Environmental Industry Letters
https://ijitis.org/index.php/EIL
ISSN:
Volume 1, Issue 1
DOI: ***https://doi.org/10.15157/EIL.2023.1.1.1-9***
Received: 05.01.2023, Accepted: 10.02.2023

# Evaluation of Ceramic Water Filters' Performance and Analysis of Managerial Insights by SWOT Matrix

**Mohammad Gheibi[1*], Benyamin Chahkandi[2], Kourosh Behzadian[3], Mehran Akrami[4], Reza Moezzi[1,5]**
[1]Association of Talent under Liberty in Technology (TULTECH), Tallinn, Estonia
[2]School of Civil Engineering, University of Tehran, Tehran, Iran
[3]School of Computing and Engineering, University of West London, London, UK
[4]Departamento de Ingeniería Industrial, Tecnologico de Monterrey, Puebla, Mexico
[5]Institute for Nanomaterials, Advanced Technologies and Innovation, Technical University of Liberec, Czech Republic
*** Mohammad.Gheibi@tultech.eu**

**Abstract**
Filtration is a crucial step in the water treatment process, typically preceding disinfection. Filters trap microorganisms and suspended solids, reducing their amount in the environment. The latest technology in filtration is ceramic filters, and in this study, the performance of silicon carbide ceramic filters (SIC) is evaluated. These filters were installed at three different locations within a water treatment plant (entrance storage, raw water, and backwash water), and changes in physical and chemical water parameters were measured. Results indicate high efficiency in turbidity removal, effectively clarifying volatile suspended solids (VSS) and fixed suspended solids (FSS). The turbidity removal efficiency was 99% for entrance storage and 65% for raw water. The SWOT (Strengths, Weaknesses, Opportunities, and Threats) matrix was used to analyse the results of the SIC and highlight its strengths, weaknesses, opportunities, and threats.

**Keywords**: *Water Treatment; Silicon Carbide filters; Experimental Practices; SWOT Matrix; Managerial Insights*

## INTRODUCTION

The significance of potable water in the distribution network has made water treatment a priority for managers [1]. Due to its direct contact with the human body, drinking water is particularly sensitive, making the treatment process all the more crucial. This has prompted managers to focus more on the water treatment process, leading to various projects aimed at evaluating both existing processes and new methods. With the recent advancements in science and technology, many alternative options have emerged in the water treatment industry [2]. These innovations include new primary measurement equipment, innovative filters, and advanced disinfectants. It is essential for managers to thoroughly evaluate these new products before implementing them to ensure the safety and quality of the drinking water [3], [4].

Filtration is a physical method of removing suspended solids in liquids, including water. These suspended solids can include silt, sludge, dyes, organic material, plankton, bacteria, and other microorganisms. In 1827, Henry Dalton invented a modern form of ceramic cylindrical water filter for sanitation purposes. By 1846, Dalton's ceramics were widely acknowledged as an effective solution for treating infected water. Filters are divided into two categories:

depth filters, which separate suspended particles from the liquid through the depth of the bed (gravity and pressure filters), and surface filters, which perform filtration through surface separation of suspended particles (strainers). As a type of surface filter, ceramic filters rely on their small pore size to filter out suspended solids from water. To prevent microbial contamination, ceramic filters are infused with silver. Ceramic filters have a broad definition, encompassing both potted ceramic filters for household use and wide plate ceramic filters used in water treatment plants. Recently, the use of ceramic filters in household water purifiers has become popular, and ceramic pot filters have been the focus of international health organizations for water purification in underdeveloped countries and impoverished areas due to their low production and operational costs and lack of advanced technology [5], [6].

Many universities and public institutions globally are currently supporting the development of ceramic filters for drinking water purification, often in the form of clay pot filters. This form of filtration is widely used in developing countries due to its effectiveness in eliminating bacteria and pathogens, cultural compatibility, and low cost. Ron Rivera, a researcher based in Guatemala, played a key role in introducing ceramic pot filters to a wider audience and providing affordable drinking water to nations. He conducted extensive research in this field and was part of an innovative research group that aimed to introduce these filters beyond the borders of his country. To support this product and sustain the livelihood of potters in developing countries, Ron established the Pottery for Peace Foundation on a global scale. Through his efforts, he sought to support the product and maintain the jobs of potters in these regions [7].

Numerous studies have been conducted to investigate the efficiency of ceramic filters in drinking water purification. In [7], Bielefeldt explored the efficacy of point-of-use ceramic filters for bacterial purification. In [8] Craver et al. evaluated the effects of local materials and the production process on the silver absorption and resistance of ceramic filters. Salvinelli et al. in [9] modelled the relationship between the filtration rate and turbidity of flowerpot ceramic filters. Ndebele et al. in [10] examined the point-of-use of ceramic filters for removing biological contaminants using silver nitrate as a raw material. In [11] the effectiveness of ceramic pot filters for rural area water purification is analysed in reducing total dissolved solids (TDS), pH, and turbidity. Okechukwu et al. in [12] studied the water purification process using dried duckweed plant in a ceramic filter to assess the removal efficiency of turbidity, total organic carbon (TOC), chloride, nitrate, phosphate, chemical oxygen demand (COD), biological oxygen demand (BOD), total hardness, TDS, and pH. Panchal et al. in [13] initiated research on the adsorption capacity and TDS reduction of water using a new ceramic composite with silica as the base material and activated carbon and eggshell nanoparticles as filler materials using the gel casting technique. Mustapha et al. in [14] researched the removal of biological contaminants and reduction of COD, BOD, chloride, nitrates, sulfate, TDS, total suspended solids (TSS), total solids (TS), and total hardness in wastewater using different compositions of kaolin and sawdust ceramic pot filters. Shafiquzzaman et al. in [15] investigated the potential of iron-amended ceramic filters in households for removing arsenic from groundwater with single-unit and double-unit configurations. In [16], Florent studied the application of ceramic filters for removing microbial contaminants in water treatment. Yang et al. in [17] explored the effectiveness of Lanthanum (III)-coated ceramic filters for point-of-use water treatment to remove bacterial contaminants. Putri et al. in [18] conducted research on the efficiency of reducing TDS using different compositions of ceramic filters fabricated using a residue catalytic cracking (RCC) unit spent catalyst, clay, and Dioscorea hispida starch (DHS) at various compositions.

In this study, the capabilities of a cutting-edge silicon carbide ceramic filtration system in delivering desirable drinking water parameters are analysed using a SWOT (strengths, weaknesses, opportunities, and threats) analysis matrix.

## MATERIALS AND METHODS

In order to evaluate the performance of new generation of silicon carbide ceramic filter, pilot sizes were prepared and installed in three different parts of the treatment plant. The whole experiment was done in a local treatment plant located in Razavi Khorasan province, Iran.

### *Ceramic Filter*

One of the newest filters are ceramic filters which have high porosity and can eliminate contaminants using adsorption process. Ceramic filters are usually made of a mixture of clay and combustible material such as sawdust. Also, some additive compounds like colloidal silver, activated carbon and carbide is added to the mixture before or after firing. They work by allowing water to flow through the millions of tiny pores on the casing of the ceramic cartridge. These pores, a half micron in size, trap impurities as the water passes through them

In the present study, the pilot size was installed in three different location including entrance storage, raw water and backwash water. The performance of new generation silicon carbide ceramic filtration system was evaluated by measuring the physical and chemical parameters of water in and out of the filter in these three different locations. Twenty parameters including (1) turbidity (NTU), (2) electrical conductivity (µs/cm), (3) pH, (4) nitrate (mg/l), (5) sulphate (mg/l), (6) chlorine (mg/l), (7) sodium (mg/l), (8) potassium (mg/l), (9) dry residue (mg/l), (10) calcium hardness (mg/l-$CaCO_3$), (11) magnesium hardness (mg/l-$CaCO_3$), (12) total hardness (mg/l-$CaCO_3$), (13) total alkalinity (mg/l-$CaCO_3$), (14) free carbonic gas (mg/l), (15) total carbonic gas (mg/l) (16) bicarbonate (mg/l), (17) calcium (mg/l), (18) magnesium (mg/l), (19) Heterotrophic Plate Counts (HPC), and (20) Total Organic Carbon (TOC) (mg/l) were measured.

All the experimental practices of this research is done in a Water Treatment Plant No. 1, Mashhad City, Iran. Likewise, all the measurement process is done according to Standard Methods for the Examination of Water and Wastewater [19]. The structure of evaluated water treatment plant and sampling points for SIC performance experimental tests is demonstrated as per Figure 1. In this research the applied ceramic filtration is put in three points including a) entrance of dam (as water storage), b) entrance of water treatment plant (as raw water), and c) for treatment of backwash water. In each place the declared twenty features elimination performance is evaluated.

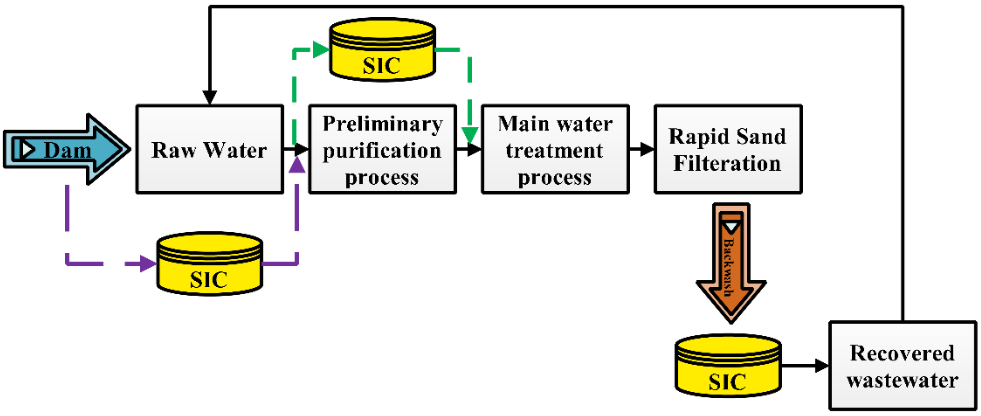


**Figure 1**. The details of water treatment in the case study and sampling points

## *SWOT Analysis*

The SWOT analysis is a useful tool in strategic planning that helps to identify the strengths, weaknesses, opportunities, and threats of a project. This approach was first introduced by George Albert Smith and Roland Christensen, two graduates from Harvard Business School in the 1960s. SWOT analysis involves a quantitative approach to evaluation, making use of multi-layer designs and simplifying information, which enables a simultaneous analysis of several basic parameters and thus, an evaluation of the overall performance of the filter. The method involves gathering data from various sources, such as consulting companies, past examples, and reference books.

The first step in strategic planning is to establish the organization's goals and objectives. Then, through SWOT analysis, a suitable plan can be developed to ensure that the organization's strengths and weaknesses are balanced. Strength refers to the superior competencies of the organization, such as financial resources, positive customer perception, strong supplier relationships, and others. Weakness, on the other hand, is any limitation or shortage of resources, skills, facilities, or abilities that hinder the organization's performance. Opportunities are major external successes, such as untapped markets, changes in competition, improvements in customer and supplier relations, and others. Threats are external dangers, such as the bargaining power of key buyers or suppliers, sudden changes in technology, and other factors that could harm the organization's success.

A SWOT analysis can vary in detail and complexity depending on the scope and size of the subject being analysed. In a more comprehensive SWOT analysis, the following factors should be considered:

- The likelihood of being able to take advantage of opportunities
- The feasibility of overcoming weaknesses and leveraging strengths
- The possibility and potential impact of a specific risk (threat) occurring
- The ability to continually monitor for risks and identify them early on
- The capacity to mitigate a potential risk if it becomes a threat.

The format of the utilized SWOT matrix is depicted in Figure 2. It should be noted that the derivation of the revealed managerial insights was achieved through the interview of five experts in the case study.

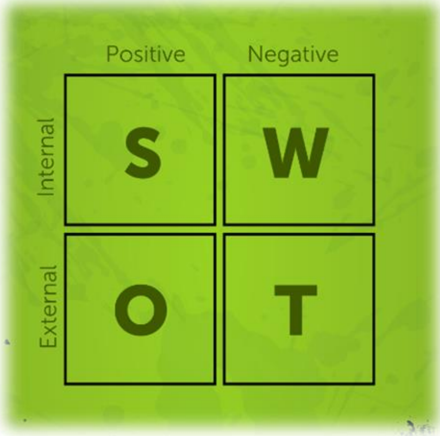


**Figure 2.** The structure of SWOT matrix for managerial insights about SIC application in the water treatment plant [20]

## RESULTS AND DISCUSSION

The water was tested for its most crucial physical and chemical indicators both before entering the filter and at the filter outlet. Samples were taken from three different points of the treatment plant - the inlet basin, raw water inlet, and return water - and the results were recorded. Figures 3, 4, and 5 show the findings from the experiments in each of these locations. The results showed a significant reduction in turbidity by 99.2%, indicating that fixed and volatile suspended solids (FSS & VSS) were effectively eliminated. However, the system did not have a significant impact on removing volatile and fixed dissolved solids (VDS & FDS). The low efficiency in removing total organic carbon (TOC) suggests that FSS constituted the majority of total suspended solids (TSS). The Figures 3 and 4 indicate that the silicon carbide ceramic filters (SIC) system used in this study had a high efficiency in removing heterotrophic microorganisms. This confirms the reliability of the system in removing HPC. The high removal of turbidity was expected given these results.

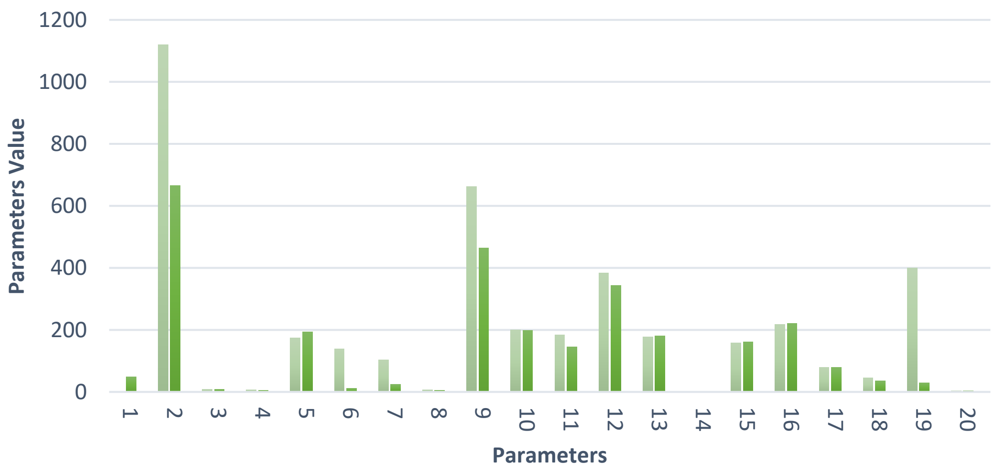


**Figure 3.** Comparison the performance of the SIC system in entrance storage of water treatment, changes in physical and chemical parameters (red and blue columns represent influent and effluent characteristics, respectively)

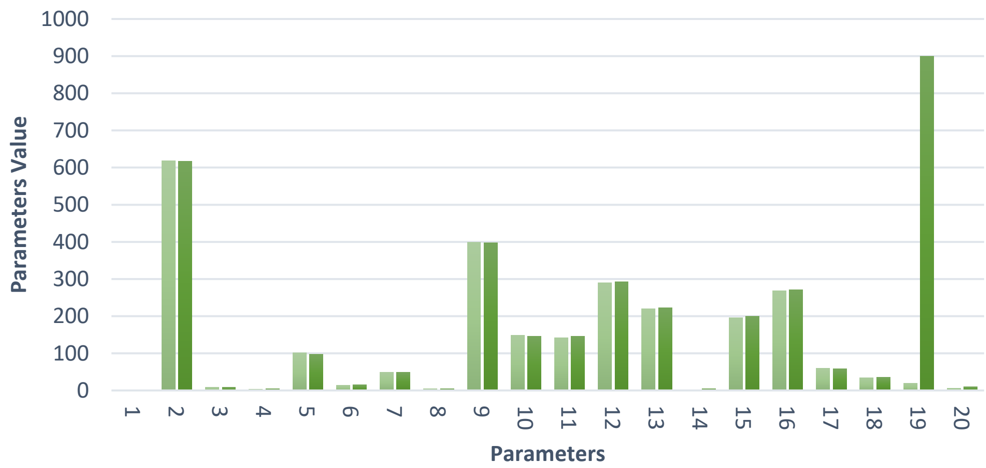


**Figure 4.** The comparison of SIC system performance in raw water treatment, changes in physical and chemical parameters (red and blue columns represent influent and effluent characteristics, respectively)

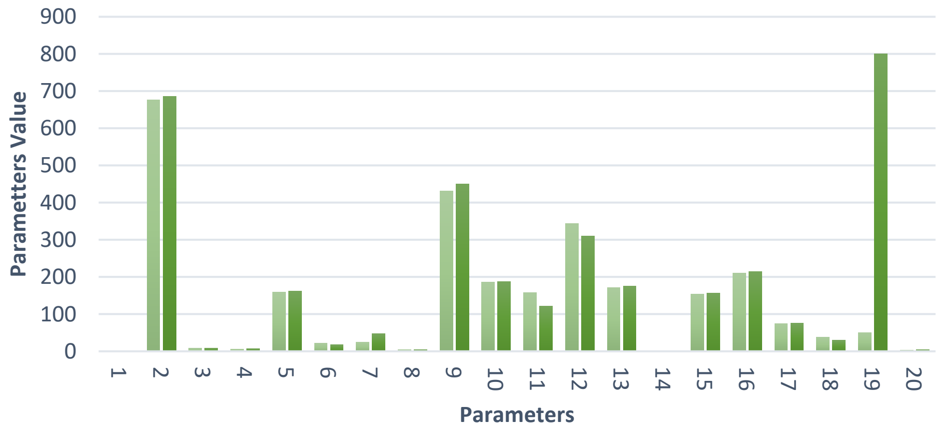


**Figure 5.** The comparison of SIC system performance in backwash water treatment, changes in physical and chemical parameters (red and blue columns represent influent and effluent water characteristics, respectively)

According to [12], the application of dried duckweed plant in a ceramic filter resulted in 100% reduction in turbidity, 81.2% reduction in TOC, 95.41% reduction in chloride, 92.34% reduction in nitrates, 97.75% reduction in phosphate, 46.82% reduction in total hardness, and 76.15% reduction in TDS in water characteristics. Mustapha et al. in [14] reported that a ceramic filter made from kaolin and sawdust reduced nitrates by 49.07%, sulphate by 82.97%, TSS by 78.70%, and TDS by 86.84%. Putri et al. in [18] found that using a ceramic filter composed of 37.5% activated spent catalyst, 60% clay, and 2.5% Dioscorea hispida starch reduced TDS by 51.44%. Ndebele et al. in [10] showed that using silver nitrate as a raw material in ceramic water filters reduced total coliforms and E. coli by 95% and 99% respectively.

The results of SWOT analysis are shown in Table 1. The strengths, weaknesses, opportunities and threats of using SIC system is discussed in detail. All the outcomes of Table 1 are obtained as per knowledge management of the water treatment plant in the case study.

**Table 1.** Evaluation the performance of SIC filters using SWOT analysis

| | |
|---|---|
| Strengths | 1. High efficiency in decreasing water turbidity.<br>2. Due to the small space occupation, the costs of investing on lands would considerably reduce.<br>3. This system is flexible and it can easily be moved<br>4. This system can work well at high microbial loads and would improve water standards.<br>5. Due to its geometrical, physical and structural properties; it allows the operator to serialize and parallelize.<br>6. Due to plate filtration system and low-pressure operation the amount of energy consuming and other operating costs are reduced. |
| Weaknesses | 1. This system is not capable of removing fixed and volatile dissolved solids (FDS and VDS) which may affect water standards.<br>2. Behaviour and the durability of the system under high or low acidity is not clear.<br>3. Due to its small pore size, this system could be clogged that would make the operation difficult.<br>4. The dispersion and advection processes which are dependent on flow rate in contaminants transition mechanism would work better in this system due to the lateral adsorption. |
| Opportunities | 1. Due to its high porosity, this system will work properly under intentional and unintentional contamination that treatment plants are not designed to treat.<br>2. These systems can be used as a pretreatment system in water treatment process, so the use of chemicals and primary disinfection would reduce. |
| Threats | 1. The major threat of this system is the probability of biofilm formation. In this case, the value of TSS in the effluent water would increase and consequently water quality and subsequent processes such as chlorination may be significantly reduced.<br>2. These systems may have some unknown issues in the long run that will reduce the system efficiency. |

## CONCLUSION

The provision of safe drinking water is a critical concern for managers and citizens alike, and water purification plays a vital role in this process. The multi-step purification process removes pollutants and other substances to bring water within the limits specified by standards. Filters are commonly used at different stages of the treatment process, one of which is ceramic filters, which have gained popularity over the last two decades. The present study evaluated the effectiveness of a new generation of silicon carbide ceramic filters (SIC). The filtration process reduced water contaminants and solids, and the performance of the SIC was measured against 20 parameters of the water influent and effluent. Results showed a decrease in turbidity of 99.2%, while there was no improvement in the elimination of VDS and FDS. A SWOT analysis was also conducted to assess the performance of the ceramic filters.

## ACKNOWLEDGMENT

The authors would like to thank the Association of Talent under Liberty in Technology (TULTECH) in Estonia for supporting this research project.

## CONFLICT OF INTERESTS

The authors confirm that there is no conflict of interests associated with this publication.

## REFERENCES

[1] Nakhaei, M., Akrami, M., Gheibi, M., Coronado, P.D.U., Hajiaghaei-Keshteli, M. and Mahlknecht, J., 2022. A novel framework for technical performance evaluation of water distribution networks based on the water-energy nexus concept. Energy Conversion and Management, 273, p.116422.

[2] Gheibi, M., Emrani, N., Eftekhari, M., Akrami, M., Abdollahi, J., Ramezani, M. and Sedghian, A., 2019. Experimental investigation and mathematical modeling for microbial removal using potassium permanganate as an oxidant—case study: water treatment plant No. 1, Mashhad, Iran. Environmental monitoring and assessment, 191, pp.1-10.

[3] Arab, M., Akbarian, H., Gheibi, M., Akrami, M., Fathollahi-Fard, A.M., Hajiaghaei-Keshteli, M. and Tian, G., 2022. A soft-sensor for sustainable operation of coagulation and flocculation units. Engineering Applications of Artificial Intelligence, 115, p.105315.

[4] Pouresmaeil, H., Faramarz, M.G., ZamaniKherad, M., Gheibi, M., Fathollahi-Fard, A.M., Behzadian, K. and Tian, G., 2022. A decision support system for coagulation and flocculation processes using the adaptive neuro-fuzzy inference system. International Journal of Environmental Science and Technology, 19(10), pp.10363-10374.

[5] Ahmed, K.J., 2019. Development Of Low-Cost Water Purification Technology for Rural Community (Doctoral dissertation, Addis Ababa Science and Technology University)

[6] Plappally, A.K., 2010. Theoretical and empirical modelling of flow, strength, leaching and micro-structural characteristics of V shaped porous ceramic water filters (Doctoral dissertation, The Ohio State University).

[7] Bielefeldt, A.R., Kowalski, K. and Summers, R.S., 2009. Bacterial treatment effectiveness of point-of-use ceramic water filters. Water research, 43(14), pp.3559-3565.

[8] Vinka Oyanedel-Craver, Sophia Narkiewicz, Richard Genovesi, Aaron Bradshaw, Dawn Cardace, Effect of local materials on the silver sorption and strength of ceramic water filters, Journal of Environmental Chemical Engineering, Volume 2, Issue 2, June 2014, Pages 841-848.

[9] Salvinelli, C., Elmore, A.C., Reidmeyer, M.R., Drake, K.D. and Ahmad, K.I., 2016. Characterization of the relationship between ceramic pot filter water production and turbidity in source water. Water research, 104, pp.28-33.

[10] Ndebele, N., Edokpayi, J.N., Odiyo, J.O. and Smith, J.A., 2021. Field Investigation and Economic Benefit of a Novel Method of Silver Application to Ceramic Water Filters for Point-Of-Use Water Treatment in Low-Income Settings. Water, 13(3), p.285.

[11] Grema, A.S., Idriss, I.M., Alkali, A.N., Ahmed, M.M. and Iyodo, M.H., 2021. Production of Clay-based Ceramic Filter for Water Purification. European Journal of Engineering and Technology Research, 6(7), pp.140-143.

[12] Okechukwu, J.O., Osemeahon, S.A. and Dimas, B.J., 2021. Development and Evaluation of the Performance of Ceramic Water Filter Prepared from Dried Duckweed Plant. DEVELOPMENT, 4(1), pp.53-61.

[13] Panchal, M., Raghavendra, G., Omprakash, M. and Ojha, S., 2021. Fabrication and Characterization of Silica Based Ceramic Composite for Filtration Applications. Silicon, 13(6), pp.1951-1960.

[14] Mustapha, S., Oladejo, T.J., Muhammed, N.M., Saka, A.A., Oluwabunmi, A.A., Abdulkabir, M. and Joel, O.O., 2021. Fabrication of porous ceramic pot filters for adsorptive removal of pollutants in tannery wastewater. Scientific African, 11, p.e00705.

[15] Shafiquzzaman, M., Hasan, M.M., Haider, H., Bari, Q.H., Yassine, E.G. and Nakajima, J., 2022. Arsenic removal by household-based ceramic filters: Evaluating mode of operations and influence of groundwater compositions. Journal of Water Process Engineering, 46, p.102598.
[16] Florent, P., Cauchie, H.M., Herold, M. and Ogorzaly, L., 2022. Bacteriophages pass through candle-shaped porous ceramic filters: Application for the collection of viruses in soil water. MicrobiologyOpen, 11(5), p.e1314.
[17] Yang, H., Zhu, S., Lin, X., Wu, J., Du, X., Chen, R., Wang, Y., Xu, S., Hu, L.X. and Ying, G.G., 2022. Lanthanum (III)-Coated Ceramic Filters in Point-of-Use Water Treatment for Bacterial Removal. ACS ES&T Water, 2(4), pp.583-592.
[18] Putri, R.E.D., Nasir, S. and Hadiah, F., 2022. Application of Ceramic Filter and Reverse Osmosis Membrane for Produced Water Treatment. Pollution, 8(4), pp.1103-1115.
[19] Rice, E.W., Bridgewater, L. and American Public Health Association eds., 2012. Standard methods for the examination of water and wastewater (Vol. 10). Washington, DC: American public health association.
[20] Gheibi, M., Karrabi, M., Mohammadi, A. and Dadvar, A., 2018. Controlling air pollution in a city: A perspective from SOAR-PESTLE analysis. Integrated environmental assessment and management, 14(4), pp.480-488.