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Improvement of Water Quality after Implementation of Water Safety Plans (WSPs) in Semarang City, Indonesia

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ABSTRACT

We implemented Water Safety Plans (WSPs) program at previous work due to poor of water quality in the coastal area of Semarang, Indonesia. The aimed of the research was to evaluate water quality before and after implementation of WSPs program in Bandarharjo village, Semarang city. This was an experimental design with steps for implementations of WSPs program adopted the guidelines and tools of the World Health Organization. Numbered 80 samples before and after implementation of WSPs and fulfilled by purposive sampling technique. The main parameters of drinking water were total coliform with MPN method, turbidity with turbidity meter, salinity and pH with potentiometer instrument. Data were analyzed using Wilcoxon match-paired signed-rank test at $\alpha = 5\%$. Bacteriological quality of drinking water in Bandarharjo village has increased 17.5% after implementation of WSPs program. There were significant difference between total coliform ($p = 0.016$), salinity ($p = 0.028$), and turbidity ($p < 0.001$) before and after implementation of WSPs. Implementation of WSPs program has improved water quality, however regularly monitoring of the water supply system and bacteriological treatment are needed.

***Keywords**: implementation of WSPs program, water supply system, drinking water, coastal area, water quality improvement.*

INTRODUCTION

People in coastal area of Semarang, Indonesia used the deep ground water or artesian wells for daily needs (i.e., drinking, cooking, and washing). The number of deep ground water were not met the requirement in terms of bacteriological quality was 9 out of 20 water samples. Microbial contamination of major urban drinking water has the potential to cause outbreaks of waterborne disease. [1]

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Our field risk assessment of water supply system in previous study in the coastal area revealed a very high degree of risk at source system, at a reservoir, at processing system, and at costumer or household system. We obtained a high degree of risk at distribution system.[2]

The water safety plans (WSPs) program implemented[3] in the coastal area of Semarang in accordance with the WHO guidelines.[4] The steps of WSPs program consist of introducing WSPs program, team building, training the team, examination of water safety before risk assessment, risk assessment, minor repair I, examination of water safety risk, minor repair II after monitoring.[5]

Introducing of WSPs program to the community conducted by presented the results of research related to water quality in the region to the representative community. The value of drinking water (i.e., reduce future water borne disease) also was informed. The team of WSPs was built and legalized by decree of village office. The WSPs team was well-trained using the materials adapted from the WHO training module.[4] Methods of training included presentation and discussion, simulation, field visit, and working group. Risk assessment and minor repairs were implemented in source system, distribution system, and household system.[3]

However, implementation of WSPs program has not been evaluated. Evaluation of the implementation of WSPs program could be evaluated due to the parameters of quality of the drinking water. The aim of the research is to evaluate the water quality before and after the implementation of Water Safety Plans (WSPs) program in the coastal area of Semarang.

METHOD

Study Design: The location was in the Bandarharjo village, Semarang is chosen based on bacteriological water quality in the supply system. The samples numbered 40 out of 73 customers withdrawn by a purposive sampling technique. The parameters of drinking water are total coliform [6-8] with MPN method [9], turbidity with turbidity meter, salinity, and pH with potentiometer.[1,7,10,11] The examination of drinking water quality was performed in the Local Health Laboratory of Central Java Province. Research activities used the framework of WSPs guidelines [5], steps included: Introducing of WSPs to community by presentation and discussion method; WSPs team building and training by class, exercise and field visit method; examination of water safety before risk assessment by laboratory examination; risk assessment of water safety by WSPs team using tools of WHO; minor repair I: after risk assessment; examination of water safety risk after minor repair; monitoring of water safety risk; minor repair II: after monitoring of WSPs field trial in rob area.[7] This work used experimental with pretest and posttest design.[12-14]

In accordance with sample representativeness, it was being taken from locations that are representative of the points of use 6. The time between sampling and analysis were kept to a minimum and it was storage in clean a glass or polyethylene bottles at a low temperature (4°C) in the dark sampler. Acidify (pH) and turbidity of water was tested immediately after sampling to prevent change during storage and transport [6].

STATISTICAL ANALYSIS

Description of data conducted by compared water quality before and after of the WSPs implementation. Kolmogorov-Smirnov was performed to analyze normality of data (MPN coliform, turbidity, pH, and salinity). Wilcoxon match-paired test was performed to analyze the quality of drinking water before and after implementation of WSPs program at $\alpha = 0.05$ [15]. All statistical analyses were performed using SPSS statistical software version 20.0 (IBM™ Corp.).

RESULTS AND DISCUSSIONS

Table 1, in term of pH and salinity, all water sample qualify the standard, yet two of 40 samples exceed turbidity standard (> 25 mg/l). Eighty percent of water sample at customer level did not meet specified standard according to Decree of Ministry Health of Republic of Indonesia number 416/1990, which is maximum 10/100 ml water sample. Water quality does not require BOD parameter. The BOD examination was performed to estimate a possibility of piping leakage, loose connections, or water contamination by sewer or tidal inundation, also possibility sedimentation in inner pipe. In addition, from the results of our spot check by cutting distribution pipeline, we found in the inner wall of the pipe has a lot of stick impurity deposition.

On physical examination at household level of deep ground water, the turbidity levels before the repair were found in two samples of 40 samples tested, that did not qualify at more than 25 mg/litter. However, the physical examination of the water quality parameters of turbidity after the improvement of drinking water supply system, it is no longer found turbidity levels that exceed the requirements of Ministry of Health regulation number 416/1990.

Bacteriological quality of the water in the deep ground well at customers level is qualified according to Ministry of Health regulation number 416/1990 as much as 13 (32.5%) of the 40 samples tested (same sample before risk assessment). While the quality of deep ground well on customers who do not qualify the requirements as much as 27 (67.5%) of the 40 samples tested. Bacteriological quality of water that met the requirements have increased 17.5%, from 6 (15%) to 13 (32.5%). The most bacteriological quality of the water samples examined (67.5%) remained not met its specified requirements.

As a conclusion, test results of water quality parameters of physics, chemistry, and biology at the consumer level after the improvement of drinking water supply as follow (Table 1): (a) Physical quality parameters of turbidity of water with as many as 40 samples (100%) were eligible; (b) Bacteriological quality (total coliform) from deep ground well water to customers who still have not qualified as much as 27 (67.5%) of the 40 samples examined; (c) Parameters pH and salinity and BOD all (100%) were eligible.

Table 1: The category of standard of water quality before and after minor repairs of implementation of the WSPs program

Water parameters	Before (n = 40)	After (n = 40)
MPN coliform		
Met standard	17.5	32.5
Not met standard	82.5	67.5
Turbidity (NTU)		
Met standard	95	100
Not met standard	5	0
Salinity (mg/L)		
Met standard	100	100
No met standard	0	0
pH		
Met standard	100	100
Not met standard	0	0
BOD (mg/L)		
Met standard	100	100
Not met standard		

Conted…

*According Ministry of Health of Republic of Indonesia 416/1990

Table 2 showed the statistical analysis of parameters of the water quality before and after minor repairs of implementation of the WSPs program in Bandarharjo village. The average level of the MPN coliform, turbidity, and salinity were significant difference before and after implementation of WSPs program (p=0.016, p<0.001, and p=0.0028). There were no difference between pH and BOD before and after implementation of WSPs program (p=-, p=0.697).

Table 2: The water quality before and after minor repairs of implementation of WSPs program

Water parameters	Before (n=40)			After (n=40)			p-value	Remark*
	Mean ± SD	Min.	Max.	Mean ± SD	Min.	Max.		
MPN coliform	740.2 ± 1012	3	2400	273.93 ± 641.3	3	2400	0.016	Not met standard
Turbidity (NTU)	4.28 ± 11.5	0.18	65.9	0.26 ± 0.23	0.02	1.34	<0.001	Met standard
Salinity (mg/L)	0.12 ± 0.09	0.018	0.66	0.24 ± 0.15	0.04	0.4	0.028	
pH	7.0 ± 0	7.0	7.0	7.0 ± 0	7.0	7.0	-	Met standard
BOD (mg/L)	0.45 ± 0.5	0.1	2.91	0.42 ± 0.22	0.1	0.94	0.697	-

*According Ministry of Health of Republic of Indonesia 416/1990

The local government drinking water supply system consists of intake of raw water, physical and chemical treatment, distribution and household connection. Complete water treatment included screening, coagulation, sedimentation, filtration, disinfection, and distribution. [16] However, the minimum requirement for ground water is disinfection. One way to disinfect water is using chlorine. An effective disinfection using chlorine kills bacteria, viruses, and protozoa such as Giardia and Cryptosporidium.[1]

Coliform bacteria is an intestinal bacteria leaves in human digestion tract, has a pathogenic capacity which used to be an indicator of sanitation. The most widely used in drinking water indicators are coliforms (total coliforms), fecal or thermo tolerant coliforms, Escherichia coli, enterococci (fecal streptococci or intestinal enterococci) and bacteriophages.[17]The presence of fecal coliform, which counted by a number of colonies, is positively correlated with the presence of pathogenic bacteria. In addition, the detection of the coliform is cheaper, faster, and simpler than detection of other pathogenic bacteria method. Therefore, a coliform determination could be used as an indicator of water quality. Although E. coli is a part of the normal microbial digestive tract, the presence of certain strains could cause moderate to severe gastroenteritis level in humans and animals. Feces can be a source of pathogenic bacteria, viruses, protozoa, and helminth.[7] The presence of coliforms in the distribution system, while possibly due to inadequate treatment, could also be due to cross-connections or failure to maintain an adequate disinfectant residual.[18]

Water supply system in Bandarharjo village mostly relies on deep ground wells. The water has undertaken neither physical nor chemical treatment processing to secure water quality and safety. Disinfection is an effective barrier to many pathogens (especially bacteria) during drinking-water treatment and should be used for surface waters and for groundwater subject to fecal contamination.[7]

The average number of MPN coliform before and after implementation of WSPs program remain not met the standard in accordance with Ministry of Health of Indonesia number 406/1990 (Table 2). Although the average number of MPN coliform significantly decreased before and after implementation of WSPs program ($p = 0.016$). This probably because the minor repair of the water system that only focused on the improvement of physical infrastructure to prevent contamination, rather than chemical aspects. Chemical treatment such as water disinfection had not been done due to community rejection. Thus the bacteria remain contaminated water from the source and distributed to costumers. Although at water source the bacteriological quality actually improved, the improvement was not significant in accordance with a standard. A recent study revealed groundwater to be vulnerable to contamination both in the vulnerable and critical zones in the north and the east of Semarang. This groundwater was unsuitable for drinking water due to seawater intrusion in the damage area.[19]

The presence of microbial may also influence by organic materials [20] deposition in the inner of type pipe [21] in distribution and the process included three stages.[22] It was indicated the presence of BOD, although in a small amount. The BOD level was lower after WSPs program implemented even it was not statistically significant. The pipe deposition may cause of microbial growth.[23] Several studies have demonstrated presence of coliforms in drinking water distribution systems associated with biofilm growth problems.[24,25]

The salinity of drinking water was very low, despite the increase in salinity after minor repair of the water supply system. The water salinity level met the requirement in accordance with the quality of drinking water. Biofilm growth is influenced by a number of physical, chemical, and biological processes. The level of acidifying (pH) of water was 7 (in neutral pH) and its good chemical condition for growing microbial in the water.[22] There was no significant difference (constant) of pH before and after implementation of WSPs program. There was no treatment process in the water supply system, a primarily addition of the chemical agent. So the pH remained constant in average.[26] The pH is an important operational water quality parameter, for effective disinfection with chlorine, the pH should preferably be 6-8, because chlorination may be ineffective above pH 9.[7]

Turbidity was met a standard and significantly reduced in average (difference) before and after implementation of WSPs program ($p < 0.001$). Water supply system: at the source (i.e., cisterns, pipe, and cisterns cover), at distribution pipe (i.e., leakage pipe, lost connection, flushing), and at customer connection (i.e., water meter, connection pipe) were improved. Turbidity correlates with changes of suspended bacterial concentration [21] and adversely affects the efficiency of disinfection.[7] As the turbidity decreased, the number of MPN also showed a significant decrease.

CONCLUSIONS

The bacteriological quality of water supply system in Bandarharjo village increased 17.5% after implementation of WSPs program. The implementation of WSPs program is able to improve the quality of drinking water and can be replicated. However need continuous assistance and improvement particularly to maintain the team, disinfection process using acceptable method, periodically flushing, and monitoring drinking water supply system.

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