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IMPROVING DRINKING WATER PRODUCTION QUALITY THROUGH STANDARD OPERATING PROCEDURES: A CASE STUDY OF AN INSTITUTIONAL DRINKING WATER FACILITY

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ABSTRACT

This study aims to develop Standard Operating Procedures (SOPs) for the production of UKHUWAH UMI bottled drinking water to enhance product quality by integrating the Six Sigma DMAIC, Taguchi, and House of Ergonomics (HOE) methods. Key issues include product quality inconsistency, the emergence of unwanted odors and tastes, and elevated defect rates resulting from suboptimal SOP implementation. The study employs an applied quantitative approach utilizing observation, documentation, experimentation, and statistical analysis. The DMAIC framework is used to identify root causes, the Taguchi method optimizes production process parameters, and HOE ensures the integration of ergonomic aspects into system improvements. The research output is a production SOP model capable of minimizing process variation, enhancing quality consistency, and strengthening continuous quality control. Expected outcomes include reduced product defect rates, improved drinking water quality, increased consumer confidence, and the establishment of a production system that is effective, safe, healthy, comfortable, and efficient—thereby supporting the development of a sustainable halal industry at UKHUWAH UMI through the implementation of SOPs grounded in quality, ergonomics, and continuous improvement.

Keywords: Bottled Drinking Water (AMDK), Standard Operating Procedure (SOP), Six Sigma DMAIC, Taguchi Method, House of Ergonomics (HOE)

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1. INTRODUCTION

The bottled drinking water (BDW) industry has experienced significant growth in response to increasing public awareness of the importance of safe, hygienic, and high-quality drinking water. Along with increasing market competition, manufacturers are required to consistently produce products that comply with quality standards while maintaining consumer trust. Product quality has become one of the primary determinants of organizational competitiveness because consumers expect bottled drinking water to possess consistent taste, odor, clarity, and chemical characteristics throughout every production batch. Consequently, production systems must be supported by standardized operational procedures capable of minimizing process variation and ensuring continuous quality improvement.

One of the major challenges in bottled drinking water production is maintaining consistent product quality despite utilizing identical raw materials and production facilities. Process variability frequently results in defects such as unpleasant taste, odor, and inconsistent physicochemical properties that ultimately reduce customer satisfaction and organizational performance. These conditions are also experienced by UKHUWAH UMI Bottled Drinking Water (AMDK UKHUWAH UMI), where fluctuations in product quality have contributed to increasing consumer complaints and declining market confidence. Furthermore, inadequate implementation of Standard Operating Procedures (SOPs), insufficient production monitoring, and inconsistent documentation have been identified as contributing factors affecting production quality.

Standard Operating Procedures (SOPs) serve as fundamental management tools that define standardized work instructions for repetitive operational activities. Effective SOP implementation ensures process consistency, minimizes operational errors, enhances product reliability, and facilitates continuous quality improvement. Within bottled drinking water production, SOP compliance is particularly important because every production stage—including raw water treatment, coagulation, filtration, storage, filling, and packaging—directly influences product safety and consumer acceptance. Therefore, developing comprehensive and evidence-based production SOPs represents a strategic approach to improving manufacturing performance.

To address production quality problems systematically, Six Sigma has become one of the most widely adopted quality management methodologies in manufacturing industries. Through its Define–Measure–Analyze–Improve–Control (DMAIC) framework, Six Sigma enables organizations to identify Critical-to-Quality (CTQ) characteristics, quantify process capability, determine root causes of defects, implement corrective actions, and establish sustainable quality control mechanisms. The structured nature of DMAIC makes it particularly suitable for organizations seeking continuous process improvement based on objective performance measurements.

Although Six Sigma effectively identifies process deficiencies, determining the optimal production parameters requires a complementary optimization technique. The Taguchi method offers an efficient experimental design approach capable of identifying the optimal combination of controllable process factors while reducing process variability. Through orthogonal arrays and signal-to-noise ratio analysis, Taguchi minimizes the number of experiments required while producing statistically reliable parameter optimization. Consequently, integrating Taguchi within the Improve stage of DMAIC provides an effective strategy for improving production stability and reducing product defects.

In addition to technical process optimization, sustainable production quality also depends on human performance and workplace conditions. Operators who experience excessive workload, inadequate workplace design, or unclear operational procedures are more likely to commit production errors that contribute to product variability. Therefore, this research incorporates the House of Ergonomic (HOE) approach to ensure that production improvements consider not only technical quality but also ergonomic principles encompassing effectiveness, safety, health, comfort, and efficiency. The integration of ergonomic considerations is expected to improve operator performance while simultaneously strengthening compliance with standardized production procedures.

The literature has extensively reported the application of Six Sigma and Taguchi methods across various manufacturing industries for reducing process variation and improving product quality. However, previous studies have primarily focused on statistical quality improvement and technical process optimization. Limited attention has been given to integrating ergonomic principles into production standard development, particularly within bottled drinking water manufacturing systems. As a result, there remains an important research gap concerning the development of an integrated production quality framework that simultaneously addresses statistical process control, parameter optimization, ergonomic performance, and standardized operational procedures.

Therefore, this study aims to develop an integrated production Standard Operating Procedure for UKHUWAH UMI Bottled Drinking Water by combining the Six Sigma DMAIC methodology, the Taguchi optimization method, and the House of Ergonomic approach. The proposed framework is expected to identify the root causes of quality problems, determine optimal production parameters, improve operator performance through ergonomic work systems, and establish standardized production procedures capable of reducing defects and enhancing product consistency. In addition to providing practical recommendations for UKHUWAH UMI, this study contributes to the advancement of integrated quality management by incorporating statistical quality control, experimental optimization, and ergonomic principles into a comprehensive production improvement model applicable to bottled drinking water industries and similar manufacturing sectors.

2. METHODS

Research on quality control has advanced rapidly in response to increasing industrial demands for high-quality, consistent products that meet customer needs. Various approaches have been developed to reduce process variation, minimize defect rates, and enhance production process capability. Among these methods, Six Sigma, Taguchi, and the House of Ergonomics (HOE) are widely used because they address quality issues through statistical analysis, process optimization, and human factor considerations (Harahap et al, 2018) and (Hia, 2024).

Six Sigma is a data-driven quality improvement methodology that employs the Define, Measure, Analyze, Improve, and Control (DMAIC) framework. This approach has been applied across various manufacturing sectors to identify Critical to Quality (CTQ) characteristics, measure process capability, analyze root causes of defects, and systematically design corrective actions. Research by Harahap et al. demonstrated that Six Sigma implementation reduces the number of defective products through DPMO and sigma level analysis, while studies by Lestari and Purwatmini proved that DMAIC enhances production process stability in the textile industry. Yu et al. also developed a DMAIC model capable of improving the quality of multi-characteristic production processes through a more comprehensive statistical approach (Lestari, F. A., & Purwatmini, N. 2021), (Yu, C. M., Huang et al, 2022), and (Shanmugaraja et al, (2011).

Although Six Sigma is highly effective at identifying sources of process variation, it does not specifically determine the most optimal combination of process parameters.

Consequently, various studies have combined Six Sigma with the Taguchi method. The Taguchi method utilizes orthogonal arrays and signal-to-noise ratio analysis to identify the combination of process factors that yields minimal variation. Hiremath et al. demonstrated that integrating Six Sigma and Taguchi successfully reduced defect rates in metal casting processes, while Shanmugaraja et al. proved that combining these methods enhances both quality and productivity in manufacturing firms. Research by Al-Faritsy and Rachman in the Indonesian cardboard industry also showed that optimizing raw material composition using the Six Sigma–Taguchi approach significantly reduced DPMO values and improved process capability (Hiremath, V., et al. 2019), (Al-Faritsy et al, 2023), and (Setyo Pradana, E., & Sulistiyowati, W, 2022)

Beyond technical aspects, recent research indicates that human factors significantly influence the successful implementation of quality control. Operators working in environments lacking ergonomic design tend to experience fatigue and reduced concentration, leading to a higher likelihood of production errors. Consequently, the House of Ergonomic (HOE) concept has emerged as an approach that integrates principles of effectiveness, comfort, safety, health, and efficiency into production systems. An ergonomic approach not only boosts operator productivity but also reinforces adherence to Standard Operating Procedures (SOPs), thereby ensuring sustained product quality (Dio et al., 2021), and Fahim, F., 2023).

In the Bottled Drinking Water (AMDK) industry, research has largely focused on raw water quality, coagulation processes, Total Dissolved Solids (TDS) control, and the microbiological safety of the water. Ahmed et al. explained that storage temperature fluctuations affect the quality of bottled drinking water. Manga et al. found that storage media and water handling practices influence quality changes during distribution. Studies by Ramadhan et al., as well as Ngalung and Lolo, demonstrated that coagulant dosage settings are critical in determining the turbidity and TDS levels of treated water. These findings indicate that AMDK product quality is heavily dependent on the stability of production process parameters (Ahmed et al., 2021), (Manga et al., 2021), (Ramadhan et al., 2024), and (Ngalung & Lolo, 2023).

Although research regarding Six Sigma, the Taguchi method, and water treatment has advanced significantly, most studies still implement these methods in isolation. Previous research has generally focused on optimizing process parameters or statistical quality control without integrating operator ergonomics or the development of sustainable Standard Operating Procedures (SOPs). Yet, the successful implementation of quality improvements relies heavily on an organization's ability to translate analytical findings into work procedures that are easily understood, consistently applied, and supportive of operator performance.

Based on this review, a research gap exists: few studies have integrated Six Sigma DMAIC, the Taguchi method, and the House of Ergonomic (HOE) into a unified framework for developing production SOPs, particularly within the bottled drinking water industry. This study aims to bridge that gap by developing a quality improvement model that not only identifies the root causes of defects and optimizes production process parameters but also integrates ergonomic principles into the formulation of Standard Operating Procedures (SOPs), thereby ensuring the sustainability of quality improvements at AMDK UKHUWAH UMI.

3. FINDINGS AND DISCUSSION

3.1 EXISTING PRODUCTION CONDITION

Observations indicate that the production process for UKHUWAH UMI bottled drinking water comprises the following stages: raw water intake, pre-treatment, filtration, sterilization, filling, capping, labeling, and storage. Variations in product quality—manifested as changes in taste and odor, as well as inconsistent Total

Dissolved Solids (TDS) levels—were observed during production. Furthermore, certain production activities lack systematically documented Standard Operating Procedures (SOPs), meaning that work execution relies heavily on operator experience. These conditions result in process variations that have the potential to compromise product quality.

3.2 DEFINE PHASE

The Define phase is conducted to identify quality characteristics (Critical to Quality/CTQ) and determine the scope of the problem. The identification results indicate that key quality attributes include taste, odor, clarity, pH, TDS, packaging cleanliness, and bottle sealing quality. A SIPOC analysis illustrates the relationships among suppliers, inputs, processes, outputs, and customers, thereby providing a comprehensive map of the production process. Based on the Voice of the Customer, consumers expect a product that is safe, odorless, has a neutral taste, is clear, and is hygienically packaged.

3.3 MEASURE PHASE

In the Measure phase, quality data is collected using check sheets to determine the frequency of each defect type. Subsequently, a Pareto analysis is conducted to identify the most dominant defect types. Metrics such as Defects per Unit (DPU), Defects per Opportunity (DPO), Defects per Million Opportunities (DPMO), and sigma levels are calculated to evaluate production process capability. The measurement results indicate that the production process still exhibits significant variation; therefore, the likelihood of producing defective items needs to be reduced through a structured improvement program.

Tabel 1. Table CTQ

No	**CTQ**	**Number of Defect (Packaging)**	**Percentage**	**%Cumulative**
1.	Berbau	1610	40%	**40%**
2.	Berasa	2415	60%	**100%**
No	CTQ	Number of Defect (Packaging)	Percentage	**%Cumulative**
Total		**4026**	**100%**	

3.4 ANALYZE PHASE

The Analyze phase aims to identify the root causes of quality non-conformities. Fishbone Diagram analysis reveals that the primary causes stem from five factors: man, machine, method, material, and environment. The "man" factor relates to operators' lack of understanding regarding Standard Operating Procedures (SOPs) and the absence of periodic training. The "machine" factor is attributed to sub-optimal maintenance scheduling. The "method" factor indicates a lack of well-documented process standards, while the "material" factor is influenced by fluctuations in raw water quality. The "environment" factor encompasses production area cleanliness and operator working conditions. FMEA analysis is subsequently employed to prioritize improvements based on Risk Priority Number (RPN) values, ensuring that causes with the highest risk levels become the focus of corrective actions.

3.5 IMPROVE PHASE

The "Improve" phase was carried out using the Taguchi method to determine the optimal combination of process parameters. Factors influencing product quality were designated as control factors and structured using an Orthogonal Array. Signal-to-Noise (S/N) ratio analysis and ANOVA identified the parameter combination that yielded the least process variation. Implementing these optimal parameters enhanced production process stability, reduced variations in drinking water quality, and improved the consistency of product characteristics.

3.6 HOUSE OF ERGONOMIC (HOE)

The House of Ergonomics (HOE) approach is employed to integrate ergonomic aspects into the production system. Identifying operator needs reveals that clear Standard Operating Procedures (SOPs), a comfortable work environment, anthropometrically appropriate equipment, and job training are primary requirements. These needs are translated into technical responses via the HOE matrix, resulting in prioritized improvements: developing new SOPs, enhancing operator training, organizing the workspace, standardizing quality inspections, and establishing a machine maintenance schedule. Implementing these recommendations is expected to boost operator work effectiveness while simultaneously reducing errors during the production process.

3.7 DEVELOPMENT OF STANDARD OPERATING PROCEDURE

Based on the results of Six Sigma analysis, Taguchi optimization, and ergonomic evaluation, a more comprehensive production Standard Operating Procedure (SOP) was developed. The SOP covers raw water inspection procedures, process parameter settings, machine operation, quality inspection, packaging, storage, and corrective actions for any identified non-conformities. It also incorporates inspection forms, operator checklists, and documentation mechanisms to ensure the entire production process is carried out consistently and is well-documented.

3.8 CONTROL PHASE

The Control phase is implemented to ensure that all improvements are sustained over the long term. Control measures involve monitoring quality parameters, auditing SOP compliance, evaluating operator performance, conducting routine inspections of production machinery, and recording quality indicators during each production cycle. This control system enables the company to detect deviations early and take corrective action before producing items that fail to meet specifications.

3.9 SUMMARY OF RESULT

Research findings indicate that integrating Six Sigma DMAIC, the Taguchi method, and the House of Ergonomics (HOE) creates a comprehensive quality improvement system. Six Sigma serves to identify and analyze the causes of process variation, the Taguchi method yields optimal production parameters, and HOE enhances ergonomic aspects as well as operator adherence to work procedures. The integration of these three approaches results in more standardized production SOPs, improves process stability, reduces the potential for defects, and supports the continuous quality improvement of UKHUWAH UMI bottled drinking water products.

4.CONCLUSION AND SUGGESTION

This study developed an integrated production quality improvement framework for bottled drinking water production at AMDK UKHUWAH UMI by combining the Six Sigma DMAIC methodology, the Taguchi optimization method, and the House of Ergonomic (HOE) approach. The integration of these three methods enabled a systematic evaluation of production activities, beginning with problem identification, process performance measurement, root cause analysis, process optimization, ergonomic improvement, and the development of standardized production procedures.

The implementation of the DMAIC framework successfully identified the critical quality characteristics (CTQs) affecting product quality and revealed the primary sources of process variation throughout the production system. The Taguchi method provided an effective approach for determining the optimal production parameter settings, thereby reducing process variability and improving production consistency. Meanwhile, the House of Ergonomic approach ensured that the proposed improvements not only addressed technical aspects of production but also enhanced operator performance, workplace efficiency, and compliance with standardized work procedures.

Based on the integrated analysis, a comprehensive Standard Operating Procedure (SOP) was developed to standardize every stage of the production process, including raw water inspection, water treatment, filling, packaging, quality inspection, equipment maintenance, and production documentation. The proposed SOP is expected to improve process consistency, minimize operational errors, strengthen quality control activities, and support continuous improvement within the production system.

The findings demonstrate that integrating statistical quality improvement, process optimization, and ergonomic principles provides a comprehensive strategy for improving bottled drinking water production. This approach contributes both theoretically, by expanding the application of integrated quality management methodologies, and practically, by providing a structured quality improvement model that can be adapted by other bottled drinking water manufacturers and small-to-medium manufacturing industries.

Future research is recommended to validate the proposed SOP through long-term industrial implementation and to evaluate its impact on process capability, production efficiency, product quality, and customer satisfaction. Further studies may also incorporate real-time monitoring technologies and Industry 4.0-based quality management systems to support sustainable manufacturing performance.

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