# The effectiveness of horizontal water filtering system on deep rainwater harvesting wells

**L Sudiajeng[1], I W Wiraga[1], I G L M Parwita[1], I M Budiadi[1]**

[1] Department of Civil Engineering, Politeknik Negeri Bali, Kampus Bukit Jimbaran, Bali, Indonesia

E-mail: sudiajeng@pnb.ac.id

**Abstract**. The main requirement in recharging aquifers is the quality of refill water must meet the groundwater quality standards. Therefore, the role of the filtration system is important. The horizontal water filtering system has designed to lengthen the filtering process. First step: Rainwater falls that contaminated with various substances flows into the 20 cm thick and 1 m depth of gravels; Second Step: Rainwater continued flowing into the horizontal pipe, 4” of diameter, 20 cm length, with the fibre palm tree inside. The filtered water comes out and collected in a reservoir, flows into a recharge wells with 4” diameter and 32 m depth, and fills the aquifer after going through the soil layer. Laboratory tests shows that the horizontal water filtering system is effective to reduce the content of substances, except the TDS for filtering system in Plaga Village. It decreased from 135.00 uS/cm to 81.90 uS/cm (26.55 percentage) in Tegallalang village, but it increased from 95.00 uS/cm to 154.00 uS/cm (62.21 percentage) in Plaga village, although it still meets to the groundwater quality standard. The increasing of TDS might be cause by gravels or palm tree fibres that not thoroughly cleaned and still contained TDS.

## 1. Introduction

Groundwater is a renewable resource, however if the exploitation is much more than the capacity, then it will lead to the water crises. This phenomenon is common in all over the world, especially in developing countries such as Indonesia. As tropical country, Indonesia has very much rain water, 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. This adds to the misery of the community. Of course, this is a serious problem both technically and socio-culturally aspects, included in Bali, which is known as the very famous tourism destination in the world. The tourists increase gradually as well as the number of hotels. The Bali provincial statistics bureau reported that foreign tourist arrivals to Bali Province in July 2019 recorded 604.493 visits, 604.480 arrivals through the airport, and 13 seaports through the seaport. The number of foreign tourists to the Bali Province in July 2019 rose as high as 9.96 % compared to the June 2019 record. Occupancy Rate of starred hotel rooms in July 2019 was recorded at 61.71 %, up 1.34 points compared to the previous month, which reached 60.37 %. The number of started hotels in 2017 is 551, rose as high as 96.09 % compared to 2015-2016. The increasing of Tourism industry followed by the increasing of population. According to the 2015 Population Survey, the population in Bali Province in 2019 reached

4.36 million increased about 3.81% compare to 2018 [1]. This condition increased the needs of clean water, both tourism industry and domestic. The report from the head of the Bali-Penida River Basin Office submitted in the commemoration of World Water Day on March 22, 2019 shows that the total water demand in Bali is 1.37 billion $m^3$, consisting of: Irrigation 1.005 billion m3 of water; Domestic 0.325 billion $m^3$; Non-Domestic 0.04 billion $m^3$. While total water availability is 0.90 billion $m^3$. Moreover, the total potential water is 7.57 billion $m^3$, consisting of: surface water / run-off 6.55 billion $m^3$; spring 0.73 billion $m^3$; and ground water 0.29 billion $m^3$. The data shows that all water needs cannot be met. Therefore, to meet the needs of clean water, the tourism industry uses groundwater through deep wells. If the exploitation of ground water continues, it will threaten the availability of ground water and eventually Bali will face a water crisis as has been feared. The report from the head of the Bali-Penida River Basin Office submitted in the commemoration of World Water Day on March 22, 2019 shows that the total water demand in Bali is 1.37 billion $m^3$, consisting of: Irrigation 1.005 billion $m^3$ of water; Domestic 0.325 billion $m^3$; Non-Domestic 0.04 billion $m^3$. While total water availability is 0.90 billion m3. Moreover, the total potential water is 7.57 billion $m^3$, consisting of: surface water / run-off 6.55 billion $m^3$; spring 0.73 billion $m^3$; and ground water 0.29 billion $m^3$. The data shows that all water needs cannot be met. Therefore, to meet the needs of clean water, the tourism industry uses groundwater through deep wells. If the exploitation of ground water continues, it will threaten the availability of ground water and eventually Bali will face a water crisis as has been feared. To balance for the exploitation of ground water, it is very important to preserve groundwater sources, including by making artificial recharge wells [2]. Groundwater is a valuable freshwater resource and constitutes about two thirds of the world's freshwater reserves [3]. Naturally, hydrology process will keep the balance between water recharge and discharge [4]. However, the developments of industries and the change of people’s behaviour, especially in the urban city disturbed its balance, leads to a decrease of groundwater table, subsidence and water quality [5]. Groundwater quantity and quality currently become one of the big challenges in the industrial era 4.0. The development of high technology that are very fast require adequate infrastructure which requires increasing water resources for the routine operational and maintenance through a deep well, even some more than 100 to 200 m depth. The exploitation of groundwater through deep wells leads the seawater intrusion, especially in the area along coastal line. One simple way to maintain the groundwater level and to prevent seawater intrusion is to build a recharge wells for rainwater harvesting that can be done at individual household level and at community level in both urban as well as rural areas [6]. Rainwater is collected in the wells, re-absorbed into the ground, and the excess is drained into the drainage channel or used for other needs. One of the important requirements of recharge wells is that the water absorbed should meet to the water standard; therefore, the role of the filtration system is very important.

## 2. Materials and methods

This research is part of the multi-years research on water conservation program in Bali, which more focus on the horizontal water filtering system on deep rainwater harvesting wells. This horizontal system is an innovative redesign from the vertical one as describes in Figure 1. It shows the detail of horizontal water filtering system. The horizontal water filtering system is designed in 2 steps. 1) Rainwater that falls in the yard and has been contaminated with various substances and bacteria flows into the gravels as thick as 20 cm and 1 m depth. Solid contents such as mud will settle, and then enter the second step. 2) Rain water with less of solid contents flows into the horizontal pipe, 4” of diameter, 20 cm length, with the fibre of palm tree inside. The water comes out of the filtration pipe is collected in a tub, then flows into a recharge wells with 4” diameter and 32 m depth, and fills the aquifer after going through the soil layer between the bottom end of the pipe and the surface of the aquifer. The previous research showed that although the vertical water filtering system was decreased the value of some parameters, but it still up of the maximum value, included BOD, Pb, and Cd. The content of BOD after rainwater flowed into the water filtering system was 3.761 mg/l (> 2.0 mg/l), Pb was 0.202 mg/l (> 0.03 mg/l), and Cd was 0.738 mg/l (> 0.01 mg/l) [7]. Therefore, it needs innovation redesign. The idea to change the vertical water filtering system into the horizontal was in order to lengthen the water flow paths through filtering system.

Rainwater quality pre-post test was conducted both for rainwater from the roof and rainwater that already dropped on the farmland. There were 8 samples for each pre-post-test, which were analysing in the laboratory, with the parameters based on the water quality standard. The effectiveness of the horizontal water filtering system was assessed by the indicator of the reducing of each water quality parameter before and after rainwater flows into pipes filled with palm tree fibbers.

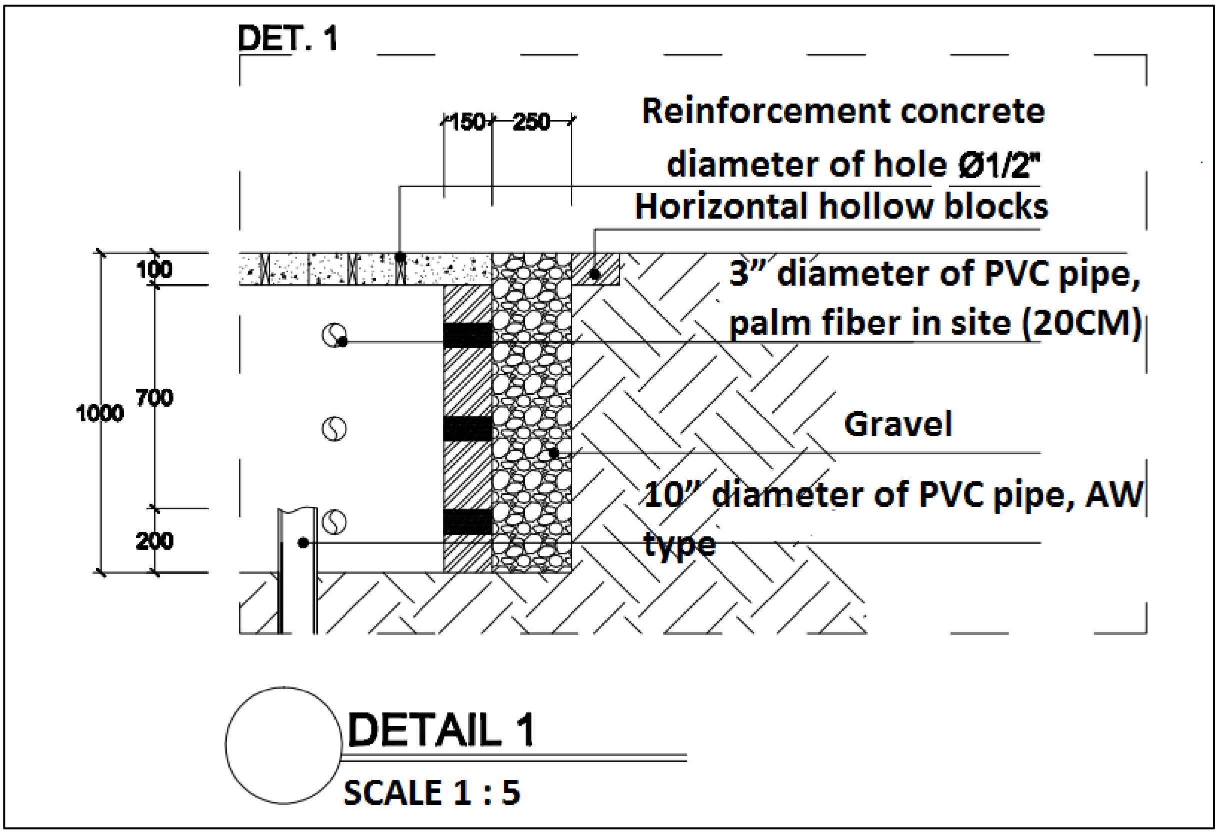


**Figure 1**. The horizontal water filtering system.

## 3. Results and discussion

### *3.1. Groundwater standard quality*

Some substances, which are in groundwater and can cause problems is as describe in Table 1 [8] and the groundwater quality standards is describe in Table 2. About the groundwater quality standard, it common that each country, even each district issues its own standard, however, it generally is similar. Table 2 compared the water quality standard refers to Todd 1980 [9] and the Ministry of health Republic Indonesia 1990 [10]. From those two standards, there are some quite big differences, such as the TDS, Mg, Cl. In addition, there are many parameters that are required / measured in the Indonesian Republic Minister of Health standard 1990 (RI Standard), but not required / measured in Todd standards. Table 2 shows that some parameters that can cause various problems including health problems are also not required or measured either in Todd's standards or RI standards. This is most likely due to differences in analysis and perceptions of each country.

**Table 1**. Substances in groundwater, which cause problems.

| Substance | Type of Problems |
|---|---|
| Iron ($Fe^{+2}$, $FE^{+3}$) | Encrustation, staining of laundry and toilet fixtures |
| Manganese ($Mn^{-2}$) | Encrustation, staining of laundry and toilet fixtures |
| Silica ($SiO^2$) | Encrustation |
| Chloride (Cl) | Portability, corrosiveness |
| Fluoride (F) | Fluorosis |
| Nitrate ($NO_3$) | Methemoglobemia |
| Sulphate ($SO_4^{-2}$) | Portability |
| Dissolved Gases | Corrosiveness |
| Dissolved Oxygen | Corrosiveness |
| Hydrogen Sulphide ($H_2S$) | Corrosiveness |
| Carbon dioxide ($CO_2$) | Corrosiveness |
| Radio Nuclides | Portability, health aspect |
| Calcium and Magnesium ($Ca^{2+}$, $Mg^{2+}$) | Encrustation |

**Table 2**. Groundwater Quality Standard.

| Parameters | Unit | Todd Standard [7] | Ministry of Health RI Standard [8] |
|---|---|---|---|
| Dissolve Solids (TDS) | mg/l | < 5,000 | < 1500 |
| Nitrate (NO3) | mg/l | < 10 | < 10 mg/l |
| Sodium (Na) | mg/l | <200 | - |
| Potassium (K) | mg/l | < 10 | - |
| Calcium (Ca) | mg/l | < 100 | - |
| Magnesium (Mg) | mg/l | < 50 | 0.5 |
| Carbonate (H2CO3) | mg/l | < 10 | |
| Bicarbonate (HCO3) | mg/l | < 500 | |
| Chloride (Cl) | mg/l | < 10 | < 600 |
| Sulphate (SO4) | mg/l | < 300 | < 400 |
| Fe | mg/l | - | < 1 |
| Zn | mg/l | - | < 15 |
| Cadmium (Cd) | mg/l | - | < 0.005 |
| Pb | mg/l | - | < 0.05 |
| Hg | mg/l | - | < 0.001 |
| As | mg/l | - | < 0.05 |
| Se | mg/l | - | < 0.01 |
| Fluoride | mg/l | - | < 1.5 |
| Organic substances | mg/l | - | < 10 |
| Cyanide | mg/l | - | < 0.1 |
| pH | mg/l | - | 6.5 – 9 |
| Detergent | mg/l | - | < 0.5 |
| Color | TCU | - | < 50 |
| Turbidity | NTU | - | < 25 |
| TDS | mg/l | - | < 1500 |
| Hardness | mg/l | - | < 500 |

### *3.2. Effectiveness of Horizontal water filtering system*

The assessments of the effectiveness of horizontal water filtering system was conducted in two places where the deep recharge wells were built, there are in the tourism area Plaga Village Badung Regency and Tegalalang Village Gianyar Regency. Table 3 and Table 4 showed that the horizontal water filtering system effective in reducing the volume of substances, except TDS substance for the recharge wells in Plaga village and TSS, $KMNO_4$, and Fe for the recharge wells in Tegalalang village. It means that the additional substances were certain from the corals or palm tree fibres, which fill the filtration pipe. Based on this result, it means that the fibre must be washed thoroughly before putting in the pipe.

**Table 3.** The effectiveness of horizontal water filtering system for Deep recharge wells in Plaga Village Badung Regency.

| No | Parameter | Unit | Mean (pre) | Mean (post) | Decreasing (%) |
|---|---|---|---|---|---|
| A | Physical Parameters | | | | |
| 1 | Temperature | $^0$C | 0.400 | 0.300 | 0.35 |
| 2 | TDS | uS/cm | 95.000 | 154.100 | 62.21 |
| 3 | Hardness | mg/lt | 0.270 | -0.47 | -0.1 |
| 4 | TSS | ppm | -0.020 | 0.22 | 0.1 |
| B | Organic Chemical Parameters | | 0.000 | 0 | 0 |
| 5 | pH (*potential Hydrogen*) | ppm | 0.000 | 0 | 0 |
| 6 | DO (Dissolved Oxygen) | ppm | 0.000 | 0 | 0 |
| 7 | KMnO4 | ppm | 0.000 | 0 | 0 |
| 8 | COD | ppm | 0.050 | 0 | 0.025 |
| 9 | BOD5 | ppm | 0.250 | 0 | 0.125 |
| 10 | Nitrate ($NO_3$) | ppm | 0.225 | 0.054 | 0.1395 |
| 11 | Nitrite (NO2) | ppm | 0.030 | 0 | 0.015 |
| 12 | Ammonia (NH3) | ppm | 0.000 | 0.02 | 0.01 |
| 13 | Phosphor (PO4) | ppm | 0.050 | 0 | 0.025 |
| 14 | Cadmium (Cd) | ppm | 0.000 | 0 | 0 |
| 15 | Chrome (Cr) | ppm | -0.010 | 0 | -0.005 |
| 16 | Mercury (Hg) | ppm | 0.000 | 0 | 0 |
| 17 | Cuprum (Cu) | ppm | 0.000 | 0 | 0 |
| 18 | Nickel (Ni) | ppm | 0.000 | 0 | 0 |
| 19 | Zn | ppm | 0.440 | -0.09 | 0.175 |
| 20 | Lead (Pb) | ppm | 0.000 | 0 | 0 |
| 21 | Fe (Total) | ppm | 0.000 | 0 | 0 |
| 22 | Fe (dissolved) | ppm | 0.010 | 0 | 0.005 |

Thomas Harter [11], the Hydrogeology Specialist, University of California reported that Water with a TDS above 500 mg/l is not recommended for use as drinking water (EPA secondary drinking water guidelines). Water with a TDS above 1,500 to 2,600 mg/l (EC greater than 2.25 to 4 mmho/cm) is generally considered problematic for irrigation use on crops with low or medium salt tolerance. Both Table 3 and Table 4 showed that the quality of rainwater is less than 1,500 and after get through the filtering system, it decreased. The particles of Zn, Fe, NO3 and NO2 all below the recommendation limit. It means that the rainwater which has filtering and enter the wells is meet the standard and safe for the ground water. It is very important since most of drinking water resources is ground water. In European countries, the usage of groundwater as the drinking water resource is more than 65%, even in Austria, it is 99% [12], it is similar with Bali Indonesia which still use more than 70% of groundwater as the drinking water resource.

**Table 4.** The effectiveness of horizontal water filtering system for Deep recharge wells in Tegalalang Village Gianyar Regency.

| No | Parameter | Unit | Mean - pre | Mean - post | Decreasing (%) |
|---|---|---|---|---|---|
| A | Physical Parameters | | | | |
| 1 | Temperature | $^0$C | 0.100 | 0.000 | 0.05 |
| 2 | TDS | uS/cm | 135.000 | 81.900 | 26.55 |
| 3 | Hardness | mg/lt | 0.040 | -0.65 | 0.345 |
| 4 | TSS | ppm | 0.000 | 0.3 | -0.15 |
| B | Organic Chemical Parameters | | 0.000 | 0 | 0 |
| 5 | pH (potential Hydrogen) | ppm | 0.000 | 0 | 0 |
| 6 | DO (Dissolved Oxygen) | ppm | 0.000 | 0 | 0 |
| 7 | KMnO4 | ppm | -0.050 | 0 | -0.025 |
| 8 | COD | ppm | 0.100 | 0 | 0.05 |
| 9 | BOD5 | ppm | 0.250 | 0 | 0.125 |
| 10 | Nitrate ($NO_3$) | ppm | 0.250 | 0 | 0.125 |
| 11 | Nitrite (NO2) | ppm | 0.000 | 0 | 0 |
| 12 | Ammonia (NH3) | ppm | 0.000 | 0 | 0 |
| 13 | Phosphor (PO4) | ppm | 0.000 | 0 | 0 |
| 14 | Cadmium (Cd) | ppm | 0.000 | 0 | 0 |
| 15 | Chrome (Cr) | ppm | 0.000 | 0 | 0 |
| 16 | Mercury (Hg) | ppm | 0.000 | 0 | 0 |
| 17 | Cuprum (Cu) | ppm | 0.000 | 0 | 0 |
| 18 | Nickel (Ni) | ppm | 0.000 | 0 | 0 |
| 19 | Zn | ppm | 0.000 | 0 | 0 |
| 20 | Lead (Pb) | ppm | 0.000 | 0 | 0 |
| 21 | Fe Total | ppm | -0.010 | 0 | -0.005 |
| 22 | Dissolved Fe | ppm | -0.010 | 0 | -0.005 |

## 4. Conclusions

Refers to the result and discussions, it can be concluded that there is difference standard of water quality in each country; The horizontal water filtering system is effective to reduce the content of substances, although there are some parameters increased after the rainwater flows into the filtering system, but still meet the recommendation limit of water quality standard; The fibre must be washed thoroughly before putting in the pipe to make sure that there will not be additional substances during the filtering process.

## 5. References

[1] Bali Provincial Statistics Agency 2019 (Indonesia: Bali in Numbers)
[2] Ministry Of Water Resources 2000 *Guide On Artificial Recharge To Ground Water* (New Delhi: Central Ground Water Board Ministry Of Water Resources)
[3] Stephen F, John C, Marcus M, Franklin C and Manuel S 2000 *The International Bank for Reconstruction and Development (*Swiss: The World Bank)
[4] Todd J 1990 *Introduction to Hydrogeology* (Canada: Geology Department Faculty of Science University of Alberta Edmonton)
[5] Bouwer H 2001 *Artificial Recharge Of Groundwater: Hydrogeology and Engineering. Hydrogeology Journal* **10** 121-142
[6] Central Pollution Control Board, Ministry of Environment & Forests 2001 *Concepts And Practices For Rainwater Harvesting* (New Delhi: Resource Recycling Series)
[7] Sudiajeng L, Wiraga I W, Lanang I G P and Mudhina M 2017 *Advance Science Letter Journal-*

*USA* **1**
[8] Dohare D, Desphande S and Kotiya A 2014 *Journal of Engineering Science* **3** 26 – 31.
[9] Todd D K 1980 *Groundwater hydrology 2nd ed* (New York : Willey)
[10] Minister of Health 1990 *Regulation of the Minister of Health of the Republic of Indonesia* (Indonesia: Requirements and Supervision of Water Quality)
[11] Thomas H 2003 *Groundwater Quality and Groundwater Pollution. University Of California Division of Agriculture and Natural Resources*
[12] Oliver S, Guy H, John C and Ingrid C 2006 *World Health Organization WHO* (Padstow Cornwall UK: TJ International Ltd)

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