International Journal of Constructive Research in Civil Engineering (ijcrce)
Volume 8, Issue 1, 2024, PP 1-15
ISSN 2454-8693 (Online)
DOI: https:// doi.org/10.20431/2454-8693.0801001
www.arcjournals.org

Selection of Most Suitable Wastewater Treatment Process using Analytical Hierarchy Process

Abdullahi Mohamed Sheikh Ali1[1,2*], Prashant Joshi[1], Pushkar Kumar[1], Jatin Bansal1, Arvind K. Nema[1]

[1]*Department of Civil Engineering, Indian Institute of Technology, DelhiHauzKhas, New Delhi, 110016*

[2]*Department of Civil Engineering, College of Engineering and Technology, Abrar University, Hodan district, Mogadishu, Somalia*

Corresponding Author:*Abdullahi Mohamed Sheikh Ali, *Department of Civil Engineering, College of Engineering and Technology, Abrar University, Hodan district, Mogadishu, Somalia.*

Abstract: *Water is universally acknowledged as an essential element in ecosystems and surroundings, vital to human existence and well-being. Nevertheless, only a restricted fraction of aquatic environments are reachable by humans, and numerous of these water reservoirs have been polluted due to industrialization and urbanization.*

Water pollution continues to be a pressing problem that requires the implementation of efficient wastewater treatment measures. This research aims to determine the optimal wastewater treatment method using the Analytical Hierarchy Process (AHP). The study assesses the effectiveness of three key technologies: Trickling Filter (TF), Sequencing Batch Reactor (SBR), and Up-flow Anaerobic Sludge Blanket (UASB). The study used multiple criteria decision-making (MCDM) approaches to systematically organize the assessment process, considering economic, technical, and environmental-social factors.

The AHP framework enables prioritizing criteria and sub-criteria via a thorough examination, including literature analysis, expert discussions, and site visits. The findings indicate that the sequencing batch reactor (SBR) has exceptional adaptability, efficiency in treatment, and ease of operation, making it the most appropriate choice with a priority score of 0.457. The results emphasize the significance of including a variety of assessment standards to enhance decision-making in the creation of wastewater treatment facilities, eventually promoting long-term ecological sustainability.

Keywords: *AHP (Analytic Hierarchy Process), Decision-making, Sequencing Batch Reactor, Trickling Filter, Up-flow Anaerobic Sludge Blanket, Wastewater Technology Selection.*

1. INTRODUCTION

The exponential growth of the worldwide population presents a substantial peril and rivalry for the Earth's finite resources. The use of two key resources, namely energy, and water, by human intervention, presents significant risks in terms of global warming and water pollution, respectively.

Water is an essential requirement and fundamental entitlement of individuals. Water is essential for multiple domestic functions such as drinking, cooking, sanitation, irrigation, and power generation. In addition to its household use, water is also necessary for various other vocations, such as animal rearing. Furthermore, water is vital for sustaining life in our bodies. Water is a vital ingredient for livestock production and plays a crucial role in various activities, including the regulation of body temperature and growth.[1]

Water pollution is increasingly becoming a significant impediment to the sustainable development of any community. In economically fragile nations undergoing transitions or in other emerging countries, the management of water quality is a significant challenge. One of the issues is the tendency to design ambitious and flawless programs that are ultimately impossible to achieve, resulting in frequent delays. Most notably, practical and systematic solutions were disregarded, failing to implement even achievable initiatives[2].

The majority of existing research has mostly concentrated on the many methodologies employed in wastewater treatment, with limited emphasis on the concept of sustainability.

The preceding research has explored several typical strategies for wastewater treatment, including chemic al treatment, physical treatment, the utilization of biological organisms, and sludge treatment[3].

For long-term ecological sustainability, the objective of this study of the selection of a wastewater treatment processisto go beyond mere technical performance, encompassing the optimization of energy and resource utilization. The effective establishment and functioning of wastewater treatment facilities (WWTPs) are contingent upon the meticulous choice of wastewater treatment methodologies. The present work employs multicriteria decision-making (MCDM) approaches to systematically structure the problem, enabling decision-makers to evaluate and prioritize criteria based on their significance. MCDM must oversee intricate decisions involving numerous conflicting criteria, guaranteeing a comprehensive and equitable assessment. Inherently, WWTP decisions are multi-criteria in nature, as they must simultaneously evaluate environmental impact, economic feasibility, regulatory compliance, technical feasibility, and social acceptability [1], [2].

The focal point of our research revolves around the amalgamation of multiple methodologies, with a particular focus on the analytical hierarchy process (AHP).The Analytic Hierarchy Process (AHP) provides a structured method for decision-making by breaking down complex decisions into a hierarchy of simpler, interrelated criteria. It justifies its use by allowing subjective judgments to be systematically incorporated, ensuring that quantitative and qualitative factors are considered. AHP also addresses the interconnectivity between criteria, enabling a comprehensive and consistent evaluation process [3]. The AHP is renowned for its efficacy in tackling diverse goals, including socio-cultural and environmental issues, alongside economic factors.

The optimal choice of wastewater treatment methods plays a crucial role in the planning and implementationof wastewater treatment facilities. It requires a systematic strategy that enables decision-makers to evaluate and rank different factors based on their significance. MCDM approaches are important for evaluating alternatives and selecting the most appropriate wastewater treatment option. The use of diverse approaches in Multiple Criteria Decision Making (MCDM) frameworks enhances the decision-making process by efficiently addressing a broad spectrum of objectives and considerations. One of the primary methodologies employed in this particular context is the analytical hierarchy process (AHP), which offers a methodical approach to comprehensively address diverse criteria. These criteria encompass socio-cultural and environmental issues, as well as economic considerations.

In multicriteria decision-making, the analytical hierarchy process (AHP) is a systematic analytical procedure that allows decision-makers to develop distinct priorities and preferences [3], [4]**.** The paper's limitations are restricted to the demonstration of the effectiveness of a multi-criteria hierarchical decision-making process.

The Analytic Hierarchy Process (AHP) is a flexible and powerful approach for tackling complex problems that involve both qualitative and quantitative factors. The hierarchical structure of a problem, resembling a family tree, aids analysts in organizing the essential elements of the problem. This methodology facilitates the process of rating decision alternatives and selecting the most optimal choice when decision-makers are confronted with various criteria [5]. Although the traditional Analytic Hierarchy Process (AHP) usually requires accurate or predictable assessments, it offers a strong structure for dealing with intricate decision situations. Within the framework of this study, our objective is to conduct a comparative analysis of three prominent methods employed in wastewater treatment. UASB, which is an anaerobic process, and SBR and TF are predominantly aerobic. There are numerous technologies available for wastewater remediation, including the Activated Sludge Process (ASP), MBBR (Moving Bed Biofilm Reactor), septic tank, and oxidation pond. The group inspected the SBR facility in Noida, Delhi, and reviewed the Nemours literature regarding UASB and TF respectively.

1. Trickling Filter (TF)
2. Sequencing Batch Reactor (SBR)
3. Up-flow Anaerobic Sludge Blanket (UASB)

This analysis aims to provide a comprehensive understanding of the strengths and limits associated with each method, taking into account a range of criteria and objectives relevant to the wastewater treatment field. Through the utilization of Multiple Criteria Decision Making (MCDM) approaches, specifically the Analytic Hierarchy Strategy (AHP) approach, we aim to obtain valuable insights that will assist decision-makers in choosing the best suitable wastewater treatment strategy for their unique requirements and circumstances.

1.1 Trickling Filters

William Joseph Dibdin, a British inventor, developed the trickling filter during the late 19th century. This innovative technology plays a vital role in the process of treating wastewater. By around 1893, Dibdin initiated the development of this system, which was subsequently enhanced by engineers such as George W. Fuller in the United States. The first significant installation in the United States took place in Madison, Wisconsin, in 1912. Trickling filters (TFs) are used to remove organic compounds from wastewater. The TF treatment system utilizes aerobic microorganisms attached to a medium to effectively remove organic pollutants from wastewater. This specific approach is commonly utilized in several technologies, such as rotating biological contactors and packed-bed reactors. These mechanisms are occasionally called connected growth systems. Conversely, systems in which microorganisms are kept in a liquid media are typically known as suspended-growth methods[4].

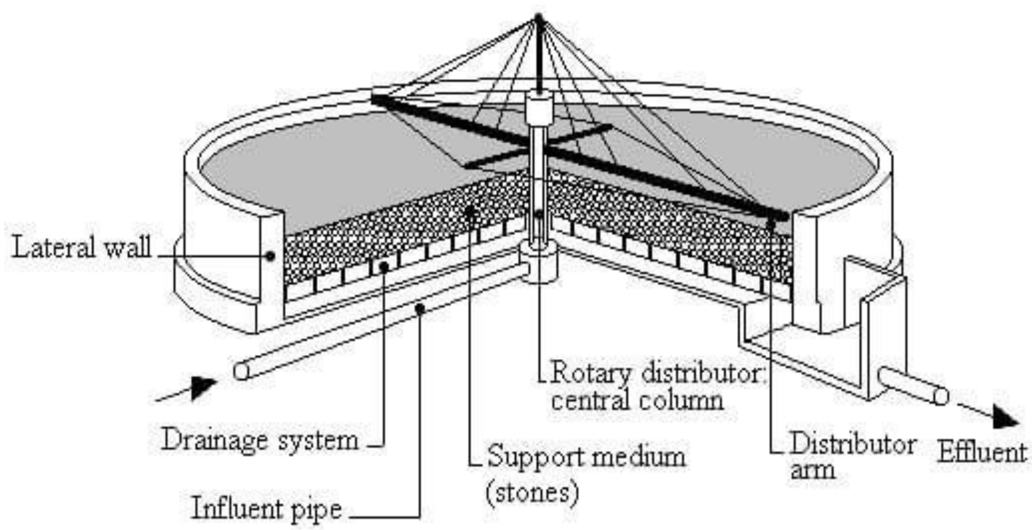

Fig1: *Typical Trickling Filter[6]*.

TFs enhance the absorption of organic materials in wastewater by a wide range of microorganisms, such as aerobic, anaerobic, and facultative bacteria, fungi, algae, and protozoa. The microorganisms attach themselves to the medium in the form of a biological film or slimy coating, usually with a thickness of approximately 0.1 to 0.2 mm. As the wastewater flows through the medium, the microorganisms already present in the water gradually stick to the surface of the rock, slag, or plastic, creating a film. The aerobic microorganisms located in the outer region of the slime layer decompose the organic matter. As the layer thickens due to the growth of microorganisms, the medium becomes unable to allow oxygen to pass through, resulting in the appearance of anaerobic organisms. As the biological film expands, the microorganisms at the surface gradually lose their ability to adhere to the medium. This results in a segment of the slime layer detaching from the filter. The procedure in question is referred to as sloughing. The underdrain system gathers the detached solid particles and subsequently conveys them to a clarifier for extraction from the wastewater.

1.1.1 Advantages

- Straightforward, dependable, biological procedure.
- This approach is ideal for regions where large land expanses are not easily accessible for treatment systems that require a lot of land. May satisfy the requirements for secondary discharge standards that are comparable.
- The efficacy of organic treatment varies depending on the specific medium employed.
- Suitable for communities of small to medium size. Accelerate the reduction of soluble BOD5 in the wastewater that is applied.

1.1.2 Disadvantages

- An excessive accumulation of biomass can disrupt the maintenance of an aerobic environment, leading to a decline in the performance of the TF (the maximum biomass thickness is influenced by factors such as hydraulic dose rate, medium type, organic matter type, temperature, and biological growth characteristics).
- Regular operator attention is necessary.
- The prevalence of blockages is relatively elevated.
- The issues about vectors and odors

1.2 Sequencing Batch Reactor

Dr. R.D. "Rock" Lawrence and his colleagues created the Sequencing Batch Reactor (SBR) in the 1970s. The objective of developing SBR technology was to enhance the adaptability and effectiveness of wastewater treatment operations. The system was specifically engineered to accommodate fluctuating quantities of wastewater and was especially well-suited for treatment plants of small to medium size or those with inconsistent flow rates.

The Sequencing Batch Reactor (SBR) System is a fill-and-draw activated sludge system. It does the processes of clarifying, aerating, and equalizing in one tank, instead of having these processes happen in separate tanks as is common in other activated sludge systems.The SBR system involves the introduction of wastewater into a tank, treatment to remove undesirable components, and finally the release of the treated wastewater[5].The Sequencing Batch Reactor systems generally consist of a series of five consecutive steps:

1. Complete
2. React (aeration)
3. Achieve a state of sedimentation or clarity.
4. Produce a decantation of wastewater.
5. Idle

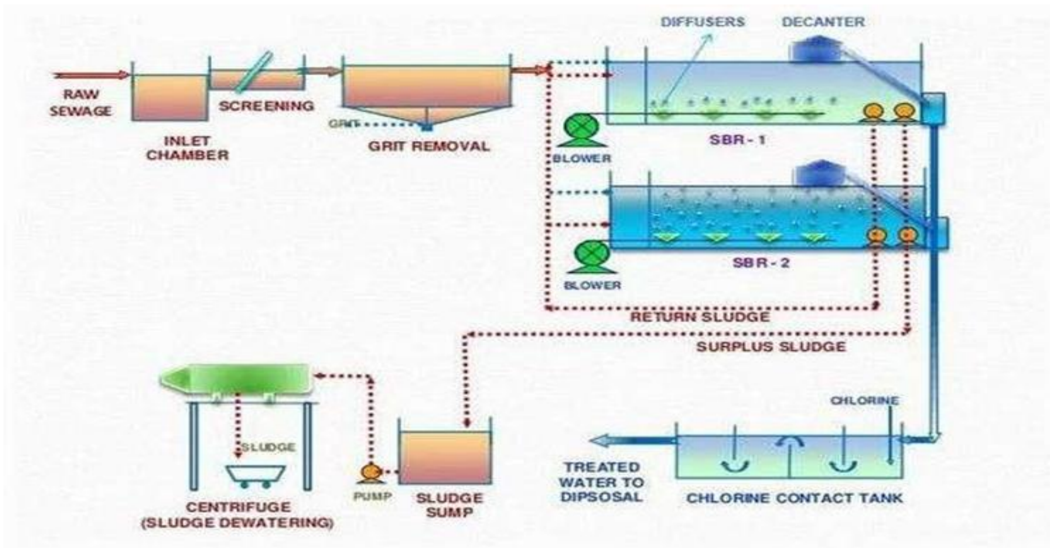

Fig2:*Typical flow diagram of a Sequencing Batch Reactor[7].*

1.2.1 Advantages

- Flexibility in operation
- Efficient nutrient removal
- Space efficiency
- Reduced sludge production
- Enhanced process control
- Resilience to shock loads

1.2.2 Disadvantages

- Complex operation and control
- Higher capital costs
- Increased footprint for equalization
- Potential for process upsets
- Longer treatment cycle times
- Risk of foaming and bulking
- Limited flexibility for expansion

1.3 Upflow Anaerobic Sludge Blanket

Professor GatzeLettinga and his colleagues created the Up-flow Anaerobic Sludge Blanket (UASB) reactor during the late 1970s at Wageningen University in the Netherlands. The UASB technology was a notable breakthrough in the domain of wastewater treatment, namely for the purification of concentrated industrial and municipal wastes.

The UASB System is composed of a tank containing a sludge bed, in which the organic matter found in wastewater is subjected to deterioration, resulting in the generation of biogas. The introduction of wastewater occurs at the lower section of the reactor, whilst biogas accumulates at the upper section, and the effluent of treated water is expelled. In the reactor, a region known as the blanket zone emerges above the sludge bed, effectively segregating the water that flows upwards from the biomass that is suspended. UASB systems are widely employed for the treatment of wastewater containing a significant amount of organic matter, such as wastewater generated by the food sector[6].

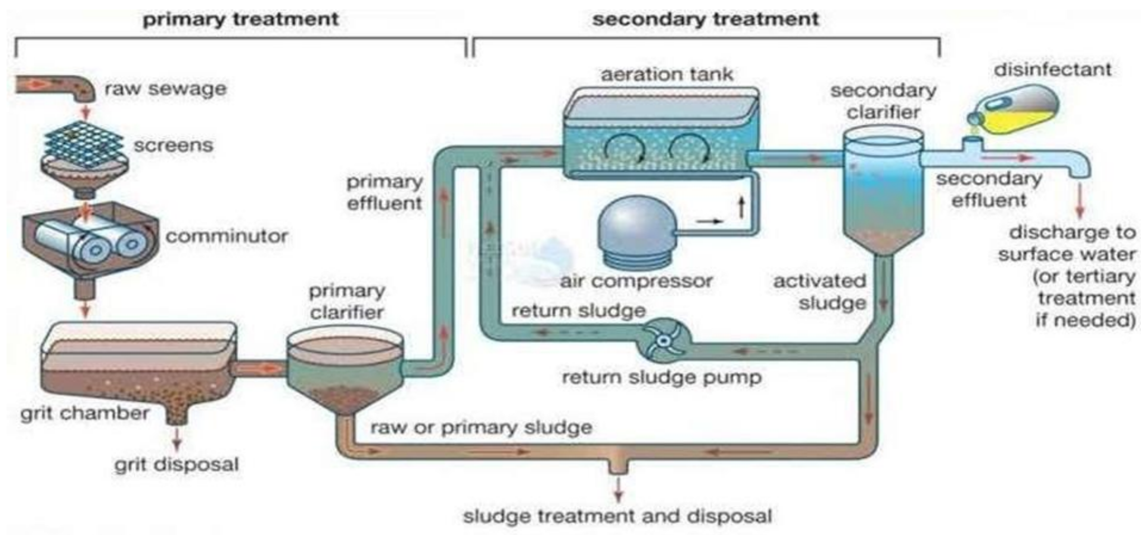

Fig3: *Typical Flow Diagram of Up-flow Anaerobic Sludge Blanket [8]*.

1.3.1 Advantages

- Efficient treatment of high-strength wastewater
- Minimal energy requirements
- Reduced sludge production
- Compact design, suitable for areas with limited space
- Effective removal of suspended solids and organic matter
- Lower operating costs compared to aerobic treatment systems
- Minimal nutrient requirements
- Robust and simple operation

1.3.2 Disadvantage

- Sensitivity to temperature variations
- Long start-up periods required for microbial acclimation
- Limited treatment efficiency for low-strength wastewaters
- Susceptibility to hydraulic and organic shock loads
- Potential for biomass washout during high flow events
- The generation of methane, a potent greenhouse gas, requires appropriate management
- Limited removal of nutrients such as nitrogen and phosphorus

2. METHODOLOGY

In this chapter, the research methodologies used to carry out the study are clearly described. This section explains the methodology the team of investigators used to gather, present, and analyze the necessary data and information to successfully respond to study goals and inquiries. This section provides rationales and reasons for the chosen research design, research instruments, data sources, data collection methodologies, data presentation approaches, and analytical techniques used in the study.

2.1. Design Alternatives Identification

The purpose of this study is to determine the most suitable wastewater technology among three options for a WWT plant. There are three distinct technologies, which are:

Option (A): Trickling Filter (TF)

Option (B): Sequencing batch reactor (SBR)

Option (C): Upflow Anaerobic Sludge Blanket (UASB).

Option (A):A trickling filter (TF) is used to remove organic matter from wastewater. The TF is an aerobic treatment system that utilizes microorganisms attached to a medium to remove organic matter from wastewater [9]**.**

Option (B):sequencing batch reactor (SBR). SBR can accomplish equalization, primary clarification, biological treatment, and secondary clarification inside a single reactor. The five or six phases involved in the SBR system are anoxic fill, aerated fill, react, and settle decant. The SBR system has shown efficient removal of nitrogen, phosphate, and heavy metals [10]**.**

Option (C): An up-flow anaerobic sludge blanket technology, sometimes referred to as a UASB reactor, is a kind of anaerobic digester used in the treatment of wastewater. The UASB reactor is a digester that produces methane via an anaerobic processthe outcome of this process is the creation of a stratum of granular sludge, which is subsequently decomposed by anaerobic bacteria. [11].

A comprehensive assessment is carried out to collect data from past publications on research academics, visits to plant sites (consultants and plant designers), and government officials responsible for wastewater treatment.

2.2. Analytical Hierarchical Process (AHP)

The Analytic Hierarchy Process (AHP) tool, created by Saaty in 1980, is a popular and widely utilized multi-criteria decision-making (MCDM) technique for addressing many intricate decision-making situations. The process involves a methodical approach that takes into account both intuition and logic when making final decisions. The relative value of various criteria and sub-criteria is determined via the input of consultants and expert opinions. The AHP tool is capable of effectively managing the subjective decision-making process of an individual. The fundamental procedures included in the AHP tool are [12].

A: First, the decision-making process is broken down into basic parts. B: Assign each element to its appropriate hierarchical level.

Allocate a weight to the subjective judgment.

D: Consolidate the assessment for determining the ultimate ranking of performances by combining relative weights.

2.3. Pair-Wise Comparison

Pairwise comparison is a crucial component of the analysis. The Analytic Hierarchy Process (AHP) assigns preferences on a scale of 1 to 9, as seen in Table 1: Pairwise comparison scale. A higher number signifies more priority. Then we calculate the value of the consistency index (CI).

Table 2 displays the randomness index value used to determine the CR and is further required for finding the consistency ratio (CR). Inconsistent judgment is indicated when the CR value surpasses

0.10. Higher levels of inconsistency indicate a deficiency in comprehension or knowledge.

$$CI = \frac{(\lambda max - n)}{(n-1)} \quad (1)$$

$$CR = \frac{CI}{RI} \quad (2)$$

The process of developing a priority ranking involves establishing a decision matrix that includes sub-criteria and criteria. This matrix allows for the determination of the overall ranking of alternatives and their accompanying weights. The ultimate priority value of each choice is calculated by multiplying its priority vector by its weight and adding the results.

Table1: *Pairwise comparison scale (Saaty, 1987) [*3]

Numerical Rating	Judgments of Preferences
9	Extremely Preferred
7	Very Strongly Preferred
5	Strongly Preferred
3	Moderately Preferred
1	Equally Preferred
2,4,6,8	Intermediate Values

Table2:*Average Randomness Index [3]*

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

2.4.Criteria And Sub-Criteria Selection

The literature and expert opinions are utilized to establish the three primary criteria relating to the objective: the economic aspects, the technological aspects, and the environmental and socialimpacts, respectively [13], [14], [15], and [16].

The AHP decision network is created by applying the chosen criteria and sub-criteria through the essential steps of the analysis process, as depicted in Figure 4.

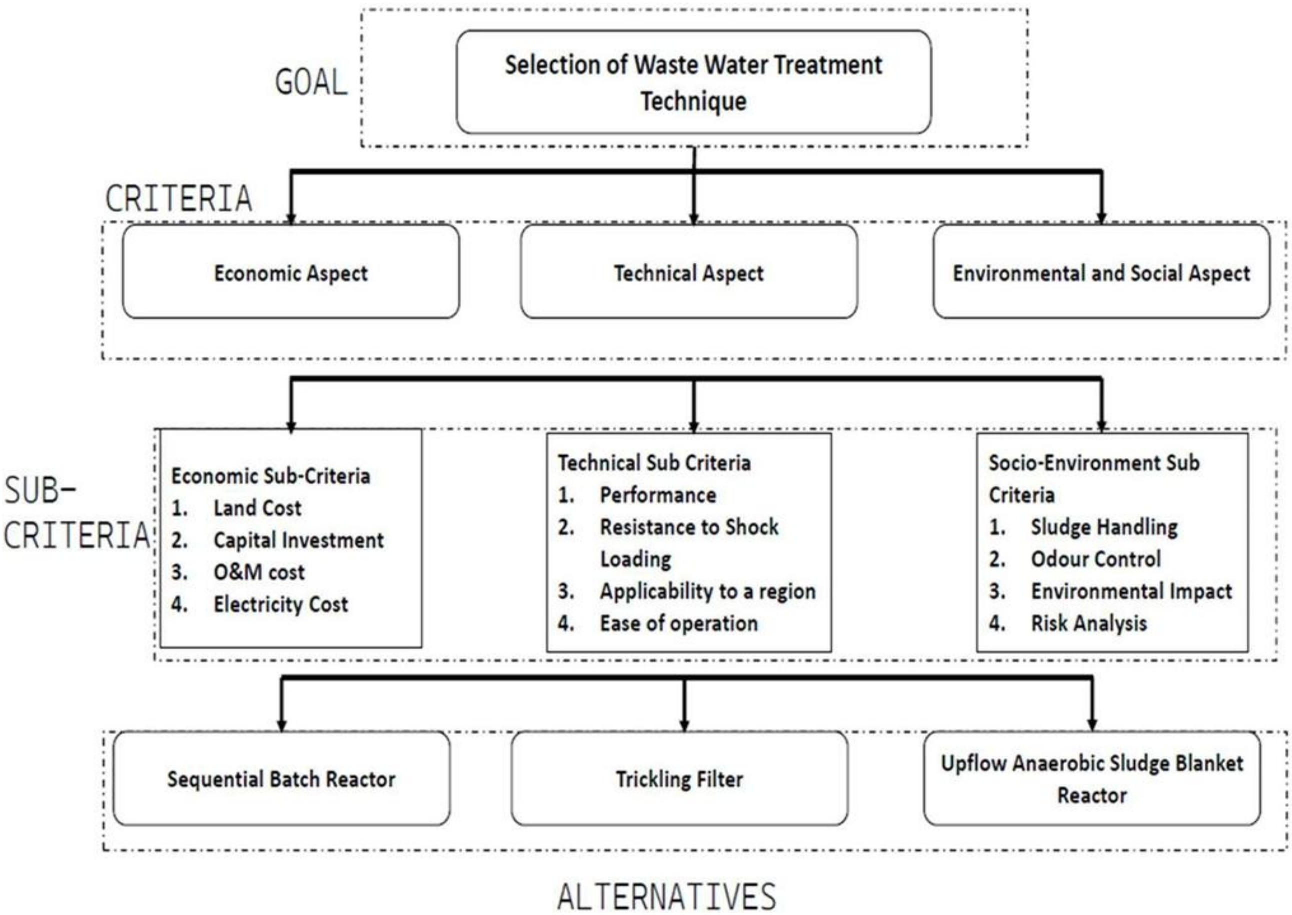

Fig 4*: Schematic Presentation of the AHP Decision Model.*

3. RESULTS AND DISCUSSION

Using the aforementioned methodology, the decision maker, comprising four master students, performed pairwise comparisons for many criteria and sub-criteria. The group assessed and evaluated each priority based on a range of criteria and sub-criteria, and then made collective judgments. The group convergence approach is employed to attain consensus for every data point. This technique is based on professional judgment and is tailored to individual sites. Thus, any alteration in the allotted weightage will impact the ultimate selection of an option. In addition to performing a comprehensive evaluation of UASB and TF, the decision-maker group also visited the SBR facility. The sensitivity analysis involves the computation of normalized priority vectors and consistency ratios. The normalized priority vectors and consistency ratios are calculated and presented in Table 3, Table 4, Table 5, Table 6, Table 7, Table 8, and Table 9. The graphical representation illustrates that the criteria prioritize environmental and social issues with the highest relevance (0.517), followed by economic aspects with a lower priority (0.286), and technological aspects with the least priority (0.196). Upon comparing sub-criteria Figure 5, Figure 6, Figure 7, and Figure 8, it is evident that the land cost sub-criteria inside the economic aspects criteria holds the highest priority vector, with a value of 0.4386. Similarly, the performance sub-criteria holds the utmost importance (0.444) in the technological aspect, while the environmental effect sub-criteria holds the highest priority (0.566) in the environmental and social aspects.

Table3: *Comparison matrix of criteria concerning goal*

Main Criteria	Economic Aspects	Technical Aspects	Environmental and Social Aspects	Criteria Weight	λmax	Consistency Index	Consistency Ratio
Economic Aspects	1.00	2.00	0.40	0.2868	3.0945	0.0472	0.0815
Technical Aspects	0.50	1.00	0.50	0.1961			
Environmental and Social Aspects	2.50	2.00	1.00	0.5171			

Table 4: *Pairwise Comparison matrix for economic sub-criteria*

Sub Criteria	Land Cost	Capital Investment	O&M Cost	Electricity Cost	Criteria Weight	λmax	Consistency Index	Consistency Ratio
Land Cost	1.00	1.50	3.00	3.00	0.4386	4.0277	0.0092	0.0103
Capital Investment	0.67	1.00	1.25	1.25	0.2324			
O&M Cost	0.33	0.80	1.00	1.00	0.1645			
Electricity Cost	0.33	0.80	1.00	1.00	0.1645			

Table5: *Pairwise Comparison matrix for technical sub-criteria*

Sub Criteria	Performance	Resistance to shock loading	Applicability	Ease of operation	Criteria Weight	λmax	Consistency Index	Consistency Ratio
Performance	1	3.5	2	3	0.4445	4.2407	0.0802	0.0891
Resistance to shock loading	0.29	1	0.25	0.33	0.0846			
Applicability	0.5	4	1	0.5	0.2194			
Ease of operation	0.33	3	2	1	0.2515			

Table6: *Pairwise Comparison matrix for Socio-Economic sub-criteria*

Sub Criteria	Sludge	Odor	Environment Impact	Risk Analysis	Criteria Weight	λmax	Consistency Index	Consistency Ratio
Sludge	1.00	0.50	0.20	1.50	0.1175	4.0444	0.0148	0.0164
Odor	2.00	1.00	0.50	2.00	0.2287			
Environment Impact	5.00	2.00	1.00	8.00	0.5662			
Risk Analysis	0.67	0.50	0.13	1.00	0.0876			

Table7: *Pairwise Comparison matrix of economic sub-criteria with alternatives*

SC-1 Land Cost							
Alternatives	**Trickling Filter**	**SBR**	**UASB**	**Criteria Weight**	**λmax**	**Consistency Index**	**Consistency Ratio**
Trickling Filter	1	0.75	0.95	0.2957	3.0003	0.0002	0.0003
SBR	1.33	1	1.2	0.3873			
UASB	1.05	0.83	1	0.317			
SC-2 Capital Cost							
Alternatives	**Trickling Filter**	**SBR**	**UASB**	**Criteria Weight**	**λmax**	**Consistency Index**	**Consistency Ratio**
Trickling Filter	1	0.7	1.11	0.3013	3.0004	0.0002	0.0003
SBR	1.43	1	1.5	0.4224			
UASB	0.9	0.67	1	0.2763			
SC-3 O&M Cost							
Alternatives	**Trickling Filter**	**SBR**	**UASB**	**Criteria Weight**	**λmax**	**Consistency Index**	**Consistency Ratio**
Trickling Filter	1	0.5	1.25	0.2691	3.0055	0.0028	0.0048
SBR	2	1	2	0.499			
UASB	0.8	0.5	1	0.2319			
SC-4 Electricity Cost							
Alternatives	**Trickling Filter**	**SBR**	**UASB**	**Criteria Weight**	**λmax**	**Consistency Index**	**Consistency Ratio**
Trickling Filter	1	0.3	1.2	0.2084	3.0247	0.0123	0.0213
SBR	3.33	1	2.5	0.5884			
UASB	0.83	0.4	1	0.2031			

Table 8: *Pairwise Comparison matrix for technical sub-criteria with alternatives*

SC-5 Performance							
Alternatives	**Trickling Filter**	**SBR**	**UASB**	**Criteria Weight**	**λmax**	**Consistency Index**	**Consistency Ratio**
Trickling Filter	1.00	0.67	1.20	0.2978	3.0012	0.0006	0.0011
SBR	1.50	1.00	2.00	0.4626			
UASB	0.83	0.50	1.00	0.2396			
SC-6 Resistance to Shock Loading							
Alternatives	**Trickling Filter**	**SBR**	**UASB**	**Criteria Weight**	**λmax**	**Consistency Index**	**Consistency Ratio**
Trickling Filter	1.00	0.50	0.70	0.2251			

SBR	2.00	1.00	1.50	0.4606	3.0005	0.0003	0.0005
UASB	1.43	0.67	1.00	0.3143			
SC-7 Applicability							
Alternatives	**Trickling Filter**	**SBR**	**UASB**	**Criteria Weight**	**λmax**	**Consistency Index**	**Consistency Ratio**
Trickling Filter	1.00	0.50	1.25	0.2580	3.0037	0.0018	0.0032
SBR	2.00	1.00	3.00	0.5477			
UASB	0.80	0.33	1.00	0.1943			
SC-8 Ease of Operation							
Alternatives	**Trickling Filter**	**SBR**	**UASB**	**Criteria Weight**	**λmax**	**Consistency Index**	**Consistency Ratio**
Trickling Filter	1.00	1.20	1.00	0.3462	3.0291	0.0145	0.0251
SBR	0.83	1.00	0.50	0.2441			
UASB	1.00	2.00	1.00	0.4097			

Table 9: *Pairwise comparison matrix of environmental and social sub-criteria with alternatives*

SC-9 Sludge Generation and Handling							
Alternatives	**Trickling Filter**	**SBR**	**UASB**	**Criteria Weight**	**λmax**	**Consistency Index**	**Consistency Ratio**
Trickling Filter	1.00	0.80	1.20	0.3243	3.0000	0.0000	0.0000
SBR	1.25	1.00	1.50	0.4054			
UASB	0.83	0.67	1.00	0.2703			
SC-10 Odor							
Alternatives	**Trickling Filter**	**SBR**	**UASB**	**Criteria Weight**	**λmax**	**Consistency Index**	**Consistency Ratio**
Trickling Filter	1.00	0.20	0.80	0.1215	3.0750	0.0375	0.0647
SBR	5.00	1.00	9.00	0.7619			
UASB	1.25	0.11	1.00	0.1166			
SC-11 Environmental Impact							
Alternatives	**Trickling Filter**	**SBR**	**UASB**	**Criteria Weight**	**λmax**	**Consistency Index**	**Consistency Ratio**
Trickling Filter	1.00	0.80	1.11	0.3136	3.0075	0.0038	0.0065
SBR	1.25	1.00	1.80	0.4272			
UASB	0.90	0.56	1.00	0.2592			
SC-12 Risk Analysis							
Alternatives	**Trickling Filter**	**SBR**	**UASB**	**Criteria Weight**	**λmax**	**Consistency Index**	**Consistency Ratio**
Trickling Filter	1.00	0.75	1.00	0.2995	3.0003	0.0001	0.0002
SBR	1.33	1.00	1.40	0.4059			
UASB	1.00	0.71	1.00	0.2947			

Table10: *Decision Matrix via AHP*

Criteria	Economic Aspect (0.2868)				Technical Aspect (0.1961)				Environmental and Social Aspects -0.5171			
Criteria	**SC1**	**SC 2**	**SC 3**	**SC 4**	**SC 5**	**SC 6**	**SC 7**	**SC 8**	**SC 9**	**SC 10**	**SC 11**	**SC 12**
Normalized	0.439	0.232	0.164	0.164	0.444	0.085	0.219	0.252	0.117	0.229	0.566	0.088
TF	0.296	0.301	0.269	0.208	0.298	0.225	0.258	0.346	0.324	0.122	0.314	0.299
SBR	0.387	0.422	0.499	0.588	0.463	0.461	0.548	0.244	0.405	0.762	0.427	0.406
UASB	0.317	0.276	0.232	0.203	0.24	0.314	0.194	0.41	0.27	0.117	0.259	0.295
TF	0.13	0.07	0.044	0.034	0.132	0.019	0.057	0.087	0.038	0.028	0.178	0.026
SBR	0.17	0.098	0.082	0.097	0.206	0.039	0.12	0.061	0.048	0.174	0.242	0.036
UASB	0.139	0.064	0.038	0.033	0.107	0.027	0.043	0.103	0.032	0.027	0.147	0.026
TF	0.281	**Priority 2**										
SBR	0.457	**Priority 1**										
UASB	0.262	**riority 3**										

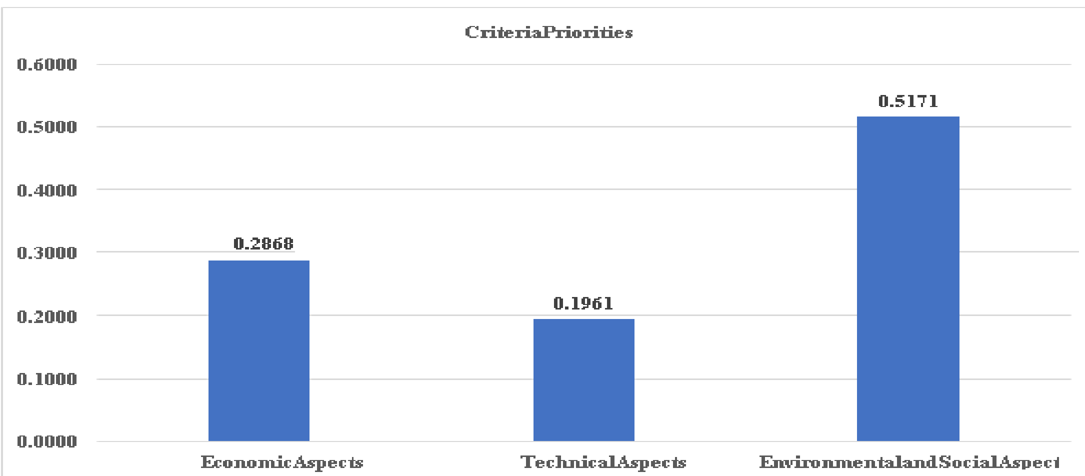

Fig5: *Criteria Priorities*

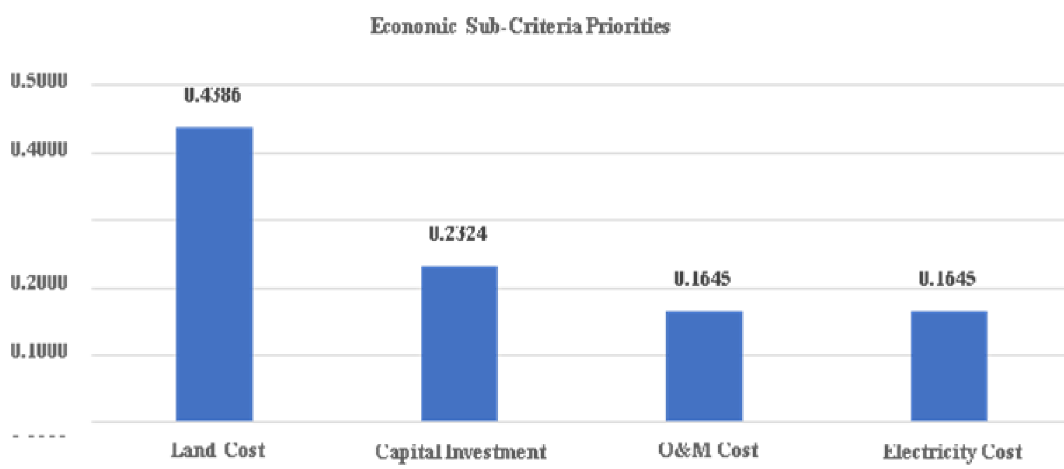

Fig6: *Economic Sub-criteria Priorities*

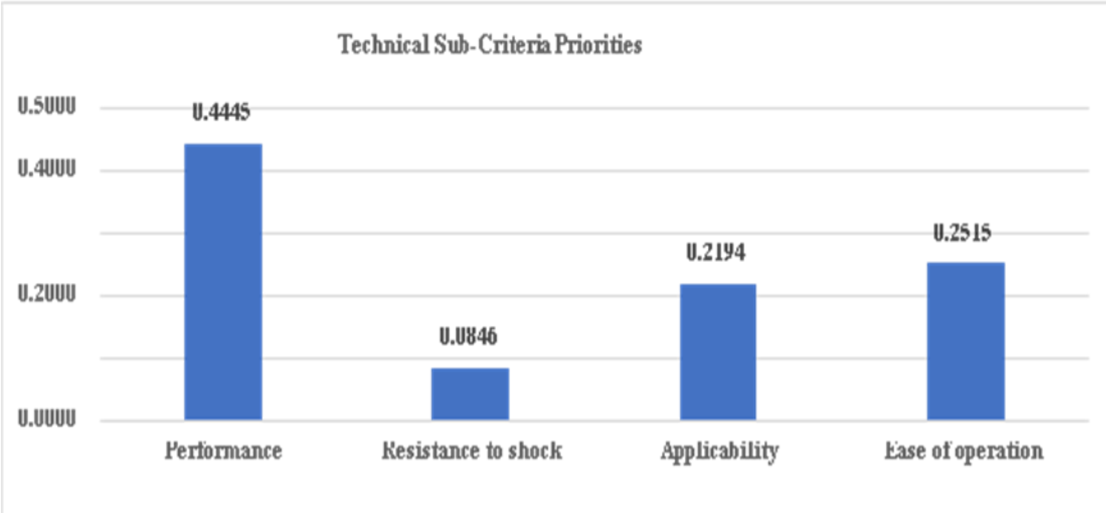

Fig7: *Technical Sub-criteria Priorities*

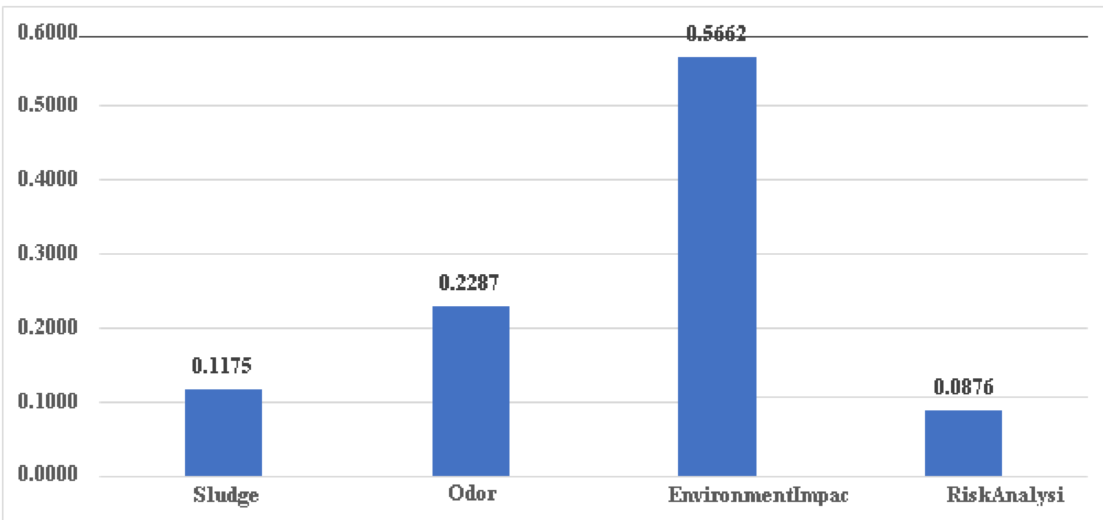

Fig8: *Environmental and Social Sub-criteria Priorities*

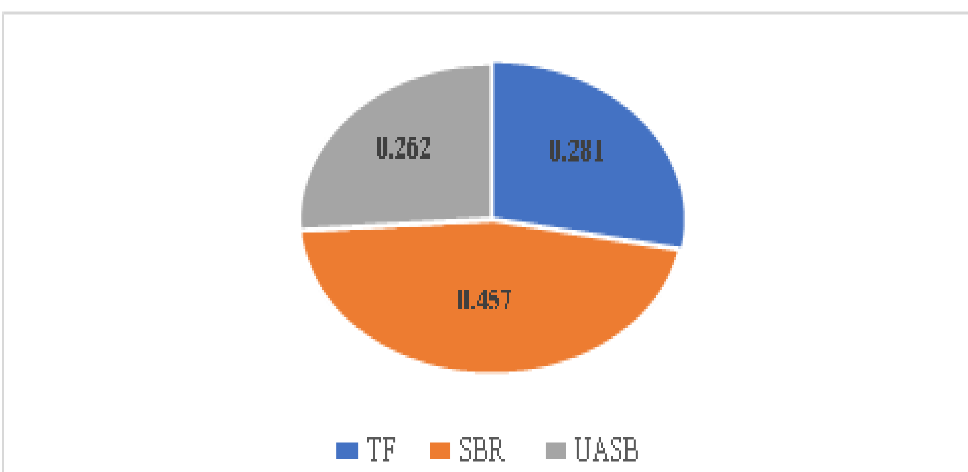

Fig9*: Overall Priorities of Alternatives*

By taking into account the normalized priorities of all the criteria and sub-criteria, a decision matrix, Table 10, is created to determine the priorities of the alternatives. Figure 9 displays the final priority rankings of the different alternatives. Multiple research papers have been published on the comparison of wastewater treatment plants (WWTP) using the Analytic Hierarchy Process (AHP). We have reviewed around 15 literature sources and assigned weights to each criterion and sub-criterion. This study involves a comprehensive comparison of three different wastewater treatment methods: sequencing batchreactors (SBR), trickling filters (TF),and up-flowanaerobic sludge blankets (UASB). The results of the comparison indicate that SBR is the most favorable option.

4. CONCLUSION

This study aimed to assess several options for treating municipal wastewater. The AHP methods are employed to evaluate several options, relying on the qualitative and quantitative viewpoints of the group members. Throughout our investigation, the Sequential Batch Reactor demonstrated several compelling advantages. Firstly, its flexibility in handling variable influent characteristics makes it adaptable to a wide range of wastewater compositions and flow rates. This flexibility is particularly crucial in accommodating fluctuations in wastewater volume and composition, often encountered in real-world wastewater treatment scenarios.

Secondly, the sequentialbatch reactor exhibited superior treatment performance, effectively removing organic matter, nutrients, and pathogens from the wastewater. Its cyclic operation allows for optimal conditions for biological reactions, leading to enhanced pollutant removal efficiencies compared to other methods.

Moreover, the sequential batch reactor offers operational simplicity and ease of maintenance. Its batch-wise operation allows for better control over the treatment process, facilitating monitoring and adjustment of operating parameters to optimize treatment performance. Additionally, the absence of continuous flow reduces the risk of hydraulic short-circuiting and enhances treatment efficiency.

Considering these factors collectively, it is evident that the sequential batch reactor presents a compelling solution for wastewater treatment, offering efficiency, flexibility, and operational simplicity. However, it is essential to acknowledge that the selection of the most appropriate treatment method should consider various factors such as site-specific conditions, treatment objectives, and economic considerations. Nonetheless, based on our evaluation, according to the AHP recommendation the Sequential Batch Reactor emerges as a promising option for efficient and effective wastewater treatment.

The paper's limitations are confined to demonstrating the effectiveness of a multi-criteria hierarchical decision-making process.

REFERENCES

[1] R. W. Saaty, “The analytic hierarchy process-what it is and how it is used,” Math. Model., vol. 9, no. 3–5, pp. 161–176, 1987, doi: 10.1016/0270-0255(87)90473-8.

[2] G. Zeng, R. Jiang, G. Huang, M. Xu, and J. Li, “Optimization of wastewater treatment alternative selection by hierarchy grey relational analysis,” J. Environ. Manage., vol. 82, no. 2, pp. 250–259, 2007, doi: 10.1016/j.jenvman.2005.12.024.

[3] M. Chaisar and S. K. Garg, “Selection of Sewage Treatment Technology using Analytic Hierarchy Process,” Mater. Today Proc., vol. 56, pp. 3433–3440, 2022, doi: 10.1016/j.matpr.2021.10.486.

[4] “Typical configuration and main parts of a classic trickling filter.... | Download Scientific Diagram.” Accessed: May 19, 2024. [Online]. Available: https://www.researchgate.net/figure/Typical-configuration-and-main-parts-of-a-classic-trickling-filter-Figure-adapted-from_fig9_266736009

[5] “Sequential Batch Reactor (SBR) Based Sewage Treatment Plant - We Are Environmental Consultants.” Accessed: May 19, 2024. [Online]. Available: https://naturesenvirocare.com/waste-water-treatment/sequential-batch-reactor-sbr-based-sewage-treatment-plant/

[6] “What is anaerobic process in wastewater treatment.” Accessed: May 19, 2024. [Online]. Available:

https://www.netsolwater.com/uasb,-a-wastewater-anaerobic-process.php?blog=1020

[7] Environment Agency, "Wastewater Technology Fact Sheet Dechlorination," Environ. Prot. Agency, no. 2, pp. 1–7, 2000.

[8] K. Koobum, "The characteristic of the sequencing batch reactor (SBR), anaerobic sequencing batch reactor (ASBR) and a sequencing batch biofilm reactor (SBBR)," 2007.

[9] "Up Flow - Anaerobic Sludge Blanket Reactor (UASB) | IWA Publishing." Accessed: May 20, 2024. [Online]. Available: https://www.iwapublishing.com/news/flow-anaerobic-sludge-blanket-reactor-uasb

[10] A. Sharma and N. Rawal, "The selection of wastewater treatment units based on analytical hierarchical process," vol. 77, no. January, pp. 1003–1019, 2021, doi: 10.1007/978-981-15-5195-6_73.

[11] R. Karimi, A. R.; Mehrdadi. N.; Hashemian, S. J.; NabiBidhendi, G. R.; TavakkoliMoghaddam, "Selection of Wastewater Treatment Process Based on Analytical Hierarchy Process," Int. J. Civ. Eng. Technol., vol. 5, no. 9, pp. 27–33, 2011.

[12] G. Eseoglu, K. Yapsakli, H. Tozan, and O. Vayvay, "A novel fuzzy framework for technology selection of sustainable wastewater treatment plants based on TODIM methodology in developing urban areas," Sci. Rep., vol. 12, no. 1, pp. 1–23, 2022, doi: 10.1038/s41598-022-12643-1.

[13] I. Nwaogazie, O. Bovwe, and L. Uba, "Analytical Hierarchy Process in Concept Selection of Wastewater Treatment Plant," Br. J. Appl. Sci. Technol., vol. 17, no. 4, pp. 1–10, 2016, doi: 10.9734/bjast/2016/28978.

[14] Y. Tian, "Selection of Municipal Wastewater Treatment Process Based on Improved Analytic Hierarchy Process," IOP Conf. Ser. Earth Environ. Sci., vol. 295, no. 4, 2019, doi: 10.1088/1755-1315/295/4/042132.

[15] B. Zmaic, "Common problems in wastewater treatment plants function GoranaCosicFlajsig Croatian Water-Zagreb 7WWZ^e6,6%^a(/a ^0X^220," vol. 26, 1999, [Online]. Available: www.witpress.com,

[16] J. A. Silva, "Water Supply and Wastewater Treatment and Reuse in Future Cities: A Systematic Literature Review," Water (Switzerland), vol. 15, no. 17, 2023, doi: 10.3390/w15173064.

[17] G. Zeng et al., "Optimization of wastewater treatment alternative selection by hierarchy grey relational analysis," Sci. Rep., vol. 9, no. 2, pp. 1–7, 2022, doi: 10.1007/978-981-15-5195-6_73.

[18] S. K. Gupta, A. Ramakrishnan, and Y. T. Hung, "Sequencing batch reactors," Handb. Environ. Waste Manag. Air Water Pollut. Control, pp. 511–562, 2012, doi 10.1142/9789814327701_0014.

[19] "Up Flow - Anaerobic Sludge Blanket Reactor (UASB) | IWA Publishing." Accessed: Jun. 23, 2024. [Online]. Available: https://www.iwapublishing.com/news/flow-anaerobic-sludge-blanket-reactor-uasb

[20] A. Mohamed Sheikh Ali, A. Mohamed Ahmed, A. Warsame Hassan Arale, and A. Abdullahi Di, "Water Supply Management and Sustainability in Afgoi District, Somalia," vol. 11, no. January, pp. 0–8, 2021

Citation: *Abdullahi Mohamed Sheikh Ali, et.al (2024). "Selection of Most Suitable Wastewater Treatment Process using Analytical Hierarchy Process ". International Journal of Constructive Research in Civil Engineering (IJCRCE), vol. 8, no. 1, pp. 1-15, 2024. Available: DOI: https:// doi.org/10.20431/2454-8693.0801001*

Copyright: *© 2024 Authors. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited*