a Case of Substituting Chemical Solution with Cartridge Filtration for Small Water Treatment Unit

Gamawan Ananto#, Retno Hadi#, Indra Priasmara#

#Manufacture Engineering Department, Bandung State Polytechnic For Manufacturing (POLMAN)
Jl.Kanayakan 23, Bandung 40135, Indonesia

[1]waloeyo_gamawan@yahoo.co.uk

Abstract— **A small Water Treatment unit in an educational institution has been in operation for about six years, provided clean and drinking water for the inhabitants of such organization. The chemical solution process that combined with media filtration is applied for such machine. Although there was no complaint from inhabitants as the customer, the manager in charge who responsible in operation noticed that sometimes is not easy to control the technicians in carrying out its routine and periodic detail technical procedure consistently, that might influence the output quality. To make the operation easier, a few lab scale experiments are initiated due to find out whether using cartridge filtration that is still combined with media filtration could reduce their efforts. The experiments skipped chemical features and added Micro Filtration (MF) cartridge to get the lab result of output water. Reverse Engineering and Redesign is used for analyze its design aspect whereas Westinghouse approach measured its efforts in handling. The result shows that using cartridge gave a moderate quality in water composition of element content that is still in standard range of health provision; but it needed lower effort and had better aspect of design.**

Keywords **—water treatment, chemical solution, sand filtration, micro filtration, design modification**

I. Introduction

As known, water is a vital issue for human being. Since nowadays there are a lot of factors that influenced natural water sources quality by contamination or pollution, people are pushed to manage and develop various technologies in water processing, in order to get their purposes for clean and drinking water with appropriate health quality standard. Referred to capacity needed, various water treatment system are built for towns, districts, small community and even family house; either by Government, corporate or private.

As a case, small Water Treatment unit with 1m^3 per hour capacity in an educational institution has been in operation for about six years, provided clean and drinking water for the inhabitants of such organization. The chosen system for such unit is chemical solution for oxidation and disinfection process that combined with media filtration. This system worked well from quality output point of view, as far as its operation procedure carried and managed tidily.

Although there was no complaint from inhabitants as the customer, the manager in charge who responsible in operation noticed that sometimes is not easy to control his technicians in carrying out its routine and periodic detail technical procedure consistently. As soon as a certain action is not done, it might influence the output water quality worse. Therefore a modification is considered to be initiated in order to make the system safer and its operation procedure easier.

II. Literature Review

A. Water Treatment technology

The quality standard for clean water and drinking water are defined such as in SNI 01-3553-2006, Indonesian 'Badan Standardisasi Nasional'[1]. It classified to physical, chemical and microbiological criteria. As known, standards are the portion of a rule that defines theallowable amount of a constituent in water. Referred to such rule, the technology that will be used for water treatment could be chosen in addition of considering its raw water quality as its input; whether it is taken from well/ ground, or surface water like lake/ river. Expressed in simple way, a few technologies in water treatment are chemical solution, physical filtration, radiation, and some others. Besides, chemical reactions are used in such treatment process to change the physical,chemical, and biological nature of water to accomplish water quality objectives[2].

Although there are many methods in chemical addition process but only oxidation and disinfection that will be reviewed due to relevant discussed case. Oxidation is the addition of an oxidant to thewater that then reacts directly with the target contaminant. The commonuses of oxidation are taste and odor control, color removal,and hydrogen sulfide removal. In many cases, several oxidants are also disinfectants.

In physical filtration process there is rapid sand filter or rapid gravity filter, a type of filter used in water purification and is commonly used in municipal drinking water facilities as part of a multiple-stage treatment system. Rapid sand filters use sand and other granular media to remove particles and impurities that -in some cases- have been trapped in a flock through the use of flocculation chemicals.Water and flock flows through the filter medium and the flocculated material is trapped in the sand matrix. Thus, chemical additivesare often used in conjunction with the filtration system [3]. Meanwhile, a few grades of physical filtration in Fig. 1 [4] shows that conventional filtration process may overcome undissolved compound content up to around 1µm dimension, whereas themost extreme condition such as seawater or brackish with salts content has to use RO (reverse osmosis) membrane.

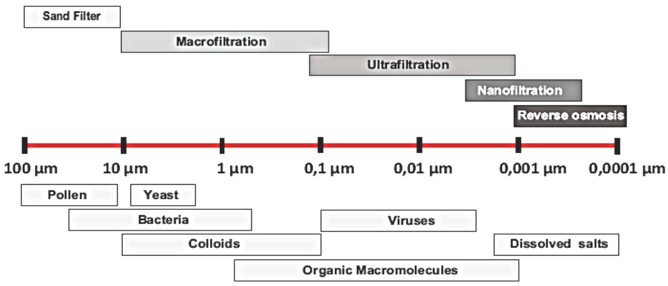

Fig.. 1 Water Treatment physycal filtrationgrade [4] (*Heijman S.G.J, CT4471, Nanofiltration and Reverse Osmosis, 2007)*

Generally, membranes technology could be used for non terrible condition since a low fouling potential could be obtained by membranes whereas sand filter is better at removing manganese and dissolved organic matter. It is experimented that combining aeration, sand filtration and membrane techniques might be a good option for pesticide removal without any addition of chemical and also minimized membrane maintenance [5]. For certain cases; combining chemical addition and physical filtration is a good solution for certain input and output water quality level, where its design has to be defined conditionally.

B. Reverse Engineering

Veryfew methodologies exist that focus on the class ofproblems known as redesign (adaptive, variant, etc.). As with original design, redesignproblems include the many of process steps referred as'reverse engineering'. Reverse engineeringinitiates the redesign process, wherein a product ispredicted, observed, disassembled, analyzed, tested,'experienced', and documented in terms of itsfunctionality, form, physical principles, manufacturabilityand assemb-lability. The intent of this processstep is to fully understand and represent the currentinstantaneous of a product. Based on the resultingrepresentation and understanding, a product may beevolved, either at the subsystem, configuration,component or parametric level[6].

Fig. 2 shows the simplified steps in reverse engineering methodology [7] that adopted from Otto and Wood's 'Reverse Engineering and Redesign methodology' UT Austin [6].

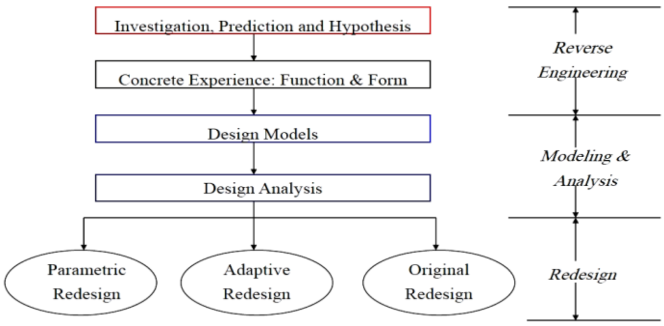

Fig. 2 Reverse Engineering steps

It consists of three distinct phases; reverse engineering, modeling and analysis, andredesignthat are covering its each sub phases. On the final stage that initiatedthe product redesign based on theresults of the reverse engineering and modelingphases; there are parametric redesign, adaptive redesign and original redesign as the alternatives. Regarding original redesign there might be effort needed to satisfy thecustomer needs since it implies that a major conflict exists between thecustomer or user needs and the current product in the fact [6].

C. Westinghouse

As a part of time study method to determine the workers time, Westinghouse based on four factors that are used while regarding the performance of the operator; skill, effort, conditions and consistency;with a scale of crisp numerical values for each factor. In Westinghouse method, there are six classes (poor, fair, average, good, excellent and super skill) of each factor where each class has further two degrees (higher or lower). The worker is evaluated in order to obtainperformance rate [8].There are many more theoretical calculation in details that will not explain in this manuscript. Thus such method will only support the main issue in water technology design or decision.It calculated the workers effort that is using above mentioned factors and other all relevant and necessary data such as rating factor, allowance etc. At the end it generated a table of effort from workers that consists of activities with each average cycle time (Tc), normal time (Tn), rating factor (RF) allowance (l) and standard work time (Ts).

III. Methodology

Referred to the way of thinking of such Otto and Wood's Reverse Engineering and Redesign methodology, the stages to find appropriate things for the case as shown on Fig. 3.

Fig. 3The stages in improving small Water Treatment case

On investigation, the original or existing design is treated through 'black box' model that is reviewing its input and output only; and exploring the working principles, block diagram, product assembly drawing with exploded view, and other necessary technical specification. Developing idea stage includes lab scale trials with new or addition sub system, and this will be a basic to follow up the redesign concept. The theoretical evaluation then could be calculated to compare existing and new design.

IV. Result and Discussion

A. Existing design investigation

Since the discussed case is using raw water from the ground or well, the treatment do not need any process that usually applied for surface water source such as coagulation and flocculation. According to the raw water contents, the machine is designed originally with chemical oxidation and disinfection process only, where these processes are controlled by each dosing pump in order to make its chemical solution doses keep consistent as required, as shown in the block diagram on Fig. 4.

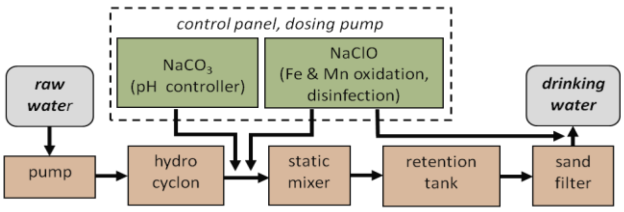

Fig. 4Water Treatment with chemical solution block diagram

Raw water input that is taken by feeding pump flows through hydro cyclone as first rough process in separating and removing the most solid suspended substances with parts size larger than 0.2 mm. The chemical solution for pH controller, oxidation and pre-disinfection then are added into the flow by dosing pumps in the control panel box and it is following with mixing up by static mixer, it then goes into retention tank to optimize the mixing process. These chemical processes then followed with physical filtration by granular media that put in two media tanks. On final stage, the disinfection process is added before the output water is collected into the accumulation tank. All mentioned components are illustrated by Fig. 5 except dosing pumps that mounted in the control panel box.

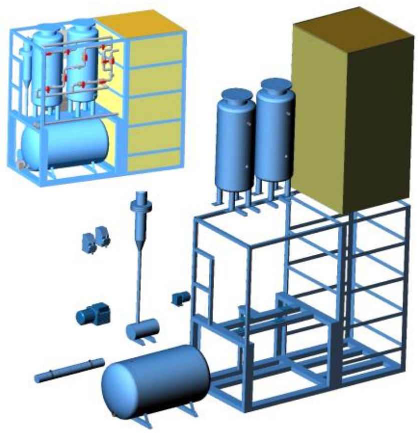

Fig. 5 Original product assembly (left) and exploded view (right)

Regarding black box model point of view in investigating, the samples from raw water that stated as input and produced result water as output of such original design are tested and checked by authorized water lab.

B. Develop idea

To make the water treatment operation easier due to mentioned potential obstacle in operation procedure, a few lab scale experiments are initiated due to find out whether using cartridge that is still combined with media filtration could reduce their efforts. The experiments skipped chemical features and added Micro Filtration (MF) cartridge to get the lab result of output water with the developed idea stated in theoretical block diagram explained on Fig. 6. By valves arrangement, the flow of water goes from hydro cyclone directly to sand filter, then filtrated by Micro Filtration cartridge. Assumed that Ultra Violet light is common, proved and mature product, such experiments did not make any test for this kind of disinfection that supposed will substitute chemical disinfection.

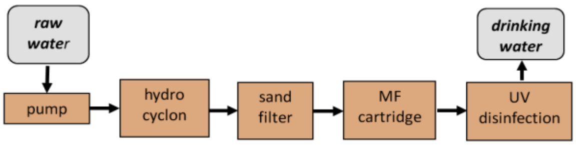

Fig. 6Water Treatment with cartridge and UV block diagram

Below mentioned Fig. 7 is the modified product assembly illustration with its exploded view, referred to Fig. 6 block diagram. It is clearly shown that previous static mixer and retention tank are not used any longer since they are needed for chemical process only. Due to retention tank dimension that relatively big, the total height of new design seemed could be reduced, with a minor consequence that accumulation tank capacity will be a bit lower, too.The same as original design investigating, the samples of produced result water as output of this modified design are tested and checked by water lab.

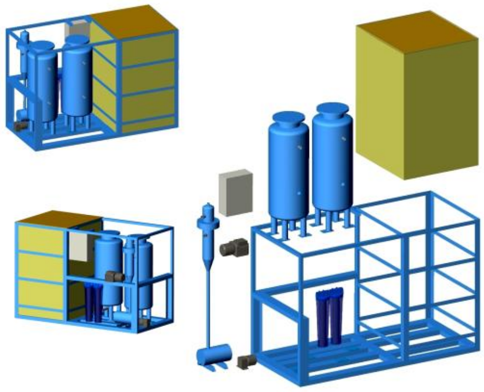

Fig. 7Modified product assembly (left side, above and below) and exploded view (right side)

C. Evaluate, comparing existing and new design

The result shows that using cartridge, instead of chemical ingredient, gave a moderate quality in water composition of element content that is still in standard range of health provision; in this case, referred to Indonesian Government rule for drinking water 'Permenkes 492/2010', as shown in Table 1. The explained values are actually the most important parameters only, as stated. It is fortunately right that all parameters of raw water input are already in acceptable range of value, but operate the system without using any chemical ingredients mainly due to smaller space required and less sensitivity to input water quality variations [9] that could be influenced by weather changes.

TABLE 1
WATER LABORATORIUM CHECK RESULTS

parameter	**unit**	**max. standard**	**result**		
			raw	**chem**	**cartdg**
turbidity	NTU	5	0,38	0,40	0,82
TDS	mg/l	500	120	205	190
colour	PtCo)*	15	5	5	5
Fe	mg/l	0,3	< 0,04	< 0,04	< 0,04
pH	mg/l	6.5-9.0	7,27	7,58	7,31
Mn	mg/l	0,4	0,26	0,14	0,03
KMnO4	mg/l	10	< 0,10	< 0,10	2,08

) TCU scale*

From design aspects that reviewed through Reverse Engineering and Redesign tools it is found that by using modified design with Micro Filtration cartridge, a few advantages are occurred compared with chemical solution design; these are 1)smaller space required, 2)total weight of machine is reduced, and 3)less cost investment is needed. These parameters are analyzed from number of more detail calculation. Retention tank deletion for instance, with approximately 600 diameter times 1000 length (in mm) dimension could decrease space and weight significantly. Nullification of dosing pump that relatively expensive, might contribute cost down as well.

Resulted by Westinghouse method; Table 2 of small water treatment unit case shows that compared with chemical solution, using micro filtration cartridge had a smaller effort from the assigned technicians side. The detail calculation is not mentioned due to limitation space of paper work.

V. CONCLUSION

As a case, a small Water Treatment unit (1m^3 per hour) that is using chemical solution process combined with media filtration is analyzed by Reverse Engineering and Redesign tools from design aspect, Westinghouse for measure the technicians effort in operation and a few lab scale experiments with micro filtration cartridge. The result shows that using cartridge, instead of chemical ingredient, gave a moderate quality in water composition of element content that is still in standard range of health provision; needed lower effort and had better aspect of design. However, more experiments and detail measures is recommended to be explored and developed.

REFERENCES

[1] Badan Standardisasi Nasional,*Air Minum Dalam Kemasan,* (SNI 01-3553-2006), 2006.

[2] Howe Kerry J, Hand Davis W, Crittenden John C, Trussell P Rhodhes, Tchobanoglous George, *Principles of Water Treatment*, John Wiley & Sons, Inc, New Jersey, 2012.

[3] Rafi Mahammad, Rachamar T, Umamahesh M, Babu B Arun, *Fabrication & Testing of Rapid Sand Filter Equipment,* Global Journal of Researches In Engineering, Chemical Engineering, vol 12 issue 2 ver 1.0, ISSN 2249-4596), 2012.

[4] Heijman S G J, *CT4471, Nanofiltration and Reverse Osmosis,* TU Delft, p2, 2007.

[5] Kowalski Krzysztof P, Madsen Henrik T, Sogaard Erik G, *Comparison of sand and membrane filtration as non-chemical pre-treatment strategies for pesticide removal with nanofiltration/ low pressure reverse osmosis membranes,* Water Sciennce & Technology: Water Sully vol 14 no 4 pp 532-539, IWA Publishing 2014 doi 10.2166/ws.2014.004), 2014.

[6] Otto Kevin N, Wood Kristin L, *Product Evolution: A Reverse Engineering and Redesign Methodology,* Research in Engineering Design (1998)10:226-243, Springer-Verlag London Limited, 1998.

[7] Bani Younis Mohammed, *Reverse Engineering,* Technische Universitaet Kaiserlautern.

[8] Cevikcan Emre, Selcuk Kilic Huseyin and Zaim Selim, *Westinghouse Method Oriented Fuzzy Rule Based Tempo Rating Approach*, Proceedings of the 2012 International Conference on Industrial Engineering and Operations management Istanbul, turkey, p1670-1677, 2012.

[9] SJ Haig, G Collins, RL Davies, CC Dorea and C Quince, *Biological Aspects of Slow Sand Filtration: Past, Present and Future,* from http://userweb.eng.gla.ac.uk/christopher.quince/sarah.haig/sarahhaigYWPfinished.pdf

TABLE 2
STANDARD TIME COMPARISON

nbr	activity	chemical solution						cartridge membrane					
		Tc	Tn	RF	l	Ts	total T	Tc	Tn	RF	l	Ts	total T
1	Check filter pressure	1825	2.098,7	1,15	10%	2.308,6	8.568	1825	1843,2	1,01	10%	2027,6	5.007
2	Check dosing pump hose	1825	2.098,7	1,15	12%	2.350,6		-	-	-	-	-	
3	Check water quality	520	598,0	1,15	22%	729,5		520	525,2	1,01	22%	640,7	
4	System backwash	1440	1.656,0	1,15	27%	2.103,1		1440	1454,4	1,01	15%	1672,5	
5	Refill NaClO	30	34,5	1,15	15%	39,6		-	-	-	-	-	
6	Setup dosing pump-1	120	138,0	1,15	25%	172,5		-	-	-	-	-	
7	Wash and replace media	540	621,0	1,15	21%	751,4		540	545,4	1,01	21%	659,9	
8	Refill NaCO3	15	17,2	1,15	15%	19,8		-	-	-	-	-	
9	Setup dosing pump-2	5	5,7	1,15	14%	6,5		-	-	-	-	-	
10	Probe calibration	60	69,0	1,15	24%	85,5		-	-	-	-	-	
11	Cartridge replacing	-	-	-	-	-		5	5,05	1,01	16%	5,8	

Note: Tc = average cycle time, Tn = normal time, RF = rating factor, l = allowance and Ts = standard work time