OPTIMIZATION OF PUMPING AND WATER FILTRATION FOR SUBTERRANEAN RIVER OF *GOA TUK SARINING KEMBANG* IN THE INTEREST OF WATER FULFILLMENT IN GEBANG HAMLET AND ITS SURROUNDING

Heru Sigit Purwanto*, Bambang Sugiarto, Dedi Fatchurohman
Universitas Pembangunan Nasional Veteran Yogyakarta, Indonesia
**Corresponding author e-mail*: sigitgeologi@hotmail.com

Abstract
Water is the primary needs for the livelihood of people in Gebang hamlet, Girisuko village, Gunung Kidul Regency, Special Region of Yogyakarta. Gebang is a hamlet in Panggang district, Gunug Kidul Regency, of which water supply is insufficient to meet the needs. There are 170 households with an average of 4 lives each, thus about approximately 680 people don't have sufficient water supply. Water supply to the hamlet is constrained by the pumping ability.
The neighborhood rely on overflowing raw water in high rainfall season that is channelled through pipe to the certain water tank prepared as reserves for dry season and few of them had used water from a cave. However, the pump is now broken so in a long dry season they need to buy water using tank truck. Based on the observation, this research planned to design water pump arrangement with high capacity so water can easily be channeled to the water tank and distributed to people in the neighborhood.
The material absorbed in karst medium is related to each other, between organic (coliform parameter) and anorganic material (TDS parameter). The water puryfying process was conducted in laboratory and another process engaging gravity sand filter was chosen using zeolith with thickness of 40-50 cm that is able to decrease TDS from 232 – 268 ppm up to 180 ppm.
Keywords: *air, gravity sand filter, and tds*

INTRODUCTION

Water is a primary need of which the consumption is always increasing as the living condition increases. Water is not only essential for humans but all living things need water to live. The water consumed by community could be obtained from surface water or groundwater. Water scarcity could create the disruption of the life of organism (USGS, 2010). There are some places on Earth where clean water is rare, typically in developing countries (IWRM, 2009). One of them is in Gunungkidul, Special Region of Yogyakarta, Indonesia where water scarcity occured (Evani, 2004).

Gunungkidul Region is an area with karst topography formed by dissolution mechanism of limestone. The area is a part of Sewu Highland where karst Formation consists of carbonate rocks with high solubility and high infiltration rate. Rain water fell on the surface of the Earth would be directly absorbed into the soil and formed subterranean river. This type of water cycle made it difficult to obtain clean water on the surface notably on dry season. Karst has a unique characteristic however, where an abundant amount of high quality water could be found underground on dry season, though it decreases on wet season and it could be brought up to the surface using an appropriate technology (Nestman at.al., 2011).

The huge subsurface water reserves in Gunungkidul could benefit us by bringing it up to the surface, and needed to be processed using an appropriate technology before it can be used by the community.

Goal and Purposes

The goal and purposes of this research are :

1) Analyzing the effect of length, transit/head assembly on the pump power requirement.
2) Performing simple fitration system that is suitable and easy to manage.
3) Analyzing water quality before and after treatment.

Outcomes

The outcome of this research will benefit as follows:

1) Understanding the optimum condition of water filtration and pumping from subterranean river of Goa Gebang into water tank on the surface.
2) Providing solution for Gebang community in obtaining clean water for daily need.

LITERATURE REVIEW

Water is a tasteless, transparent, and odorless liquid containing hydrogen and oxygen with chemical formula H_2O. It is a universal solvent as water could dissolve most of natural and human products to some extent. Therefore, water contains dissolved substances which often called as pollutants found in water (Linsley, 1991). Water quality is a term to describe the condition of water with respect to its suitability for particular purposes, such as drinking water, fisheries, industry, recreation, and so on.

The quality parameter of clean water or drinking water established by Minister of Health Number : 492/Permenkes/IV/2010 consists of physical, chemical, radioactive parameter and microbiology parameter.

Table 1. Key Parameter of water : physical, chemical, radioactive, and microbiology

Parameter		Unit	Maximum allowable
1	Parameters were directly related to healthy		
	a. Microbiological parameters		
	1) E.Coli	MPN per 100mL of sample	0
	2) Total coliform bacteria	MPN per 100mL of sample	0
	b. Inorganic Chemicals		
	1) Arsen	mg/l	0,01
	2) Fluoride	mg/l	1,5
	3) Total Chromium	mg/l	0,05
	4) Cadmium	mg/l	0,003
	5) Nitrite (NO_2)	mg/l	3
	6) Nitrate (NO_3)	mg/l	50
	7) Cyanide	mg/l	0,07
	8) Selenium	mg/l	0,01
2	Parameters were indirectly related to healthy		
	a. Physical parameters		
	1) Odour		Odorless
	2) Colour	TCU	15
	3) Total Dissolved Solid	Mg/l	500
	4) Turbidity	NTU	5
	5) Taste		Tasteless
	6) Temperature	C	Temperatures ± 3
	b. Chemical parameters		
	1) Aluminium	mg/l	0,2
	2) Iron	mg/l	0,3
	3) Water Hardness	mg/l	500
	4) Chloride	mg/l	250
	5) Manganese	mg/l	0,4
	6) pH		6,5-8,5
	7) Zinc	mg/l	
	8) Sulfate	mg/l	
	9) Copper	mg/l	
	10) Ammonia	mg/l	

 ISSN. 2461-1484

Table 2. Additional Parameters of Water: Inorganic and Organic

Parameter		Unit	Maximum allowable
1	CHEMICAL		
	a. Inorganic Materials		
	Mercury	mg/l	0,001
	Antimony	mg/l	0,02
	Barium	mg/l	0,7
	Boron	mg/l	0,5
	Molybdenum	mg/l	0,07
	Nickel	mg/l	0,07
	Sodium	mg/l	200
	Lead	mg/l	0,01
	Uranium	mg/l	0,015
	b. Organic Materials		
	Organic Substances ($KMnO_4$)	mg/l	10
	Detergent	mg/l	0,05
	Chlorinated alkanes		
	Carbon tetrachloride	mg/l	0,004
	Dichloromethane	mg/l	0,02
	1,2-Dichloroethane	mg/l	0,05
	Chlorinated ethenes		
	1,2-Dichloroethene	mg/l	0,05
	Trichloroethene	mg/l	0,02
	Tetrachloroethene	mg/l	0,04
	Aromatic hydrocarbons		
	Benzene	mg/l	0,01
	Toluene	mg/l	0,7
	Xylenes	mg/l	0,5
	Ethylbenzene	mg/l	0,3
	Styrene	mg/l	0,02
	Chlorinated benzenes		
	1,2-Dichlorobenzene (1,2-DCB)	mg/l	1
	1,4-Dichlorobenzene (1,4-DCB)	mg/l	0,3
	Others		
	Di(2-ethylhexyl) phthalate	mg/l	0,008
	Acrylamide	mg/l	0,0005
	Epichlorohydrin	mg/l	0,0004
	Hexachlorobutadiene	mg/l	0,0006

Drinking Water Treatment Model

a. **Sedimetation**

Sedimentation or settling is a process to separate solid particles dissolved in water which is naturally found in lake or pond. However, it takes a while for the particles to completely settled, thus a chemical process is often combined in order to accelerate the settling process of particles in the water. Considering the effects of chemical substances used on the composition of processed water and the chemical waste formed during the process, as well as the complicated process invloved, natural and environmentally friendly precipitating agents were chosen. If the level e-coli is high, then alum, moringa seed powder and chlorine gas were used.

Reaction of Aluminium Sulfate with Calcium Bicarbonate in water :

$$Al_2(SO_4)_3.18H_2O + Ca3Ca(HCO_3)_2 \longrightarrow 2Al(OH)_3 + 3CaSO_4 + 6CO_2 + 18H_2O$$

However, if e-coli level is close to 0, and the particles are dominated by fine particles from carbonate, bicarbonate, calsite, silica and magnesite, then CaO or cement is used. By targetting fine particles, few e-coli could be trapped in cross link agent formed by CaO or cement spreaded and they could settled together in the bottom of the basin.

The accelerated sedimentation by adding chemical substances is called coagulation, a clumping event of particles that had been destabilized by adding chemical substances, forming larger particles easy to settle.

The initial mixing is giving energy to create collision between suspended and colloidal particles to form lump thus can be separated by further sedimentation process and filtering. It is also intended to accelerate and evenly spread the chemical substances through the processed water.

Factors affecting coagulation process :

1) pH Level
   pH level of waste water was used as indicator for acidity or basicity of which affect the performance of coagulant used. By having the information of water pH level, our coagulant will be able to perform well. However, the pH level of each coagulants are different depending on the properties and characteristics of that particular coagulant.
2) Types of Coagulant
   Coagulants have their own characteristics. The coagulant addition in the purifying process of water will create chemical physical processes, thus forming small particles of which the amount depends on the variable to that coagulant.

3) Turbidity Level of Water
   Destabilization process will be difficult in water of low turbidity level, but it will be easier in high turbidity level. That is also the case for collision between particles which is dificult to occur in water with low turbidity level.
4) Mixing Duration
   The duration of mixing will affect the sedimentation process. The longer is the mixing duration, the floc formed will shatter, and it will disturb the coagulation process.
5) Sedimentation Duration
   The longer is the sedimentation, the filtrate produced will be clearer because the formed flocs could all settled. The sedimentation duration for coagulation process is approximately between 45 minutes up to 2 hours.

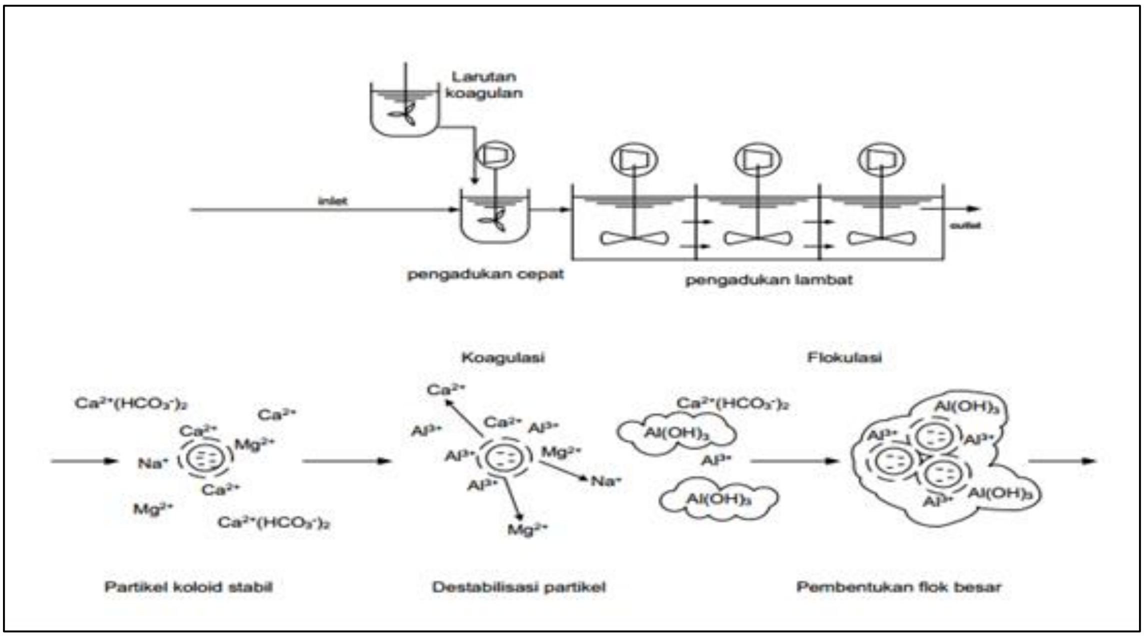

Figure 1. Sedimentation

b. Slow Sand Filtration

Slow Sand Filtration is a filtration method to yield clean water, it is known since year 1804. First made and desiged by John Gibb in Scotland and he succeeded in selling his own filtered water to the public at a very cheap price per gallon. In the year of 1829 James Simpson built water treatment instalation for water supply in London by adapting slow sand filtration method. Then in 1852 the method became very popular and well designed, since the slow sand filtration as a mechanical filtration method could filter dissolved particles which decrease the water turbidity. The existence of pathogenic bacteria and the ability of slow sand filtration to eliminate them was absolutely unknown at that time (Huisman & Wood, 1974)

Slow sand filtration may be the most economical, simplest, and most reliable water treatment process for getting clean water. This process differs from rapid sand filtration, particularly at the filtration rate applied. Slow sand filter is a water treatment process that allows raw water to seep from the surface through fine sand media which then exits through the bottom outlet. The effective grain size (d10) used in this system is finer than in the rapid sand filter, where the effective grain size is usually in the range of 0.15-0.30 mm with uniformity coefficient (Cu) of less than 5 and preferably less than 3 as stated in Table 1.1 (Visscher, 1990). This fine grain size gives a very small gap in the filter between grains which allows water to flow slowly through the filtering media, the filtration rate is usually between 0.1-0.2 m/h (Visscher, 1990). The suspended solids, colloidal material, and bacteria from raw water that accumulates in the most upper layer that is not cleaned regularly, has made the purifying bacteria thrive and it plays the most important role in the slow sand filter process to produce good water quality. This is the reason why slow sand filtration is also called biological filtration (Huisman & Wood, 1974)

Table 3. Design criteria for slow sand filter (Visscher,1990)

Design criteria	**Recommended value**
Design period	10-15 years
Period of operation	24 h/d
Filtration rate	0,1-0,2 m/h
Filter bed area	5-200 m2*per filter, minimum of 2 unit
Height of filter bed	
Initial	0,8- 0,9 m
Final before resanding	0,5- 0,6 m
Sand characteristhics	
Effective size d10	0,15- 0,30 mm
Uniformity coefficient Cu	<5, preferably below 0,30 mm
Height of underdrains including gravel layer	0,3- 0,5 m
Height of supernatant water	1 m

(*) *To Facilitate manual cleaning*

The slow sand filter elements used nowadays are as follows (Huisman & Wood, 1974) and Manz (2004):

- Supernatant water layer, the function of this section is to maintain a constant limit of water in the top of sand, providing pressure that helps water pass through the filter layer. The supernatant water layer is also important to reduce disturbance from water entering the top layer of the sand filter. Therefore a depth as high as 1 m above the surface is needed.
- Filter layer, all granulated material can be used as filter media.

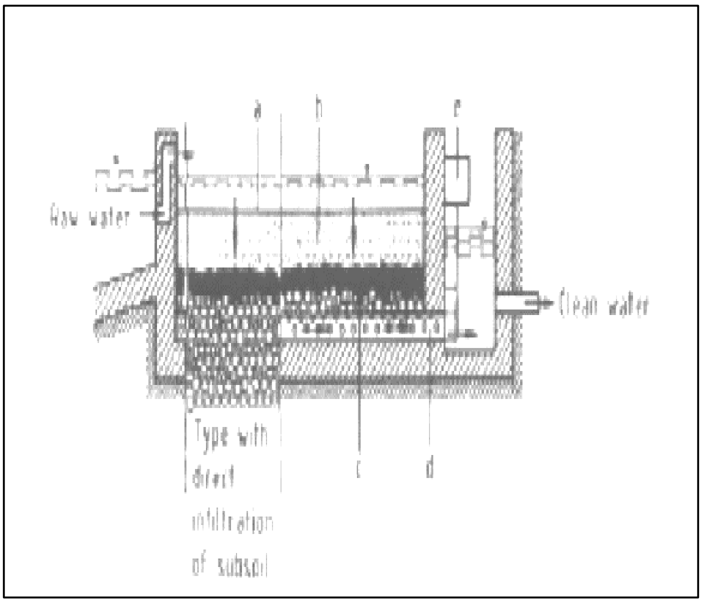

Figure 2. Gravity Sand Filter

c. Carbon Filter

The function of the carbon filter is to adsorb the remaining chlorine after water is sterilized using Cl_2 or chlorine, so that the taste, odor and color of the water are in accordance with the quality standards.

RESEARCH METHOD

Generally, there are other similar researches but the soil model and contour of each cave with subterranean river are extremely different thus they need different kind of handling.

Materials

This research used water from subterranean river of Goa Tuk Sarining Kembang.

 ISSN. 2461-1484

Instrument Setting

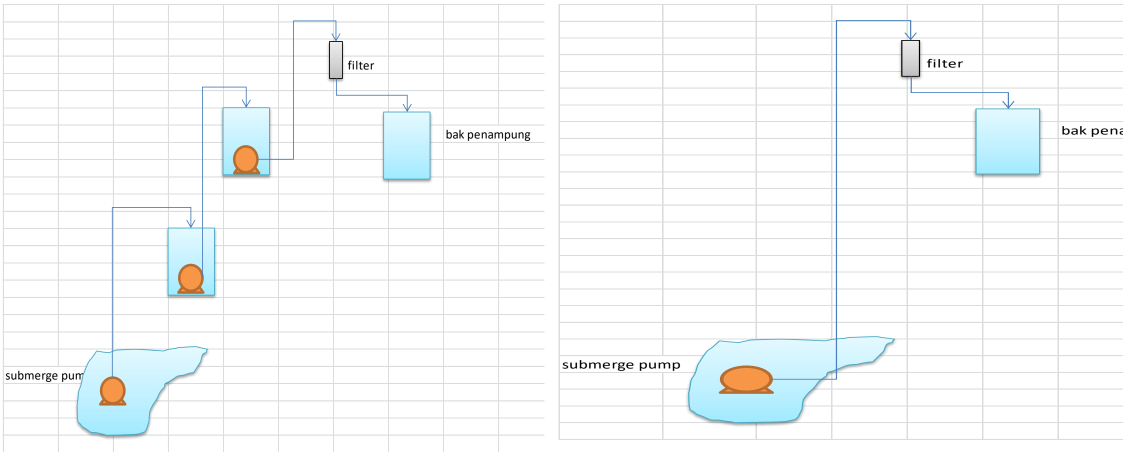

Figure 3. Instrument Setting of Model 1 and 2

FINDINGS AND DISCUSSION

1. Prototype of Water to be Developed

Based on the literature study, researches and the funding requirements, as well as the available human resources for management and care, we chose pumping equipped with simple filtration so that the community could manage and use it with ease.

Work Preparation

Work preparation includes preparation of all necessities needed in the execution of research, such as permit, collection of primary data, secondary data, literatures, preparation of instruments and materials, and also field observation as preliminary survey. The preliminary field survey is conducted to get an overview of field initial condition to be observed, topographic condition, rock formation, and people using water in karst area.

Laboratory and Field Work

Field work was conducted by surveying the presence of the subterranean river source, sampling, physical observation of water, laboratory testing, mapping, and water volume prediction. Surveying materials for filtration media such as the source of sand, charcoal manufacturer and or mining location of zeolith.

Laboratory work consists of:

a. Activation of filtration media (sand, zeolith and carbon media) in terms of physical and chemical.

b. Designing equipment and performing water treatment using the laboratory scale prototype of slow sand filter using sand, zeolith, and carbon media.

2. Prototype Plan of Water Treatment in Gebang

Based on the model above and the assessment conducted to the water quality, our team proposed a water treatment prototype as follows:

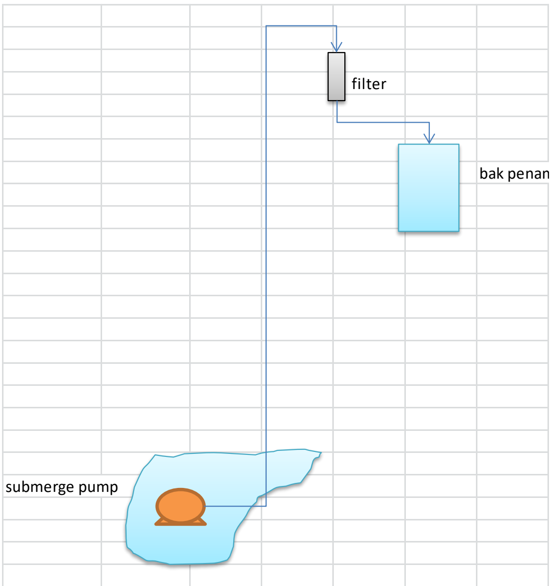

Figure 4. Prototype plan and layout of water treatment instrument in Gebang

3. Description of Water Treatment

The water was pumped from water source in Gebang cave directly using submerge pump 3 HP 1 phase to the water tank prepared at the cave's entrance. Before getting into the tank, the water was passed through the filter installed.

Data of Results and Calculation

Pumping Optimization

To determine a pump that is compatible, durable and energy saving, we need data of: water position from the mouth of cave is 5 m, distance of tank installation from cave's mouth is 450 m, and elevation os 30°.

 ISSN. 2461-1484

Table 5.1. Result of Calculation of the Pump

No	Pump characteristic	Type Multi Stage		Type Stage Tunggal	
		Centrifugal	Submerge	Centrifugal	Submerge
1	Pump Capacity, gpm	0,13	0,13	0,1330	0,1330
2	Le, m	150	150	485	485
3	Head, m	605,35	605,35	1883,06	1915,48
4	Number of Suctions	1	1	1	1
5	RPM	1400	1400	1400	1400
6	Power, hp	1	1	2	2
7	Specific Velocity, rad	0,02	0,02	0,01	0,01
8	Efisiensi, %	35	35	35	35
9	Storage Tank	6	6	4	4
10	Elbow extra	4	4	-	-
11	Number of Pumps	3	3	1	1

 ISSN. 2461-1484

Thickness Optimization of Zeolith Filter Media

In determining filtration using zeolith sand media, optimization of effective thickness of zeolith sand is needed by considering the usage of lowest concentration of flocculant or without flocculant, to the water TDS value of sample, as provided in the data table below.

Table 4. The effect of Flocculation and Thickness of Zeolith Media Thickness to TDS

Tawas 0.5 ppm	Volume Tawas, ml	PASCA FLOAKULASI Tds (Pengendapan), ppm , Δt = 30 menit					PASCA FILTRASI TINGGI BED BSK = 2,5; 2,5; 2,5 Tds (Pengendapan), ppm , Δt = 30 menit					pH	Suhu (◦C)
		0	30	60	90	120	0	30	60	90	120		
1	0	268	265	251	241	238	293	282	259	237	232	7,5	26,4
2	10	253	249	248	248	236	267	260	252	246	240	7,5	26,4
3	20	239	235	213	208	191	244	243	219	232	237	7,5	26,5
4	30	233	219	230	220	189	227	220	219	209	208	7,5	26,6
5	40	226	223	219	210	215	213	208	206	195	180	7,5	26,7
6	50	218	213	209	189	180	196	205	207	204	185	7,5	27

Tawas 1 ppm	Volume Tawas, ml	PASCA FLOAKULASI Tds (Pengendapan), ppm , Δt = 30 menit					PASCA FILTRASI TINGGI BED BSK = 2,5; 2,5; 2,5 Tds (Pengendapan), ppm , Δt = 30 menit					pH	Suhu (◦C)
		0	30	60	90	120	0	30	60	90	120		
1	0	268	265	251	241	238	293	282	259	237	232	7,5	26,6
2	10	245	221	221	215	208	261	260	256	245	234	7,5	26,6
3	20	241	231	225	217	216	245	224	194	228	230	7,5	26,7
4	30	238	231	232	224	232	233	225	227	207	201	7,5	26,8
5	40	222	175	186	173	175	214	209	189	177	137	7,5	26,8
6	50	214	212	211	188	185	208	193	190	205	193	7,5	27

Tawas 1.5 ppm	Volume Tawas, ml	PASCA FLOAKULASI Tds (Pengendapan), ppm , Δt = 30 menit					PASCA FILTRASI TINGGI BED BSK = 2,5; 2,5; 2,5 Tds (Pengendapan), ppm , Δt = 30 menit					pH	Suhu (◦C)
		0	30	60	90	120	0	30	60	90	120		
1	0	268	265	251	241	238	293	282	259	237	232	7,5	27
2	10	254	252	246	242	241	254	250	249	239	221	7,5	27
3	20	236	234	232	231	226	239	237	231	175	184	7,5	27
4	30	233	230	208	207	196	228	221	217	216	181	7,5	27
5	40	221	212	211	172	168	207	207	183	162	182	7,5	27
6	50	215	211	210	206	179	208	192	176	172	180	7,5	27

Table 5. The effect of Flocculation and Thickness of Zeolith Media Thickness to TDS (continued)

Tawas 2 ppm	Volume Tawas, ml	PASCA FLOAKULASI Tds (Pengendapan), ppm , Δt = 30 menit					PASCA FILTRASI TINGGI BED BSK = 2,5; 2,5; 2,5 Tds (Pengendapan), ppm , Δt = 30 menit					pH	Suhu (◦C)
		0	30	60	90	120	0	30	60	90	120		
1	0	268	265	251	241	238	293	282	259	237	232	7,5	27
2	10	253	247	236	227	217	252	241	224	223	188	7,5	27
3	20	240	236	234	233	222	231	237	229	231	188	7,5	27
4	30	227	224	210	194	179	222	219	224	222	180	7,5	27
5	40	215	210	208	206	185	210	190	179	169	196	7,5	27
6	50	265	216	214	191	180	209	204	190	186	183	7,5	27

Tawas 2.5 ppm	Volume Tawas, ml	PASCA FLOAKULASI Tds (Pengendapan), ppm , Δt = 30 menit					PASCA FILTRASI TINGGI BED BSK = 2,5; 2,5; 2,5 Tds (Pengendapan), ppm , Δt = 30 menit					pH	Suhu (◦C)
		0	30	60	90	120	0	30	60	90	120		
1	0	268	265	251	241	238	293	282	259	237	232	7,5	27
2	10	256	254	253	252	226	237	226	221	219	187	7,5	27
3	20	267	250	243	246	248	246	245	226	223	234	7,5	27
4	30	242	238	226	212	207	239	237	236	234	231	7,5	27
5	40	230	232	224	224	219	229	230	230	231	213	7,5	27
6	50	222	220	220	215	195	224	222	221	215	191	7,5	27

Tawas 3 ppm	Volume Tawas, ml	PASCA FLOAKULASI Tds (Pengendapan), ppm , Δt = 30 menit					PASCA FILTRASI TINGGI BED BSK = 2,5; 2,5; 2,5 Tds (Pengendapan), ppm , Δt = 30 menit					pH	Suhu (◦C)
		0	30	60	90	120	0	30	60	90	120		
1	0	268	265	251	241	238	293	282	259	237	232	7,5	27
2	10	261	250	243	243	239	245	235	219	214	206	7,5	27
3	20	247	227	230	219	217	235	227	223	221	213	7,5	27
4	30	240	228	213	220	213	233	228	222	213	194	7,5	27
5	40	230	213	210	215	208	228	224	217	191	190	7,5	27
6	50	224	207	191	184	178	218	213	211	184	167	7,5	27

Discussion

Based on the table, the effect of flocculant and sedimentation duration to the TDS is provided in graphs as follows:

 ISSN. 2461-1484

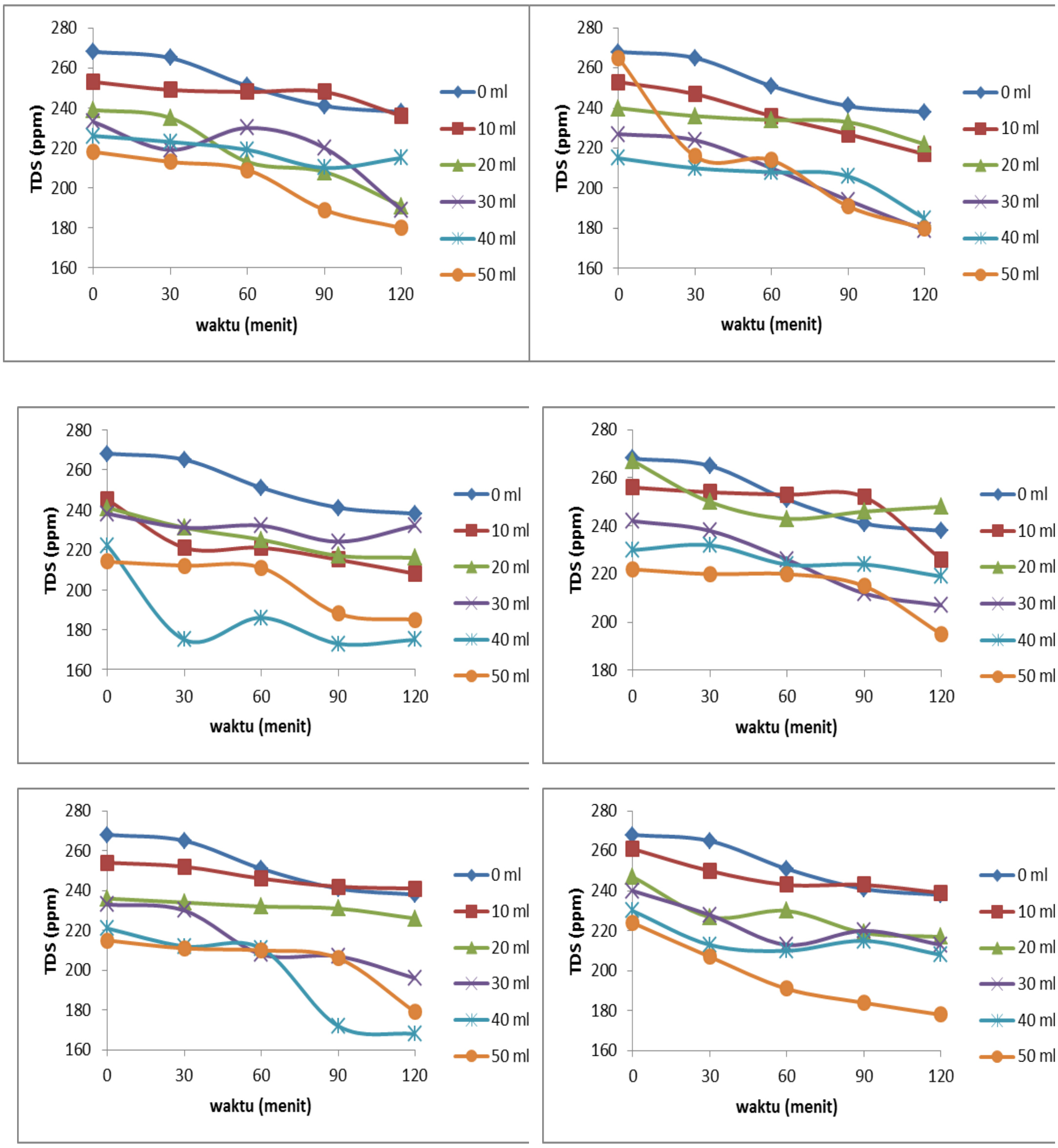

Figure 5. Graphs showing the effect of the amount of flocculnt and sedimentation duration to the TDS value. Based on the graph, we could see that the more is flocculant volume and the longer is settling duration, the TDS decreased significantly.

Based on the table, the effect of flocculant amount and filtration to the TDS value every 30 minutes observation is provided as follows:

 ISSN. 2461-1484

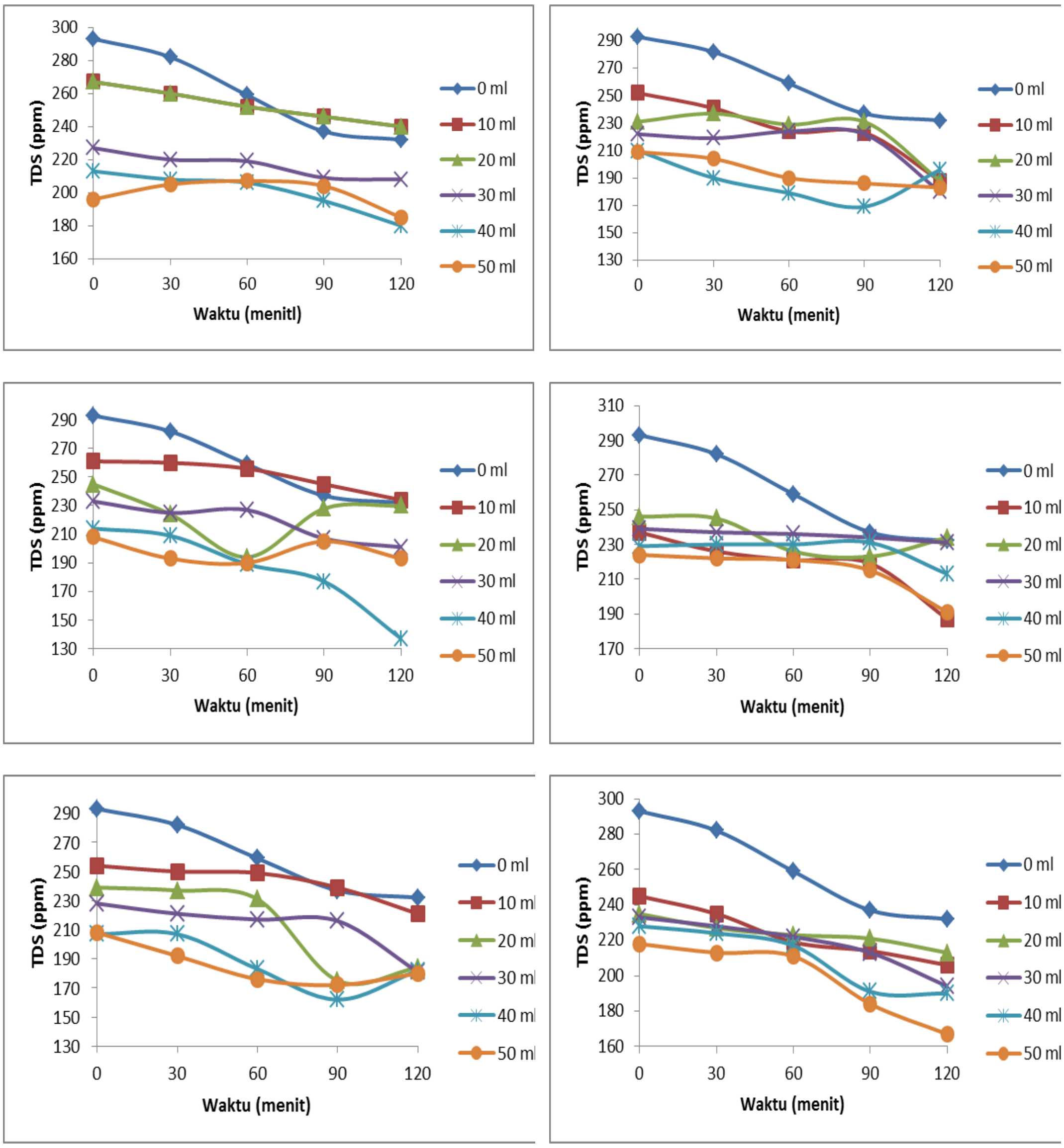

Figure 6. Graphs showing the effect of thickness of zeolith sand media to the TDS value of processed water.

From the graphs, we could see that as the zeolith sand filter is thicker, and as the duration of sedimentation is longer, TDS value was decreased sinificantly. In the graph of flocculant addition, we got the largest decrease of TDS value and the fastest almost in all thickness of zeolith. This means, of any thickness of zeolith sand, the TDS will siginificantly decrease. This because zeolith served as the trappers of particles in the water.

CONCLUSION

1. The suitable method is by using 1 ESP pump directly to the filter.

2. Water filtration process is needed before getting into water tank, as the quality is not good for health.
3. Filtration using zeolith sand media was conducted with several filtering gauze levels, as zeolith served as particle barrier in the water.

REFERENCES

Adji, T.N., 2005, Agresivitas Airtanah Karst Sungai Bawah Tanah Bribin, Gunungsewu, *Indonesia Cave and Karst Journal*, vol 1 No 1, HIKESPI.

Ausland, G., Stevik, T.K., Hansen, J.F.Kohler, J.C., Jensen, P.D. 2002, *Intermittent Filtration Of Wastewater- Removal PF Fecal Coliforms And Fecal Streptococci. Water Research 36.*

Badingah, 2013, Laporan Status Lingkungan Hidup Daerah Kabupaten Gunung Kidul, *Pemerintah Kabupaten Gunung Kidul Daerah Istimewa Yogyakarta*

*Benefield, ETAC, 198*2, " Process Chemistry for Water and Waste Treatment", Mc Graw Hill Book Co., Inc., New York

Effendi, H. 2003*, Telaah Kualitas Air Bagi Pengelolaan Sumber Daya dan Lingkungan Perairan. Cetakan ke lima. Yogyakarta:Kanisius.*

Evani, F.S. 2004, *Gua Bribin akan atasi kekurangan air gunungkidul,* *http://www.suarapembaruan.com/News/2004/2008/08/03/Nusantar/Nusa04.htm*, Last accessed 22 april 2010.

Fakultas Kehutanan, 1993, Penyusunan Arahan Konservasi Tanah dan Air Daerah Tangkapan Air Gua Bribin Kabupaten Gunungkidul DIY. Kerjasama antara Dinas kehutanan DIY –Fakultas Kehutanan UGM Yogyakarta.

Foerd, D. and William, P., 1992 Karst Geomorphology and Hydrology, Chapan and Hall, London.

Haryono, E., Adji T., N., 2004 Pengantar Geomorfologi dan Hidrologi Karst, Kelompok Studi Karst, Fakultas Geografi, UGM, Yogyakarta.

Jack Broughton, "Process Utility Sistem, Introduction to Design Operation and Maintenance" Institution of Chemical Engineers, 1994

Kurita , 1980 " Industrial Water Treatment", Kurita Publ. & Co, Tokyo

Nugraha, M.P.H., 2016, Kajian Kualitas Air Sungai Bawah Tanah Pada Daerah Imbuhan Dan Daerah Pengolahan Air Goa Bribin, Kabupaten Gunungkidul, Daerah Istimewa Yogyakarta.

Reynolds, T.D, 1982, " Unit Operations and Process Environmental Engineering", Texas & M. University, PWS Publishers is a division of Wadswoath. Inc., California

Salmin, 2005, Oksigen Terlarut (DO) dan Kebutuhan Oksigen Biologi (BOD) Sebagai salah satu Indikator Untuk Menentukan Kualitas Perairan, Oseana, Volume XXX, Nomor 3, 2005 : 21 – 26

Sanks, 1980, "Water Treatment Plant Design" Science Publisher, New York

Wirosarjono, S. 1974. Masalah-masalah yang dihadapi dalam penyusunan kriteria kualitas air guna berbagai peruntukan. PPMKL-DKI Jaya, Seminar Pengelolaan Sumber Daya Air. , eds. Lembaga Ekologi UNPAD. Bandung, 27 - 29 Maret 1974, hal 9 – 15