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Identification of Most Influential Parameter for Designing a Low-Cost Water Filter- MCDM Approach

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***Abstract*— An essential requirement for human survival is access to clean, safe drinking water. However, due to a lack of accessible water filtration systems, many communities worldwide, particularly in developing nations, have been affected by waterborne illnesses. The objective of the present study is to find out the most significant factors for designing a low-cost water filter to provide clean drinking water to the rural population. In this aspect, two MCDM methods, AHP, and ELECTRE, have been used. Different factors have been considered that influence the performance and cost-effectiveness of water filters, including filter size, filter rate, filter materials, and designs that are tested for their ability to remove impurities, including bacteria, viruses, and chemical pollutants. Results suggest the hardness of water is the most significant parameter to consider when designing a low-cost water filter. The investigation could be extremely beneficial for the design of low-cost water filters, which are simple to manufacture and can be quickly installed in locations with limited resources.**

***Index Terms*— Water filter, Low-cost Water Filter, MCDM, AHP, ELECTRE.**

I. INTRODUCTION

Access to clean and safe drinking water is a fundamental necessity for human life. However, many communities around the world, in developing countries, have been struggling with waterborne diseases due to lack of affordable water filter system. A water filter removes impurities by lowering contamination of water using a fine physical barrier, a chemical process, or a biological process. Filters use sieving, adsorption, ion exchanges, biofilms, and other processes to remove unwanted substances from water. Water purification is a process of removing undesirable physical and chemical contaminants from water. Water purification system proposed in this project focus on providing a pure drinking water at low cost with high reliability to the rural families. There are various methods available for purification of water, but they are not economically feasible for Rural people. This method can be made portable, cost effective, user complaint and energy efficient which will be self-sufficient to meet the drinking water needs.
The MCDM method were used to identify the priority parameter for desertification. The multi-criteria decision-making methods are also known as multi criteria decision analysis (MCDA) method that include for solving problems that have multiple criteria for choosing the best alternative among available number of alternatives.

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The analytical hierarchy process (AHP) is a multi-criteria decision-making method that helps the decision-maker to solve a complex problem by converting it into hierarchy of problems. The AHP MCDM method has limitation such that the value varies according to the form of hierarchy structure. In this study, the scale is not used for matrix for direct ranking of criteria was based on its importance for the objective given by the criteria, higher magnitude is ranked high and lower magnitude is ranked least. This process of ranking maintains the consistency ratio within the limit.

ELECTRE is a family of multi-criteria decision analysis methods that originated under the French School of decision making in the mid- 1960s. ELECTRE stands for: Elimination Et Choix Tradescant la Realties (Elimination and Choice Expressing Reality).12-Jun-2020. The Electra is a multi-criteria decision- making method based on the concept of outranking, based on each appropriate criterion, using peer-to-peer comparisons of alternatives.

A. Literature Review

Ghosh et al. (2020) Develop a Low-Cost Solar Water purifier using Metaheuristic process. In this paper solar power is taken as an energy source and stores it in a battery which is a free source of energy.

Omoniyi et al. (2020) aim to design a low-cost ceramic water filters using sustainable materials to allow a wide implementation of these filters for point -of-use household water treatment in resource-poor setting in developing countries.

Oytun Oner et al. (2022) studied to identify a multi-criteria decision-making (MCDM) model to evaluate several options and identify the most feasible alternative(s). The results show that the most feasible carrier alternative is highly dependent on the application purpose.

Prabhat Kumar Singh et. Al (2023) a determining role in the selection of wastewater treatment technologies (WWTTs). Using 14 reuse purposes and a combination of 360 WWTTs.

B. Objective & Novelty

The main aim of the present study is to identify the most influencing factors for developing a low-cost water filter. To achieve the present objectives, two different MCDMs i.e., AHP and ELECTRE have been applied. In the first step of the study, AHP has been used to identify the most influencing parameters in terms of water filter. After that, ELECTRE has been applied to identify the most influencing factor for developing a low-cost water filter. This study is important because it facilitates the design and development of low-cost water filter.

1. Method Used

In this study two MCDM, AHP &ELECTRE has been used and explained in section 2.1 to 2.2.

a. *Analytical Hierarchy Process (AHP)*

Analytic Hierarchy process is an application of group decision making which was developed by Thomas L. Saaty in the 1970s (Saaty, 2008). Analytical Hierarchical Process (AHP) also called Analytical Hierarchical Process. The steps of AHP MCDM method are discussed below:

i. Ranking of each selected alternatives based on the availability of data.
ii. Ranking of criteria based on its importance for the objective of study with the help of expert's review.
iii. Comparison matrix of criteria is made using numerical equivalent of rank in the given equation 1.

$$\text{Numerical ranks (R)} = \frac{1- Rank\ of\ Criteria}{1 + Rank\ of\ Criteria} \qquad (1)$$

iv. Numerical equivalent of Rank for alternatives are calculated using equation 2

$$\text{Numerical ranks (R)} = \frac{1- Rank\ of\ Alternatives}{1+ Rank\ of\ Alternatives} \qquad (2)$$

v. To estimate the criteria weights value by comparing each criterion with each other criterion forming a comparison matrix using equation 3

$$C\ i\ j = Ci/Cj \qquad (3)$$

vi. Where C i j are the elements of the comparison matrix and C i, C j is the Numerical Equivalent of Rank for criteria.
vii. To estimate each selected alternatives weights value by comparing each alternative with each other alternatives forming a comparing matrix using equation 4

$$A_{ij} = A_i / A_j \tag{4}$$

Where A_{ij} are the elements of the pairwise comparison matrix and A_i, A_j is the Numerical Equivalent of Rank for criteria.

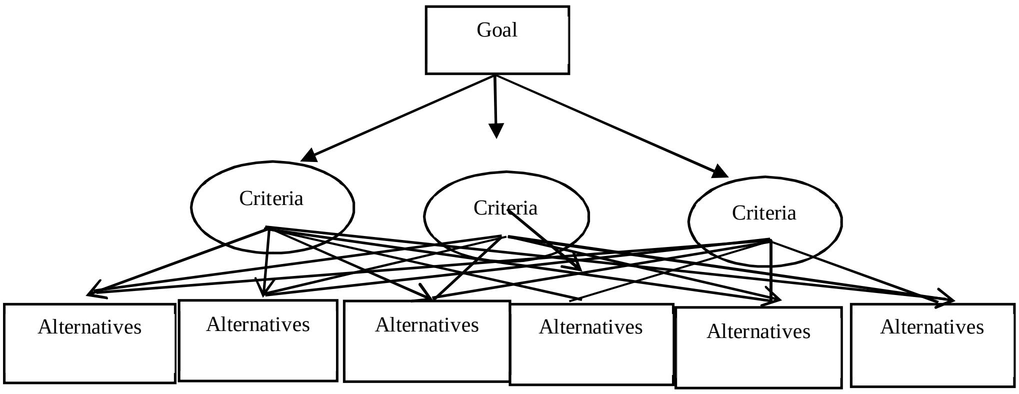

Figure 1: Hierarchy structure for AHP MCDM process

b. Elimination and Choice Expressing Reality (ELECTRE)

The Elimination and Choice Expressing Reality method that originated in Europe in the mid1960s. It brings together a family of decision aid method whose particularity is the partial aggregation based on the construction of relation of comparisons of the performance of each pair of solution.

The step involved in ELECTRE MCDM method are explained below:

1. To determine the alternative-indicator matrix
2. To determine the normalizing the datasets.
3. To compare each row of datasets with the other rows.
4. To determine the concordance and discordance quantity.
5. To determine the threshold value.
6. To determine the dominant aggregate matrix.
7. To eliminate the alternative by adding based on the aggregate dominance matrix.

II. METHODOLOGY

The flow chart of methodology is given below in the figure 1.

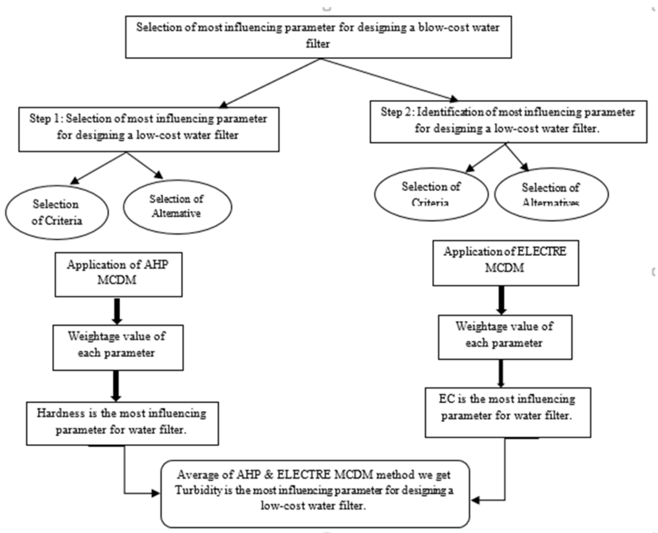

Figure 2: Flow chart of Methodology

Ten different parameters such pH, chloride, TDS, temperature, DO, BOD, hardness, TSS, EC and turbidity for water filter are determined using literature review and expert judgement. These ten parameters were act as alternatives. The pH, electric device used to measure hydrogen-ion activity in solution. A chlorometer is a measuring instrument used to determine the concentration of chloride ions. The TDS concentration of the water sample is measured with a TDS meter. The temperature of water sample is measured by HORIBA. Dissolved oxygen value of water samples was obtained from the DO meter. The BOD meter Ox direct is a device that is designed to determine the biochemical oxygen demand. The hardness of water sample is determined by the EDTA titration process. TSS was assessed by the filter paper method. The EC of the water sample was measured by the Electrical Conductivity meter. Turbidity was determined using a turbidimeter. Cost and efficiency have been selected as criteria based on literature review. After selection of criteria and alternatives AHP MCDM method has been applied. AHP MCDM shows the weight valve of each of the selected parameters. Therefore, after determining the weighted value (Wi) for all ten selected parameters.

Now, in the second step of the study, ELECTRE MCDM method has been used to identify the influencing parameters for developing a low-cost water filter. Ten indicators i.e., cost and efficiency were considered as criteria and ten parameters i.e., A1 to A10 were considered as alternatives through the expert evaluation to measure the performance of water filters.

III. Results And Discussions

The detailed results of AHP and ELECTRE MCDM has been discuss in the section 4.1 & 4.2.

A. AHP MCDM RESULTS

TABLE I. RANK WISE PARAMETER WITH RESPECT TO CRITERIA.

Parameters	Cost	Efficiency
pH	2	7
Chloride	4	10
TDS	7	2
Temperature	6	8
DO	8	4
BOD	3	5
Hardness	10	9
TSS	9	6
EC	5	3
Turbidity	1	1

TABLE II. CALCULATED WEIGHTED VALUE OF CRITERIA BY AHP

Criteria	Cost	Efficiency	GM	Weighted Value
Cost	1	0.5	0.7	0.33
Efficiency	2	1	1.41	0.66
total			2.1	

B. FOR COST

TABLE III: APPLY AHP METHOD FOR FINDING PARAMETER OF LOW-COST WATER FILTER

Alternatives	Temp	Hardness	Turbidity	DO	Chloride	TDS	pH	TSS	BOD	EC	G.M	R.W
Temp (Kelvin)	1	1.11	1.25	1.42	1.66	2	2.5	3.33	5	10	2.20	0.18
Hardness (mg/l)	0.9	1	1.12	1.28	1.5	1.8	2.25	3	4.5	9	1.98	0.16
Turbidity (NTU)	0.8	0.88	1	1.14	1.33	1.6	2	2.66	4	8	1.76	0.14
DO (mg/l)	0.7	0.77	0.87	1	1.16	1.4	1.75	2.33	3.5	7	1.54	0.12
Chloride (mg/l)	0.6	0.66	0.75	0.85	1	1.2	1.5	2	3	6	1.32	0.10
TDS (mg/l)	0.5	0.55	0.62	0.71	0.83	1	1.25	1.66	2.5	5	1.10	0.09

pH	0.4	0.44	0.5	0.57	0.66	0.8	1	1.33	2	4	0.88	0.07
TSS (mg/l)	0.3	0.33	0.37	0.42	0.5	0.6	0.75	1	1.5	3	0.66	0.05
BOD (mg/l)	0.2	0.22	0.25	0.28	0.33	0.4	0.5	0.66	1	2	0.44	0.03
EC (Ms/cm)	0.1	0.11	0.12	0.14	0.16	0.2	0.25	0.33	0.5	1	0.22	0.01
Total =											12.14	

C. For Efficiency

TABLE IV: Apply AHP Method For Finding Parameter Of Low-Cost Water Filter.

Alternatives	Temp	Hardness	Turbidity	DO	Chloride	TDS	pH	TSS	BOD	EC	G.M	R. W
Temp (Kelvin)	1	0.88	8	2	0.8	4	1.14	1.33	1.6	2.67	1.76	0.14
Hardness (mg/l)	1.125	1	9	2.25	0.9	4.5	1.28	1.5	1.8	3	1.98	0.16
Turbidity (NTU)	0.125	0.11	1	0.25	0.1	0.5	0.14	0.17	0.2	0.33	0.22	0.01
DO (mg/l)	0.5	0.44	4	1	0.4	2	0.57	0.67	0.8	1.33	0.88	0.07
Chloride (mg/l)	1.25	1.11	10	2.5	1	5	1.42	1.67	2	3.33	2.20	0.18
TDS (mg/l)	0.25	0.22	2	0.5	0.2	1	0.28	0.33	0.4	0.67	0.44	0.03
pH	0.875	0.77	7	1.75	0.7	3.5	1	1.17	1.4	2.33	1.47	0.12
TSS (mg/l)	0.75	0.66	6	1.5	0.6	3	0.85	1	1.2	2	1.32	0.10
BOD (mg/l)	0.625	0.55	5	1.25	0.5	2.5	0.71	0.83	1	1.67	1.10	0.09
EC (Ms/cm)	0.375	0.33	3	0.75	0.3	1.5	0.42	0.5	0.6	1	0.66	0.05
Total =											12.07	

Based on the geometric mean and relative weightages was calculated by using the equation is shown.

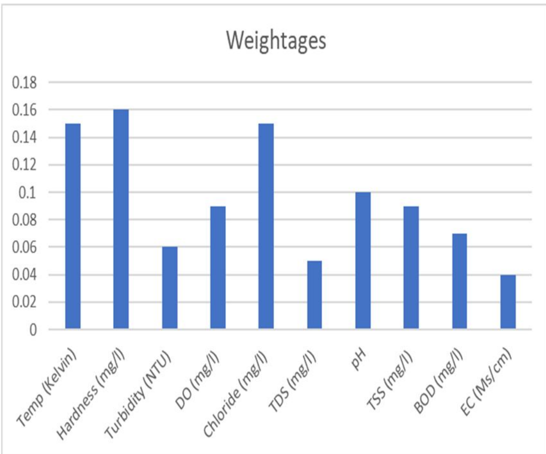

Figure 3: Final weight-age value of the AHP MCDM results

D. ELECTRE MCDM RESULTS

In the ELECTRE method the Alternative-Indicator Matrix were calculated using ELECTRE method.

TABLE V: DEVELOPMENT OF ALTERNATIVE INDICATOR MATRIX IS CREATED THAT IS ALTERNATIVE AND INDICATOR IN EQUATION.

Sl. No	Parameter	Cost	Efficiency
1	Temp (Kelvin)	2	7
2	Hardness (mg/l)	4	10
3	Turbidity (NTU)	7	2
4	DO (mg/l)	6	8
5	Chloride (mg/l)	8	4
6	TDS (mg/l)	3	5
7	pH	10	9
8	TSS (mg/l)	9	6
9	BOD (mg/l)	5	3
10	EC (Ms/cm)	1	1

TABLE VI: DEVELOPMENT OF ALTERNATIVES INDICATOR MATRIX

Alternatives	0.6	0.4
	Cost	Efficiency
Temp (Kelvin)	0.18	0.90
Hardness (mg/l)	0.26	1.03
Turbidity (NTU)	0.40	0.28
DO (mg/l)	0.37	0.91
Chloride (mg/l)	0.52	0.62
TDS (mg/l)	0.22	0.71
pH	1.67	0.97
TSS (mg/l)	0.74	0.72
BOD (mg/l)	0.29	0.57
EC (Ms/cm)	0.14	0.24

Table VII: Show the development of the Normalize Indicator Matrix or Normalized Decision matrix i.e., Square each value of the indicator and add column wise. Then find the square root of the summation. Divide each value of the indicator with the square root.

TABLE VIII: AGGREGATED WEIGHTS VALUE OF THE PARAMETERS

Alternatives	Cost	Efficiency	Sum	R.W	Rank
Temp (Kelvin)	0.15	1.67	1.82	0.06	8
Hardness (mg/l)	0.16	0.99	1.15	0.04	10
Turbidity (NTU)	0.06	4.51	4.57	0.16	1
DO (mg/l)	0.09	1.23	1.32	0.048	9
Chloride (mg/l)	0.15	2.60	2.76	0.10	6
TDS (mg/l)	0.03	3.99	4.02	0.14	2
pH	0.10	2.79	2.89	0.10	5
TSS (mg/l)	0.02	2.34	2.36	0.08	7
BOD (mg/l)	0.07	2.94	3.01	0.11	4
EC (Ms/cm)	0.04	3.10	3.15	0.11	3
Total			27.11	1	

After finding all the parameter of AHP and ELECTRE Method in MCDM method., we get the least parameter of 0.042 i.e., Hardness and the highest parameter of 0.168 i.e., Turbidity.

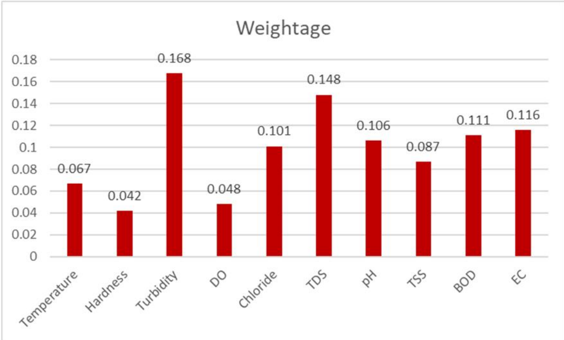

Figure 3: Final weights value of the parameters as per the MCDM results

IV. CONCLUSIONS

The aim of the present study was to identify the most influencing parameters for developing a low-cost water filter. Two MCDMs method have been applied to achieve the present objective. AHP is used to select the influencing parameters for drinking water filter and the ELECTRE method is used to identify the most influencing parameters for the design of low-cost water filters. In this study, hardness is found to be the most important parameter for drinking water filter.

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