed in the prescribed activities of Schedule 2 (S2) as 0.216. Malaysia should regulate brine waste disposal in the Environmental Quality Act 1974 (S3) is 0.224. Since this threshold value fell below 0.3, all statements in this section were permitted for further investigation because they satisfied the first requirement.

Table 8 shows the percentage of brine management practice. According to the table, for S1, 19 experts have d values less than or equal to 0.2, resulting in a 95% agreement among experts. For S2, there are only 13 experts with d values smaller than 0.2; the proportion of expert unanimity is 65%. Similarly, for S3, there are only 12 experts with d values smaller than 0.2, leading to a 60% expert consensus. Therefore, only the S1 proposal meets the criteria for acceptance by the experts, while S2 and S3 do not achieve the required level of expert consensus.

Table 8. Getting a 75% consensus for brine management practices

	Brine Management practices		
	S1	**S2**	**S3**
No of Item d ≤ 0.2	19	13	12
% No of Item d ≤ 0.2	**95.0%**	**65.0%**	**60.0%**

Table 9. Defuzzified for brine management practice

Experts	Regulation and Guideline for Brine Disposal								
	S1			S2			S3		
1	0.5	0.7	0.9	0.5	0.7	0.9	0.7	0.9	1
2	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9
3	0.3	0.5	0.7	0.3	0.5	0.7	0.3	0.5	0.7
4	0.9	1	1	0.9	1	1	0.9	1	1
5	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9
6	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9
7	0.5	0.7	0.9	0.7	0.9	1	0.3	0.5	0.7
8	0.9	1	1	0.3	0.5	0.7	0.3	0.5	0.7
9	0.7	0.9	1	0.3	0.5	0.7	0.7	0.9	1
10	0.9	1	1	0.7	0.9	1	0.7	0.9	1
11	0.5	0.7	0.9	0.3	0.5	0.7	0.3	0.5	0.7
12	0.7	0.9	1	0.7	0.9	1	0.3	0.5	0.7
13	0.9	1	1	0.9	1	1	0.9	1	1
14	0.7	0.9	1	0.7	0.9	1	0.7	0.9	1
15	0.9	1	1	0.3	0.5	0.7	0.3	0.5	0.7
16	0.7	0.9	1	0.7	0.9	1	0.5	0.7	0.9
17	0.5	0.7	0.9	0.7	0.9	1	0.7	0.9	1
18	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9
19	0.5	0.7	0.9	0.7	0.9	1	0.7	0.9	1
20	0.9	1	1	0.7	0.9	1	0.7	0.9	1
Defuzzification Process									
Average of each element	0.650	0.820	0.940	0.570	0.760	0.900	0.550	0.740	0.880
	m1	m2	m3	m1	m2	m3	m1	m2	m3
Fuzzy Score		0.803			0.743			0.725	

According to Table 9, the fuzzy score for S1 is 0.803, S2 is 0.743 and S3 is 0.725. As a result, only the S1 practice meets the required agreement threshold. However, S2 and S3 did not receive more than 75% of the consensus. Therefore, it is concluded that every application for the construction of a desalination plant requires the submission of an Environmental Impact Assessment (EIA) under the Schedule 1 prescribed activity, as these facilities can impact the environment during construction and operation.

Table 10 summarizes the brine management practice. According to the table, just one of the assertions in this table meets the Fuzzy Delphi Method's criteria. This result also revealed that S1 was rated the highest based on the fuzzy score. The expert consensus, however, rejected S2 and S3. The expert confirms that to construct a desalination plant, submitting an Environmental Impact Assessment (EIA) as a prescribed activity under Schedule 1 is mandatory. In Spain, the Royal Decree 1/2008 introduced aspects of public participation, modified the administrative process, and expanded the list of projects subject to EIA, as outlined in Annexes I and II. However, desalination plants in Spain with a new or additional capacity exceeding 3000m^3/day of water production fall under Annex II, Group 8, Section E: Water Engineering and Management Projects [26]. It is worth noting that the proposed desalination plant in Malaysia has a production capacity of only 2500m^3/day, making it fall below the specified threshold.

Table 10. Summaries of FDM for brine management strategies and technologies

Proposed Guideline	Triangular *Fuzzy* Numbers Conditions		Defuzzification Process				Consensus Within Expert	Ranking
	Threshold Value, d	Consensus Within Expert, %	m1	m2	m3	*Fuzzy* Score *(A)*		
S1	0.184	95.0%	0.650	0.820	0.940	0.803	Accept	1
S2	0.216	65.0%	0.570	0.760	0.900	0.743	Reject	2
S3	0.224	60.0%	0.550	0.740	0.885	0.725	Reject	3

The study compared Malaysia's brine waste management regulations with those of other countries, fulfilling its objectives by highlighting theoretical reasons for observed differences or similarities. Further exploration of environmental, engineering, and policy aspects is needed to achieve best practices in brine waste management.

4. CONCLUSIONS

This study classifies desalination plant construction as an Environmental Impact Assessment (EIA) activity, to enforce sustainable brine waste management policies in Malaysia's desalination industry. By comparing environmental legislation governing brine waste disposal in Malaysia and other nations, the study identifies the absence of specific regulations for brine wastewater disposal in Malaysia. As a result, this research recommends adopting practices from other countries to address this gap. The study suggests incorporating parameters such as salinity limits, impact zones, pH levels, and temperature into regulatory frameworks for brine disposal. It also proposes best management practices to mitigate the environmental impact of brine discharge in Malaysia. Due to the unique characteristics of brine, the study calls for further testing, analysis, and an expanded research scope to include a broader range of brine sources beyond desalination plants, developing comprehensive and effective management strategies.

ACKNOWLEDGMENT

The authors gratefully acknowledge the Universiti Teknologi MARA, Shah Alam and UIC Grant No: 600-TNCPI 5/3/DDF (KPK) (005/2023), provided by the Faculty of Civil Engineering, Universiti Teknologi MARA and Research Management Centre, for financial supporting this study and providing resources.

REFERENCES

[1] Soliman, M.N., Guen, F.Z., Ahmed, S.A., Saleem, H., Khalil, M.J., Zaidi, S.J. (2021). Energy consumption and environmental impact assessment of desalination plants and brine disposal strategies. Process Safety and Environmental Protection, 147: 589-608. https://doi.org/10.1016/j.psep.2020.12.038

[2] Omerspahic, M., Al-Jabri, H., Siddiqui, S.A., Saadaoui, I. (2022). Characteristics of desalination brine and its impacts on marine chemistry and health, with emphasis on the Persian/Arabian gulf: A review. Frontiers in Marine Science, 9: 845113. https://doi.org/10.3389/fmars.2022.845113

[3] Bleninger, T., Jirka, G.H., Lattemann, S. (2010). Environmental Planning, Prediction and Management of Brine Discharges from Desalination Plants. Middle East Desalination Research Center (MEDRC): Muscat, Sultanate of Oman.

[4] Ozair, G., Al-Zahrany, S.A., Al-Shubaili, A.A. (2019). MARAFIQ's Quest to Minimizing the Impact of Desalination on the Marine Environment. In IDA World Congress: Dubai, UAE.

[5] Panagopoulos, A., Haralambous, K.J. (2020). Environmental impacts of desalination and brine treatment-Challenges and mitigation measures. Marine Pollution Bulletin, 161: 111773. https://doi.org/10.1016/j.marpolbul.2020.111773

[6] Roberts, D.A., Johnston, E.L., Knott, N.A. (2010). Impacts of desalination plant discharges on the marine environment: A critical review of published studies. Water Research, 44(18): 5117-5128. https://doi.org/10.1016/j.watres.2010.04.036

[7] Fernández-Torquemada, Y., Carratalá, A., Lizaso, J.L.S. (2019). Impact of brine on the marine environment and how it can be reduced. Desalination and Water Treatment, 167: 27-37. https://doi.org/10.5004/dwt.2019.24615

[8] McIntyre, I. (2022). Desalination needed now, urges expert as floods hamper Penang's water supply. https://www.thevibes.com/articles/news/65407/desalination-needed-now-urges-expert-as-floods-curb-penangs-water-supply.

[9] MPDT Capital Berhad, (2022). Pengerang industrial petroleum complex.

[10] Ong, K. (2022). Support for PBAPP's desalination proposal. https://www.buletinmutiara.com/support-for-pbapps-desalination-proposal/.

[11] Mok, O. (2022). MPDT Capital moots RM1b desalination plant in Penang to process seawater into potable water. https://www.malaymail.com/news/money/2022/05/23/mpdt-capital-moots-rm1b-desalination-plant-in-penang-to-process-seawater-into-potable-water/8327.

[12] Abdullah, I. (2023). Teknologi penyahgaraman air laut, bantu atasi masalah air di UMS. Retrieved from Berita Harian: https://www.bharian.com.my/berita/nasional/2023/06/1110553/teknologi-penyahgaraman-air-laut-bantu-atasi-masalah-air-di-ums.

[13] Abdul Ghani, L., Ali, N.A., Nazaran, I.S., Hanafiah, M.M. (2021). Environmental performance of small-scale seawater reverse osmosis plant for rural area water supply. Membranes, 11(1): 40. https://doi.org/10.3390/membranes11010040

[14] Schoonenboom, J., Johnson, R.B. (2017). How to construct a mixed methods research design. Kolner Zeitschrift fur Soziologie und Sozialpsychologie, 69(Suppl 2): 107. https://doi.org/10.1007/s11577-017-0454-1

[15] Al-Humaiqani, M.M., Al-Ghamdi, S.G. (2022). The built environment resilience qualities to climate change impact: Concepts, frameworks, and directions for future research. Sustainable Cities and Society, 80: 103797. https://doi.org/10.1016/j.scs.2022.103797

[16] Hajkazemiha, N., Shariat, M., Monavari, M., Ataei, M. (2021). Evaluation of mine reclamation criteria using delphi-fuzzy approach. Journal of Mining and Environment, 12(2): 367-384. https://doi.org/10.22044/jme.2020.9674.1880

[17] Adler, M., Ziglio, E. (1996). Gazing into the Oracle: The Delphi Method and its Application to Social Policy and Public Health. Jessica Kingsley Publishers.

[18] Ahmad, S., Kasmuri, N., Ismail, N.A., Miskon, M.F., Ramli, N.H. (2022). Maintenance strategy selection using Fuzzy Delphi method in royal Malaysian air force. Pertanika Journal of Science & Technology, 30(2): 875-896.

[19] Khalli, M.N.M., Sintang, S., Kamu, A. (2022). The framework of socio-religious harmony in Sabah, East Malaysia: An application of Fuzzy Delphi method. Heliyon, 8(8): e09976. https://doi.org/10.1016/j.heliyon.2022.e09976

[20] Beiderbeck, D., Frevel, N., von der Gracht, H.A., Schmidt, S.L., Schweitzer, V.M. (2021). Preparing, conducting, and analyzing Delphi surveys: Cross-disciplinary practices, new directions, and advancements. MethodsX, 8: 101401. https://doi.org/10.1016/j.mex.2021.101401

[21] Mallick, J. (2021). Municipal solid waste landfill site selection based on fuzzy-AHP and geoinformation techniques in Asir Region Saudi Arabia. Sustainability, 13(3): 1538. https://doi.org/10.3390/su13031538

[22] Hsueh, S.L. (2015). Assessing the effectiveness of community-promoted environmental protection policy by using a Delphi-fuzzy method: A case study on solar power and plain afforestation in Taiwan. Renewable and Sustainable Energy Reviews, 49: 1286-1295. https://doi.org/10.1016/j.rser.2015.05.008

[23] Iqbal, M., Ma, J., Ahmad, N., Hussain, K., Waqas, M., Liang, Y. (2022). Sustainable construction through energy management practices: An integrated hierarchal framework of drivers in the construction sector. Environmental Science and Pollution Research, 29(60): 90108-90127. https://doi.org/10.1007/s11356-022-21928-x

[24] Mahadi, C., Kasmuri, N., Miskon, M.F. (2024). Brine waste from seawater desalination in Malaysia: Assessment on public awareness and understanding. In IOP Conference Series: Earth and Environmental Science, 1369(1): 012012. https://doi.org/10.1088/1755-1315/1369/1/012012

[25] Khan, M., Al-Ghouti, M.A. (2021). DPSIR framework and sustainable approaches of brine management from seawater desalination plants in Qatar. Journal of Cleaner Production, 319: 128485. https://doi.org/10.1016/j.jclepro.2021.128485

[26] Alonso, J.J.S., Melián-Martel, N. (2018). Environmental regulations—Inland and coastal desalination case studies. In Sustainable Desalination Handbook, pp. 403-435. Butterworth-Heinemann. https://doi.org/10.1016/B978-0-12-809240-8.00010-1