Determination of Weights for Criteria with SWARA Technique for Computing Groundwater Quality Index of Various Regions of Navsari District, Gujarat, India

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Abstract:

SWARA (Stepwise Weight Assessment Ratio Analysis) is one of the most effective MCDM (Multi-Criteria Decision Making) techniques. The groundwater quality index is constructed using four parameters: TDS, EC, pH, and chlorides. The proportionate weightage of each groundwater quality metric is calculated to calculate the groundwater quality index. In the study, the SWARA approach is used to obtain the relative weightage of groundwater quality characteristics for computing the groundwater quality index of several well sites in the Navsari district of Gujarat, India. To improve groundwater quality in the research region, 48 monitoring and assessment sites were selected. The key criteria for calculating the groundwater quality index were found and defined.

Keywords : MCDM, Groundwater Quality, SWARA, Groundwater Quality Index

Introduction:

The most common causes of groundwater contamination include human activities, agricultural activities, industrial activities, and others.. To further improve groundwater quality in the research region, it's crucial to assess the quality at many well locations. To assess the groundwater quality of the study region, Navsari District in Gujarat State, India, a single/unique number GWQI (Groundwater Quality Index) was assigned. To construct the groundwater quality index, each parameter must be weighted relative to the others. SWARA (Stepwise Weight Assessment Ratio Analysis) was used to find the relative weightage of groundwater quality parameters such as pH, TDS, EC, and Chlorides, resulting in final groundwater quality index values for 48 well locations in the study area. For this objective, three tasks were carried out. The first task involved monitoring groundwater quality for selected criteria at 48 well locations within the Navsari district study area. In the second task, details regarding the SWARA method were explained, and in the third and final task, The SWARA method was utilized to calculate the weightings of chosen criteria, addressing the study area's problem.

Literature Review :

The following research are relevant to the SWARA method, which establishes the criterion weights of groundwater quality measures in order to generate the groundwater quality index. This study focuses on applying the SWARA approach to make multi-criteria selections while choosing landfill sites in Baghdad Governorate for municipal solid waste management. The primary purpose is to limit environmental deterioration by preventing the spread of solid waste in unexpected locations by carefully selecting alternate dumping sites based on environmental, social, and geological factors.[1]. In this research, The Water Quality Index (WQI) stands as one of the most frequently employed methods for assessing water quality. This approach incorporates physical, chemical, and biological factors, consolidating them into a single numerical value ranging from 0 to 100. The WQI process consists of four key steps: (a) selecting specific parameters, (b) standardizing raw data to a uniform scale, (c) assigning weights, and (d) combining sub-index values..[2]. To calculate the weights of the criteria and completely satisfy the requirements, the suggested methodology which was based on the combined application of the Delphi technique and the modified SWARA Method was successfully executed in this article.[3]. This study evaluates water quality data obtained from 11 well locations in Sharjah between 2004 and 2017, utilizing particular water quality indicators such as bicarbonate, calcium, chlorine, fluoride, magnesium, sodium, and sulphate [4]. The SWARA method is employed in this study to calculate the weight of the attributes that are important for university students pursuing associate degree programs in human resources management to be hired as interns in corporate human resources departments for their mandatory summer internships. [5]. The quality of the groundwater was assessed in this study using the Water Quality Index (WQI), which was calculated from thirty wells during the 2019 pre-monsoon and post-monsoon seasons. [6]. This paper analyzed the modifications made to the SWARA method stages and evaluated an application employing SMAA-2, another MCDM technique. It was found that the alternative options and criterion weights had changed.[7]. The authors of this study selected internal auditors from among the safety officers of a construction company using (ARAS) additive ratio assessment and step-wise weight assessment ratio analysis.[8]. An integrated fuzzy SWARA-PROMETHEE technique was used in this study to rank tourist destinations. Twenty sub-criteria and five main criteria were selected to indicate the factors that influence a country's suitability as a destination for medical tourism.[9]. A combined method for selecting BPT alternatives depends on complex proportional assessment approaches and SWARA is presented, showing that the suggested framework which is advantageous and consistent with previously developed methods.[10]. The authors of the current study have offered a hybrid complex proportional assessment approach and SWARA technique for PPP projects on water supply and sewerage in Malaysia, to risk distribution. Using qualitative language concepts in risk allocation between the public and private sectors and selecting the optimal risk allocation technique for a contract are made possible by this approach. This study evaluates the Unit Weight, Rank Sum, and Analytic Hierarchy Process models of Geographical Information System-based MCDA for their capacity to forecast groundwater quality in a Southern Indian river basin..[12]. Grounded theory and fuzzy SWARA techniques were used in this study to highlight the administrative organization's transformational obstacles at Mehrabad Airport, a crucial component of any nation's transportation sector. [13]. Using the SWARA and MOORA methods of MCDM methods, the authors of this study assessed the environmental hazard level in natural locations visited for tourist purposes in Antalya province, Turkey, in order to identify the most vulnerable and endangered natural areas. [14]. Additionally, very few studies have been conducted to establish the weights of the groundwater quality factors criteria in order to employ the SWARA method to calculate the groundwater quality index..

Research methodology:

The following stages serve as an essential illustration of research methodology:

Stage 1: Compiling the necessary data (criteria) during both research and fieldwork observations on the researched topic in accordance with the research schedule, which is utilized to determine the main criterion when choosing various groundwater quality parameters in groundwater quality index determination.
Stage 2: Fieldwork for the research involved using various well locations within the study area -Navsari District to improve the quality of the groundwater.

Stage 3: Collecting information for the criteria by the use of an open questionnaire from a group of Civil, Chemical, and Environmental engineers engaged in fieldwork associated with groundwater quality.

Stage 4: By applying the SWARA technique to determine the groundwater quality index for the groundwater sample collected from the various well locations within the study area-Navsari district the weights of each Criteria ought to be taken into considerations.

Criteria for determination of Groundwater Quality Index :

The most crucial step in determining the groundwater quality index is carefully examining and evaluating each of the many groundwater quality parameters that were chosen for the selected well location within the investigating area. The main objective of the ground water quality (parameter) criteria is to obtain the exact contamination using a single number- groundwater quality index. A total of Four main criteria were chosen based on observations made during fieldwork and research. The main four criteria brought into account for determining the Groundwater Quality Index are listed in Table 1 below.

Table 1: Main Criteria

No.	Criteria (Groundwater quality parameters)
1	Total Dissolved Solids (TDS)
2	Electrical Conductivity (EC)
3	Chlorides (Ch)
4	pH

SWARA Technique:

The weightage of each groundwater quality parameter (criteria) selected for the computation of the groundwater quality index at different sites within the research area has been determined using the Step-wise Weight Assessment Ratio Analysis method. Techniques such as Multiple Criteria Decision Making are created for this reason. According to earlier research, weight elicitation techniques are crucial for determining the significance of criteria and producing the most optimal and fulfilling outcomes for decision-makers when utilized to solve MCDM challenges.[15]

STEP TO DETERMINE THE RELATIVE WEIGHT BY SWARA TECHNIQUE:

The main procedure and principle of SWARA technique to obtain the relative weights of the main criteria selected for the determination of ground water quality index of the investigating area are as follows:

STEP: 1

The factors must be ranked according to significance. For example, the most significant criteria are rated first, the least important criteria are listed last, and the criteria in between have ordered significance. The professionals (experts) in this step rank the discovered criteria based on their relevance.[1].

STEP: 2

Establish the scientific criteria (Sj) and evaluate the average values' comparative significance. It is necessary to ascertain the significance of the second-ranked criteria, or the degree to which criterion (Cj+1) is less significant than criteria (Cj)

$$Sj \leftrightarrow j + 1 = \sum_{k=1}^{r} Cj \leftrightarrow j + 1 / r \quad (1)$$

STEP: 3 Calculate the Co-efficient (Kj) as follow:

$$k_j = \begin{cases} 1 & j = 1 \\ s_{j+1} & j > 1 \end{cases} \quad (2)$$

STEP: 4 Calculate the weight (qj) as follows :

$$q_j = \begin{cases} 1 & j = 1 \\ \frac{q_{j-1}}{k_j} & j > 1 \end{cases} \quad (3)$$

STEP: 5 Determine the criteria's weight by taking the sum and setting it to 1.

$$w_j = \frac{q_j}{\sum_{k=1}^{m} q_j} \quad (4)$$

Where, Wj indicates the relative weight value for each criterion in the given instance.[1]

Detailed Information about Experts:

For deciding the weight of the main criteria used to calculate the groundwater quality index for 48 well locations chosen within the study area, 22 experts from various fields, including civil engineering, chemical engineering, environmental engineering, and agriculture, provided their valuable opinions for this research. Table 2 contains detailed information about the experts.

Table 2: Information about Experts

Sr. No.	Qualification	Area of Expertise	Department of job	Experience
1	Ph.D	Civil Engineering	Water	15
2	M.E	Civil Engineering	Irrigation	10
3	M.E	Chemical Engineering	Academic	22
4	Ph.D	Civil Engineering	Water	17
5	M.E	Agriculture	Academic	18
6	M.E	Environmental Engineering	Academic	25
7	M.E	Civil Engineering	Irrigation	25
8	Ph.D	Civil Engineering	Irrigation	21
9	Ph.D	Civil Engineering	Irrigation	22
10	Ph.D	Environmental Engineering	Academic	10
11	Ph.D	Agriculture	Academic	22
12	Ph.D	Agriculture	Academic	17
13	M.E	Agriculture	Academic	22
14	M.E	Agriculture	Academic	18
15	M.E	Civil Engineering	Water	17
16	M.E	Environmental Engineering	Academic	18
17	Ph.D	Environmental Engineering	Academic	25
18	Ph.D	Chemical Engineering	Water Quality	25
19	Ph.D	Chemical Engineering	Academic	23
20	M.E	Chemical Engineering	Academic	21

21	M.E	Civil Engineering	Water	22
22	M.E	Civil Engineering	Water	10

Rank or Order given to the criteria by The Experts opinion:

As per opinion of 22 experts, criteria ranking order were decided as follows for the purpose of determination of weight of each criteria by SWARA Technique. .All Experts provided their opinion about rating of all four criteria based on their knowledge and experience given in following table 3.

Table 3: Criteria order/rank by Experts

Experts	Criteria			
	TDS –(WQP1)	EC – (WQP2)	Chlorides – (WQP3)	pH – (WQP4)
1	2	1	3	4
2	2	1	3	4
3	1	2	3	4
4	1	3	2	4
5	2	1	3	4
6	2	3	1	4
7	2	1	3	4
8	1	2	3	4
9	1	2	3	4
10	2	1	3	4
11	1	2	3	4
12	1	2	3	4
13	2	1	3	4
14	1	2	3	4
15	1	2	3	4
16	1	3	2	4
17	1	2	3	4
18	2	1	3	4

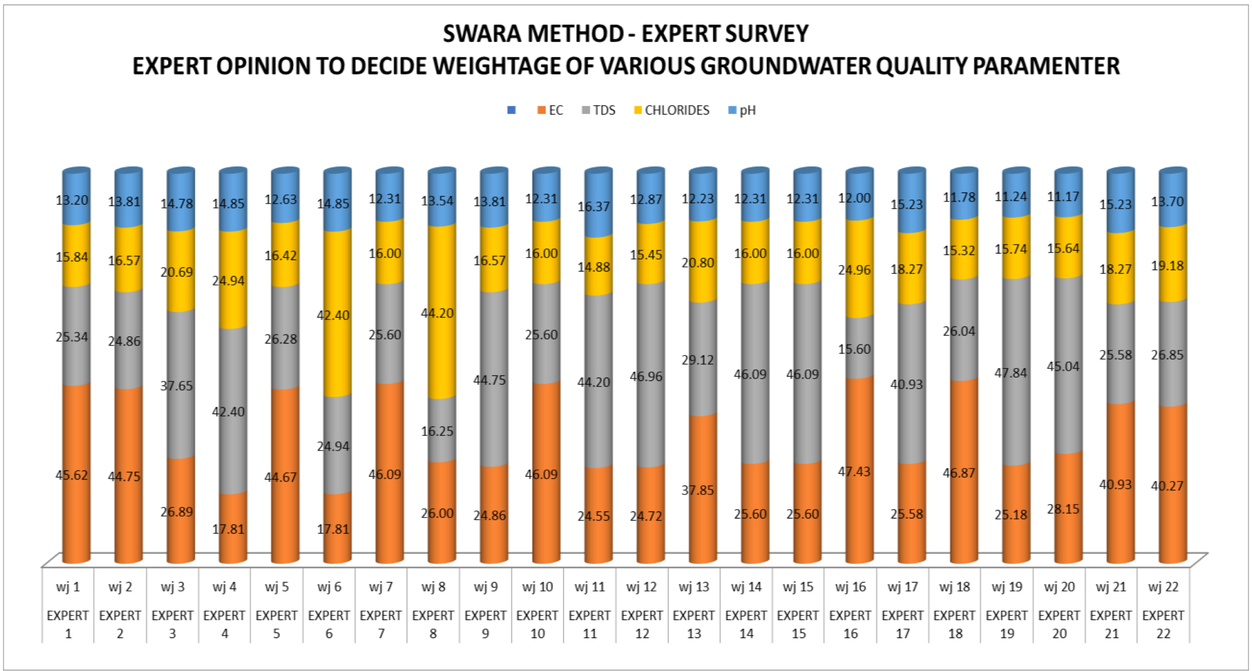
19	1	2	3	4
20	1	2	3	4
21	2	1	3	4
22	2	1	3	4

From the rank given by the experts' scientific criteria, Sj is calculated by equation 1. Based on Sj next component that is coefficient kj is calculated by equation 2, then qj is calculated by equation 3 followed by the calculation of the weight value of criteria Wj by using equation 4. This value of Wj is the relative weight value of the criteria. The following table shows the calculation of relative weight Wj for the opinion of expert 1.

Table 4: Weight of criteria by SWARA technique (opinion of expert no. 1)

Parameters/ (criteria)	Relative Significance Sj	Kj = Sj+1	qj = qj-1/Kj	Wj = qj/Σqj
EC	1	1	1	0.456
TDS	0.8	1.8	0.56	0.254
CHLORIDES	0.6	1.6	0.347222222	0.158
pH	0.2	1.2	0.289351852	0.132
				Sum = 1.000

Figure 1: Experts Survey to decide weightage of various ground water quality parameter



Final weight and rank for Selected Criteria :

Above Figure 1 shows the values of relative weight Wj calculated based on the opinion given by all experts for the criteria (1) TDS –(WQP1), (2) EC – (WQP2), (3) Chlorides – (WQP3), and (4) pH – (WQP4). From these values of relative weight final rank and weight is calculated which given in following Table.

Table 5: Final weight and rank for Selected Criteria

Criteria	Relative Weight	Weight %	RANK
TDS –(WQP1)	0.334	33.40%	1
EC – (WQP2)	0.333	33.30%	2
Chlorides – (WQP3)	0.200	20.00%	3
pH – (WQP4)	0.133	13.30%	4
	Sum= 1.000	100%	

Results & discussion:

Groundwater quality criteria are essential in the determination of the groundwater quality index of 48 well locations selected within 5 talukas of Navsari district. These criteria are (1) TDS –(WQP1), (2) EC – (WQP2), (3) Chlorides – (WQP3), and (4) pH – (WQP4) which affect the variations in groundwater quality index of various locations in the study area. There are 22 experts from various fields of Civil Engineering Chemical Engineering Environmental Engineering and Agriculture fields were selected to share their opinions on the above (Groundwater quality parameters (criteria) . These opinions from various field experts were obtained through a questionnaire. The final weight of criteria of groundwater quality parameters was (1) TDS –(WQP1)- 33.40 % with Rank-1, (2) EC – (WQP2)- 33.30% with Rank-2, (3) Chlorides – (WQP3)- 20.00% with Rank-3, and (4) pH – (WQP4)- 13.30% with Rank-4. Here in this investigation, a questionnaire was formed to assess the main criteria that will be used in the further process of determination of the groundwater quality index of various locations within the study area of Navsari district. These criteria obtained were defined from the various case studies and literature reviews. Based on the importance given by experts, the criteria were weighted by the MCDM method-SWARA technique.

Conclusion:

the purpose of the investigation was to identify the weights of the criteria used to calculate the groundwater quality index for 48 wells in the Navsari district. The study used four key criteria. In addition, 22 experts' opinions were utilized to evaluate the criteria from highest to lowest. The MCDM method-SWARA technique is an important tool useful in computing the weights of criteria. On the other hand, the issue raised in this work may be used in a variety of scenarios. Furthermore, the study may be expanded in the future to incorporate several MCDM methods, allowing the findings to be compared and studied.

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