Preface

To cite this article: 2025 *IOP Conf. Ser.: Earth Environ. Sci.* **1445** 011001

Preface

The 6th International Conference on Natural Resources and Technology (ICONART) 2024 beautifully encapsulates the spirit and significance of this esteemed event. Organized by the Center of Excellence for Mangrove (PUI Mangrove) at Universitas Sumatera Utara in collaboration with key academic institutions and organizations, ICONART 2024 continues its tradition of fostering interdisciplinary research and collaboration at the nexus of natural resources, technology, and sustainability.

With the theme, "Natural Resources and Technology for Achieving Sustainable Development Goals through Academia, Industry, and Community", this year's conference underscores its dedication to addressing global challenges through resilience and innovation. The focus on advancing sustainable practices and integrating cutting-edge technologies aligns seamlessly with the Sustainable Development Goals (SDGs), offering a platform for meaningful discourse and impactful solutions. By bridging the gap between academic excellence, industrial innovation, and community engagement, 6th ICONART 2024 aspires to generate transformative outcomes that will contribute to a more sustainable and equitable future.

The hybrid format of 6th ICONART 2024 on 27th August 2024 ensures inclusivity, allowing participants from across the globe to contribute and engage. Hosted at the Grandhika Hotel, Medan, the event also provides an opportunity for in-person attendees to explore the natural beauty of Toba Lake on 28th August 2024, during the post-conference excursion. Beyond being a venue for sharing scientific advancements, the conference fosters an atmosphere of cultural exchange, highlighting Indonesia's rich ecological and cultural heritage, and reinforcing the connection between nature and society. With six interconnected topics, from Natural science and natural product, Natural resource technology, Information systems of tropical resources, Tropical biodiversity, Food science and food technology, and Ethnobotany and ethnozoology, the conference promotes a multidisciplinary approach to sustainable resource management and innovation in technology.

The event boasts an impressive international presence, with 151 submissions from researchers across Germany, Japan, Malaysia, the Philippines, Thailand, and Indonesia. Following a rigorous peer-review process, 139 high-quality papers have been selected, reflecting the diverse and cutting-edge research being undertaken worldwide. These contributions will be published in the IOP Conference Series: Earth and Environmental Science, ensuring broad accessibility and global impact. By choosing this Scopus-indexed publication platform, 6th ICONART 2024 not only elevates the visibility of the research but also underscores its commitment to advancing knowledge sharing on a global scale.

The presence of distinguished keynote and invited speakers further elevates the event. Experts such as Prof. Dr. Martin Zimmer from Germany, Dr. Reiko Omoto from Japan, and His Excellency Tuan Shahril Nizam Abdul Malek, the Consulate General of Malaysia in Medan, Dr. Ahmad Aldrie Amir from Universiti Kebangsaan Malaysia; and Prof. Dr. Etti Sartima Siregar from Universitas Sumatera Utara. Invited speakers include Prof. Putu Deddy Sutrisna, Ph.D. (NUNI), Dr. M. Chanda Sagaran (Malaysia Green Technology Society), and Dr. Syahidah (Universitas Hasanuddin, Makassar), bring invaluable insights from their respective fields, enriching the discussions and inspiring participants. Their presentations promise to challenge conventional perspectives and encourage the exploration of innovative pathways in addressing complex environmental and technological challenges. We are also honored to welcome representatives from the Consulate General of Timor Leste in Medan.

This year's conference would not have been possible without the unwavering support of Universitas Sumatera Utara, the Faculty of Forestry at Universitas Hasanuddin, the Nationwide University Network in Indonesia (NUNI), the Malaysia Green Technology Society, and the tireless efforts of the organizing committee. The meticulous planning, teamwork, and dedication of the committee, ensure the event's success. This collective collaboration reflects the high standards of academic excellence and commitment to sustainability that 6th ICONART 2024 embodies.

As 6th ICONART 2024 unfolds, it not only celebrates the achievements of researchers and innovators but also inspires a collective commitment to sustainability. The conference serves as a dynamic platform for groundbreaking discoveries, fostering enduring collaborations and shaping the future of natural resources and technology. This legacy of excellence is a testament to the shared vision of academia, industry, and communities working together for a sustainable tomorrow. It is our hope that the discussions and partnerships formed during this event will leave a lasting impact, driving real-world change and empowering stakeholders to address pressing environmental and societal challenges with confidence and creativity.

The editors of 6th ICONART 2024 are:

1. Dr. Mohammad Basyuni Center of Excellence for Mangrove, Universitas Sumatera Utara, Medan, North Sumatra, Indonesia
2. Dr. Itchika Sivaipram Department of Marine Science, Faculty of Science, Chulalongkorn University, Bangkok, Thailand
3. Dr. Bejo Slamet Center of Excellence for Mangrove, Universitas Sumatera Utara, Medan, North Sumatra, Indonesia
4. Dr. Reiko Omoto Faculty of Regional Science, Tottori University, Japan
5. Dr. Ahmad Aldrie Amir Institute for Environment and Development, Universiti Kebangsaan Malaysia
6. Dr. Syahidah Department of Forest Engineering, Faculty of Forestry, Universitas Hasanuddin, Makassar, Indonesia

Finally, we extend our heartfelt appreciation to the organizing committee for their tireless efforts, teamwork, and meticulous planning, which have ensured the success of this event. We hope that 6th ICONART 2024 will serve as a dynamic platform for meaningful discussions, groundbreaking discoveries, and enduring collaborations. May this conference inspire innovative solutions and a renewed commitment to sustainability.

Dr. Mohammad Basyuni
Chairman of the 6th ICONART 2024
Center of Excellence for Mangrove, Universitas Sumatera Utara, Medan, North Sumatra, Indonesia

IOP Conf. Series: Earth and Environmental Science **1445** (2025) 011001 doi:10.1088/1755-1315/1445/1/011001

Committee Structure

1. Honorary Chair

a. USU Rector	: Prof. Dr. Muryanto Amin, Universitas Sumatera Utara, Indonesia
b. Vice Rector 3 of USU	: Prof. Dr. Popy Anjelisa Zaitun Hasibuan, Universitas Sumatera Utara, Indonesia
c. Head of the Research Institute	: Prof. Dr. Robert Sibarani, Universitas Sumatera Utara, Indonesia
d. Secretary of the Research Institute	: Prof. Dr. Syafruddin Ilyas, Universitas Sumatera Utara, Indonesia
c. Dean of Faculty of Forestry	: Dr. Rudi Hartono, Universitas Sumatera Utara, Indonesia
d. Vice Dean 2 of Faculty of Forestry	: Dr. Pindi Patana, Universitas Sumatera Utara, Indonesia
e. Vice Dean 3 of Faculty of Forestry	: Prof. Dr. Agus Purwoko, Universitas Sumatera Utara, Indonesia
f. Head of Center of Excellence for Mangrove	: Prof. Mohammad Basyuni, Ph.D, Universitas Sumatera Utara, Indonesia

2. General Chair

a. Chair	: Prof. Mohammad Basyuni, S.Hut, Ph.D, Universitas Sumatera Utara, Indonesia
b. Co-Chair	: Prof. Apri Heri Iswanto, Universitas Sumatera Utara, Indonesia
c. Program/Technical	
Chair	: Dr. Arif Nuryawan, Universitas Sumatera Utara, Indonesia
Co-Chair	: Dr. Iwan Risnasari, Universitas Sumatera Utara, Indonesia
Members	: 1. Dr. Masitta Tanjung, Universitas Sumatera Utara, Indonesia
	2. Desrita, Universitas Sumatera Utara, Indonesia
	3. Ipanna Enggar Susetya, Universitas Sumatera Utara, Indonesia
	4. Dr. Nelly Anna, Universitas Sumatera Utara, Indonesia
	5. Dr. Ok Hasnanda Syahputra, Universitas Sumatera Utara, Indonesia
	6. Dr. Ridwanti Batubara, Universitas Sumatera Utara, Indonesia

3. Liaison

a. Chair	: Dr. Arida Susilowati, Universitas Sumatera Utara, Indonesia
b. Co-Chair	: Dr. Oding Affandi, Universitas Sumatera Utara, Indonesia

IOP Conf. Series: Earth and Environmental Science **1445** (2025) 011001 doi:10.1088/1755-1315/1445/1/011001

Members	: 1. Dr. Yunasfi, Universitas Sumatera Utara, Indonesia 2. Prof. Delvian, Universitas Sumatera Utara, Indonesia 3. Dr. Iriany, Universitas Sumatera Utara, Indonesia 4. Dr. Jumirah, Universitas Sumatera Utara, Indonesia

4. Local Committee:

a. Chief	: Dr. Bejo Slamet, Universitas Sumatera Utara, Indonesia
b. Co-Chief	: Dr. Nurdi Sulistiyono, Universitas Sumatera Utara, Indonesia
c. Secretary	1. Ahmad Baiquni Rangkuti, Universitas Sumatera Utara, Indonesia 2. Novita Anggraini, Universitas Sumatera Utara, Indonesia 3. Astrid F. Dewinta, Universitas Sumatera Utara, Indonesia 3. Julia Syahriani, Universitas Sumatera Utara, Indonesia 4. Dr. Nelly Anna, Universitas Sumatera Utara, Indonesia
d. Treasurer	: Dr.Erni Jumilawaty, Universitas Sumatera Utara, Indonesia
e. Co-Treasurer	: Dr. Deni Elfiati, Universitas Sumatera Utara, Indonesia
f. Publicity	: Prof. Dr. Etti Sartina Siregar, Universitas Sumatera Utara, Indonesia Dr. Taslim, Universitas Sumatera Utara, Indonesia Dr Syahidah, Universitas Hasaunuddin, Indonesia Arida Fauziyah, University of Bremen, Germany

IOP Conference Series:
Earth and
Environmental Science

Peer Review Statement

To cite this article: 2025 *IOP Conf. Ser.: Earth Environ. Sci.* **1445** 011002

IOP Conf. Series: Earth and Environmental Science **1445** (2025) 011002 doi:10.1088/1755-1315/1445/1/011002

Peer Review Statement

All papers published in this volume have been reviewed through processes administered by the Editors. Reviews were conducted by expert referees to the professional and scientific standards expected of a proceedings journal published by IOP Publishing.

- **Type of peer review:** Double Anonymous
- **Conference submission management system:** Morressier
- **Number of submissions received:** 151
- **Number of submissions sent for review:** 144
- **Number of submissions accepted:** 139
- **Acceptance Rate (Submissions Accepted / Submissions Received × 100):** 92.1
- **Average number of reviews per paper:** 2
- **Total number of reviewers involved:** 25
- **Contact person for queries:**
  Name: Mohammad Basyuni
  Email: puimangrove@usu.ac.id
  Affiliation: Center of Excellence for Mangrove, Universitas Sumatera Utara

Table of contents

Volume 1445

2025

Previous issue

6th International Conference on Natural Resources and Technology 2024 (ICONART 2024)
27/08/2024 - 27/08/2024 Medan, Indonesia

Accepted papers received: 07 January 2025
Published online: 07 February 2025

Open all abstracts

Natural Science and Natural Product

Natural Resource Technology

Tropical Biodiversity

Ethnobotany and Etnozoology

Information System of Tropical Resource

View article PDF

JOURNAL LINKS

- Journal home
- Journal scope
- Information for organizers
- Information for authors
- Contact us
- Reprint services from Curran Associates

Enhancing responsible production and sustainable clean water supply: applying OEE and six big losses analysis in environmental engineering

IOP Conf. Series: Earth and Environmental Science **1445** (2025) 012065 doi:10.1088/1755-1315/1445/1/012065

Enhancing responsible production and sustainable clean water supply: applying OEE and six big losses analysis in environmental engineering

Yenny Sari[1*], Muhammad Rosiawan[1], Rifda Aulia[1] and Edy Purwanto[2]

[1] Industrial Engineering, Faculty of Engineering, University of Surabaya, Indonesia
[2] Chemical Engineering, Faculty of Engineering, University of Surabaya, Indonesia

*E-mail: ysari@staff.ubaya.ac.id

Abstract. This study aimed to identify production losses that occur in the Clearator Unit in one of the state-owned drinking water treatment companies so that the implementation of improvements can increase the effectiveness of the process. The Clearator Unit, as the object of the research, is a flocculation building used to accelerate the sedimentation in processing raw water into usable water. The methodology used to achieve the research objectives is the Six Big Losses and Overall Equipment Effectiveness (OEE) approach for production loss analysis. In addition, quality tools such as the Ishikawa Diagram and Linear Regression were used to identify the causes of losses and formulate improvement solutions. From the results of this study (based on August 2022), it was found that the losses were "reduced speed" and "defect process", with OEE values of 37%. This value indicated that the effectiveness of the Clearator Unit is below the standard limit of world-class company (OEE value should be more than 85%). The proposed improvement was to create a standardized dosing usage of Aluminium Sulfate (alum) to improve the water output quality. The alum standard dose based on the equation of the regression test results was: *"decreased water turbidity (NTU)" = 2,497 + 0,00099 "alum usage (kg)".* This solution implementation can affect the production of higher-quality clean water (SDG6) and more responsible production governance (SDG12).

1. Introduction

The Sustainable Development Goals (SDGs) are a set of global goals by the United Nations General Assembly in 2015 (undp.org, 2024) and part of the broader 2030 Agenda for Sustainable Development. By comprising 17 goals and 169 targets, The SDGs serve as a universal call to address multiple complex challenges, ensuring well-being, economic prosperity, and environmental protection, including climate change, environmental degradation, poverty, inequality, peace, and justice [1].

The development of research from various fields is required to provide real action. Each researcher works together to achieve the SDGs in every context. Engineering plays a crucial role in supporting SDG achievement; engineering-related research focuses on providing engineering design for problem-solving, developing technology for productivity improvement, and driving innovation on new materials, products, or systems [2]. For instance, engineers design the water treatment system to ensure safe drinking water or develop the infrastructure for efficient transportation (related to SDG1 and SDG6). Engineers can also develop renewable energy systems or smart city technologies to achieve sustainable energy or communities (SDG7, SDG11).

The research in this article discussed the role of Engineering Research in implementing the Overall Equipment Effectiveness method as a measurement and analysis tool. The purpose of this research is to identify the Six Big Losses and improve the water treatment process in a local government-owned company (often known as PDAM) to support clean water supply (SDG 6) and responsible production (SDG12). The achievement of SDG6 and SDG12 is to ensure the availability and management of clean water, which means that water is available whenever needed and its quality meets the requirements for use (e.g., washing, irrigation) to drinking water.

Engineering-related research on natural science and technology plays a vital role in the management of clean water, with the potential to significantly impact responsible water usage, production, consumption, and recycling [3,4]. The technology for clean water management has developed in various fields. For instance, there were two main approaches of the desalination technologies for water treatment technologies [5]: membrane filtration or thermal distillation; two different rainwater harvesting systems were examined by Pari et al. [6] for sustainable water usage practices in agriculture; a production system was proposed to generate drinkable water from seawater [7]. Other scientific and technological approaches include water efficiency, water quality monitoring equipment, data measurement and analytic methods.

1.1 PDAM's Usable Water Treatment Process

The raw water from the river enters the intake building and goes to the aerator. Then the raw water goes to the sedimentation unit for gravity settling of particles with a residence time of 2-4 hours. After the sedimentation unit, the water goes to the **Clearator Unit** for flocculation and precipitation. Flocculation is the floc formation process that occurs due to a slow mixing process. From the Clearator, the water goes from the filtration unit to the disinfection unit, after which the water is collected in the reservoir unit and ready to be distributed to users.

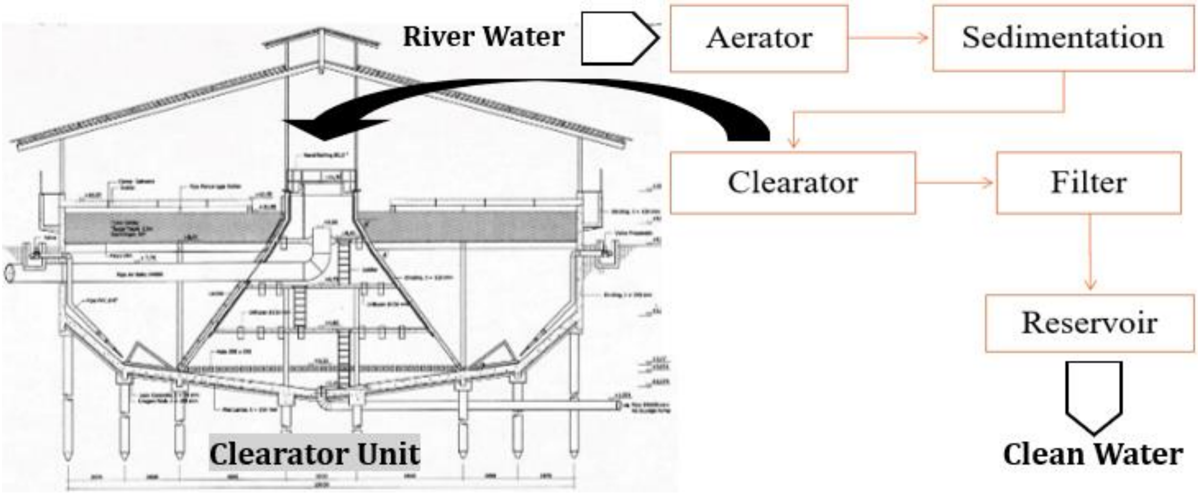

Figure 1. Usable water treatment process in a stated-owned company (*Source: PDAM, Surabaya*).

1.2 Clearator Unit

The **Clearator Unit** is a modified building of a flocculation basin that uses a tube settler with a 60° slope. The tube settler in the clearator accelerates the precipitation process by changing the flow of water from vertical to laminar with a slope of 60°, as shown in Figure 1. This unit is equipped with drainage to remove floc deposits. The target turbidity level of water output from the Clearator Unit is 7 NTU (Nephelometric Turbidity Unit). The higher the NTU, the more turbid the water. The lower the NTU, the better quality the water.

2. Methodology

This study used observation data of the production process in August 2022. Figure 2 explains the research steps; it begins from the data collection to the calculation and the identification of Six Big Losses. The research stage continues by measuring the effectiveness of the Clearator Unit. If the OEE value is below the world-class standard limit, the root cause of low OEE and related analysis should be made to formulate improvements.

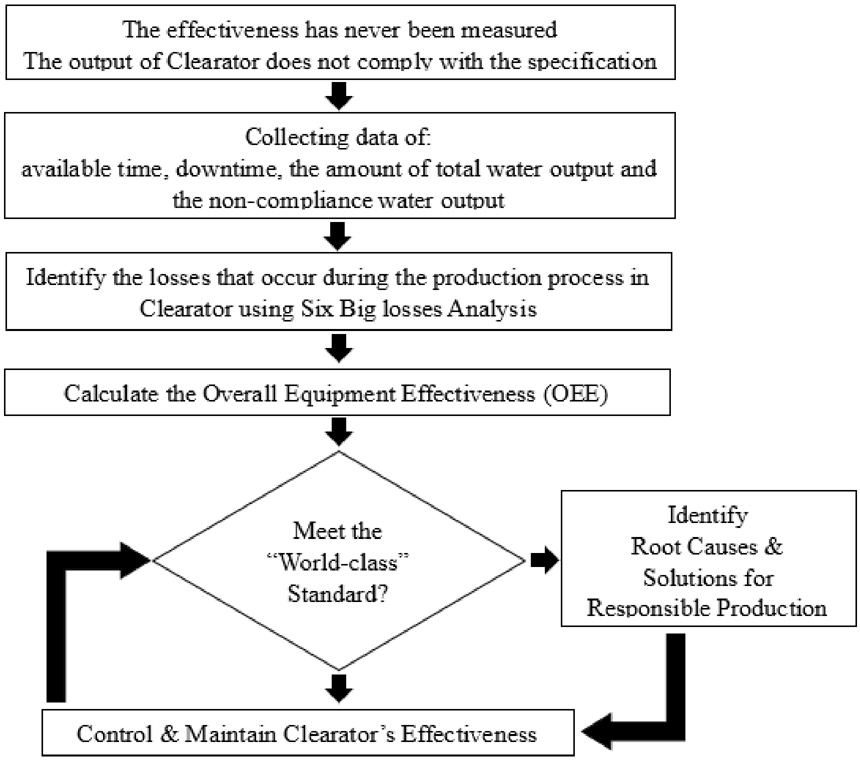

Figure 2. Research steps.

2.1 Six Big Losses

The Six Big Losses are six production losses that must be eliminated because they decrease the equipment effectiveness level [8]. The calculation of Six Big Losses is accomplished to determine the crucial factor that causes a lack of effectiveness, so the factor becomes a priority for improvement. The Six Big Losses include *(i) Equipment failure, (ii) Setup and adjustment, (iii) Idling and minor stoppages, (iv) Reduced speed, (v) Defects in process, (vi) Reduced yield* [9].

2.2 Overall Equipment Effectiveness (OEE)

Overall Equipment Effectiveness (OEE) divides the work of equipment (production machinery) into three measurable metrics, namely Availability (A), Performance efficiency (P), and Quality rate (Q). The OEE value can be obtained by the calculation of: OEE = A x P x Q [8, 10]. The OEE value for world-class standards is more than 85%, and the ideal standard conditions for each component are min 90% for Availability, 95% for Performance, and 99% for Quality [11].

IOP Conf. Series: Earth and Environmental Science **1445** (2025) 012065 doi:10.1088/1755-1315/1445/1/012065

2.3 Ishikawa diagram

The fishbone diagram, known as the Ishikawa diagram, is one of the quality tools used to find the root causes of problems [12]. It identifies the root causes from the factors of 4M and 1E, namely: (i) *Man*, human factors such as skills, training, and fatigue (ii) *Machine*, factors related to equipment or technology (iii) *Method*, factors related to the process or procedures used, (iv) *Material*, factors of materials used in the process, and (v) *Environment*, environmental factors.

2.4 Linier regression

Regression analysis describes the relationship between the independent and dependent variables. The equation for linear regression is as follows:

$$Y = b_0 + b_1 x + \varepsilon_E \text{ [13]} \quad (1)$$

Y is the dependent variable, b_0 is the constant, b_1 is the gradient of the regression line, x is the independent variable, and ε_E is the residual error. The regression coefficients were tested for significance through the *t-test* with the following hypothesis:

H_0 : ρ = 0; there is no relation between independent variable x and dependent variable y
H_A : ρ ≠ 0; there is no relation between independent variable x and dependent variable y

3. Results and discussions

3.1 Six big losses: data collection and calculation

Table 1 below presents the data required for the Six Big Losses calculation. Data was collected for a month in August 2022, but the data displayed in Table 1 is the data that occurred on August 1, 2022. Then, the data was used for the calculation of Six Big Losses' metrics.

Based on the recapitulation of the Six Big Losses calculation results in Table 1, the two main losses caused the low effectiveness of the Clearator, namely ***reducing speed*** and ***defect*** in the process. The *reduced speed* was 6.89%, and the *defect loss* in August 2022 was 58.33% whereas the target of *reducing speed* and *defect loss* in the process is 0. The *reduced speed loss* was caused by equipment not running optimally and the *defect loss* was caused by damaged products. The cause of *the reduced speed loss* was that the amount of water wasted along with the sludge can reach 100%. The cause of *the defect loss* was due to the water output turbidity levels that did not meet specifications.

Table 1. Six big losses: metrics and calculation.

Metric	The example of Data Collection (for Aug 1, 2022)	The calculation result of Six Big Losses (Aug 1, 2022)	
Output Standard	2520 ton/hour	Equipment Failure	0%
Breakdown Time	0 hours		
Loading Time	96 hour/day	Setup and Adjustment	0%
Non-productive time	0 hours		
Processed Amount	219488 ton/ day	Idling & Minor Stoppages	0%
Defects in process	219488 ton/ day		
Cycle time	0.000437 ton/hour	Reduced Speed	9,27%
Raw Water Turbidity	14,17 NTU		

Metric	The example of Data Collection (for Aug 1, 2022)	The calculation result of Six Big Losses (Aug 1, 2022)	
Output Turbidity	8,51 NTU	Defects in Process	100,00%
Reduction of Turbidity	5,66 NTU		
Alum Consumption	1152 kg	Reduced Yield	0%

$$Output\ standard\ = \frac{700\ l/detik \times 3600 detik}{1000} = \frac{2.520.000}{1000} = 2.520\ ton/hour \quad (2)$$

$$Equipment\ failure = \frac{Total\ breakdown\ time}{Loading\ time} \times 100\% = \frac{0}{96} \times 100\% = 0\% \quad (3)$$

$$Setup\ \&\ adjustment = \frac{Total\ setup\ and\ adjusment}{Loading\ time} \times 100\% = \frac{0}{96} \times 100\% = 0\% \quad (4)$$

$$Idling\ \&\ minor\ stoppages\ = \frac{Non\ productive\ time}{Loading\ time} \times 100\% = \frac{0}{96} \times 100\% = 0\% \quad (5)$$

$$Reduce\ speed\ = \frac{Operating\ time - \left(\frac{Processed\ amount}{Output\ standar}\right)}{Loading\ time} \times 100\% = \frac{96-\left(\frac{219.488}{2.520}\right)}{96} \times 100\% = 9{,}27\% \quad (6)$$

$$Defects\ in\ process = \frac{Cycle\ time \times Defect\ amount}{Loading\ time} \times 100\% = \frac{0{,}000437 \times 219.488}{96} \times 100\% = 100\% \quad (7)$$

3.2 Overall Equipment Effectiveness (OEE): calculation & analysis

After identifying losses using the Six Big Losses method, the OEE calculation is carried out to determine the effectiveness of the Clearator. Table 2 shows data and examples of calculations on the metrics of Performance (P) and Quality (Q) for August 1, 2022. Based on the data collection, the Availability (A) value of the Clearator Unit during August 2022 is 100% except on August 12, 19, and 26, when the A value is 97.92% due to 2-hour downtime in draining the Clearator.

Table 2. The calculation of OEE and its metric (for Aug 1, 2022).

Performance efficiency (P)			
Processed amount (ton/day)	Operating time (hour/day)	Planned Output (ton/day)	% Performance
219.488	96	241.920	90,73%

Quality Rate (Q)		
Processed amount (ton/day)	*Defect amount* (ton/day)	*%Quality rate*
219.488	219.488	0,00%

$$Output\ standard = \frac{700\frac{l}{second} \times 3600\ second}{1000} = \frac{2.520.000}{1000} = 2.520\ tons/hour \quad (8)$$

$$Planned\ Output\ = Operating\ time \times Output\ standar \quad (9)$$

$$= 96 \times 2.520 = 241.920\ tons/day$$

$$\%Performance\ efficiency\ = \frac{Processed\ amount \times Cycle\ time}{Operating\ time} \times 100\% \quad (10)$$

$$= \frac{Processed\ amount}{Output\ teoritis} \times 100\% = \frac{219.488}{241.920} \times 100\% = 90{,}73\%$$

$$\%Quality\ rate \quad = \frac{Processed\ amount - Defect\ amount}{Processed\ amount} \times 100\% \tag{11}$$

$$= \frac{219.488 - 219.488}{219.488} \times 100\% = 0{,}00\%$$

From the OEE recapitulation in Table 3 or the daily OEE comparison graph in Figure 3, the highest OEE value in August 2022 was 37%, and it was below the world-class standard of 85%. In addition, the daily OEE trend is strongly marked by fluctuations in the value of %Q, where %P and %A are mainly above the ideal standard value.

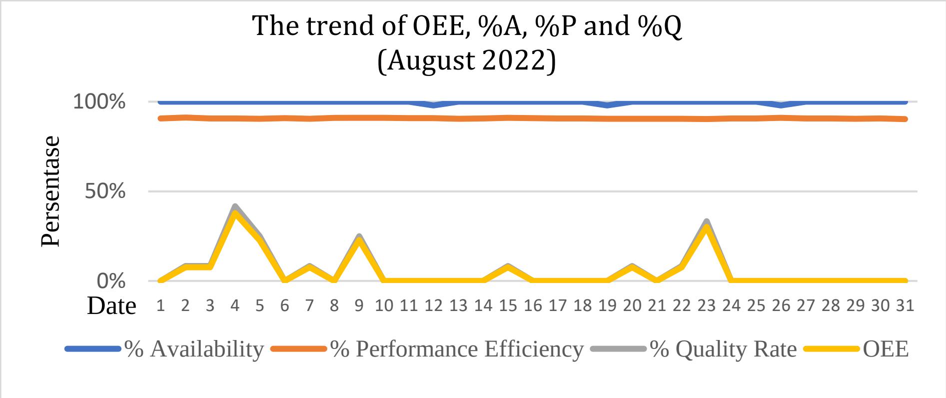

Figure 3. The trend of daily OEE (August, 2022).

Table 3. Six big losses & OEE Calculation (August 2022).

	Six Big Losses						Overall Equipment Effectiveness			
Date	Equip-ment failure	Setup & adjus-ment	Idling/ minor stoppages	Reduce speed	Defects	Reduce yield	% A	% P	% Q	% OEE
1	0%	0%	0%	9,27%	100,0%	0%	100%	90,73%	0,00%	0,00%
2	0%	0%	0%	8,86%	91,7%	0%	100%	91,14%	8,33%	7,59%
3	0%	0%	0%	9,30%	91,7%	0%	100%	90,70%	8,33%	7,56%
4	0%	0%	0%	9,30%	58,3%	0%	100%	90,70%	41,67%	37,79%
5	0%	0%	0%	9,51%	75,0%	0%	100%	90,49%	25,00%	22,62%
6	0%	0%	0%	9,15%	100,0%	0%	100%	90,85%	0,00%	0,00%
7	0%	0%	0%	9,52%	91,7%	0%	100%	90,48%	8,33%	7,54%
8	0%	0%	0%	9,04%	100,0%	0%	100%	90,96%	0,00%	0,00%
9	0%	0%	0%	8,96%	75,0%	0%	100%	91,04%	25,00%	22,76%
10	0%	0%	0%	8,95%	100,0%	0%	100%	91,05%	0,00%	0,00%
11	0%	0%	0%	9,26%	100,0%	0%	100%	90,74%	0,00%	0,00%
12	0%	2,08%	2,08%	7,13%	100,0%	0%	97.9%	90,79%	0,00%	0,00%
13	0%	0%	0%	9,54%	100,0%	0%	100%	90,46%	0,00%	0,00%
14	0%	0%	0%	9,31%	100,0%	0%	100%	90,69%	0,00%	0,00%
15	0%	0%	0%	8,99%	91,7%	0%	100%	91,01%	8,33%	7,58%
16	0%	0%	0%	9,22%	100,0%	0%	100%	90,78%	0,00%	0,00%
17	0%	0%	0%	9,44%	100,0%	0%	100%	90,56%	0,00%	0,00%
18	0%	0%	0%	9,42%	100,0%	0%	100%	90,58%	0,00%	0,00%
19	0%	2,08%	2,08%	7,46%	100,0%	0%	97.9%	90,45%	0,00%	0,00%

	Six Big Losses						Overall Equipment Effectiveness			
Date	Equip-ment failure	Setup & adjus-ment	Idling/ minor stoppages	Reduce speed	Defects	Reduce yield	% A	% P	% Q	% OEE
20	0%	0%	0%	9,61%	91,7%	0%	100%	90,39%	8,33%	7,53%
21	0%	0%	0%	9,49%	100,0%	0%	100%	90,51%	0,00%	0,00%
22	0%	0%	0%	9,61%	91,7%	0%	100%	90,39%	8,33%	7,53%
23	0%	0%	0%	9,68%	66,7%	0%	100%	90,32%	33,33%	30,10%
24	0%	0%	0%	9,45%	100,0%	0%	100%	90,55%	0,00%	0,00%
25	0%	0%	0%	9,37%	100,0%	0%	100%	90,63%	0,00%	0,00%
26	0%	2,08%	2,08%	6,89%	100,0%	0%	97.9%	91,03%	0,00%	0,00%
27	0%	0%	0%	9,37%	100,0%	0%	100%	90,63%	0,00%	0,00%
28	0%	0%	0%	9,30%	100,0%	0%	100%	90,70%	0,00%	0,00%
29	0%	0%	0%	9,60%	100,0%	0%	100%	90,40%	0,00%	0,00%
30	0%	0%	0%	9,44%	100,0%	0%	100%	90,56%	0,00%	0,00%
31	0%	0%	0%	9,67%	100,0%	0%	100%	90,33%	0,00%	0,00%

3.3 Root cause and the formulation of action plan

In finding the causes of defects in the process, identification was made using a fishbone diagram (Figure 4), and several impressive and significant facts were obtained, namely:

- Overcapacity caused turbulence in the Clearator so that the sludge sedimentation was not maximized which results in the output did not meet the specification of 7 NTU. The accuracy of the drain setting affects the water turbidity level because the drain is used for the disposal of the settling sludge. The maximum height of sludge deposition in the Clearator is 1 metre. If the sludge in the Clearator is too much, the turbulence will push the sludge up and mix with water resulting in the output quality not meeting the specification of 7 NTU.
- Unscheduled maintenance affects the water turbidity level because it causes the components of the Clearator to work poorly, thus affecting the output quality.
- The accuracy of the alum dose also affects the level of water turbidity. The alum usage is performed manually by the operator without following certain standard dose.

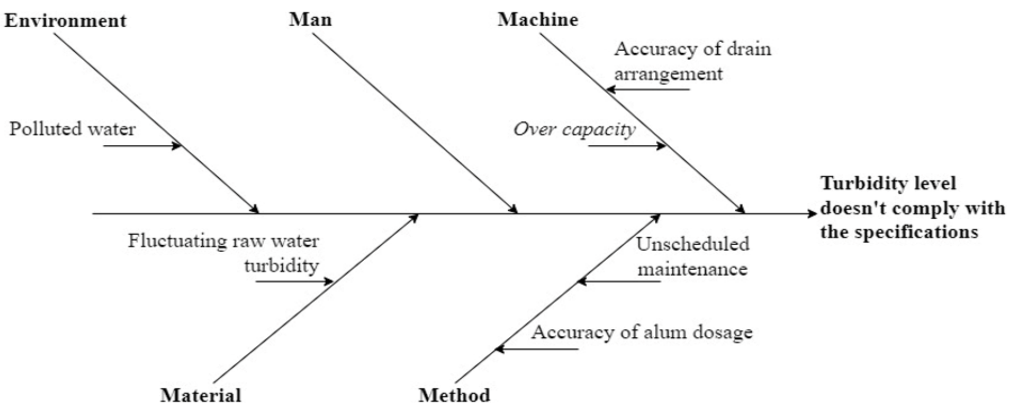

Figure 4. Root cause analysis using Diagram Ishikawa.

The suggested improvement discussed in this article is the accuracy of alum dosage. Alum (Aluminum Sulfate) is a material used for water purification in the Clearator. The accuracy of alum dosage can be gained by the standardized usage of alum dosage so that the output of the Clearator can meet the turbidity level specification of 7 NTU.

The standard for the usage of alum dosage is made based on the regression test of the amount of alum usage effect on reducing the turbidity level of raw water. The regression test was conducted using MINITAB software, with the results shown in Figure 5. Based on the equation of the regression test results, the formula obtained as follows:

[Decreased Turbidity Level = 2,497 + 0,000990 Alum Usage]

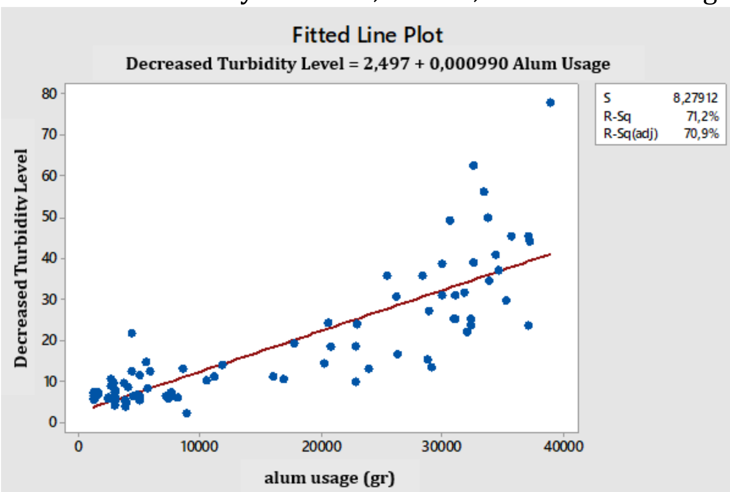

Figure 5. Linear regression: alum usage vs reduction of the turbidity level of raw water.

Based on the formulation above, a standard of alum usage designed with the draft alum usage dosage summarized in Table 4. The alum usage dosage is made with a raw water turbidity level range of 15 – 45 NTU with a maximum alum usage of about 36 kg.

Table 4. Standardized alum usage.

Water turbidity level (NTU)			Alum Usage (kg)
Raw water	Upper Specification Limit (USL)	Decreased Turbidity Level	
15	7	8	5.56
20	7	13	10.61
25	7	18	15.66
30	7	23	20.71
35	7	28	25.76
40	7	33	30.81
45	7	38	35.86

4. Conclusion

The application of OEE and Six Big Losses analysis in clean water production become vital because low effectiveness levels will affect not only the capacity of clean water supplied to the community but also the quality of the water produced. This focus of the research was on the Clearator Unit. The Clearator Unit is the middle stage of the clean water production process; it is preceded by the aerator and sedimentation process and the water processing result will continue to the filtration process and then be stored in the reservoir. This Clearator Unit is a flocculation process that uses a tube settler with a 60° slope to accelerate the sedimentation process by changing the water flow from vertical to laminar direction. As a result of the flocculation process, the flocs formed settle at the bottom of the clearator tank, then are discharged through the drain

From the perspective of Overall Equipment Effectiveness (OEE), the OEE level of the water treatment process was still low (37%) and below the ideal of a minimum of 85%. Based on the calculation of Six Big Losses, the losses in the Clearator Unit were the *reduced speed* and *defect loss*. The *defect loss* was due to the water turbidity level not according to specification (max 7 NTU) which can be caused by several factors, including polluted water, fluctuating raw water turbidity, drain setting accuracy, overcapacity, unscheduled maintenance, and alum dose accuracy. The suggested improvement is to make a standard for using alum dosage with a range of raw water turbidity levels in the initial condition of 15 - 45 NTU, and the alum dose is in the range of 5.56 to 35.86 kg. Another suggestion related to overcoming reduced speed loss was proposing a maintenance mechanism for draining the settling sludge, both in terms of frequency and cleaning method, to produce water output that meets the specified specifications.

References

[1] Diaz-Sarachaga J M, Jato-Espino D and Castro-Fresno D 2018 *Sustainable Development* **26** 663
[2] Pradhan P, Costa L, Rybski D, Lucht W and Kropp J P 2017 *Earth's Future* **5** 1169
[3] Lambooy T 2011 *J. Cleaner Production* **19** 852
[4] Cosgrove W J and Loucks D P 2015 *Water Resour. Res.* **51** 4823
[5] Macedonio F, Drioli E, Gusev A A, Bardow A, Semiat R and Kurihara M J C E 2012 *Chem. Eng. Processing: Process Intensification* **51** 2
[6] Pari L, Suardi A, Stefanoni W, Latterini F and Palmieri N 2021 *Sustainability* **13** 3871
[7] Yoon J, Kwon H J, Kang S, Brack E and Han J 2022 *Sci. Tech.* **56** 6733
[8] Stamatis D H 2017 *The OEE primer: understanding overall equipment effectiveness, reliability, and maintainability* (New York: CRC Press)
[9] Kanti T, Agustiady C and Elizabeth A 2021 *Total Productive Maintenance: Strategies and Implementation Guide* (New York: CRC Press)
[10] Hedman R, Subramaniyan M and Almström P 2016 *Procedia Cirp* **57** 128
[11] Gupta A K and Garg R K 2012 OEE *Int. J. IT. Eng. Appl. Sci. Res.* **1** 115
[12] Mehta B B 2019 *Implementing ISO/IEC 17025:2017* (Milwaukee: ASQ Quality Press)
[13] Baki O T, Aras E, Akdemir U O and Yilmaz B 2019 *Desalination and water treatment* **157** 79