IOP Conference Series: Earth and Environmental Science

PAPER • **OPEN ACCESS**

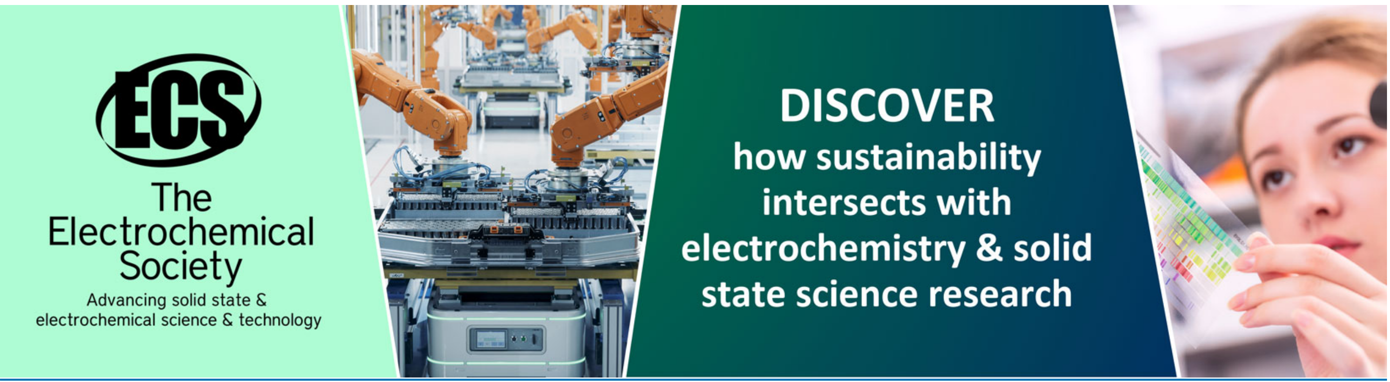
Minimizing failure risk of refill drinking water production in Rungkut district Surabaya using Failure Mode and Effect Analysis (FMEA)

To cite this article: A Wicaksono and N Karnaningroem 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **259** 012013

View the article online for updates and enhancements.

You may also like

- Deployment of an FMEA-Integrated Framework to Improve Operational Performance in Semiconductor Manufacturing: A Case Study
C F Liew, J Prakash, S Kamaruddin et al.
- Product Quality Improvement Using FMEA for Electric Parking Brake (EPB)
C D Dumitrescu, G C Gruber and I A Tic
- Implementation of the Failure Mode and Effects Analysis (FMEA) Method to Determine Project Risk Priority
S Atin and R Lubis



This content was downloaded from IP address 3.19.30.232 on 05/05/2024 at 09:36

Minimizing failure risk of refill drinking water production in Rungkut district Surabaya using Failure Mode and Effect Analysis (FMEA)

A Wicaksono[a] and N Karnaningroem[b]

Environmental Engineering Departement, Faculty of Civil, Environmental, and Geo-Engineering, Institut Teknologi Sepuluh Nopember (ITS), Surabaya, Indonesia

[a]akbarwicakso@gmail.com, [b]n.karnaningroem@gmail.com

Abstract. Human necessity toward consumable drinking water increases along with population growth. People nowadays have a hard time obtaining clean water because of polluted river. To meet daily necessity of drinking water, a lot of industries open drinking water business, particularly refill drinking water facility (DAMIU). The utilization of refill drinking water facility has its own hazardous risk because of the doubtful quality, moreover if the customers aren't paying attention towards the security and hygiene. This study used FMEA (Failure Mode Effect and Analysis) to determine the priority of failure incident in refill drinking water treatment process. This FMEA method was used because FMEA has advantage over other method in term of being more feasible and effective for operational improvement while being able to analyze risk in bigger and more complex scale. To determine the failure, we first did risk identification which contained failures information obtained from interview, quality test, and direct observation. Failure causes risk happened in refill drinking water facilities were analyzed using Fishbone method. The location of the study was in Rungkut District, Surabaya. The parameters used were turbidity, TDS, pH, and Total Coliform. Obtained risk should had a value to be measured and determined for the handling priority and to find improvement effort. The measurement value was called as RPN (Risk Priority Number) which was the multiply value of severity, occurrence, and detection. Based on analysis result using fishbone method there were 4 factors which caused failure for total coliform parameter. Then, it was analyzed using FMEA method, and it was found that failure happened within 3 highest priority, which was UV system contact duration, ozone system contact duration, and disinfection tool replacement and maintenance.

1. Introduction

Surabaya is a city with 2.848.853 people in 2015 and population growth increases by 0.52% every year. This condition makes Surabaya City a metropolitan city. Population growth increases daily drinking water consumption [1]. To fulfill daily need of drinking water, Surabaya citizen can choose to consume water from regional water company (PDAM), packaged mineral water, or refill drinking water facilities (DAMIU). Result of quality determination of river water in Sungai Surabaya based on STORET method stated that 49.4% is heavily polluted for a Class 2 river. Meanwhile, water quality status in Sungai Surabaya based on Pollution Index 100% method was medium polluted for Class 2 [2]. Looking at this condition, Surabaya citizen turns to either packaged mineral water or refill drinking water to fulfill their drinking water necessity. However, packaged mineral water are too costly for some people. Refill drinking water facilities sells way cheaper water compared to packaged mineral water. Therefore, refill

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

IOP Conf. Series: Earth and Environmental Science **259** (2019) 012013 doi:10.1088/1755-1315/259/1/012013

drinking water becomes a favorable alternative for its cheap price and availability [3]. Rungkut District was chosen as study location because of the heterogeneous people. In addition, Rungkut District was one of the densest district in Surabaya City. The area of Rungkut District was ± 21.08 km2 with 108,494 population in 2015.

Refill drinking water facility as a drinking water source alternative becomes a risk for human health if the facility's quality is still doubtful, especially for small scaled facilities, even more so if the customer aren't paying attention for its security and hygiene [4]. From previous study, refill drinking water in Surabaya City quality status was: 31 samples all met the turbidity and TDS parameter, 1 of 31 didn't meet acidity (pH) parameter, and 7 of 31 or 22.58% did not meet Kepmenkes RI No 907/Menkes/SK/VII/2002 standard for coliform bacteria [5].

Drinking water sold to customer has to be consumable, which includes clean, healthy, and meeting the health standard stated by government in Peraturan Menteri Kesehatan RI Nomor 492/Menkes/IV/2010 Tentang Persyaratan Kualitas Air Minum dan Keputusan Menteri Perindustrian dan Perdagangan RI Nomor 651/MPP/Kep/10/2004 tentang Persyaratan Teknis Depot Air Minum dan Perdagangannya. Regarding that problem, a study needs to be done to determine the cause of refill drinking water facilities not meeting standard. One of applicable failure analysis method was FMEA (Failure Mode and Effect Analysis). FMEA method was used to determine the priority of problem and its prevention. Failure Mode and Effect Analysis (FMEA) is a circulative risk analysis technique used to identify how a tool or facility/system can fail and the effect it causes. FMEA result is a recommendation to improve the safety of a facility, tools, or system. In Health and Safety context, the failure in this definition is a hazard coming from a process [6]. Product failure happens not only at the end process, but can also happen in the beginning or in the process production itself. FMEA method is applied because FMEA has the advantage of being more feasible and effective compared to other method for operational improvement and for analyzing risk in bigger and more complex scale [7].

2. Study method

This method was a reference for all things related to refill drinking water quality test based on work steps in data collecting, analysis, and discussion until desired result was obtained.

2.1. Data collecting

Data collecting was done before refill drinking water sample was analyzed. Direct survey was done to determine the number of refill drinking water facilities in Rungkut District, Surabaya. After the data was obtained, some facilities were chosen to represent all the facilities using cluster sampling method. Then, the treated water in those drinking water facilities were taken to determine the drinking water quality.

2.2. Refill drinking water analysis

In refill drinking water analysis, the sampling was done only once for every tested sample. Water sample was taken from refill water outlet, which was the filling pipe of gallon package sold to customer. Sample taking used 5 L gallon to make it resemble the container used by customers. Test was done for some parameters based on PERMENKES No.492 Tahun 2010 Tentang Persyaratan Kualitas Air Minum. Parameters used in this analysis were:

1. Total Dissolve Solid (TDS)
2. Turbidity
3. pH
4. Total Coliform

Then failure analysis was done to refill drinking water facilities whose treated water didn't meet the standard regulation stated in PERMENKES No.492 Tahun 2010 Tentang Persyaratan Kualitas Air Minum.

2.3. FMEA analysis
Then, questionnaire was spread to 20 refill drinking water facilities in Rungkut District Surabaya. This questionnaire contained questions about the machine performance, as well as the knowledge, behavior, attitude, and service of the managers or staffs to be analyzed using FMEA method. Expert judgment interview was done towards city health office, Dinas Kesehatan Surabaya, to determine the Severity, Occurrence, and Detection scale. This analysis was expected to determine the main cause of failure as well as the priority of problem to be solved to prevent further failure.

3. Result and discussion
In this study, sample water was taken from refill drinking water facility in every sub-district in Rungkut District, Surabaya. Based on survey result, there was 26 refill water facilities with 2 kind of disinfection technology, which were ozone and UV ray. From the data, facilities using UV ray technology were 18 facilities, for ozone technology were 2 facilities, and 6 facilities for both ozone and UV. For the raw water material, 18 facilities used Prigen mountain spring, 3 facilities used Pandaan mountain spring, 1 facility used Trawas mountain spring, 1 facility used Tretes mountain spring, and 1 facility used Pacet mountain spring.

To determine the facilities which would be tested, cluster sampling method and systematic sampling was done. From survey result, there were 2 clusters based on the treatment technology, which was UV technology and ozone technology. Then, systematic sampling was done, based on the order of the numbered population [8]. The number of all facilities are 26 facilities. To choose sample, 20 facilities were chosen based on the location of subdistrict in Rungkut district, then 20 water sample was obtained, in which 15 used UV technology, 1 used ozone, and 4 used both.

Table 1. Name of analyzed facilities.

Facility Name	Use of technology	Water source
Azami	UV	Prigen
Alifa	UV	Prigen
Jaya Makmur	UV	Pacet
Fresh is ulang	UV	Prigen
AMS	Ozon	Prigen
ASA	UV	Pacet
Amsal	UV	Prigen
Life water	UV	Prigen
Wahyu	UV	Prigen
Mata Air	UV, ozon	Prigen
Barokah	UV	Prigen
Heny Tirta Jaya	UV	Prigen
Tirta Jaya	UV	Prigen
Tanjung Biru	UV, ozon	Prigen
Zahara	UV	Prigen
Total Prima	UV, ozon	Pacet
Anisa	UV	Pacet
Seven Dream	UV	Prigen
Aini	UV	Pacet
Tirto Wening	UV	Pacet

3.1. Sample analysis

3.1.1. Turbidity. Turbidity is an important parameter in drinking water standard, because if water has high turbidity, it will be hard to disinfect. Disinfection itself is a process of exterminating microbes contained in the treated water. Turbidity analysis used turbidimeter tool which could directly read the turbidity value of each sample.

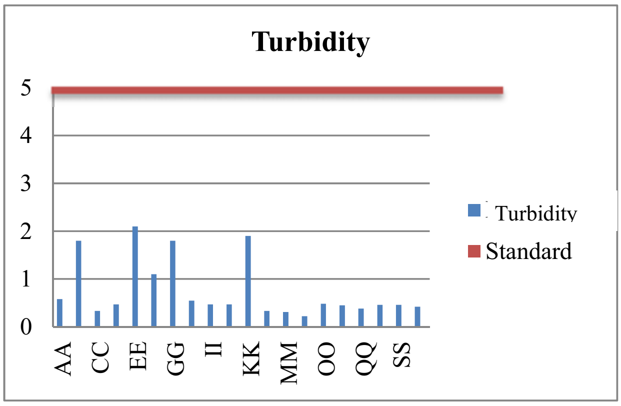


Figure 1. Turbidity of all refill drinking water facilities

From the analysis, it can be inferred that all refill drinking water facilities meet the standard stated by government in Peaturan Menteri Kesehatan Republik Indonesia Nomor 492/MENKES/PER/IV/2010 Tentang Persyaratan Kualitas Air Minum which is 5 NTU. Highest turbidity value for the samples was 2.1 NTU.

3.1.2. pH. pH or acidity is used to state the acid content in a substance, solution, or thing [9]. pH analysis in this study used pH meter.

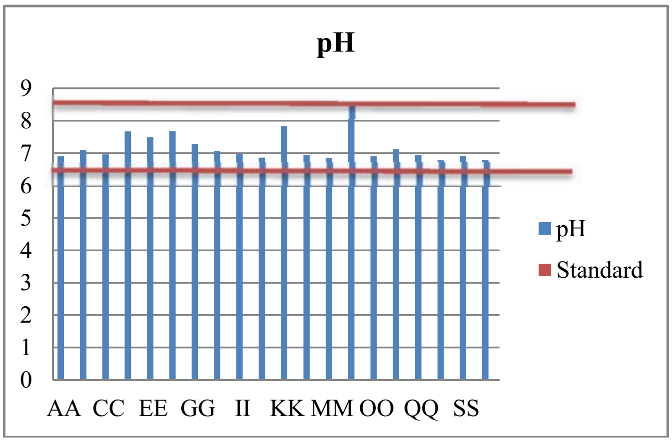


Figure 2. pH of all refill drinking water facilities

From the analysis result, it can be inferred that there is 1 facility which did not meet the standard based on Peraturan Menteri Kesehatan Republik Indonesia Nomor 492/MENKES/PER/IV/2010 Tentang Kualtas Air Minum, which was 6.5 – 8.5. However, the base pH value is good for health, so further analysis was not needed for this parameter.

3.1.3. TDS. TDS analysis in this study was done using TDS meter.

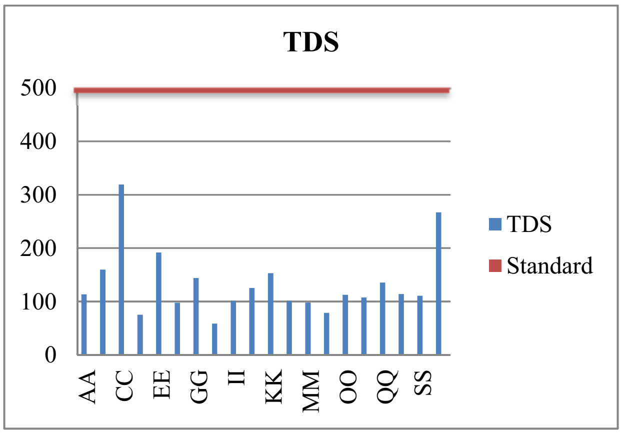


Figure 3. TDS of all refill drinking water facilities

From the analysis result, it can be inferred that all 20 facilities met the standard Peraturan Menteri Kesehatan Republik Indonesia Nomor 492/MENKES/PER/IV/2010 Tentang Persyaratan Kualitas Air Minum which was 500 mg/L. The highest TDS value out of 20 facilities was 319 mg/L, and the lowest was 58,6 mg/L.

3.1.4. Total coliform. Total coliform analysis used MPN (Most Probable Number) method. MPN method used Lactose Broth (LB) media to do presumptive test and see whether there would be positive tube. If there was, the test would proceed to confirmation analysis using BGLBB (Brilliant Green Lactose Bile Broth) and the analysis result would be read using MPN Index Table.

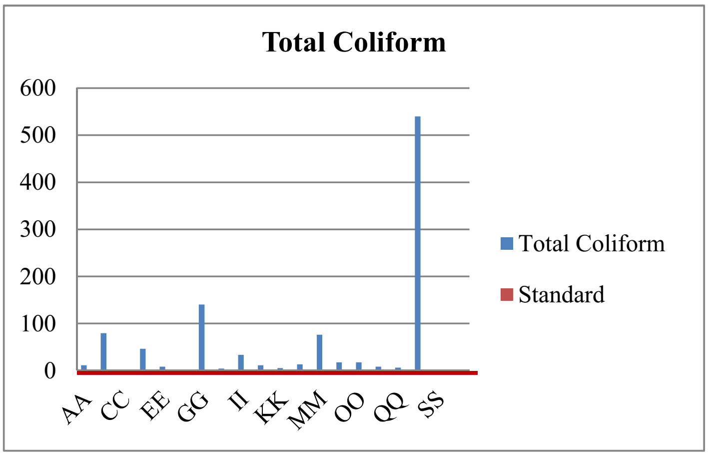


Figure 4. Total coliform of all refill drinking water facilities

From the analysis result, it can be inferred that only 1 facility had met the standard Peraturan Menteri Kesehatan Republik Indonesia Nomor 492/MENKES/PER/IV/2010 Tentang Persyaratan Kualitas Air Minum which was 0 coliform per 100 mL. In this study, the highest total coliform value out of 20 facilities was 540. Therefore, further analysis was needed to determine the cause of failure.

3.2. Risk identification
Based on the study done towards refill water facilities, there were some factors which caused water quality to decrease. Some of the components were the performance of treatment unit, lack of continuous monitoring from related health institution, lack of awareness, knowledge, and good behavior from the owner of the facilities, unhygienic packaging, and lack of effective SOP.

Factor determination for each risk was used to ease the consideration in deciding priority for optimization action. Cause factor determination for each risk was based on the amount of effect it caused. Risk importance weighing was grouped into two, which were technical and non-technical.

3.3. Deteremining main problem using FMEA method

3.3.1. Severity. Severity is an assessment towards the effect and disturbance caused by failure potential of production process based on observation result, and then appropriated by the definition of severity for each kind of disturbance. In previous severity assessment, risk value scale was made to support the determination of severity value. After risk value scale was obtained. To obtain range value, calculation was done with the following example:
- Ideal scale value (ISV) = 5
- Environmental condition assessment (ECA) = 2

$$= (ECA/ISV) \times 100\ \% \qquad (1)$$
$$= \frac{2}{5} \times 100\%$$
$$= 40\ \%$$

3.3.2. Occurrence. Occurrence can be defined as the probability of failure or fault from each disturbance based on the type of disturbance. In occurrence assessment, short questionnaire should be answered to determine the frequency of a certain facility in experiencing failure in the last year. 5 meant it was happening often and 1 meant that it never happened. This kind of analysis was done because it was impossible for the researcher to observe occurrence in such a short time. After the value was obtained, range value calculation could be done. The calculation was done as in the following example:
- Severity Value = 5
- Occurrence Value = 4-5 (because the Severity Value was 5 which meant very bad, higher failure risk meant higher chance of the failure to happen)
- Severity Value = 4
- Occurrence Value = 3-4 (because the Severity Value was 4 which meant bad, higher failure risk meant higher chance of the failure to happen)
- Severity Value = 3
- Occurrence Value = 2-3 (because the Severity Value was 3 which meant medium, smaller failure risk meant smaller chance of the failure to happen)
- Severity Value = 1-2
- Occurrence Value = 1-2 (because the Severity Value was 1-2 which meant good and very good, smaller failure risk meant smaller chance of the failure to happen, or it could not happen at all)

3.3.3. Detection. Detection is an assessment about the capability of control to detect failure cause. In detection determination, the value was taken based on the occurrence result, because higher chance of failure meant smaller capability of risk control. After those values were obtained, range value calculation could be done. Range value of Detection was made similar with Occurrence because higher failure incidents meant that failure cause detection would be more difficult.
- Occurrence Value = 5
- Detection Value = 5 (because the Occurrence Value was 5 which meant very frequently happening, then there must have been no failure detection)
- Occurrence Value = 4

- Detection Value = 4 (because the Occurrence Value was 4 which meant frequently happening, then there must have been no failure detection)
- Occurrence Value = 3
- Detection Value = 3 (because the Occurrence Value was 3 which meant it has ever happened, then there would be an ineffective failure detection)
- Occurrence Value = 1-2
- Detection Value = 1-2 (because the Occurrence Value was 1-2 which meant never happened, then the failure detection must have worked effectively)

3.3.4. Risk Priority Number (RPN). From the treatment result done to obtain severity, occurrence, and detection value, RPN could be determined by multiplying the severity (S), occurrence (O), and detection (D) value. Those values would be the reference in selecting the failures which needed improvement.

From SOD assessment of all aspect, it could be seen that the problem with the highest priority to be solved was contact duration of UV ray and ozone disinfection process. This problem was the main cause of the failure to meet the standard Peraturan Menteri Kesehatan No. 492 tahun 2010 of 0 coliform. The next priority problem was the replacement of disinfection tool, which was used to exterminate microbes in treated water. This maintenance process was important to ensure that there was no microbes in the drinking water. Lack of staff knowledge was also a problem, because the staff would think that the water was consumable even though there were some parameters which did not meet the drinking water standard.

There were four factors that caused the failure: decrease of disinfection technology performance, quality monitoring, water packaging, and behavior and knowledge of the staff and/or manager of the refill drinking water facility. Decrease of technology performance was in the form of poor disinfection technology which made the water did not meet the total coliform parameter. Quality monitoring was affected by the monitoring done by external and internal side of refill drinking water facility. External side meant city health office, Dinas Kesehatan Kota Surabaya, who should be controlling drinking water quality of drinking water facilities. Internal side meant the owner and/or manager of the facilities who were responsible for the quality of their treated water for the customers. Water packaging was affected by the cleaning of the container and the application of unusable container. Behavior and knowledge of owner and/or manager of the facility meant the knowledge of the owner regarding the regulations about drinking water facilities. Lack of knowledge from the owner and/or manager about the responsibility of providing drinking water with good quality could cause the decrease in drinking water quality treated by that facility because of the ineffective media, unknown minimal media filter replacement, unknown optimal duration for disinfection technology, reservoir lack of cleanliness, and lack of maintenance and replacement for refill drinking water treatment tools. It was also included in the behavior of the owner and/or manager of the refill drinking water facility.

4. Conclusions

From the research and analysis, it could be concluded that:

1. Factors causing failure for refill drinking water facility analyzed by fishbone analysis were knowledge and behavior of the facility owner, water packaging, decreasing performance of disinfection tool, and quality monitoring of refill drinking water facility.
2. Analysis of failure happening to total coliform parameter used FMEA method and from that, 3 highest failure priority was obtained, which were UV contact duration with RPN value 100, ozone contact duration with RPN value 100, and disinfection technology maintenance and replacement with RPN value 64.
3. To minimize failure based on highest priority towards SOD assessment was to add contact duration on UV system so that water was at least exposed for 4 seconds towards UV ray, and at least 4 minutes for ozone process to maximize disinfection process, as well as maintaining and replacing the disinfection tools regularly.

References

[1] Aulia Y 2012 *Efektivitas Biofiltrasi Pada Proses Penyaringan Air Minum Isi Ulang Sebagai Pencegah Penyebaran Bakteri Patogen Di Salah Satu DAMIU Pancoran Mas* (Depok: Universitas Indonesia)
[2] Astari R. and Rofiq I 2009 *Kualitas Air dan Kinerja Unit di Instalasi Pengolahan Air Minum ITB* (Bandung: Institut Teknologi Bandung)
[3] Pratiwi A W 2007 *Gambaran Kualitas Bakteriologis Air Pada Depot Air Minum Isi Ulang Di Wilayah Kota Bogor* (Thesis) [Depok (Indonesia)] Program Sarjana. FKM-UI
[4] Sutrisno T and Suciastuti E 2002 *Teknologi Penyediaan Air Bersih* (Jakarta: Rineka Cipta)
[5] Carlson C S 2012 *Effective FMEAs: Achieving Safe, Reliable, and Economical Products and Processes Using Failure Mode and Effects Analysis 1st ed* (USA: Jhon Wiley & Sons Inc.)
[6] Gaspersz V 2002 *Pedoman Implementasi Program Six Sigma* (Jakarta: Gramedia Pustaka Utama)
[7] Jun L and Huibin X 2012 Reability Analysis Of Aircraft Equipment Based On FMECA *Physics Procedia* **25** pp 1816-22
[8] Suprihatin 2003 *Sebagai Air Minum Isi Ualang Tercemar Bakteri Coliform. Tim Penelitian Laboratorium Teknologi dan Manajemen Lingkungan IPB* (Jakarta: Kompas)
[9] Marganof 2007 *Model Pengendalian Pencemaran Perairan di Danau Maninjau Sumatera Barat* (Bogor: Kampus IPB)

Acknowledgements

Author would like to thank the final project guide lecturer and grade lecturer for the suggestion and critics towards the making of this journal. The writer would also like to thank his family for the ever present prayers and hope.