Available online at: http://proceeding.rsfpress.com/index.php/ ess/index
LPPM UPN "Veteran" Yogyakarta Conference Series
Proceeding on Engineering and Science Series (ESS)
Volume 1 Number 1 (2020): 552-561

Effectiveness of Turbidity Removal by Direct Filtration

Ekha Yogafanny, Titi Tiara Anasstasia, Vindy Fadia Utama

University of Pembangunan Nasional Veteran Yogyakarta
[1]E-mail address: ekha.yogafanny@upnyk.ac.id

Abstract

Umbulrejo Village, Ponjong District, Gunungkidul is one of the villages that has both karst and non-karst landforms. The variation of landforms that exist in this research area affects the quality of groundwater, either naturally or due to human activities. In the area obstructed by topography such as Umbulharjo Village, a centralized water management system is quite challenging, especially for those that use a piping system in its distribution. Hence, a decentralized water treatment system is required. The direct filtration method as one of the reliable methods in a decentralized water treatment system will be observed to treat water with a turbidity level of less than 10 NTU and 10 – 50 NTU. This study aims to analyze the effectiveness of turbidity removal using the direct filtration method. This research was conducted by a laboratory experiment. The coagulation, flocculation, and filtration were conducted in a continuous mode for 3 hours. The dependent variables measured were turbidity and Hydraulic loading rates (HLR). The effectiveness of turbidity removal in this experiment was all good. Better effectiveness was achieved by the filter columns operated in the lower HLR (2.88 – 3.1 m/h). The HLR was proven affecting the filter performance thus increase the workability of direct filtration. While the higher HLR (4.8 m/h) resulted in a fluctuation in effluent turbidity. However, these two HLRs as recommended in the direct filtration method were excellent resulting from the effectiveness of turbidity removal ranging from 71.7% to 100%. It can be concluded that direct filtration can be used in a decentralized water treatment system.

Keywords: direct filtration, removal, turbidity

I. INTRODUCTION

The Water Health Organization or (WHO/UNICEF, 2019) notes that more than 2 billion people do not have access to clean water and 4.2 billion people still use unsuitable sanitation facilities. The National Planning and Development Agency or BAPPENAS (2010) in the Asian Development Bank or ADB (2013), stated that the low capacity of water service providers, water supply, and sanitation in Indonesia is in poor condition. The low capacity of water service providers is partly caused by a centralized raw water treatment system / centralized water treatment system which is then distributed via pipes to only part of the community, especially those living in urban areas. Areas that have not received clean water services are areas that are far from water treatment centers

DOI: https://doi.org/10.31098/ess.v1i1.150

(remote/rural) and areas with hilly topography. Only 12% of the total population in rural areas is connected to the water supply via the piped network of the Regional Water Company (PDAM). The remaining population is 82%, depending on the water source in the form of procurement from non-governmental organizations in the form of dug wells, boreholes, rivers, springs, and reservoirs.

Umbulrejo Village, Ponjong District, Gunungkidul is one of the villages that has both karst and non-karst landforms. The variation of landforms that exist in this research area affects the quality of groundwater, either naturally or due to human activities. In karst landforms, season conditions greatly affect surface and subsurface water quality. In the dry season, the water quality is quite good and clear, while in the rainy season the water quality is poor, which is indicated by high turbidity and bacterial concentrations.

The access of PDAM is not easy to get to Umbulrejo Village, Ponjong District, Gunungkidul Regency through a piping system due to its hilly topography. In areas obstructed by topography, a centralized water management system is quite challenging, especially those that use a piping system in its distribution. Hence, a decentralized water treatment system is required. This method can provide access to clean water to residents effectively and more efficiently (Pooi and Ng, 2018).

Based on the results of water quality research conducted by several researchers, the quality of subsurface water in Ponjong Village has turbidity levels ranging from <10 NTU to 50 NTU, or even more in the rainy season. Therefore, this study will evaluate and investigate the effectiveness of the direct filtration method using these two kinds of raw water i.e. <10 NTU and 10-50 NTU. The water needs to be treated first before being used as raw water for the community. The direct filtration method as one of the reliable methods in a decentralized water treatment system will be observed to treat water with this turbidity level. Unlike conventional filtration, direct filtration does not require sedimentation (sometimes without flocculation) in the water treatment process. Therefore, this method is expected to save initial and operational costs.

The purpose of this study is to evaluate the effectiveness of direct filtration by observing the performance of its filtration process to remove turbidity. Direct filtration is a water treatment method where the sedimentation process is not carried out after coagulation and flocculation. After the coagulation-flocculation process, the water goes directly into the filtration reactor. The eminence of direct filtration is that this method could reduce the operational cost as well as the initial cost of construction due to the omitted sedimentation process (and flocculation). The variables observed to be further evaluated are HLR and effluent turbidity. By knowing so, we could evaluate the effectiveness of turbidity removal.

II. LITERATURE REVIEW

II.1. The Decentralized Water Treatment System (DWTS)

There are many water management systems whose use is adjusted to the needs and conditions of the area served (Omarova *et al.*, 2019; WHO, 2019). In remote areas and urban areas, the water treatment system required will be different. Also, upland areas will be different from lowland areas. In addition, the socio-economic conditions of the community will also affect the need for an appropriate water management system. For remote areas with low economic conditions usually do not use a piped system, the community prefers to look for other water sources (Eichelberger, Hickel, and Thomas, 2020). The community mostly uses surface water sources. Some of the surface water sources used are rivers, springs, and wells. Whereas water quality that does not come from piped water and proper sanitation can potentially cause health problems. The absence of a piped water system will greatly affect the high cost of obtaining water. So we need an alternative water supply that is cheaper, easier to apply, and safer (Rabaey *et al.*, 2020).

DWTS is a water supply system for areas that have their own water source, usually used for remote areas with topographical barriers (Klingel and Diener, 2014). According to (Leigh and Lee, 2019), first, the system can increase the resilience and sustainability of water treatment. Second, a decentralized system of water treatment accompanied by the selection of the right technology can reduce the risk of problems and failures in the future (Kohler, Silverstein and Rajagopalan, 2016). Third, if the technology is socially and economically acceptable, it will run efficiently, flexibly, and sustainably (Zaharia, 2017). Economically, this is related to the realistic level of public consumption, so data related to water consumption per capita is needed (Klingel and Diener, 2014). It needs to be accompanied by strong infrastructure development to implement it (Lu *et al.*, 2019), simple structure, and easy to operate (Jeon *et al.*, 2016). In the context of sustainability, decentralized water treatment systems also have the potential to be recycled more easily (Zraunig *et al.*, 2019). So that it can reduce, prevent, and control the potential for pollution around the served areas (Zaharia, 2017).

The advantages of Direct filtration compared to conventional processing are: (1)lower costs, because the dosage of chemicals such as coagulants is lower, (2)does not require sedimentation (and sometimes flocculation) tanks resulting in lower capital costs, and (3)Relatively lower operating and maintenance costs as the sedimentation (and sometimes flocculating) tank does not need to be powered or maintained. While the disadvantages of direct filtration include: (1)It is not suitable for treating water with high levels of turbidity and/or color, (2)Needs quick adjustment and treatment of changes in quality, and (3)Less detention time in controlling problems taste and smell (EPA, 1995; WHO, 2007; Al-Kathily, 2014).

Many studies have been carried out to determine the ability of the direct filtration method to treat raw water. There are lots of media that can be used, such as alum, seeds, coal, to sand. The direct filtration method can adsorb 83.8% to 91.7% of ferrous iron with Coal or carbonaceous shale media from groundwater (George and Chaudhuri, 1977). By using alum, the direct filtration method is able to remove turbidity with an efficiency of up to 99% (Fouad *et al.*, 2005).

III. RESEARCH METHODOLOGY

This research was conducted by a laboratory experiment and quantitatively analyzed. This study aims to analyze the performance of the direct filtration process to treat the raw water with different variations in turbidity values, namely Raw Water A (<10 NTU) (according to theory) and Raw Water B (10 - 50 NTU). The flow chart of the laboratory experiment presents in Figure. 1 and the design criteria can be seen in Table 1.

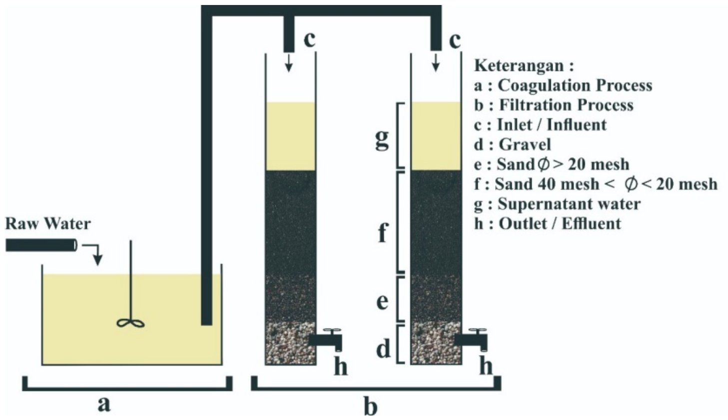

Figure 1. Flow Chart of Laboratory Experiment

Table 1. Design Criteria for Laboratory Experiment

Parameters	Raw water A (<10 NTU)		Raw water B (10-50 NTU)	
Initial Raw water (0) (NTU)	6.23		32.4	
Coagulation				
Coagulant dosage (mg/L)	5		15	
Mixing time (minute)	1		1	
Flocculation (minute)	3		3	
Filtration				
Sand type	Lava sand (Merapi)		Lava sand (Merapi)	
Sand diameter (mesh)	Ø>20 mesh (0.8mm) and 40 mesh (0.4mm)<Ø<20 mesh (0.8mm)		Ø>20 mesh (0.8mm) and 40 mesh (0.4mm)<Ø<20 mesh (0.8mm)	
Filter column configuration	Supernatant water (20 cm) 40 mesh<Ø<20 mesh (40 cm) Ø>20 mesh (10 cm) Gravel (10 cm)		Supernatant water (20 cm) 40 mesh<Ø<20 mesh (40 cm) Ø>20 mesh (10 cm) Gravel (10 cm)	
Operation time (hour)	3		3	
Measurement time (minute)	10		10	
Hydraulic loading rate (HLR) (m/h)	3.1	4.8	2.8	4.8
HLR by time (m/h)	Observed	Observed	Observed	Observed
Turbidity in the effluent (NTU)	Observed	Observed	Observed	Observed

In the scientific method, some factors may change during the experiment namely variable. There are three types of variables i.e. dependent variable, independent variable, and fixed variable. The dependent variable is the factor that will be investigated or observed during the experiment. The independent variable is a factor that is controlled in the experiment, this variable will affect the dependent variable. In this experiment, there are three types of variables as follows:

- Dependent variable: hydraulic loading rate (HLR) and effluent turbidity
- Independent variable: sand type, sand grain size, filter thickness, the height of supernatant water, valve opening
- Fixed variable: influent turbidity

IV. FINDING AND DISCUSSION

IV.1. Effectiveness of Turbidity Removal

The overall results of this study can be seen in Tables 2 and 3. The table presents the effluent turbidity as well as its effectiveness in every 10 minutes during the operation time (3 hours) in a certain HLR. This study investigated the effect of two different HLR in the filtration process on the performance of direct filtration in both raw water A and B. The process was started by the dosing of 5 mg/L of alum for raw water A (<10 NTU) and 15 mg/L of alum for raw water B (10-50 mg/L). The 15 mg/L of alum was dosed to the raw water B due to the higher value of turbidity and it was a dosage of alum given in a direct filtration study conducted by Al-Kathily (Al-Kathily, 2014). On the other hand, the 5 mg/L of alum was added to the raw water A that was less turbidity value than that of raw water B. The advantage of direct filtration is reducing the dosage of alum used in the treatment process. The effectiveness was not only affected by the alum dosage but also by the filtration process.

Table 2. Results of Laboratory Experiment of Raw Water A

Minutes	Raw Water A					
	HLR (m/h)	Turbidity (NTU)	Effectiveness (%)	HLR (m/h)	Turbidity (NTU)	Effectiveness (%)
0	4,8	5,53	0	3,1	5,53	0
10	4,8	0,24	95,7	3,1	0	100
20	4,39	0	100	3	0	100
30	4,32	1,18	78,7	3	0	100
40	4,3	0,01	99,8	2,93	0	100
50	3,72	1,33	75,9	2,9	0	100
60	3,7	0	100	2,83	0	100
70	3,64	0	100	2,83	0	100
80	3,28	2,67	51,7	2,8	0,46	91,7
90	3,2	0	100	2,8	0	100
100	3	0	100	2,76	0	100
110	2,32	1,37	75,2	2,76	0	100
120	1,92	0	100	2,64	0	100
130	1,48	0	100	2,64	0	100
140	0,98	0	100	2,37	0	100
150	0,96	0	100	2,5	0	100
160	0,9	1,6	71,1	2,28	0	100
170	0,84	0	100	2,3	0,49	91,1
180	0,7	0	100	2,06	0	100

The effectiveness of the filtration process operated in 3 hours experiment presented in Figure. 2. This effectiveness was controlled by HLR given for each column in two different kinds of raw water turbidity. In raw water A, the removal effectiveness was fluctuated ranging from 51.7% to 100% in higher HLR and achieved better effectiveness in lower HLR ranging from 91.1% to 100%. It can be concluded that the lower HLR resulted in more stable effectiveness due to the more contact time given for the suspended solids to be attached to the sand filter. However, the effluent turbidity from raw water A in both HLR values was meet the water quality standard regulated by the Indonesian Government (PMK no 32 the Year 2017).

Table 3. Results of Laboratory Experiment of Raw Water B

Minute	Raw Water B					
	HLR (m/h)	Turbidity (NTU)	Effectiveness (%)	HLR (m/h)	Turbidity (NTU)	Effectiveness (%)
0	4,8	32,4	0	2,88	32,4	0
10	4,8	0	100	2,88	0,19	99,4
20	4,36	0	100	2,88	0	100
30	3,12	0	100	2,88	0	100
40	2,88	0	100	2,85	0	100
50	2,64	0	100	2,84	0	100
60	2,4	0	100	2,83	0	100
70	2,28	0,16	99,5	2,8	0	100
80	2,16	0,2	99,4	2,78	0	100
90	2,1	0	100	2,73	0	100
100	2,04	0	100	2,68	0	100
110	1,56	0	100	2,52	0	100
120	1,44	0	100	2,35	0	100
130	1,22	0,01	100	2,28	0	100
140	0,96	0	100	2,2	0	100
150	0,84	0	100	2,13	0	100
160	0,72	0	100	2,04	0	100
170	0,67	2,12	93,5	1,99	0	100
180	0,6	0,299	99,1	1,94	0	100

The removal effectiveness achieved with the raw water B in the higher and lower HLR was ranging from 99.1% to 100% and 99.4% to 100% respectively. In these two cases, the removal effectiveness was more stable resulting in a very acceptable value of turbidity in the effluent (< 5 NTU). It was caused by the high value of turbidity (tend to more suspended solids) leads to bringing more suspended to be attached in the sand surface and then blocks its voids thus reduce the size of the voids. This phenomenon resulted in a better water filtration process by the attachment removal mechanism. Moreover, the lower HLR performed better than the higher HLR in removing the turbidity proven by almost 90% of effluent water measured in the experiment, resulting in 100% removal effectiveness. The effluent turbidity attained by the direct filtration from the raw water B met the water quality standard both for hygiene and sanitation and water supply (Menteri Kesehatan Republik Indonesia, 2017). Overall, the efficiency of turbidity removal achieved by direct filtration from both raw water A and B in two different HLRs was satisfactory. The excellent results by direct filtration method in treating the surface water were also achieved by other researches up to 98% of efficiency (Al-Kathily, 2014).

Generally, the effectiveness of turbidity removal in this experiment was all good. Better effectiveness was achieved by the filter columns operated in the lower HLR (2.88 – 3.1 m/h). The HLR was proven affecting the filter performance thus increase the workability of direct filtration.

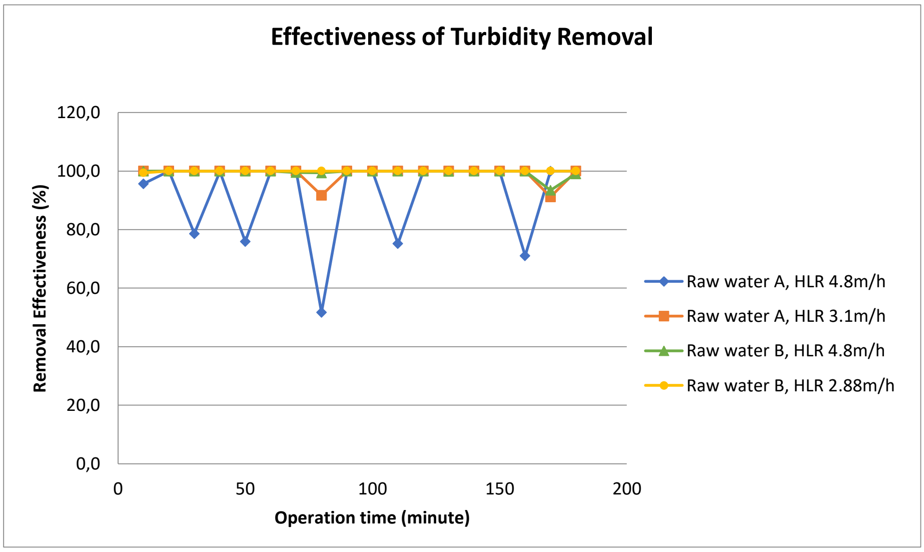

Figure 2. Effectiveness of Turbidity Removal

IV.2. Effect of HLR To The Effluent Water Turbidity

The effects of HLR on the effluent turbidity present in Figure. 3 and 4. The decrease in the HLR value was influenced by the length of time the filter operates. The longer the operating time, the greater the water contact time with the sand in the sand filter. The lower the HLR, the higher the effectiveness, and the lower the amount of turbidity in the effluent.

Figure 4 shows the relationship between HLR and effluent turbidity. It describes that the longer the filter operation time, the more the total amount of treated water. The column with an HLR of 4.8 m/h allowed more amount of suspended solids attached and stuck in the filter which causes a decrease in HLR to 0.6 m/h at 180 minutes of operation time. On the other hand, HLR of 2.88 m/h, the decrease in HLR was not too significant; it was because the amount of treated water was less so that the number of suspended solids caught in the filter was reduced. Figure 3 shows the relationship between HLR and effluent turbidity with low turbidity of raw water. According to this low turbidity, the turbidity was already less in the effluent, but it found a fluctuation in effluent turbidity in the HLR of 4.8 m/h. It was due to the higher HLR lead to the shorter contact time between water and grain sand that happened in the filter.

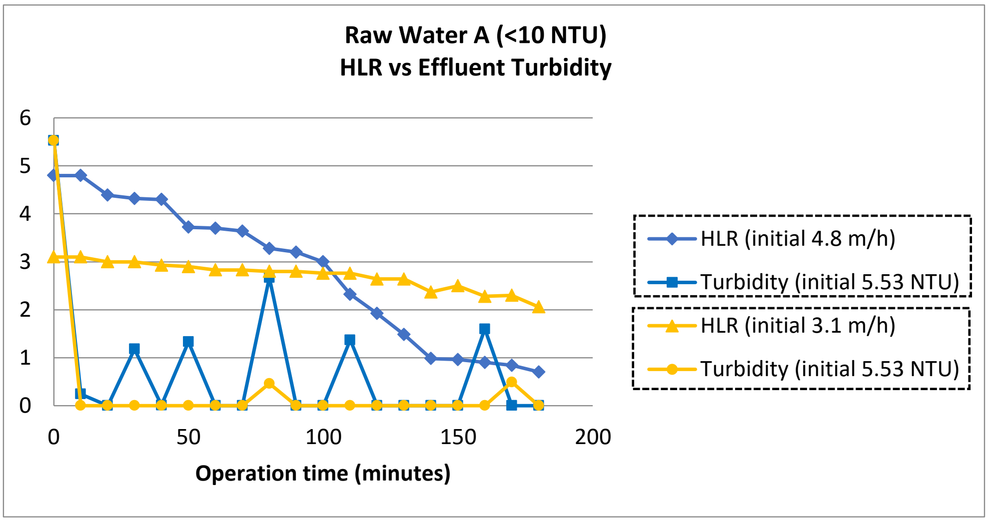

Figure 3. Effect of HLR in effluent turbidity in the raw water A

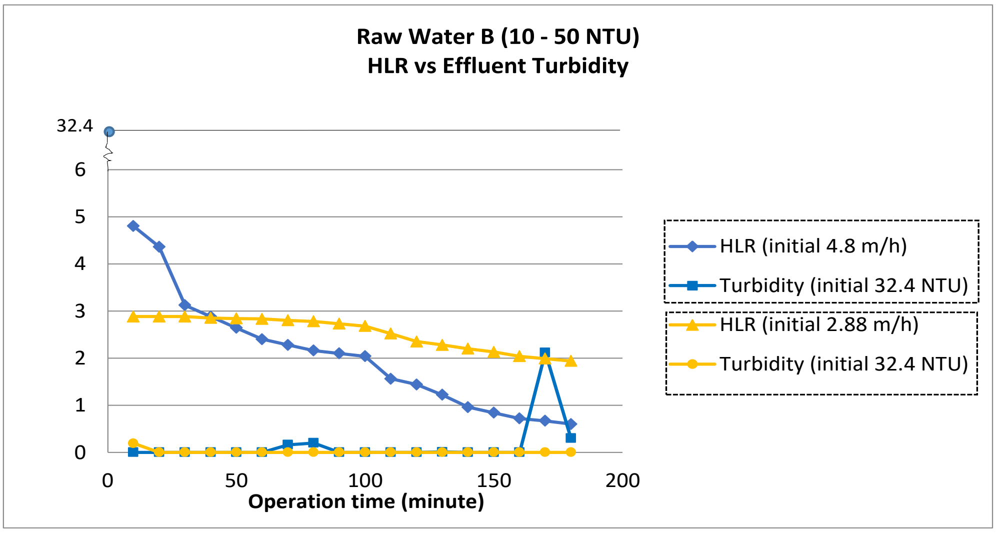

Figure 4. Effect of HLR in effluent turbidity in the raw water B

V. CONCLUSION AND FURTHER RESEARCH

This research concludes that the effectiveness of turbidity removal in this experiment was all good. Better effectiveness was achieved by the filter columns operated in the lower HLR (2.88 – 3.1 m/h) ranging from 91.9% to 100% and 99.4% to 100% for raw water A and B respectively. The HLR was proven affecting the filter performance in terms of turbidity thus increase the workability of direct filtration.

VI. REFERENCES

Al-Kathily, F. (2014) 'Direct Filtration using Surface Lakes Water in Iraq', *Global Journal of Researches in Engineering: E Civil and Structural Engineering*, 14(2), pp. 39–60.

Eichelberger, L., Hickel, K. and Thomas, T. K. (2020) 'A community approach to promote household water security: Combining centralized and decentralized access in remote Alaskan communities', *Water Security*. Elsevier, 10(March), p. 100066. DOI: 10.1016/j.wasec.2020.100066.

EPA (1995) *Water treatment manuals Filtration*, *Environmental Protection Agency*. DOI: 10.1036/1097-8542.739400.

Fouad, M. *et al.* (2005) 'a Simplified Empirical Model for the One-Stage', (January), pp. 765–774.

George, A. D. and Chaudhuri, M. (1977) 'Removal of Iron From Groundwater By Filtration Through Coal.', *Journal / American Water Works Association*, 69(7), pp. 385–389. DOI: 10.1002/j.1551-8833.1977.tb06771.x.

Jeon, S. B. *et al.* (2016) 'Self-powered electro-coagulation system driven by a wind energy harvesting triboelectric nanogenerator for decentralized water treatment', *Nano Energy*. Elsevier, 28, pp. 288–295. DOI: 10.1016/j.nanoen.2016.08.051.

Klingel, F. and Diener, S. (2014) *Guidebook for the implementation of decentralized water supply systems in Moldova*. Moldova: Skat Consulting Ltd.

Kohler, L. E., Silverstein, J. A. and Rajagopalan, B. (2016) 'Predicting Life Cycle Failures of On-Site Wastewater Treatment Systems Using Generalized Additive Models', *Environmental Engineering Science*, 33(2), pp. 112–124. DOI: 10.1089/ees.2015.0275.

Leigh, N. G., and Lee, H. (2019) 'Sustainable and resilient urban water systems: The role of decentralization and planning', *Sustainability (Switzerland)*, 11(3). DOI: 10.3390/su11030918.

Lu, Z. *et al.* (2019) 'Decentralized water collection systems for households and communities: Household preferences in Atlanta and Boston', *Water Research*. Elsevier Ltd, 167, p. 115134. DOI: 10.1016/j.watres.2019.115134.

Menteri Kesehatan Republik Indonesia (2017) *Peraturan Menteri Kesehatan Republik Indonesia Nomor 32 Tahun 2017 Tentang Standar Baku Mutu Kesehatan Lingkungan Dan Persyaratan Kesehatan Air Untuk Keperluan Higiene Sanitasi, Kolam Renang, Solus Per Aqua dan Pemandian Umum*, *Peraturan Menteri kesehatan Republik Indonesia*.

Omarova, A. *et al.* (2019) 'Water supply challenges in rural areas: A case study from central Kazakhstan', *International Journal of Environmental Research and Public Health*, 16(5). DOI: 10.3390/ijerph16050688.

Pooi, C. K. and Ng, H. Y. (2018) 'Review of low-cost point-of-use water treatment systems for developing communities', *npj Clean Water*. Springer US, 1(1). DOI: 10.1038/s41545-018-0011-0.

Rabaey, K. *et al.* (2020) 'The Third Route: Using Extreme Decentralization to Create Resilient Urban Water Systems', *Water Research*. Elsevier Ltd, 185, p. 116276. DOI: 10.1016/j.watres.2020.116276.

WHO (2007) 'Physical removal processes: sedimentation and filtration', pp. 21–50.

WHO (2019) *National Systems to Support Drinking-Water, Sanitation, and Hygiene: Global Status Report 2019*.

WHO/UNICEF (2019) *Progress on Drinking Water, Sanitation, and Hygiene*, *Launch version July 12 Main report Progress on Drinking Water, Sanitation, and Hygiene*. DOI: 10.1111 / tmi.12329.

Zaharia, C. (2017) 'Decentralized wastewater treatment systems: Efficiency and its estimated impact against onsite natural water pollution status. A Romanian case study', *Process Safety and Environmental Protection*. Institution of Chemical Engineers, 108(Azapagic 2003), pp. 74–88. DOI: 10.1016/j.psep.2017.02.004.

Zraunig, A. *et al.* (2019) 'Long term decentralized greywater treatment for water reuse purposes in a tourist facility by vertical ecosystem', *Ecological Engineering*. Elsevier, 138(July), pp. 138–147. DOI: 10.1016/j.ecoleng.2019.07.003.