The Role of HACCP Method in Determining Drinking Water Quality

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Abstract. One of the main daily needs of human beings is drinking water. Clean drinking water can sustain every aspect of human life. From time to time, humankind already discovered multiple water resources which can be used in various ways. One of them is mineral bottled water. Yet not even this water source is guaranteed safe to be consumed. There might be many contaminants contained in the mineral bottled water production process. This triggers the need to form an applicable, comprehensive, and standardized method to determine which drinking water sources are safe for consumption. One of the methods which can fulfill the requirements is HACCP. HACCP (Hazard Analysis and Critical Control Point) is a system to analyze risks by determining a sufficient controlling and supervision method to avoid irregularity in the production system. There are five primary principles in HACCP method, i.e. analyzing the risks on the system, determining critical control points and critical limits, arranging monitoring procedure and organizing corrective action in the diversion of critical limit which surpassed toleration limit. Mineral bottled water production system can be an ideal subject for the application of HACCP method due to its detailed system which can be analyzed further.

1. Introduction

Basically, drinking water is an essential which cannot be discarded from human daily needs. Clean and healthy drinking water is needed by every single human being to perform everyday activities, from high-income to low-income communities. One of the community drinking water sources is PDAM or tap water. The other choice, widely used among Indonesia communities, is mineral bottled water. Mineral bottled water is industrialized and produced from raw water processed by using high technology and several treatments in order to remove all the contaminants within. However, not all mineral bottled waters are guaranteed safe to be consumed. Almost 70% of mineral bottled water companies are not using proper treatments in producing clean drinking water, nor comply with the government quality standards like SNI 3553:2015 and PERMENKES Number 492 Year 2010. Based on SNI 3553:2015, bottled water quality standard is created for protecting the health and interest of consumers.

In order to achieve the standard to ensure the quality of drinking water, the HACCP method is essentially needed. Based on SNI 01-4852-1998, HACCP (Hazard Analysis and Critical Control Point) is a system to analyze risks by determining a sufficient controlling and supervision method to avoid irregularity in the production system. This method is based on preventive measure and it is believed to be more effective instead of the conventional method, which emphasizes on the result of...
laboratory testing and takes longer time (Daulay, 2014). Codex Alimentarius Commission from World Health Organization (WHO) recommended and acknowledged HACCP as the international food safety standard which validated all over the world in Guidelines for Application of Hazard Analysis and Critical Control Point System. Therefore, HACCP has been applied in every international food industry production system, including drinking water, and it is a mandatory rule (WHO, 1997). HACCP method is also featured and recommended in ISO 22000 and ISO 9001.

In this context, this study aimed to form an applicable, comprehensive, and standardized method to determine if mineral bottled water production system is safe for consumption, such as HACCP. With HACCP method application, mineral bottled water industries can produce safe-to-consume products for the customers. (Dahlan et al, 2016).

2. Methods
This study is particularly conducted in the technical aspect. This aspect is believed to deliver an immense understanding of applying HACCP method in mineral bottled water production system generally. In a further study, the other aspects can be analyzed to enhance the HACCP system plan in the future.

2.1 Data collection
Collecting data was previously needed to gather more information for the analysis. Primary data and secondary data were utilized in supporting the technical aspect of the study.

- The primary data needed were the laboratory test results of samples from raw water resources and all the effluents from the drinking water treatment units such as Escherichia Coli content, Total Dissolved Solid (TDS) content, turbidity, and pH level. All the parameters of lab test result referred to SNI 3553:2015. The analysis procedure of Escherichia Coli content referred to Standard Method (APHA 9221-G.2-1998) using MPN Index method, while pH level and Total Dissolved Solid content referred to SNI 3554:2015 using pH meter and gravimetric method, and turbidity level referred to SNI 06-6989.25-2005 using nephelometer.
- Then the secondary data were the process flow diagram of Mineral Bottled Water Treatment Plant, Standard Operating Procedures (SOP) of conducting mineral bottled water production process, raw water volume and the production period of every mineral bottled water batch.

2.2 Existing Condition Analysis
After gathering primary and secondary data, the existing condition of the mineral bottled water production system was analyzed. According to SNI 01-4852-1998, the existing condition analysis is followed by determining the pre-requisite method of HACCP, which would be compatible with the first principle of HACCP method plan. Pre-requisite is a method to give guidance on conducting a risk analysis. There are two methods that can be used in a pre-requisite, i.e. the fishbone diagram and FMEA (Failure Mode and Effect Analysis):

- In a Fishbone diagram, the factors from all production system problems can be identified. There would be a full analysis to predict the main issues of product defect (Aulia, 2016).
- Another HACCP pre-requisite method is FMEA. FMEA (Failure Mode and Effect Analysis) is a method to evaluate the potential failure of a system, design, process or services (Puspitasari, 2016). Identifying the potential failure can be conducted by giving scores or values for every potential failure aspect based on severity, occurrence, and detection. All these three scores would be multiplied to acquire a Risk Priority Number (Sari et al, 2011).

2.3 HACCP Method Plan
According to SNI 01-4852-1998, there are five basic principles of HACCP method plan which needed to be conducted in order to determine which process in mineral bottled water production system needs immediate attention. The five principles are:
1st principle: Identifying Risk Analysis
The objective of this step is to identify the prospects of hazard which might occur in the production system from physical, chemical, and biological perspectives. Pre-requisite methods like fishbone diagram and FMEA are also part of this principle to help identify the risks.

2nd principle: Determining the Critical Control Points (CCPs)
A Critical Control Point is the main focus which is highly potential in causing problems in the production system and has a great impact on the product quality. Critical Control points can be varied. It can be in the form of material, a location, a treatment, or even a finished product.

3rd principle: Establishing Critical Limits
It is necessary to determine the critical limits. A critical limit is a toleration limit of the critical control points which can still be accepted and it must not be violated or surpassed to avoid the disruption of the production system. Critical limits are mostly based on standard rules and valid regulations.

4th principle: Establishing Critical Control Points Monitoring System
A monitoring system is a crucial step of HACCP method plan. Considering the previous principles of HACCP method plan, a monitoring system comprises of controlling the process of each Critical Control Point, examining the CCP controlling process effectiveness, observing critical limits in every CCP in order to assure the critical limit/standard has not been surpassed. A monitoring procedure would ideally give reliable information before any disruption occurs in the production system. Therefore, it can be corrected and will not affect the water quality any further.

5th principle: Establishing Corrective Action
The last principle is specifically needed when some troubles in the production system cause critical limits to be surpassed and cannot be tolerated. Therefore, the quality of water can be affected and water safety issue threatened. Specific corrective actions must be developed to every critical control point in a HACCP method plan in order to regulate all the disruptions in the production system. A precise and well-thought plan is essential to determine the corrective actions, so that no new harmful potential would occur.

3 Results and Discussion
After gathering all the primary and secondary data, also identifying the risks using pre-requisite methods, the next step to start HACCP method plan is completing all the principles. Therefore, the HACCP method plan can be used to resolve the issue of choosing safe-to-consume drinking water sources.

3.1 Mineral Bottled Water Process Flow Diagram
In pursuance of obtaining clean and healthy drinking water, mineral bottled water has to be processed thoroughly and meticulously from raw water into safe-to-consume water. The treatment process itself needs several steps to remove all the physical, chemical, and biological contaminants which may be contained in the raw water. Mineral bottled water treatment process consists of raw water collection, filtration process, and disinfection.

Generally, the mineral bottled water industries have a similar water treatment process diagram. However, the difference lies in the filtration system which can be varied in every water treatment plant. It would be based on the condition and the contaminants carried in the raw water. The filtration system can be combined from several filtration processes, such as rapid sand filter combined with cartridge filter, and it can also be added with a reverse osmosis unit (Agustini, 2009).

Disinfection process can also be combined and varied on each water treatment plant. Due to the possibility of Escherichia Coli existence in the raw water, which can be highly harmful to consumer health, the disinfection process is a crucial step in a drinking water treatment plant. The widely used unit for disinfection process is an ozone generator, but it can be complemented with UV lamps to ensure the safety of drinking water more. The figure below shows the common mineral bottled water
process flow diagram.

![Mineral Bottled Water Process Flow Diagram](image)

**Figure 1.** Mineral Bottled Water Process Flow Diagram

### 3.2 HACCP Method Plan

After getting the process flow diagram of mineral bottled water production system, then conducting the pre-requisite methods like fishbone diagram and FMEA, every HACCP basic principle can be applied. The tables below will explain each principles of HACCP when applied in the water treatment plant.

#### 3.2.1 Principle 1

After conducting pre-requisite methods like fishbone diagram and FMEA, the risks in mineral bottled water treatment plant can be identified. In Table 1, there are 10 types of potential failures and each potential that might happen in the process of producing mineral bottled water is elaborated. Then, the risks deriving from each potential failure can be analyzed, e.g. the possibilities of mineral bottled water to be contaminated by pathogens or other contaminants and the inability of filter media to filter particles in water effectively. These risks can ensue in every water treatment plant unit process.

#### 3.2.2 Principle 2

The second principle is focusing on determining Critical Control Points. Critical control points are the main targets to be analyzed in HACCP method. Critical control points can be chosen after conducting FMEA (Failure Method and Effect Analysis) and obtaining the Risk Priority Numbers. The item with the highest RPN score should be the first critical control point which needs to be addressed. The tables below elaborate critical control points in mineral bottled water treatment plant, such as ozone generator and filter media usage period, water treatment plant sanitation schedule and procedure, and water quality analysis points for the laboratory test.

#### 3.2.3 Principle 3

To ensure the critical control points are still within reasonable limits and do not affect the mineral bottled water production process, critical limits are needed. Critical limits can be determined based on each critical control point itself. The critical limits in this study are the period usage of each water treatment plant unit, e.g. 3-5 years for ozone generator and filtration unit, the unit backwashing schedule e.g. every 24 hours, while for sanitation procedure the proper sanitation practice in every sector of the production system is explained. Every critical limit should be based on valid rules and regulations, such as the United States Environmental Protection Agency (EPA) manuals, PERMENPERINDAG Number 705 Year 2003, and SNI 6774:2008.
Table 1. Critical Control Points and Critical Limits of Mineral Bottled Water Treatment Plant

| Number | Type of Potential Failure | Risk Analysis from Potential Failure | Critical Control Points | Critical Limits | Regulations |
|--------|--------------------------|-------------------------------------|-------------------------|-----------------|-------------|
| 1      | Ozone dose generator period usage | Decreasing of ozone generator effectiveness in removing pathogens in water | Ozone generator usage period | 5 years | EPA 2011 Water Treatment Manual (Disinfection) |
| 2      | Lack of sampling points in every WTP influent and effluent channel | Unable to understand the disinfection process in the water | Water quality analysis points | In every WTP units inlet and outlet | PERMENPERINDA G Number 705 Year 2003 |
| 3      | Violate the Standard Operating Procedures of Water Treatment Plant Sanitation | Mineral water production are contaminated by pathogens | WTP Sanitation schedule | Every day | PERMENPERINDA G Number 705 Year 2003 |
| 4      | Overdue filtration unit media period usage | The media is unable to filter particles in the water effectively | Filtration media usage period | 3 years | EPA 1995 Water Treatment Manuals (Filtration) |
| 5      | Violate the Standard Operating Procedure of employee Sanitation | Mineral water production are contaminated by pathogens | Sanitation procedure and the mandatory personal protection equipment | Employee special uniform, mandatory hand washing habit, mouth and hair cover | PERMENPERINDA G Number 705 Year 2003 |
| 6      | Overdue filtration media backwashing period | The attached contaminants in the filtration media are dissolved in the water | Filtration unit backwash schedule | 24 hours | SNI 6774:2008 |
| 7      | Overdue reverse osmosis membrane backwashing period | The attached contaminants in the reverse osmosis membrane are dissolved in the water | Reverse Osmosis unit backwash schedule | 24 hours | |
| 8      | Overdue cartridge filter membranes backwashing period | The attached contaminants in the cartridge filter membrane are dissolved in the water | Cartridge Filter unit backwash schedule | 24 hours | EPA 2005 Membrane Filtration Guidance Manual |
| 9      | Overdue reverse osmosis membrane | Reverse osmosis membranes are unable to filter fine particles, sodium, ions, and pathogens in the water | Reverse Osmosis membrane usage period | 3 years | |
| 10     | Overdue cartridge filter membranes | Cartridge Filters membranes are unable to filter fine particles in the water | Cartridge Filter membrane usage period | 1 month | |
### Table 2. Monitoring System and Corrective Actions of Mineral Bottled Water Treatment Plant

| Number | Critical Control Points                     | Critical Limits | Monitoring Point | Procedures                                                                 | Frequency                  | Person in Charge       | Corrective Action                                      |
|--------|--------------------------------------------|-----------------|------------------|---------------------------------------------------------------------------|----------------------------|------------------------|--------------------------------------------------------|
| 1      | Ozone generator usage period               | 2 years         | Ozone generator  | Check the report of water quality analysis in Escherichia Coli content at ozone generator outlet | Every start of the year   | Quality Control Staff | Ozone generator replacement                             |
| 2      | Water quality analysis points              | In every WTP unit inlet and outlet | WTP units inlet and outlet points | Monitor the sampling procedure along with observing the sampling points | Every day | The head of laboratory analysis | Do proper sampling in raw water site, WTP inlet and outlet units |
| 3      | WTP limitation schedule                    | Everyday        | Production room  | Monitor the sanitation process entirely                                   | Every start of the shift   | Quality Control Staff | Do proper sanitation in production room                 |
|        | Mandatory facility in production room      | Full function drainage, hand washing facility, special storage room | Production room | Monitor the process entirely                                                 | Every start of the year | Quality Control Staff | Replace the silica sand                                 |
| 4      | Filtration media usage period              | 5 years         | Filtration Unit  | Monitor the media condition (color, height, and volume of sand)            | Every start of the year   | Quality Control Staff | Replace the silica sand                                 |
| 5      | Sanitation procedure and the mandatory personal protection equipment | Employee special uniform, mandatory hand washing habit, mouth and hair cover | Production room | Monitor the sanitation process entirely                                     | Every start of the shift   | Quality Control Staff | Do proper sanitation check of every employee            |
| 6      | Filtration unit backwash schedule          | 24 hours        | Filtration unit  | Check the tank headspace and the laboratory report physical parameter data of filtration unit | Every shift | Filtration Unit operator | Do backwash to filtration unit every day for 10 minutes |
| 7      | Reverse Osmosis unit backwash schedule     | 24 hours        | Reverse Osmosis unit | Analyze the laboratory report physical parameter data of RO unit outlet | Every shift | Reverse Osmosis Unit operator | Do backwash to reverse osmosis unit every day for 10 minutes |
| 8      | Cartridge Filter unit backwash schedule    | 24 hours        | Cartridge Filter unit | Analyze the laboratory report physical parameter data of CF unit outlet | Every shift | Cartridge Filter Unit operator | Do backwash to cartridge filter unit every day for 10 minutes |
| 9      | Reverse Osmosis membrane usage period      | 3 years         | Reverse Osmosis unit | Monitor the RO membrane condition (color, porosity, and appearance)       | Every start of the year | Quality Control Staff | Replace the reverse osmosis membrane                     |
| 10     | Cartridge Filter membrane usage period     | 1 month         | Cartridge Filter unit | Monitor the CF membrane condition (color, porosity, and appearance)       | Every start of the week   | Quality Control Staff | Replace the cartridge filter membrane                   |
3.2.4 **Principle 4**
The monitoring system is a crucial step to control critical control points before any of them surpasses critical limits. It should be organized and evident in order to avoid misunderstanding of the procedures, so that the person in charge can do their task easily and correctly. A monitoring system always consists of four main aspects, which are the monitoring point in which CCPs need to be controlled, the procedures of monitoring, the frequency or the schedule of monitoring of the CCPs, and the person in charge of doing the monitoring system. Neither of these aspects can be eliminated or the problems would occur in the production process and might affect the water quality. For example, the monitoring point in filtration unit has a procedure to check the headloss and the laboratory report physical parameter data and it should be monitored in every shift of production, then the person in charge to do the monitor should be the filtration unit operator.

3.2.5 **Principle 5**
The last basic principle of HACCP method plan is corrective action. Corrective action is needed when the monitoring system informs some issues occurring in the water treatment plant. In order to maintain the quality of water and avoid any production process disruption, a corrective action is an immediate help to fix the critical control points when they surpass the critical limits. The correction needs to be precise, specific, and thorough. For example, an ozone generator usage period only lasts for 5 years, if the monitoring system states the pathogens contained in water might not be removed effectively, the corrective action is replacing the ozone generator before the usage period is overdue.

4 **Conclusion**
HACCP method plan is a suitable method to determine if a drinking water source is safe for consumption, especially mineral bottled water that is widely consumed in the community. It is easy to be applied, precise, and specifically aims at the issues which might occur in the water treatment plant with the five basic principles. The HACCP method plan is focused on maintaining and enhancing the performance of Water Treatment Plant units in order to get high-quality drinking water for human needs.

**References**
[1] Agustini S 2009 Analisa Bahaya dan Identifikasi Titik Kendali Kritis pada Industri Air Minum alam Kemasan 11 65
[2] Aulia N 2016 Analisis dan Evaluasi Sisa Material Konstruksi Menggunakan Metode Pareto dan Fishbone Diagram (Malang: Universitas Brawijaya) p 5
[3] Dahlan A and Wahyunus 2016 Rencana HACCP (Hazard Analysis Critical Control Point) Pengolahan Kecap (Bogor: Institut Pertanian Bogor) p 11
[4] Daulay S 2014 Hazard Analysis Critical Control Point (HACCP) dan Implentasinya dalam Industri Pangan (Jakarta) p 10
[5] Puspitasari N and Martanto A 2014 Penggunaan FMEA dalam Mengidentifikasi Resiko Kegagalan Produksi Sarung ATM (Alat Tenun Mesin) 9 pp 93 – 98
[6] Sari D Rosyada Z and Rahmadhani N 2011 Analisa Penyebab Kegagalan Produk Woven dengan Menggunakan Metode Failure Mode and Effect Analysis 6 pp 6 – 11
[7] SNI 01-4852-1998 Sistem Analisa Bahaya dan Pengendalian Titik Kritis (HACCP) serta Pedoman Penerapannya (Jakarta: Badan Standardisasi Nasional) p 2
[8] SNI 3553-2015 Air Mineral (Jakarta: Badan Standardisasi Nasional) p 3
[9] World Health Organization 1997 Introduction of HACCP p 4