Study of the potential use of rainwater as clean water with simple media gravity filters: A review

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Abstract. Clean water plays an essential role in all living things. However, the availability of clean water in Indonesia is insufficient to fulfill the total need for clean water, especially during the dry season. One of the alternative sources of clean water is rainwater. This study aims to understand the characteristics of rainwater in Indonesia as well as the effect of the variations of type, arrangement, and thickness of the simple filter media on the rainwater in Indonesia. A literature study from several studies is conducted regarding the use of rainwater as clean water with filters made from simple media to improve clean water by utilizing gravity filtration technology. The key descriptors used in this review include “rainwater filtration”, “filtration”, “rainwater harvesting” and “media filtration”. The quality standard used in this study is based on the Ministry of Health Regulation No.416/Menkes/Per/IV/1990. Based on the literature, simple filtration technology can significantly reduce some parameters value where the value of efficiency is more than 50% for parameter turbidity, TDS, Pb, arsenic, total coliform, hardness and nitrate. However, it has not been able to reduce the parameter of sulfate, nitrite, chloride, magnesium significantly. The review shows that the filter medium that is effective and easily accessible are gravel, zeolite, activated carbon, sand, cotton, sponges with a total media thickness of 20 cm, 70 cm, 80 cm, 100 cm, and 105 cm and the time required to perform the filtration is about 10-15 minutes.

1. Introduction
In Indonesia, the need for clean water will increase continuously in line with population growth. Clean water plays an important role and benefits all living things. A massive amount of daily water consumption will affect the amount of water demanded. Nowadays, clean water is difficult to obtain due to a decreasing amount and quality of the water resources. The quality of water in several cities in Indonesia is mostly unstandardized as clean water [1]. To overcome this problem, developing the utilization of rainwater filtration from simple materials that are easily found is a promising alternative
solution since the amount of rainfall in Indonesia is relatively high at about 2000-3000 mm/year [2]. Additionally, it is also because some people have a lack of knowledge to utilize rainwater as clean water [3], the role of people needs to be maximized and necessary for the utilization of rainwater [4]. Thus, the utilization of rainwater using simple materials would be easy and optimally applied to the community.

Rainwater is an important water source in areas that do not have clean water supply systems and important to surface water quality where groundwater is unavailable [5]. Rainwater consists of 99.9% mass H2O, and the rest consists of substances that are mixed with rainwater. The nature of rainwater is relatively pure before it reaches the soil. It lacks microorganisms with the chemical nature of pH 5-7 and low concentrations of minerals and metals. In contrast, simple filtration is a filtering technology with a variety of media (multi-filter) for instance sand, gravel, activated carbon, and zeolite [6]. A method to develop a simple filtration technology is by collecting rainwater and then filtering the water using a filter media. The filtration uses the force of gravity to provide alternative environmentally friendly technologies that are easy, cheap, and practical. Media filters that are used are easily found with various types and heights of the media. Rainwater that was filtered using simple filtration technology turned into clean water that could be used for everyday needs while fulfilling health requirements. This study discusses variations of type, arrangement, and thickness of the filter media that can be effectively and efficiently used to filter rainwater into clean water. Therefore, a literature study was conducted from several studies on using rainwater as clean water with a filter made from simple media that is easy to find. This review aims to understand the characteristics of rainwater in Indonesia; to highlight the effect of the variation of type, arrangement, and thickness of the filter media on the rainwater that has been filtrated; and to know simple filtration technology effectiveness and efficiency.

2. Materials and Methods
A literature study from several studies is conducted regarding rainwater as clean water with the filter made from simple materials to improve access to freshwater by utilizing simple filtration technology. The literature review focuses on finding various theories, laws, propositions, principles, or ideas to analyze and solve research questions. The literature review is based on a systematic in-depth study and analysis of accessible literature rainwater filtration including title, abstract, and keywords within the time frame of 2010–2020. A search was done on these key descriptors: “rainwater filtration”, “filtration”, “rainwater harvesting”, and “media filtration”; literature including journal articles, conference papers, thesis reports, and books accrued for review and analysis. These articles have been accessed from top English and Bahasa journals databases through Science Direct (Elsevier), ProQuest, Springer link, and Brawijaya repository. Even though this investigation was not extensive, it assists as an inclusive base for an insight into rainwater filtration research. The search under these criteria is all four databases in the total number of 38,300 publications. A total of 4,788 articles from journals were found by searching keywords and then were screened. The others were excluded because there was no full-text article available. Fifty (50) articles were reviewed, the others were excluded because of redundancy or did not fit the inclusion criteria. The criteria include: (1) the filter material used for rainwater filtration, (2) the natural filter media, (3) papers published in peer-reviewed journals. 50 journals were reviewed based on the description key described earlier.

3. Results and Discussion

3.1 Characteristics of rainwater
Rainwater has characteristics which can be known through laboratory tests on physical, chemical, and biological properties. Commonly, the aspects of rainwater are odorless and tasteless [6,7]. The quality of rainwater depends on the location of the rainfall. Generally, the rain that falls in urban areas will attract dust particles from fossil fuels [8]. The average pH of rainwater in Indonesia is 4-7 [9]. The pH of rain in the rainy season at high elevation is above 5.6. While rainwater pH in the rainy season in the lowlands does not show any difference because it has a pH above 5.6. Topographic differences in the
valleys do not affect the rainwater’s acidity in both the rainy season and dry season. Still, the difference in the seasons affects the acidity of the rainwater [10].

Rainwater turbidity can be caused by human activities such as coal-burning by factories and vehicle fumes [11]. The high level of turbidity shows that rainwater is experiencing physical, chemical, and biological pollution. Physical pollution consists of animal waste (birds), dust from burning fields, and plantations. Chemical pollution comes from fuel emissions, including zinc roofing chemicals used as rainwater catchers and reservoirs. While microbiological pollution comes from viruses and bacteria that are in the air. The existence of pollutants in the air and zinc roofing material causes high rain turbidity, making it inconsumable [12]. Rainwater that falls in the mountain slopes, such as the slopes of Mount Merapi, has an inferior quality when consumed as clean water. This can be observed visually, with the level of turbidity above that of standard quality, consumable, clean water [1]. The cause of acidic pH (acid rain) is a high level of NOx and SOx gas [10]. The characteristics of rainwater in various regions can be seen in Table 1.

### Table 1. Characteristics of rainwater in various sectors.

| No | Sector          | Characteristics                                                                 |
|----|-----------------|---------------------------------------------------------------------------------|
| 1  | Industrial Sector | pH is 6.1 – 7 [13, 14, 15], 6.5 [16], 6.35-7.85 [17,18], 5.6 [19], 5.29-5.56 [20], 7.07-8.55 (alkaline) [21]; manganese; cadmium; and lead [22] |
| 2  | Mountains Sector | pH is <5.6 (acid) [23]; 3.73-6.54 (acid) [24] 7-8.11 (alkaline) [25] and turbidity [1] |
| 3  | City            | Ammonium [11], pH [9], organic substance (KMnO4) 16[26], and nitrit [11]         |

#### 3.2 Simple filtration media

Filtration treatment is one of the promising methods to reduce dissolved and particulate matters in water or wastewater [27]. Filter media can be divided into natural and synthetic filter media. Natural media filtration that can be used includes sand ± 4-30 mesh, gravel 8-6 mesh, activated carbon, zeolite 5-30 mm, palm fiber limestone, broken bricks 5-20 mm, split stones, and coconut fibers. Synthetic media filters are sponges and plastic scraps. The karst area can use simple filter media in silica sand, zeolite, activated carbon, and aquarium filter cotton [28]. The gravel’s function is to absorb solids/impurities that still escape [6]; it can be used as a gap for water to flow through the hole [29]. The gravel in the pipe supported the growth of bacteria where nitrification and other biological oxidation processes occurred. Gravel supported bacteria attachment and growth while leaving a relatively large void space that greatly reduced any likelihood for “clogging” of the media, reduced backwashing frequency, and allowed air bubbles to move through the pipe [30]. Silica sand serves to absorb solids/impurities that still escape, filtering small particles [6], eliminating physical properties, including smell and turbidity [31].

Removal of ammonia, nitrite, nitrate, and phosphorus by sand and other organic media can be achieved using natural, functionalized, and/or engineered filter media [32]. Palm fiber serves as a natural adsorbent to remove various impurities [4], and as a medium to retain sand, so it does not pass to the lower layer [29]. Coconut fibers are used to filter out particles dissolved in rainwater. It can be an alternative substitute for palm fiber filters [28]. Granular-activated carbon may also be employed in the treatment of rainwater. The activated carbon has a large surface area, which allows for the removal of microbial and chemical pollutants [33]. Activated carbon is used to clear the color of rainwater [28], filter out small particles [6], remove odors and filter out chlorine. While it could be used to adsorb organic compounds, the activated carbon can replace the use of anthracite as a filter medium. Its principal applications have been for taste and odor control, but it can also be used for removing organic compounds suspected of being carcinogenic or causing adverse health effects [34]. Granular activated carbon has been used in the so-called “filter adsorbers” to reduce taste and odor and turbidity [35].
Limestone is a filtration media that can reduce hardness and iron inside water [36]. Broken brick (5-20 mm) filter media has the ability of porous media to hold suspended substances, including dissolved microorganisms that are very easy to absorb water and particles contained in water [37]. The function of split stone is similar to palm fiber, which removes various impurities. Sponges are used to absorb water sediment, which makes the water’s color turbid [38]. The sponge has high internal porosity and a specific surface, which facilitates absorption. Besides, the sponge can be easily compacted to a minimal volume to help with disposal, and is cost-effective, so that it can be applied in small communities [39]. Plastic cutting filter media is used to reduce the level of turbidity in water [40].

Zeolite has a cavity/pore that is able to absorb solids through the physical and chemical processes. Moreover, zeolite can reduce turbidity and iron concentration [41]. Zeolite also adsorbs solutes that cause a bad taste, color, bad smell, minerals, and heavy metals [6]. Zeolite has a promising application to be used as a filter or biofilter media in water treatment [42]. Moreover, zeolites’ function might not even be their adsorption capacity or their function as molecular sieves but rather their property to swell upon water infiltration, thus regulating the filter’s hydraulic conductivity [43]. The filter media used in several studies can be seen in Table 2.

**Table 2. The filter media used.**

| Reference  | Filter Media                                                                 |
|------------|------------------------------------------------------------------------------|
| [1]        | gravel, limestone, broken bricks, slit stones, plastic pieces, and fibers    |
| [7, 9]     | Gravel 8-10 mesh and 16-32 mesh, zeolite, activated carbon (GAC) 6-8 mesh, sand 4-8 mesh and 20 up mesh, cotton, and sponges |
| [41]       | gravel, silica sand, coconut fiber, and activated carbon                      |
| [44]       | gravel, activated carbon 0.2-5 mm, and sand 0.2-5 mm                         |
| [45]       | gravel, activated carbon 14-20 mesh, and sand 0.3 mm                         |
| [28]       | sponges, silica sand 0.1-0.2 mm, zeolite 1-4 cm, and activated carbon 0.5-2 cm |
| [26]       | zeolite and activated carbon                                                 |

3.3 The effect of type of variation and thickness of filter media on the quality of clean water produced

Several parameters must be fulfilled in clean water quality standards, such as physical, chemical, and biological parameters. The first article using simple filter media such as gravel, limestone, broken bricks, slit stones, plastic pieces, and fibers [1]. However, the turbidity and organic matter parameters exceed the standard. Turbidity increases due to the gutters’ conditions that are not treated resulting in corrosion due to zinc, moss, and dust on the bamboo gutters [1]. The second article using simple filter media such as gravel, zeolite, activated carbon, sand, cotton, and sponges [7, 9]. While the third article using simple filter media such as gravel, silica sand, coconut fiber, and activated carbon [41]. The fourth article using simple filter media such as sand, activated carbon, and gravel [30]. However, Pb exceeded the quality standard in rainwater that is caused by the Pb layer on the zinc roof, which is also soluble in acid rainwater [44]. The fifth article using simple filter media such as gravel, activated carbon, and sand [45]. While the sixth article using simple filter media such as sponges, silica sand, zeolite, and activated carbon [17]. The seventh article using simple filter media such as zeolite and activated carbon [26]. The results of rainwater quality from filtration can be seen in Table 3. The quality standard used is the Regulation of the Minister of Health of the Republic of Indonesia No.416/MENKES/PER/IX/1990 [46].

The thickness of the filter media would affect the quality of the water produced and the filtering time. Each research uses a different thickness of filter media depending on the standard of the water used. The difference in thickness in the adsorbent application affects the results of water clarity [4]. The water quality is measured based on several parameters in the applicable quality standards. The thicker the adsorbent given, the cleaner the results obtained. However, the time needed is quite long. High thickness can reduce higher amounts of impurities [4]. The width of the filter media will affect the time to perform
simple filtration. The time required for a total filter media thickness of 105 cm is 10-15 minutes [6], but the width of 100 cm is 5 minutes [1]. Based on the literature, the quality of rainwater filtration results for 10-15 minutes with a total thickness of filter media of 105 cm produces better rainwater quality than other literatures.

The quality of rainwater in various parameters can be known in Table 3. The effect of the variation in the type, arrangement, and thickness of the filter media on the quality of rainwater depends on the parameters used due to differences in rainwater characteristics. The thicker filter media so the cleaner the water will be obtained, but the time required will be longer. This is according to literature stating that the quality of rainwater filtration results will be better with the thicker filter media used because the water will be obtained, but the time required will be longer. This is according to literature stating that the quality of rainwater filtration results will be better with the thicker filter media used because the thick filter media will reduce more dirt [47]. The technology’s challenges were when the filter media was saturated mainly and needed to be replaced or rejuvenated (approximately every 6 months) [48].

Table 3. The results of rainwater quality from filtration.

| Parameters Units | Quality Standard | Media Filter | The Results of Rainwater Quality from Filtration |
|------------------|------------------|--------------|--------------------------------------------------|
|                  |                  | gravel, limestone, broken bricks, slit stones, plastic pieces, and fibers [1] | gravel, zeolite, and activated carbon | gravel, activated carbon, and sand [41] | gravel, activated carbon, and sand [44] | gravel, activated carbon, and sand [45] | zeolite and activated carbon [26] |
| Total Thickness  | cm               | 100 cm       | 105 cm | 80 cm | 100 cm | 140 cm | 70 cm | 20 cm |
| Physical properties |                  |              |        |       |        |        |      |      |
| Smell            | Odorless         | Odorless     | Odorless | Odorless | Odorless | Odorless | Odorless | Odorless |
| TDS (mg/L)       | 1500             | 555.6        | 116    | 20.48 | 5.67   | 1.528   | 4.2    | 12.3 |
| Turbidity (NTU)  | 5                | 46.76        | 1.02   | 2.02  | 5.67   | 1.528   | 4.2    | 12.3 |
| Taste            | Tasteless        | Tasteless    | Tasteless | Tasteless | Tasteless | Tasteless | Tasteless | Tasteless |
| Temperature (°C) | ± 3              | 27.36        | 24.50  | 28    | -      | -       | -      | -     |
| Color            | TCU              | 4.05         | <0.26  | -     | -      | -       | -      | -     |
| Chemical properties |                  |              |        |       |        |        |      |      |
| pH               | 6.5-9            | 7.1          | 7.30   | 7.96  | 6.95   | -       | 6.5    | 6.8   |
| Total hardness (mg/L) | 500         | 16.27        | 34     | -     | -      | -       | 12     | 10    |
| Chloride (mg/L)  | 600              | 8.38         | 6      | -     | -      | -       | 85.4   | 65.5  |
| Sulfate (mg/L)   | 400              | 10.2         | 7.31   | -     | -      | <0.23   | -      | -     |
| Iron (mg/L)      | 0.5              | 0.0039       | unknown | -     | -      | -       | -      | -     |
| Manganese (mg/L) | 0.5              | 0.0068       | unknown | -     | -      | -       | -      | 0.182 |
| Zinc (mg/L)      | 15               | 0.018        | unknown | -     | -      | -       | -      | -     |
| Copper (mg/L)    | 1                | unknown      | -      | -     | -      | -       | -      | -     |
| Ammonia (mg/L)   | 1.3              | 0.13         | -      | -     | -      | -       | 0.077  | -     |
| Nitrate (mg/L)   | 50               | 0.91         | 0.60   | -     | -      | <0.123  | 2.8567 | -     |
| Nitrite (mg/L)   | 1                | 0.03         | 0.07   | -     | -      | -       | -      | -     |
| Organic substances (mg/L) | 10           | 12.49        | 0.50   | -     | -      | -       | 16.5   | -     |
| (K(MnO4))        |                  |              |        |       |        |        |      |      |
| Pb (µg/L)        | 0.05             | -            | -      | -     | 0.71   | -       | -      | unknown |
| Fluoride (mg/L)  | 1.3              | 0.32         | -      | -     | -      | -       | -      | -     |
| Detergent (mg/L) | 0.5              | 0.05         | -      | -     | -      | -       | -      | -     |
| Arsenic (mg/L)   | 0.05             | 0.03         | -      | -     | -      | -       | -      | -     |
| Biological properties |              |              |        |       |        |        |      |      |
| Total coliform (MPN/100 ml) | 50          | -            | 2      | -     | -      | 18.6    | -      | 50    |
| Efficiency removal |              |              |        |       |        |        |      |      |

Using this simple filtration technology to filter rainwater has the potential to overcome drought problems in Indonesia. It used simple materials that are easily found and can be easily applied in communities because Indonesia is a tropical country with heavy rainfall. This is in accordance with Sari
and Suhendri (2018) who argued that simple filtration technology is also usable for domestic needs [49]. According to Sudijajeng et al. (2019), as a tropical country, Indonesia has very much rainwater, but the reality is that there is drought everywhere, many people in remote areas find it difficult to get clean water because the source is dry and not infrequently followed by fires. Conversely, during the rainy season floods occur everywhere and the victims are generally people with very low economic levels [50]. So, the use of simple filtration technology can solve the problem in Indonesia. The type of filter media that are feasible to use are gravel, zeolite, activated carbon, sand, cotton, and sponges.

4. Conclusions
Filtered rainwater using simple filtration technology shows promising potential as an alternative source of clean water in Indonesia to solve drought issues during the dry season. The characteristics of rainwater are not in accordance with the quality standard (the Ministry of Health Regulation No.416/Menkes/Per/IV/1990) for clean water quality in industrial areas, mountains regions, and cities, whole villages have been in line with such standards. The effect of the variation in the type, arrangement, and thickness of the filter media on the quality of rainwater depends on the parameters used due to differences in rainwater characteristics. The thicker filter media (105 cm) so the cleaner the water will be obtained, but the time required will be longer. Based on the literature, simple filtration technology can significantly reduce some parameters value where the value of efficiency is more than 50 percent for parameter turbidity, TDS, Pb, arsenic, total coliform, hardness, nitrate, but have not been able to reduce parameter sulfate, nitrite, chloride, and magnesium. So, the result of the review about the filter medium that is effective and easy to find are gravel, zeolite, activated carbon, sand, cotton, and sponges.

The total thickness of media is 105 cm and the time required to perform the filtration is about 10-15 minutes.

References
[1] Samudro G, R Abadi R E 2011 Studi penurunan kekeruhan dan total suspended solid (TSS) dalam bak penampung air hujan (PAH) menggunakan reaktor gravity roughing filter (GRF) (A study of turbidity and total suspended solid (TSS) removal in a rainwater collection tub (PAH) using a gravity roughing filter (GRF)) J. Presipitasi 8 1 14-20 [In Indonesian]
[2] Marpaung S 2010 Pengaruh topografi terhadap curah hujan musiman dan tahunan di Provinsi Bali berdasarkan data observasi resolusi tinggi (Effect of topography on seasonal and annual rainfall in Bali Province based on high-resolution observational data). Proceedings of the National Seminar on Flight and Space 2010 [In Indonesian]
[3] Handarsari E, Fitria F H, Yunan K S 2017 Deseminasi: pembuatan air bersih dengan memanfaatkan air hujan melalui penyaringan pipa bersusun berbasis adsorben alami (Desemination: making clean water by using rainwater through adsorben based piping compostion natural). Proceedings of the National Seminar on Publication of Research and Community Service Result 2017 496-503 [In Indonesian]
[4] Zulkarnain I, Ismadi R, Kelik I 2013 Rancang bangun alat penjernih air berbasis masyarakat pedesaan dengan konsep rucef (reuse, cheap, easy, and flexible) (Water purification equipment design based on the rural communities with concept rucef (reuse, cheap, easy, and flexible) J. Ilmiah Teknik Pertanian 5 3 160–169 [In Indonesian]
[5] Abdulla F A, A W Al-Shareef 2009 Roof rainwater harvesting system for household water supply in Jordan. J. of Desalination 243 1 195-207
[6] Untari T, Joni K 2015 Pemanfaatan air hujan sebagai air layak konsumsi di Kota Malang dengan metode modifikasi filtrasi sederhana (Utilization rainwater as a viable water consumption in the malang city with a simple filtration modification method) J. Pangan dan Agroindustri 3 4 1492-1502 [In Indonesian]
[7] Adinugraha F, Bryan S, Nicolas A W, Brilliant J W 2018 Perancangan desain alat pemanenan air hujan dengan media filter dan pembangkit listrik mikrohidro (yogipure) (Desain of rainwater...
harvesting equipment design with filter media and microhydro (yogipure) J. Faktor Excta 11 2 118-127 [In Indonesian]

[8] Putra T P 2018 Perancangan dan pemanfaatan penampungan air hujan skala unit rumah di perumahan alam sinar sari dramaga (Design and utilization of rainwater tank home scale units in alam sinar sari residence at dramaga) Undergraduate Thesis Institut Pertanian Bogor [In Indonesian]

[9] Badan Meteorologi, Klimatologi, dan Geofisika 2020 Informasi kimia air hujan (Rainwater chemical information) Accessed from https://www.bmkg.go.id/kualitas-udara/informasi-kimia-air-hujan.bmkg on 30 July 2020 [In Indonesian]

[10] Paridawati 2015 Tingkat laju korosi knalpot kendaraan type C 100 produksi industri kecil di Kabupaten Purbalingga (The level of exhaust corrosion rate of vehicle type C 100 produced by small industries in Purbalingga Regency) J. Ilmiah Teknik Mesin 3 2 127-132 [In Indonesian]

[11] Matahelumual B C 2010 Potensi terjadinya hujan asam di Kota Bandung (Potential acid rain in the city of Bandung) J. Lingkungan dan Bencana Geologi 1 2 59-70 [In Indonesian]

[12] Khayan K, Taufik A 2016 Efektivitas pasir dan karbon aktif dalam menurunkan kekeruhan dan timbal pada air hujan (Effectiveness of sand and activated carbon in reducing turbidity and lead in rainwater) J. Kesehatan Lingkungan 2 2 143-151 [In Indonesian]

[13] Handriyono R E, Amrita W S D 2018 Studi kandungan asam pada air hujan di kawasan surabaya timur (The study on the water deposits of the acid rainfall east surabaya) J. Envirosan 1 2 52-55 [In Indonesian]

[14] Hynes N R J, J Senthil K, Husam K, J Angela J S, Omar A A, Yasemin K, Antoaneta E, B Suresh k 2020 Modern enabling techniques and adsorbents based dye removal withsustainability concerns in textile industrial sector -A comprehensive review J. Clean. Prod. 272 122636 1-17

[15] Aljerf L 2018 Advanced highly polluted rainwater treatment process J. Urban Environ. 12 1 50-58

[16] Izzati T, Wiwit S, Woro S, Fuji S F, Martina N R, Jerjer R J 2016 An initial study of industrial area’s effects for the air pollution through rainwater in east Jakarta J. Mech. Civ. Eng. 13 4 159-162

[17] Izzati T 2016 An initial study of the air pollution through rainwater in an industrial area of Cikarang, West Java, Indonesia (a case study) J. Sci. Int.28 4 3695-3697

[18] Izzati T 2017 Water quality analysis of residential and industrial areas in Bogor, West Java, Indonesia J. Sci. Int. 29 2 37-370

[19] Izzati T 2016 An initial study of the air pollution through rainwater in an industrial area of Bekasi J. World Chem. Eng. 1 2 17-19

[20] Hasan N Y, Driejana, Aminudin S, Herto D A 2018 Acidic wet deposition in Bandung city Indonesia Mattec Web of Conferences 147 08007

[21] Campo A M, Paula A Z, Natasha P 2013 Precipitation and rainwater pH spatial distribution in Bahia Blanca and Tandil, Argentina J. Earth Sci. Eng. 3 683-689

[22] Rahmayanti A E, Prayatni S 2015 Penyediaan air minum di daerah pesisir kota bandar lampung melalui rainwater harvesting (The supplies of drinking water in the coastal regions of the bandar lampung city through rainwater harvesting) J. Teknik Lingkungan 21 2 115-126 [In Indonesian]

[23] Supriatin L S, Waluyo E, Cahyono, Syafirzono 2017 Pengaruh kualitas air hujan pada konsentrasi metana (The effect of the rainwater quality on the methane concentration J. Kimia dan Pendidikan Kimia 2 2 103-109 [In Indonesian]

[24] Nadzir M S M, Chin Y L, Md Firoz K, Mohd T L, Doreena D, Haris H A H, Noorlin M, Khairul N A M, Muhammad I A W, Nurul F K, Mohammad A S M L 2017 Characterization of rainwater chemical composition after a southeast asia haze event: insight of transboundary pollutant transport during the northeast monsoon Environ. Sci. Pollut. Res. 24 15278-15290
[25] Sivanappan R K 2006 Rainwater harvesting, conservation and management strategies for urban and rural sectors. National Seminar on Rainwater Harvesting and Water Management 14 641-043

[26] Yulistyorni A, Gilang I, Evy D F 2018 Enhanced rooftop rainwater harvesting quality through filtration using zeolite and activated carbon Matec Web of Conferences 204 03016 2018

[27] Suhartini S, Nur H, Esti R 2013 Influence of powdered Moringa oleifera seeds and natural filter media on the characteristics of tapioca starch wastewater J. recycl. org. waste agric. 2 12 1-11

[28] Prihadi L R, Anie Y, Mujiyono 2019 Desain sistem pemanenan air hujan pada rumah hunian di daerah karst Kabupaten Malang (Design of rainwater harvesting system for a single house in karst region of malang regency) J. Manajemen Aset Infrastruktur & Fasilitas 3 1 59-74 [In Indonesian]

[29] Fajri M N, Yohanna L H, Sigit S 2017 Efektivitas rapid sand filter untuk meningkatkan kualitas air daerah gambut di Provinsi Riau (The effectiveness of rapid sand filters to improve water quality in peat areas in Riau Province) J. Fteknik 4 1 319-333

[30] Lytle D A, Daniel W, Christy M, Eugenis R, Maily P 2020 The removal of ammonia, arsenic, iron and manganese by biological treatment from a small Iowa drinking water system Environ. Sci. Water Res. 6 3142-3156

[31] Kusnaedi 2010 Mengolah air kotor untuk air minum penebar swadaya (Treat dirty water for drinking water self-help spreader) Jakarta [In Indonesian]

[32] Hossain F, Ni-Bin C, Marty W 2010 Modeling kinetics and isotherms of functionalized filter media for nutrient removal from stormwater dry ponds Environ. Prog. Sustain. Energy 29 3 319-333

[33] Kwaadsteniet M D, Dobrowsky P H, Deventer A V, Khan W, Cloete T E 2013 Domestic rainwater harvesting: microbial and chemical water quality and point-of-use treatment systems. J. Water Air Pollut. 224 1629 1-19

[34] American Water Work Association 2003 Principles and Practice of Water Supply Operations Water Treatment Third Edition (United States of America: West Quincy Avenue) chapter 6 pp 122

[35] Elif S, Omer A, Nursen O E, Ahmet M S 2010 Crushed recycled glass as a filter medium and comparison with silica sand J. Clean-Soil, Air, Water 38 10 927-935

[36] Nirhayati I 2010 Inasiate filter media to reduce hardness and iron J. Teknik Waktu 8 1 108-116 [In Indonesian]

[37] Rosliana N, Karyono 2016 Efektivitas media saring dalam menurunkan kandungan E.Coli pada air sungai lamaran Desa Tegalurung Kecamatan Legonkulon Kabupaten Subang (The effectiveness of filter media in reducing the content of E.Coli in the river water application Tegalurung Village District Legonkulon Subang Regency) J. Sehat Masada 10 2 33-41 [In Indonesian]

[38] Solihin, Bambang S 2010 Tinjauan teknis dasar efisiensi sistem resapan dalam usaha pengendalian banjir (Basic technical review of the efficiency of the infiltration system in flood control efforts) J. Teknologi 2 16 76-91 [In Indonesian]

[39] Tien V N, Saravanamuthu V, Huu H N, Damodar P, Thiruvenkatachari V 2006 Iron-Coated Sponge as Effective Media to Remove Arsenic from Drinking Water Water Qual. Res. J. 41 2 164-170

[40] Sasmittha D 2017 Pemanfaatan sampah plastik polyethylene terephthalate (PET) sebagai media pada unit pre-filter (Use of polyethylene terephthalate (PET) plastic as pre-filter media) Undergraduate Thesis Institut Teknologi Sepuluh Nopember [In Indonesian]

[41] Asnaning A R, Surya, Andy E S 2018 Uji kualitas air hujan hasil filtrasi untuk penyedian air bersih (Rainwater quality test from filtration result for clean water supply). Proceedings of the National Seminar of Agricultural Technology Development 2018 288-293 [In Indonesian]

[42] Wang C, Fu-Shen Z 2013 Zeolite loaded ceramsite developed from construction and demolition waste Mater. Lett. 93 380-382
[43] Bruch I, Johannes F, Dominik B, Ulrike A, Michael S, Heinz H, Ralf H, Christine A 2011 Improving the treatment efficiency of constructed wetlands with zeolite-containing filter sands *J. Biore. Technol.* **102** 937-941

[44] Khayan K, Adi H H, Indwiani A, Sudarmadji S, Tjut S D 2019 Rainwater as a source of drinking water: health impacts and rainwater treatment *Int. J. Environ. Res. Public Health* **17**60950 1-11

[45] Arimawanti F W, Lucky H, F X Amanto R 2013 Penggunaan rangkaian filtrasi FM2FV untuk menurunkan kadar kekeruhan dan coliform air hujan di rs bethesda yogyakarta tahun 2012 (Use of FM2FV filtration series to reduce levels of turbidity and coliform rainwater in bethesda hospital yogyakarta in 2012) *J. Kesehatan Lingkungan* **4** 4 151-159 [In Indonesian]

[46] Minister of Health No.416/MENKES/PER/IX/1990 Regulation of the Minister of Health of the Republic of Indonesia (Indonesia: Requirements and Supervision of Water Quality)

[47] Saifudin M R, Dwi A 2005 Kombinasi media filter untuk menurunkan kadar besi (Fe) (Filter media combination for decreasing iron degree (Fe)). *J. Penelitian Sains & Teknologi* **6** 1 49-64 [In Indonesian]

[48] Ballantine D J, Chris C T 2010 Substrate and filter materials to enhance phosphorus removal in constructed wetlands treating diffuse farm runoff: a review *J. Agric. Res.* **53** 1 71-95

[49] Sari S P, Suhendri 2018 Potential of rainwater system for domestic building in Jakarta *IOP Conference Series: Earth and Environmental Science* **152** (2018) 012002

[50] Sudiajeng L, Wiraga I W, Parwita I G L M, Budiadi I M 2019 The effectiveness of horizontal water filtering system on deep rainwater harvesting wells *J. Physics* **1450** (2020) 012029