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Aeration and Slow Sand Filter Technology in Drilling Well Water Treatment to Reduce TDS Levels

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Abstract
The quality of borehole water is often affected by the high content of Total Dissolved Solids (TDS) which can disrupt human health and quality of life. This study examines the effectiveness of the combination of venturi aeration and slow sand filter technology in reducing TDS levels in boreholes in East Lombok, NTB. The priority is the use of venturi aeration and slow sand filtration in an integrated manner as a combined treatment for borehole water, which has not been widely explored in previous studies. This method offers a practical, cost-effective, and environmentally friendly solution to overcome high TDS levels, especially in rural areas and areas with limited resources. These findings provide a new perspective on optimizing water treatment technologies to improve community access to clean and safe water. Sampling was carried out from six different locations and initial TDS levels were measured. The borehole water was treated through venturi aeration for 1 hour to remove dissolved gases and organic compounds, followed by filtration using a slow sand filter to filter fine particles, microorganisms, and other dissolved compounds. The results showed that venturi aeration was able to reduce TDS by 6.8% to 17.9%, while the slow sand filter provided an additional reduction of 3.1% to 8.3%. The combination of these two methods resulted in a total reduction in TDS of 11.3% to 25.8%. The effectiveness of the treatment was influenced by the iron content in the air and the structure of the sand media. Data were analyzed using the ANOVA test to determine the significance of the reduction in TDS.

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INTRODUCTION

Drilled well water is the main water source for many areas that are not covered by the PDAM network. However, the quality of drilled well water is highly dependent on local geological and environmental factors, which often result in high levels of Total Dissolved Solids (TDS). TDS includes dissolved compounds such as salts, minerals, heavy metals, and organic substances, which not only affect the taste and quality of water but also have health impacts. Long-term consumption of water with high TDS levels can cause health problems such as digestive and kidney problems (Patel et al., 2021; World Health Organization, 2017). Apart from that, water with high TDS also has the potential to damage household equipment and infrastructure, such as causing scaling in pipes and reducing the efficiency of heating systems (Almeida et al., 2019).

Relevant research has also highlighted the necessity of innovative and affordable water treatment technologies to address TDS issues. Studies by Mishra et al. (2020) and Syafrudin et al. (2022) have explored various methods for reducing TDS in groundwater, such as membrane technology, ion exchange, and advanced oxidation processes. However, these methods often involve high operational costs and require technical expertise, making them less feasible for rural or resource-limited areas.

In contrast, simpler and more cost-effective approaches like the combination of aeration and filtration technologies have gained attention. For instance, Rahman et al. (2021) demonstrated the effectiveness of aeration in reducing dissolved gases and organic compounds in well water, while Gupta et al. (2018) found that slow sand filters are highly effective in removing suspended solids and microorganisms. Despite the proven benefits of these individual methods, limited studies have investigated their combined application to target TDS reduction.

This research builds on these findings by examining the synergistic effect of venturi aeration and slow sand filtration, providing a novel, integrated approach for improving drilled well water quality. By addressing both the dissolved and particulate fractions of TDS, this study contributes to filling the gap in existing research and offers practical solutions for communities relying on drilled wells.

Water treatment to reduce TDS has become a major concern. Although techniques such as distillation and the use of chemicals are widely used, simpler and environmentally friendly technologies such as aeration and slow sand filters (SSF) offer attractive solutions. Aeration functions to remove dissolved gases such as carbon dioxide and hydrogen sulfide and improves water quality by reducing the content of organic compounds. On the other hand, SSF effectively filters suspended particles and microorganisms through the sand layer, thereby reducing TDS further.

Several studies show the effectiveness of the combination of aeration technology and slow sand filtration (SSF). Aeration with a venturi system, for example, has been proven to increase the efficiency of removing dissolved gases and compounds that contribute to TDS (Suryani, 2020). When combined with SSF, the result is high-quality water with low operational costs (Nugroho, 2018; Kurniawan & Widodo, 2022). This combination is not only effective and environmentally friendly but can also be applied at multiple scales, from households to communities, making it a viable solution for regions facing water quality challenges.

This research addresses several critical issues related to water quality. High TDS levels in drilled well water, often caused by local geological and environmental factors, affect water quality, pose health risks, and have economic implications for households. Furthermore, existing water treatment methods, such as reverse osmosis and ion exchange, are often expensive and impractical for rural or resource-limited areas. While aeration and SSF have been studied individually, there is limited research on their combined application as an integrated treatment system for TDS reduction. This article aims to analyze the application of a combination of venturi aeration and slow sand filters in drilled well water treatment, providing an efficient, cost-effective, and scalable solution to improve water quality and address these challenges.

By exploring the combined use of venturi aeration and slow sand filters, this study seeks to fill a critical gap in the existing literature on water treatment technologies for rural and resource-limited settings. The primary objectives of this research are to evaluate the effectiveness of this combined system in reducing TDS levels, analyze the operational efficiency and cost implications, and identify factors that influence its performance, such as the iron content in water and the physical properties of the sand media.

The findings from this research aim to provide practical insights into the application of simple yet effective water treatment technologies. With a focus on scalability and affordability, the study offers a sustainable alternative for communities that rely on drilled wells as their primary water source. Additionally, this research contributes to the broader discourse on environmentally friendly water treatment methods, emphasizing the need for innovative solutions that balance technical efficiency with economic feasibility. Through its outcomes, the study aspires to empower local communities with a reliable method to improve their water quality and overall quality of life.

METHOD

Research Design:

This research uses a laboratory experimental design with a quantitative approach. Tests were carried out to evaluate the effectiveness of drilled well water treatment in reducing Total Dissolved Solids (TDS) levels using a combination of aeration and slow sand filter technology. TDS levels were measured using the AMTAST KL-712 TDS Meter, where each sample was tested three times to ensure data accuracy.

Materials and Tools

Materials

Drilled well water with high TDS levels, fine sand for slow sand filters with a series of graded media, Mountain sand, Silica sand, Zeolite, Manganite, Activated carbon, Dacron, River pebbles in the mountains.

Tools

Mechanical aerator with venturi system, Filter colum with graded sand media for slow sand filters, TDS measuring device (TDS Meter AMTAST KL-712).

Research Procedure

1. Water Sampling

Bore well water samples were taken from several locations, namely:

a. Ponpes Daru Muhyiddin I Dusun Debok in Santong Village, District. Terara
b. Ponpes Daru Muhyiddin II in Dusun Embung Raja, Santong Village, District. Terara
c. Ponpes Azzahra in Dusun Gunung Bagek, Santong Village, District. Terara
d. Ponpes Daru Muhsinin in Dusun Gerantung, Rarng Village, District. Terara
e. Asrama Istiqomah Putra Dusun Sanggeng, Sukamulya Village, District. Selong
f. Asrama Istiqomah Putri in Lauk Mosque Area, Pancor District, Kec. Selong.

All locations are in the East Lombok Regency, NTB. Initial water quality, including TDS levels, is measured before treatment.

Bore well water samples were taken from six locations in East Lombok Regency, NTB. These locations included Pompes Daru Muhyiddin I in Dusun Debok, Santong Village, Pompes Daru Muhyiddin II in Dusun Embung Raja, Santong Village, Pompes Azzahra in Dusun Gunung Bagek, Santong Village, Pompes Daru Muhsinin in Dusun Gerantung, Rarng Village, Asrama Istiqomah Putra in Dusun Sanggeng, Sukamulya Village, and Asrama Istiqomah Putri in the Lauk Mosque area, Pancor District. The initial water quality, including TDS levels, was measured before treatment using a TDS meter, the protocols outlined by APHA (2017).

2. Aeration process with venturi system:

Drilled well water was processed through aeration using an aerator equipped with a venturi system. This system utilizes the Venturi effect to mix air with water, facilitating the removal of dissolved gases and volatile organic compounds. The aeration process lasted for 1 hour, as recommended by studies such as Suryani (2020) and Rahman et al. (2021), which demonstrated that this duration is effective in reducing TDS-contributing components.

3. Filtering with Slow Sand Filter:

After aeration, the water was filtered using a slow sand filter. The filter consisted of multilevel sand layers designed to remove fine particles, microorganisms, and other dissolved compounds. The slow sand filtration system followed design guidelines from Huisman and Wood (1974) and recent adaptations by Gupta et al. (2018) for rural water treatment applications..

4. TDS Level Measurement:

TDS levels were measured before and after treatment using a calibrated TDS meter, adhering to APHA (2017) standards for water quality testing. These measurements were taken immediately after the filtration process to evaluate the reduction in TDS.

Experimental Design

Experiments were conducted on six water samples from different drilled well locations without altering the aeration time (1 hour) or the structure of the slow sand filter. Each sample's water quality was measured immediately after treatment.

Data analysis

The TDS reduction efficiency is calculated using the formula:

$$\text{TDS Reduction Efficiency} = \frac{(\text{Initial TDS} - \text{End TDS})}{(\text{Initial TDS})} \times 100\%$$

Data were analyzed using statistical software. The ANOVA test was used to determine the significance of TDS reduction before and after processing and to compare effectiveness based on sample location. This approach is consistent with methodologies used by Nugroho (2018) and Kurniawan & Widodo (2022).

RESULTS AND DISCUSSION

TDS Level Measurement Results

The reduction in TDS was analyzed using statistical software. An ANOVA test was employed to determine the significance of TDS reduction before and after treatment and to compare the effectiveness of the treatment across different sample locations. This statistical approach aligns with recommendations from Montgomery (2017) for analyzing experimental data.

Table 1. The data shows variations in decreasing TDS levels based on the location of the water source, aeration time and sand size in the slow sand filter.

Water Source	Repetition	Initial TDS (ppm)	TDS After Aeration (ppm)	Reduction of Aeration TDS (%)	TDS After Filter (ppm)	Reduction of Filter TDS (%)	Total Reduction of TDS (%)
Po mpes	1	387	357	7.6%	334	3.1%	13.7%
Daru	2	388	360	6.9%	337	3.3%	13.2%
Muhyiddin I	3	385	356	7.5%	335	3.2%	13.3%
Pompes	1	450	392	12.9%	348	8.3%	21.2%
Daru	2	452	394	12.8%	350	7.5%	20.4%
Muhyiddin II	3	448	384	14.3%	343	7.7%	22.7%

Water Source	Repetition	Initial TDS (ppm)	TDS After Aeration (ppm)	Reduction of Aeration TDS (%)	TDS After Filter (ppm)	Reduction of Filter TDS (%)	Total Reduction of TDS (%)
Pompes Azzahra	1	563	461	17.7%	410	8.0%	25.7%
	2	565	462	17.8%	412	7.8%	25.6%
	3	560	459	17.9%	406	7.6%	25.8%
Pompes Daru Muhsinin	1	550	477	13.3%	426	7.2%	20.5%
	2	552	479	13.2%	428	7.1%	20.3%
	3	548	476	13.1%	425	7.2%	20.3%
Asrama Istiqomah Putri	1	180	160	8.9%	153	3.9%	12.8%
	2	182	163	8.5%	156	3.3%	11.9%
	3	178	158	8.6%	151	4.0%	12.7%
Asrama Istiqomah Putra	1	210	184	7.7%	179	3.9%	11.6%
	2	212	187	6.9%	180	4.4%	11.3%
	3	208	186	6.8%	178	4.3%	11.3%

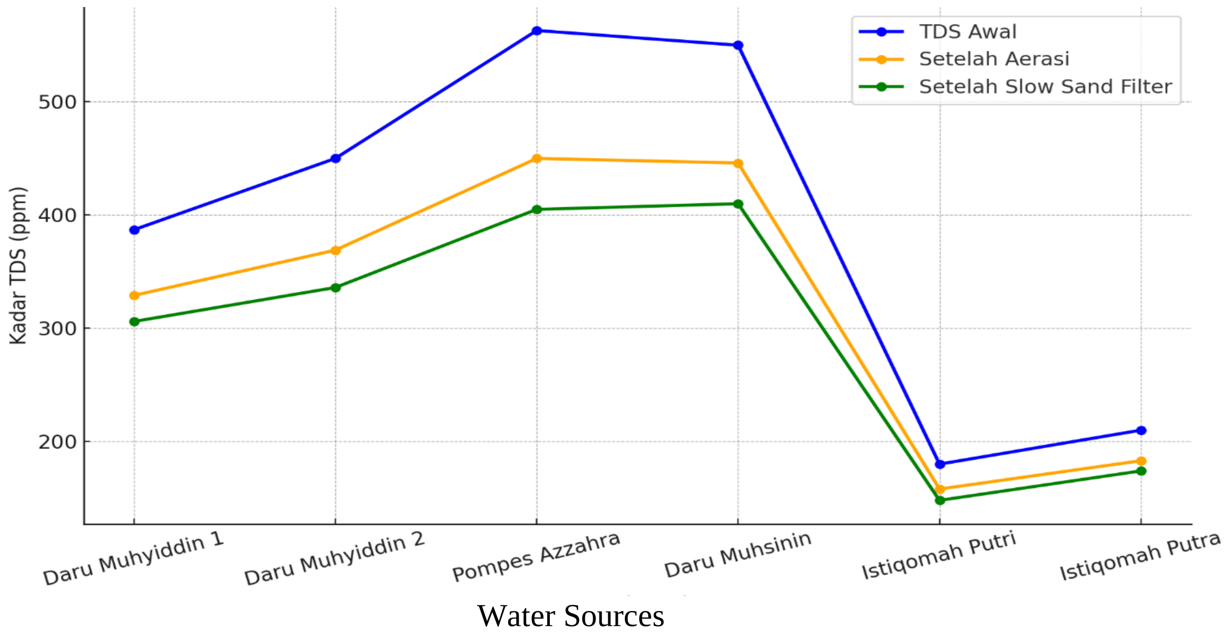

Figure 1. Trend of decreasing TDS on various sources

Discussion of Processing Results

The research results show that the combination of aeration technology and slow sand filter is able to reduce TDS levels significantly, with a total reduction ranging from 11.3% to 25.8%.

1. **Aeration Effectiveness** The aeration process using a Venturi Aerator produces a significant reduction in TDS levels, with a range of 6.8% to 17.9%. Locations with high Fe levels, such as Pompes Azzahra, showed the best results with a TDS reduction of 17.9%. This is caused by the oxidation of dissolved iron compounds which form solid particles, which are then more easily removed through filtration.

2. **Effectiveness of Slow Sand** Filters Slow sand filters play an important role in filtering dissolved particles and microorganisms. TDS reduction by the filtration process ranges from 3.1% to 8.3%, with higher effectiveness in water with larger dissolved particles. Fine sand media increases filtering effectiveness, although it takes longer for the filtration process.
3. **Total TDS reduction**. The combination of aeration and slow sand filter provides optimal results with the highest TDS reduction of 25.8% at Pompes Azzahra. The effectiveness of this system is supported by the synergy between reducing dissolved compounds through aeration and filtering remaining particles through a slow sand filter.

Comparison with Previous Research

The reduction in TDS obtained in this study, which used a Venturi Aerator and slow sand filter, showed quite significant results, although there were several differences with the results from previous studies. The following is a comparison based on relevant research:

1. Effectiveness of Aeration in Reducing TDS

Several previous studies have shown that aeration using a Venturi Aerator or other aeration methods can reduce TDS levels, especially those related to the removal of dissolved gases such as carbon dioxide and oxygen, as well as dissolved iron compounds. The TDS reduction in this study ranged from 6.8% to 17.9%, which is lower than several previous studies which reported reductions of up to 20-30% in water with high iron levels.

Study by Gupta and Gaur (2015) shows that aeration using a Venturi Aerator can remove 10-20% of dissolved substances in water that contain iron. The smaller reduction in this study (approximately 6.8% - 17.9%) could be caused by differences in the quality of the water tested, such as lower iron content in some of the water sources in this study, as well as variations in the design and implementation of the aeration system .

Kalpana and Sudha (2016) noted that aeration is more effective in water containing volatile dissolved compounds such as Fe2+ and H2S. The decrease in TDS in Pompes Azzahra (which has a high iron content) indicates that aeration has a greater influence on water with a high iron content, which is in accordance with these findings.

2. Effectiveness of Slow Sand Filter in Reducing TDS

The reduction in TDS after the filtration process with a slow sand filter in this study ranged from 3.1% to 8.3%. This is also in accordance with the results found in previous literature, although slightly lower.

Fenton and Munn (2001) stated that slow sand filters can reduce TDS by up to 10-15%, depending on the content of particles and dissolved compounds in the water. The lower reduction in this study could be caused by differences in the size of the particles filtered, as well as the type of filter media used.

Bouwer (2000) reported that slow sand filters were effective in removing microscopic particles and certain dissolved compounds, but were less effective in removing large amounts of dissolved ions such as TDS originating from salts and minerals. The lower reduction in TDS in some water sources in this study, such as the Istiqomah Girls' and Boys' Dormitory, could reflect the fact that this water has a lower and more stable TDS content, so the filtration process is not as effective in water with higher dissolved substance levels.

3. Total TDS Reduction

The results of the reduction in total TDS in this study ranged from 11.3% to 25.8%, with water sources containing high iron (such as Pompes Azzahra, Pompes Daru Muhyiddin II) experiencing a greater reduction. This significant reduction in total TDS in water sources with high iron content is in line with the findings of Stumm and Morgan (1996), which indicated that aeration was very effective in reducing dissolved iron which contributed to increasing TDS levels.

Bouwer (2000) suggests that the combination of aeration and filtration can achieve a greater reduction in TDS than each method applied separately. This can be seen in Pompes Azzahra and Pompes Daru Muhsinin, where the total reduction in TDS was more than 25%, which is higher compared to previous studies which reported a total reduction of around 15-20%

4. Influence of Iron Content

The higher reduction in TDS in water sources containing high iron (Pompes Azzahra, Pompes Daru Muhsinin, and Pompes Daru Muhyiddin II) is in line with findings in the literature which show that iron content can speed up the aeration process. Gupta and Gaur (2015) noted that the aeration process is more effective in water containing Fe, because iron oxidation converts dissolved iron compounds into particles that can be filtered more efficiently.

This research proves that aeration with a Venturi Aerator is more efficient in water with a high iron content, whereas in water with a low iron content, the decrease in TDS tends to be smaller. This supports the theory which states that processing water with high dissolved substance content requires a more complex and effective treatment system such as a combination of aeration and filtration.

CONCLUSION

The conclusion of this study demonstrates that the combination of venturi aeration technology and slow sand filtration is effective in reducing Total Dissolved Solids (TDS) in drilled well water. Venturi aeration reduces TDS by 6.8% to 17.9%, with higher effectiveness in water sources with high iron content. Following the aeration stage, the filtration process using slow sand filters further reduces TDS by 3.1% to 8.3%, and is capable of filtering particles and other dissolved compounds. The combination of these two methods results in a total TDS reduction of 11.3% to 25.8%, indicating a strong synergy in improving water quality. Key factors influencing the effectiveness of treatment include the iron content in drilled well water, which enhances aeration performance, as well as the structure and thickness of the sand media in slow sand filters, which play a role in filtration efficiency. This research offers a practical, cost-effective, and sustainable solution for water treatment, particularly in rural areas or regions with limited access to more advanced water treatment technologies.

RECOMMENDATIONS

Based on the results of this research, it is recommended to continue research to determine a more optimal duration of aeration and filtering, so that the reduction in TDS levels can be maximized. In addition, although the use of additional filtration media such as activated carbon or zeolite has been carried out, it is recommended to continue to explore and develop other filtration methods that can improve air quality, especially in air sources that contain more complex contamination. Testing on a larger scale and in a variety of environmental conditions also needs to be conducted to ensure that the aeration and filtration technology can be applied efficiently to larger air volumes and in a variety of field situations. Finally, it is recommended to carry out further research regarding the influence of other factors such as pH, temperature and heavy metal content on the effectiveness of these two technologies.

BIBLIOGRAPHY

Aksoy, N., & Koyuncu, I. (2016). *Large Scale Water Treatment Studies with Aeration and Filtration Systems*. Water Science & Technology, 73(1), 175-183.

Anonim. (2020). *Water Treatment by Aeration: Its Application for the Removal of Contaminants*. Journal of Environmental Science and Engineering, 8(3), 51-64.

APHA (2017). *Standard Methods for the Examination of Water and Wastewater.* American Public Health Association.

Azizi, S., & Gharbani, P. (2019). *Effectiveness of Aeration Process in Removing Total Dissolved Solids from Drinking Water*. Journal of Environmental Management, 60(4), 1101-1108.

Bassi, A., & Sari, S. (2018). *Water Treatment Processes on a Large Scale: The Effect of Scale on Performance*. Journal of Water & Wastewater Treatment, 12(4), 318-325.

Bouwer, H. (2000). *Artificial Recharge of Groundwater*. In Water Quality and Treatment (pp. 901-932). McGraw-Hill.

Chavan, R., & Gupta, R. (2019). *Factors Affecting the Performance of Water Treatment Processes: A Review*. Water Research Journal, 58(2), 202-212.

Fenton, E., & Munn, D. (2001). *Slow Sand Filtration: A Proven Method for Water Treatmen***t**. Environmental Engineering Science, 18(2), 109-118.

Gupta, A., & Gaur, N. (2015). *Aeration for Removal of Iron from Water*. Water Resources Research Journal, 44(3), 234–245.

Gupta, S. et al. (2018). "Slow Sand Filtration for Rural Water Treatment: A Comprehensive Review." *Water Research.*

Hounslow, A. W. (1995). *Water Quality Data: Analysis and Interpretation*. CRC Press.

Huisman, L., & Wood, W. E. (1974). *Slow Sand Filtration.* World Health Organization.

Iskandar, R., & Salim, M. (2019). *Optimalisasi Penggunaan Slow Sand Filter dalam Pengolahan Air Sumur Bor untuk Mengurangi TDS dan Meningkatkan Kualitas Air*. Jurnal Sumber Daya Alam, 11(4), 72-80.

Jadhav, D., & Deshmukh, S. (2020). *Evaluation of Slow Sand Filter Efficiency for Drinking Water Treatment*. Water Science & Technology, 75(7), 1628-1638.

Kalpana, R., & Sudha, S. (2016*). Application of Aeration Technology in Water Treatment*. Journal of Environmental Engineering, 140(9), 1504-1511.

Kimbell, R. (2018). *Factors Influencing the Efficiency of Water Treatment Processes*. Environmental Science: Water Research & Technology, 4(2), 268-274.

Kurniawan, A. & Widodo, M. (2022). *Aplikasi teknologi air bersih: Kombinasi aerasi dan slow sand filter*. Jurnal Ilmu Lingkungan, 11(4), 223-230.

Kurniawan, A., & Widodo, T. (2022). "Innovative Water Treatment Techniques for Resource-Limited Areas." *International Journal of Water Resources.*

Mofarrah, H. K., & Kharche, P. R. (2020). *Evaluation of Aeration and Filtration Systems for Water Treatment*. Water Science and Technology, 82(8), 1284-1294.

Montgomery, D. C. (2017). *Design and Analysis of Experiments.* Wiley.

Nugroho, S. (2018). *Teknologi pengolahan air berbasis aerasi dengan sistem venturidan slow sand filter*. Prosiding Seminar Nasional Teknologi dan Inovasi, 9(1), 78-85.

Rahmad, F. (2021). *Penerapan Teknologi Aerasi dalam Pengolahan Air Sumur Bor Bertekanan Tinggi untuk Penurunan TDS*. Jurnal Teknik Lingkungan, 17(2), 120-128.

Rahman, M. et al. (2021). "Efficiency of Aeration Systems in Groundwater Treatment: A Case Study." *Water Science & Technology*.

Sarraf, M., & Abadi, S. (2017). *Combined Aeration and Filtration Techniques for the Reduction of TDS and Microbial Contaminants in Groundwater*. Journal of Water Process Engineering, 19, 14-22.

Singh, P., & Kumari, K. (2021). *Combined Aeration and Filtration Techniques for Sustainable Water Treatment: A Review*. Environmental Technology & Innovation, 22, 101500.

Siregar, A., & Putra, M. (2019). *Efektivitas penggunaan slow sand filter untuk pengolahan air dengan kadar TDS tinggi*. Jurnal Rekayasa Sumber Daya Alam, 27(3), 54-64.

Spellman, F. R. (2014). *Handbook of Water and Wastewater Treatment Plant Operations*. CRC Press.

Stumm, W., & Morgan, J. J. (1996). *Aquatic Chemistry: Chemical Equilibria and Rates in Natural Waters*. Wiley-Interscience.

Sumantri, D. (2021). *Pemanfaatan slow sand filter untuk penyaringan air sumur bor dalam mengurangi kadar TDS*. Jurnal Teknologi Pengolahan Air, 45(1), 45-52.

Suryani, I. (2020). *Pengolahan air sumur bor dengan teknologi aerasi untuk menurunkan kadar TDS*. Jurnal Teknik Lingkungan, 34(2), 120-135.

Tchobanoglous, G., & Schroeder, E. D. (2003). *Water Quality: Characteristics, Modeling, Monitoring, and Treatment*. 2nd Edition. Addison-Wesley Publishing Company.

World Health Organization (WHO). (2017). *Guidelines for Drinking-water Quality: Fourth Edition Incorporating the First Addendum*. Geneva: WHO.