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Performances of Zeolite, Coconut Shell, and Zeolite+Coconut Shell-Based Water Cartridges to Minimize Contaminants of Drinking Water

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ABSTRACTS

Performances of zeolite, coconut shell, and zeolite+coconut shell-based water cartridges to minimize contaminants of drinking waters were conducted in the present study. The zeolite stones and coconut shell charcoal were powdered to be ≥ 60 meshes. The powders were packed into a cartridge to provide zeolite, coconut shell, and zeolite+coconut shell (1:2) cartridges, respectively. Well waters allowed to flow through each cartridge for a month. Thereafter, each water filtrate was harvested and analyzed numbers of parameters from four variables included in the quality table of drinking water. The total coliform found in each 100 mL of the well water equaled to 460 MPN (most possible number) while the fecal coli equaled to 150. When the well water flowed through the developing cartridges, the MPN content varied which depended on the cartridge materials qualitative compositions. Total coliform remained in water filtrates of the well waters flowed through the cartridges made of zeolite, coconut charcoal, and their mixture (1:2 by volume) were 38, 240, and 96 MPN, respectively. These developed cartridges, therefore, could remove these total coliform from the well waters by 92, 48, and 79 %, respectively. Overall, the performance of the developed cartridge made of zeolite was highest among those cartridges.

Keywords: zeolite, water cartridge, coconut shell, coconut charcoal, zeolite cartridge
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1. Introduction

Drinking water is a vital necessity for life; it is safe for the health of human beings when it meets the requirements of physics, microbiology, chemistry, and radioactivity/ inorganic (Table 1). Unqualified drinking water could induce disorders of metabolism. When contents of cadmium ions (Cd^{2+}) in drinking water, for example, are above the threshold, they induce the occurrence of metabolic disorders. These Cd^{2+} metal ions have a half-life (living in bio-membranes) of 15 to 30 years and high-affinity to the bio-membranes (Rani et al., 2014). The excretions of Cd^{2+} ions already entering the body are almost impossible; these metal ions accumulate in bio-membranes such as in the blood cells and various organs include kidneys, liver and reproductive organs. This event produces Cd^{2+} metal ion toxicity. Similar things can also be induced by other metal ions with the same or different metabolic effects. Longer resident time of pro-life metal ions in a bio-cellular system, longer their toxic effects to appear (annual or even decades) which are in contrast to the effects of microorganisms and toxic/radioactive metals.

Minimizing the negative impacts of the unworthy drinking water face a challenge to water cartridge technology. The chemical science required to apply in the cartridge technology is about the chemical structures of the surfaces of the building block materials. These surfaces play essential roles as the active sides of the cartridge materials. The interactions between those surface active sides and impurities carried by the drinking waters occur in adsorption processes and therefore washing the contaminants of the drinking water. Various zeolite-based cartridges have been produced as reported as well (Ndiege et al., 2011) which was a zeolite-based product in imaging application, (McCarthy et al., 2012) which was a patent in aluminum-based product, and (Lia et al., 2015) which was a zeolite-based product in heat pump technology. The zeolite-based cartridges were also reported to have the ability to attract free radicals, thus helping the body to capture them and offset the effects of radiation (Maunawai, 2017). These facts mean that zeolite materials could create any type of products.

A product design for the patent belongs to inventors (McCarthy et al., 2012) involved various sizes of the zeolite materials. The cartridge was reported to have sorption for various minerals but there was no data reported regarding their effects on flavors, color, hardness, turbidity and the bacteria captured by the cartridge. Based on these facts, there has been a challenge to innovate the existing zeolite-based cartridge for filtering the drinking waters. Our present innovated technology provided the zeolite-based cartridges that had a capability to capture *E-coli* (fecal coli) and *total coliform* which were reduced approximately by 90%.

Table 1: Ministry of Health Regulation No. 492 / 2010 (Summaries parameters adopted by PT. Jasa Tirta)

Variables	Drinking water quality parameters	Units	References (Max)
Microbiology	Fecal E-Coli	MPN/100 mL	0
	Total coliform	MPN/100 mL	0
Inorganic	Arsen	mg/L	0.01
	Fluoride	mg/L	1.5
	Total chromium	mg/L	0.05
	Cadmium	mg/L	0.003
	Nitrite (as NO_2^-)	mg/L	3
	Nitrate (as NO_3^-)	mg/L	50
	Cyanide	mg/L	0.07
	Selenium	mg/L	0.1
Chemicals	Aluminum	mg/L	0.2
	Fe	mg/L	0.3
	Hardness	mg/L	500
	Chloride	mg/L	250
	Mangan	mg/L	0.4
	Zn	mg/L	3
	Sulphate	mg/L	250
	Cu	mg/L	2
	Ammonia	mg/L	1.5
	pH		6.5 – 8.5
Physics	Smell		No smell
	Color in true color unit (TCU)	TCU	15
	Total dissolved solids (TDS)	mg/L	500
	Turbidity in nephelometric turbidity Unit (NTU)	NTU	5
	Taste		No taste
	Temperature	^oC	Air temperature ± 3

The coconut shell-based cartridges also showed the capability to remove impurities existing within the drinking water. Although their efficacy to capture those bacteria less than that of the zeolite-based cartridges, however their values quiet high which were up to 47%-75 % of the total bacteria existing within the drinking water. The black color of the coconut charcoal provided the no color filtrates from which the original water flowed through to producing filtrates. Overall, the performances of zeolite, coconut shell, and zeolite+coconut shell-based water cartridges minimizing contaminant contents of drinking waters were evaluated in the present study.

2. Materials and Methods

2.1. Materials

The materials used in the present study were coconut shell (charcoal) bought in Pasar Inpres Naikoten 1, Kupang. Zeolites were from Ende (Flores Island). Polyvinyl chloride (PVC) pipes, for making a tube C in Fig. 1, were bought from the market (Kupang) and water cartridge, A and B in Fig. 1. was bought from drinking water depot shops in Kupang.

2.2. Research Design

Fig. 2 below shows the lab scale design (left) and real environment of application (right). The ¾"(dim) PVC pipe, used to create cartridges for the lab scale, was cut with a size equal to 20 cm. Either zeolite (50 gram) or coconut shell (40 gram) powder (slurry) was then packed. The cartridge was balanced overnight with distilled water (DW). The well water, DW, and 0.113 µg/mL Fe (II) flowed through the cartridges made of the zeolite, coconut shell, and zeolite-coconut shell for 24 hours. Each filtrate was collected and evaluated visually the color, turbidity, and taste, while Fe (II) ion contents of their filtrates were measured spectrometrically by Atomic Sorption Spectrometry (ASS) method.

Fig. 1. Materials used for the study

The cartridge size (Fig. 1C) for application in the real environment was 22 cm (length) and 2.5" PVC. The slurry made of the zeolite (825g), coconut shell (390g), and zeolite+coconut shell (680g) in DW were then packed and balanced with DW overnight. After 3 days well water flowed through each cartridge, the filtrates (water sample) were harvested 1.5 L each their filtrates and sent them to the laboratory (PT. Jasa Tirta 1/Malang) to measure the values of each parameter of Physics, Chemistry, and Inorganic variables. Filtrate sampling for measuring the microbiology variable was performed by the lab analyst from the office.

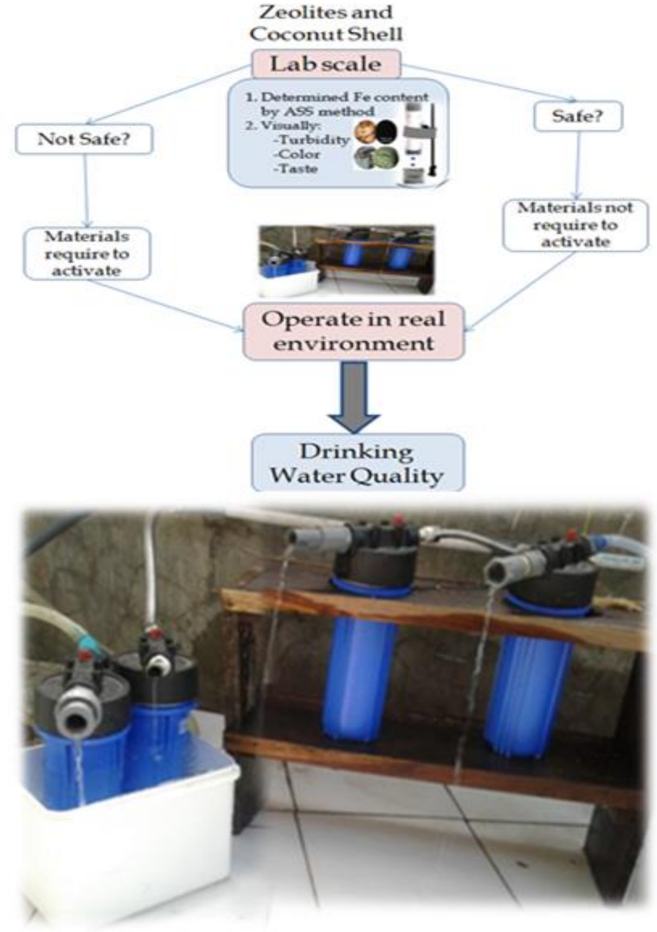

Fig. 2. Research design of the study at lab scale (upper site) and real environment (lower site)

2.3. Method

The lab scale of the study was conducted in Bioscience Laboratory of Nusa Cendana University. The real environment for the study was performed using well water addressed in Jl. Amanuban No. 30, RT/RW: 016/04 Oebufu, Oebobo District, Kupang City. The variables required to measure according to Table 1 were performed by the Laboratory analysts of PT. Jasa Tirta 1 in Malang, while microbiology variable was performed by the Laboratory analysts of Dinas Kesehatan Kota Kupang.

2.2.4. Statistical analysis

Data were expressed as mean ± standard error of the mean. Data were analyzed by one-way analysis of variance, and all differences were inspected by Duncan's new multiple-range test using SPSS statistical software. The minor (single) data was slightly reported as their original values. $P \leq 0.05$ was considered statistically significant.

3. Results and Discussion

3.1. The goals of material pre-preparations

The strategy choice on material pre-preparations depended on the goal of the study. Therefore, pertaining to this work, how to get a cartridge removing impurities of drinking water with a price low should a part of whole considerations in pre-preparations of the cartridge materials. Hence, the goal of the study was to produce water cartridges which they could purify candidate drinking water to have a quality equaled to the base mark reported data shown in Table 1. In lab scale of the study (Fig. 2 left), the visual parameters involving in considerations were taste, color, and turbidity. Those parameters indicated that all water filtrates delivered by each cartridge were no taste and their colors were less than 0.30 TCU, which was very far from references, the 15 was maximum. There was visually no turbidity which its value was less than 2.20 NTU; the 5 NTU was the maximum (Table 1). Using AAS method (Fig. 2 left), the concentrations of Fe (II) ions found in each filtrate were reported in Fig. 3.

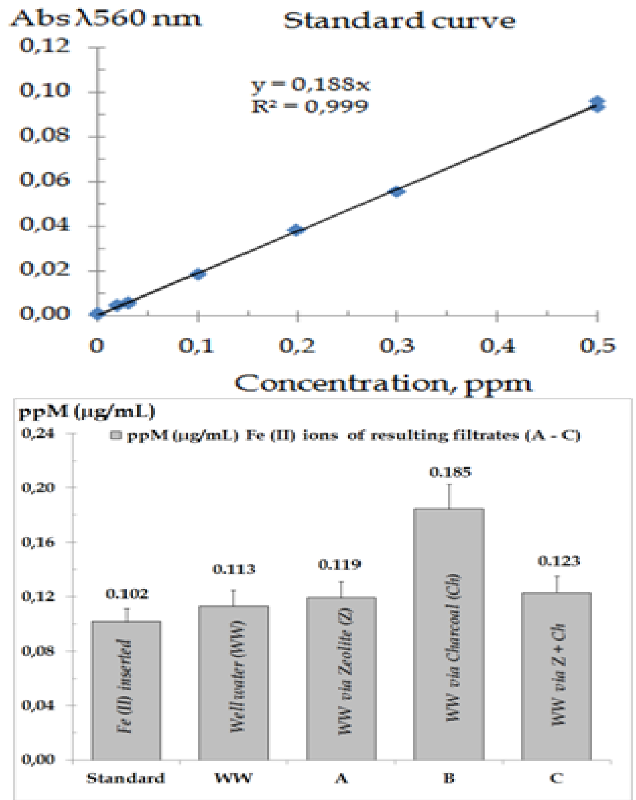

Fig. 3. The concentration of Fe (II) in water filtrates produced by cartridges

Data Fig. 3 (right) showed that concentration of prepared Fe (II) ions standard equaled to 0.102, the well water equaled to 0.113, while the filtrates of the well water flowed through the zeolite cartridge equaled to 0.119 µg/mL. This meant that cartridge materials also delivered a Fe (II) ion that was equaled to 0.006 µg/mL. The Fe (II) ion delivered by the Ch and Z+Ch cartridges were 0.072 and 0.01 µg/mL, respectively. Although these materials delivered additional Fe (II) ions into the filtrates, the Fe (II) ion contents in its filtrates were still in a range of Fe (II) ions permittable for drinking waters (Table 1). These data told that powder materials were safe to use directly for creating, feeding and packing the cartridge without activation the powder materials. These background stories of the cartridge performances were also supported by the visual data involving taste, color, and turbidity of the filtrates delivered from each cartridge. This lab scale study recommended continuing the treatment in a real environment. Overall, elimination of this stage in the preparation of the cartridge materials could reduce the production cost of the cartridge and therefore its marketing prices could be possible competitiveness.

3.2. Performance of the water cartridges based on physics, inorganic, and chemicals parameters of the candidate drinking water

The well water was the candidate drinking water used to test the performance of the candidate cartridge created in the present study. The physic parameters tested for the cartridge performances were the smell, taste, temperature, color, turbidity, and TDS of the water filtrates delivered by the cartridges. The values of each physic parameters of the water filtrates were compared with of those well water values. As shown in Table 2, either well waters or water filtrates were no taste and no smell. Their temperatures were also no differences. Those parameter values meet the base markers of the references (Table 1). The other physic parameters of the drinking waters required to treat within the cartridge performances were turbidity, TDS, and color. As shown in Fig. 4 and Table 1 that base markers for the turbidity, TDS, and color were 5, 500, and 15, respectively; while those for well water samples were 0.30, 1.66, and 480, respectively. Based on those six physic parameters, the well waters used to clarify the performances of the cartridges developed in the study met the base markers of the references. It meant that the well water used in the study was suitable for the drinking waters. This fact reinforces the population utilizing this well water daily as drinking water and various other household purposes.

Reading water filtrate data, by which well waters flowed through each cartridge (Fig. 4) for 30 days, the zeolite cartridge reduced markedly turbidity that was approximately by 39% compared to well waters. This reduction was approximately by 53% compared to coconut cartridge or 49% compared to the mixture. These data told that zeolite cartridges had the highest performance to eliminate the turbidity of the well water than the others. Looking color of the water filtrates, the mixture cartridge could totally remove (100%) the color of the well waters, however, both other cartridges removed slightly, approximately by 14 %. Looking data shown in Fig. 4, the excellence of the zeolite cartridge was to eliminate the turbidity, while the color was excellently removed by the zeolite+coconut shell (mixture) cartridge. However, the coconut cartridge excellently eliminated the TDS of the well waters which was approximately by 12%, the zeolite and mixture cartridges eliminated TDS of the well waters, approximately by 6 and 4 %, respectively.

The excellences of the zeolite cartridge to eliminate the turbidity of the well water discussed already above strengthen the fact that zeolite minerals could attract free radicals (Maunawai, 2017) in waters. The zeolite cartridges, therefore, provide multiplier effects that eliminate the turbidity and helping body to capture free radicals and offset the effects

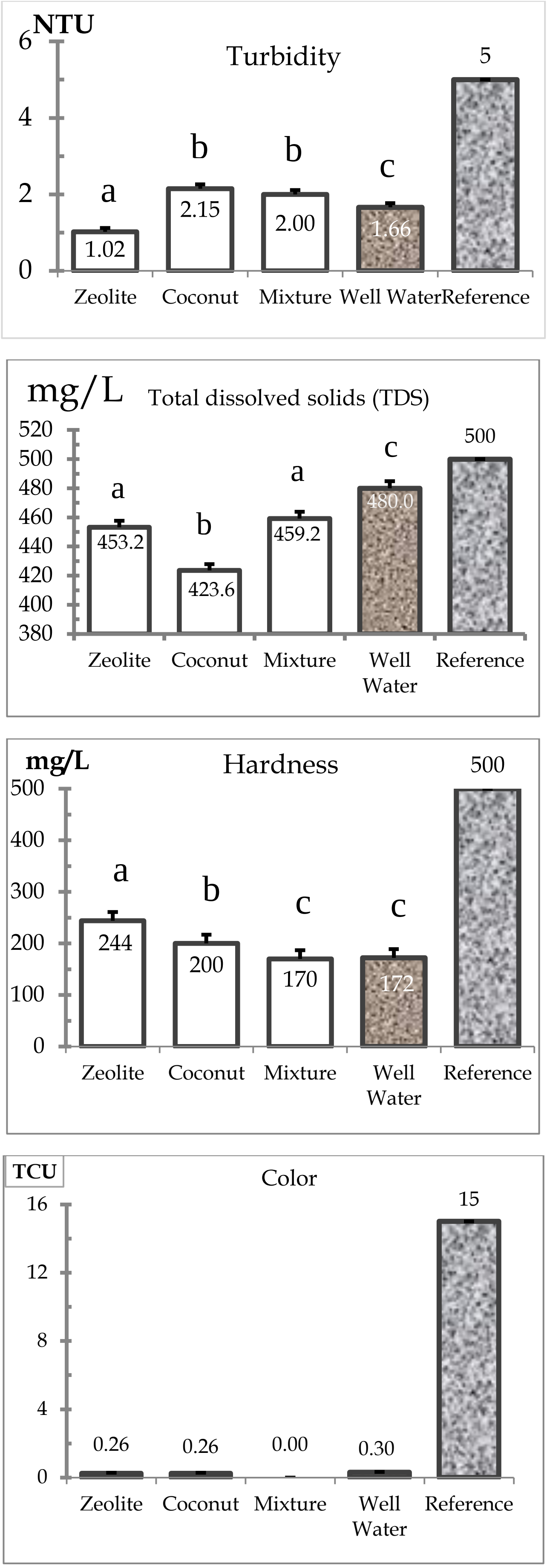

Fig. 4. Turbidity, total dissolved solids, hardness, and color

The abc different letters indicated the mean differences were significant at P ≤ 0.05.

Table 2: Performances of cartridges evaluated in various parameters

No.	Variable/Parameters	Units	Well water	Cart- Z (Zeolite)	Cart- C (Coconut) shell	Cart- ZC (Mixture)	Reference *)
1	2	3	4	5	6	7	8
1.	Temperature	^oC	24.3 ± 0.0	24.6 ± 0.0	24.6 ± 0.0	24.7± 0.1	Air temperature ± 3
2.	pH	-	6.5 ± 0.2^a	7.5 ± 0.2^b	6.5 ± 0.2^a	6.5 ± 0.2^a	6,5 – 8,5
3.	Taste	-	No taste	No taste	No taste	No taste	No taste
4.	Smell	-	No smell	No smell	No smell	No smell	No smell
5.	Fluoride	mg/L	0.620 ± 0.005^a	0.631 ± 0.004^a	0.539± 0.005^b	0.344 ± 0.004^c	1.5
6.	Chloride	mg/L	25.8 ± 0.4	25.8 ± 0.5	25.8 ± 0.5	26.4 ± 0.5	250
7.	Nitrate (NO_3^-)	mg/L	18.12 ± 0.06	15.69 ± 0.12	18.69 ± 0.14	18.64 ± 0.12	50
8.	Sulphate (SO_4^{-2})	mg/L	8.075± 0.021^a	10.449 ± 0.011^b	8.201± 0.022^a	5.883± 0.023^c	250
9.	Nitrite (NO_2^-)	mg/L	0.001± 0.000^a	0.050± 0.000^b	0.003± 0.000^c	0.005± 0.000^b	3
10.	Ammonia (NH_3)	mg/L	0.149± 0.001^a	0.193± 0.002^b	0.193± 0.003^b	0.152± 0.004^a	1.5
11.	Cyanide	mg/L	nd**)	nd**)	nd**)	nd**)	0.07
12.	Arsen	mg/L	nd**)	nd**)	nd**)	nd**)	0.01
13.	Cadmium	mg/L	nd**)	nd**)	nd**)	nd**)	0.003
14.	Cu	mg/L	nd**)	nd**)	nd**)	nd**)	2
15.	Total chromium	mg/L	nd**)	nd**)	nd**)	nd**)	0.05
16.	Fe	mg/L	nd**)	nd**)	nd**)	nd**)	0.3
17.	Mangan	mg/L	nd**)	nd**)	nd**)	nd**)	0.4
18.	Selenium	mg/L	nd**)	nd**)	nd**)	nd**)	0.1
19.	Zn	mg/L	nd**)	nd**)	nd**)	nd**)	3
20.	Aluminium	mg/L	nd**)	nd**)	nd**)	nd**)	0.2

Reference = Permenkes 492/2010, Nd** = not detected.*
The ^{abc} different letters indicated the mean differences were significant at $P \leq 0.05$

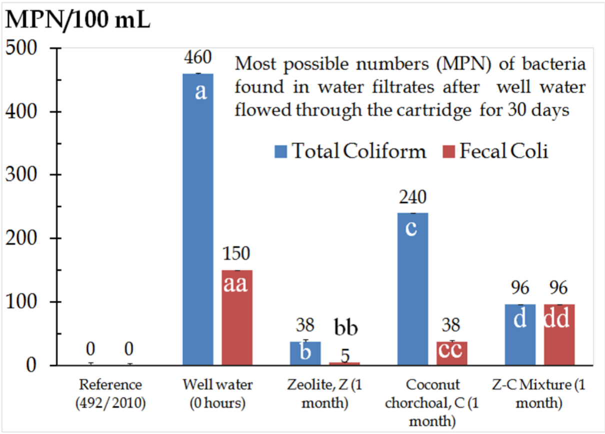

Fig. 5. The MPN numbers of bacteria found in water filtrates
The $^{a,b,c,d\ and\ aa,bb,cc,dd}$ different letters indicated the mean differences were significant at $P \leq 0.05$.

of radiation. Furthermore, higher the pH of water filtrates reported in Table 2 might indicate that zeolite cartridge strongly interacted with the electrophilic species of the well water. Hence, the electrophiles attracted by the zeolite cartridge include the acidic species of the well waters. The enhancement of the pH value was in agreement with the fact that zeolite particles make the water more alkaline (Maunawai, 2017).

3.3. *Performance of the developed cartridges on removing bacteria from drinking water*

The targeted bacteria to remove from the drinking waters were E-coli and total coliform (Table 1). The content-based markers for these bacteria in drinking waters equaled to zero in MPN (most possible number) unit. The present study indicated that total coliform found in each 100 mL of the well water equaled to 460 MPN while the fecal coli equaled to 150. When the well water flowed through the developing cartridges, the MPN content varied which depended on the cartridge materials qualitative compositions. As shown in Fig. 5, the total coliform remained in water filtrates of the well waters flowed through the cartridges made of zeolite, coconut charcoal, and their mixture (1:2 by volume) were 38, 240, and 96 MPN, respectively. These developed cartridges, therefore, could remove these total coliform from the well waters by 92 ([[460-38]/460] x 100%), 48, and 79 %, respectively. The deletions of the fecal coli are comparable (Fig. 5). Based on these data, the performance of the developed cartridge made of zeolite was highest among those cartridges compositions. The reductions of the total coliform by the zeolite cartridges were relevance with the pH increase of the water filtrates (Table 2). These facts were in agreement with the previous reports that higher pH of the incubation system higher mortality levels of the bacteria (Widjajanto et al., 2017). These facts were also accommodated by the data found in the previous study (Buang et al., 2017[a,b]). It sounds that hydroxyl ion hydrolyzed outer membranes of the E-coli bacteria (Silhavy et al., 2010).

4. Conclusion

Reading the body text of the present study, the zeolite cartridge reduced markedly turbidity of the well waters, approximately by 39%. The mixture cartridge could totally remove (100%) the color of the well waters, however, both other cartridges removed slightly, approximately by 14 %. The excellence of the zeolite cartridge was to eliminate the turbidity, while color and TDS were excellently removed by the zeolite+coconut shell and coconut shell cartridges, respectively. These developed cartridges could remove total coliform of the well waters by 92, 48, and 79 %, respectively. The reduction of total coliform by the zeolite cartridge was highest among these developed cartridges.

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Conflict of interest: Non declare