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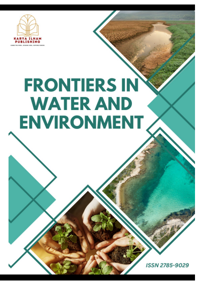

Performance Evaluation of a Mini Water Treatment Plant, Pre- and Post-Chlorination Analysis: A Case Study in Kg. Lok Dangkaan Pitas, Sabah

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ABSTRACT

Access to safe drinking water remains a challenge for rural communities in Sabah, Malaysia, due to geographical isolation, inadequate infrastructure, and economic constraints. Kampung Lok Dangkaan, a small fishing village in Pitas with approximately 300 residents, previously relied on purchased bottled water for drinking and harvested rainwater for domestic use. To address these issues, a mini water treatment plant incorporating conventional treatment processes and chlorination was established. This study evaluates its performance by comparing the physical, chemical, and microbiological quality of raw and treated water from two sources (Pond A and Pond B) against the Malaysian Drinking Water Quality Standards (MDWQS). Parameters analysed included temperature, pH, turbidity, salinity, conductivity, total dissolved solids (TDS), total suspended solids (TSS), dissolved oxygen (DO), biochemical oxygen demand (BOD_3), chemical oxygen demand (COD), ammonia nitrogen (NH_3-N), total plate count (TPC), total coliform, and Escherichia coli counts. The results showed that a complete *E. coli* removal in both ponds and significant COD reduction in Pond A (75 mg/L to 16 mg/L), with pH and TDS values within MDWQS limits. However, turbidity increased after treatment in both ponds, exceeding the 5 NTU MDWQS limit, and total coliforms remained detectable in Pond A, indicating filtration inefficiencies and possible post-treatment contamination. The findings demonstrate that the mini water treatment plant improved overall water safety and enabled treated water use for both drinking and domestic purposes. Further optimisation of filtration and disinfection processes is recommended to ensure full compliance with MDWQS.

1. Introduction

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In the state of Sabah, Pitas is one of the poorest districts, with a median household income of approximately RM 1,999 per month, a decline of 5% from RM 2,105 in 2016, and a poverty incidence of 53.6%. The inequality gap has also widened from 0.434 in 2016 to 0.458 in 2019, based on data released by the Department of Statistics Malaysia [1]. Demographic factors such as the distance between settlements and clean water sources, inadequate infrastructure, and limited access to quality water supply technology have restricted rural communities [2], particularly in Kg. Pituru, Kg. Mengkapon, and Kg. Lok Dangkaan, from achieving an inclusive quality of life. Consequently, the residents often rely on rainwater as their primary water source since the village is located far from any major rivers. The development of a mini water treatment plant by the Faculty of Science and Technology (FST), Universiti Malaysia Sabah (UMS), in collaboration with *Perbadanan Baitulmal Negeri Sabah* (PBNS) and the local community, represents a strategic initiative to provide clean water access (Figure 1). This project aims to improve residents' quality of life and productivity by supplying safe and treated water for domestic use. The mini water treatment plant in Pitas adopts a small-scale design but applies the fundamental principles of conventional drinking water treatment processes used in larger Malaysian treatment facilities. The treatment stages include rapid mixing of alum, flocculation, sedimentation, filtration, and chlorination before the water is stored in a clean water storage tank, following the sequence used in standard conventional treatment systems [3]. The treated water is required to meet the Ministry of Health Malaysia (MOH) guidelines as stated in the National Drinking Water Quality Standards [4]. Key parameters of concern include bacteriological counts, physicochemical indicators, organic matter, and pathogenic microorganisms [5].Compliance with these standards ensures that the water distributed to the community is safe for consumption and daily use.

Fig. 1. (a) Front view of the water intake Pond A & B and (b) Mini water treatment plant building at Kg. Lok Dangkaan, Pitas, Sabah, featuring a clean water storage tank for distribution to the local community.

Monitoring water quality and detecting pathogenic microorganisms, especially *Escherichia coli* (*E. coli*), is crucial for ensuring drinking water safety and public health. *E. coli* is a bacterium commonly found in the intestines of humans and animals. While some strains are harmless, others can produce toxins that cause serious illness if ingested through water or food. The presence of *E. coli* in water presents a significant health risk, including gastrointestinal diseases (diarrhea, abdominal cramps, nausea, vomiting, and fever) [6], urinary tract infections (UTI) [7], and hemolytic uremic syndrome (HUS) a severe condition, particularly among children and the elderly. *E. coli* contamination can result from sewage discharge, agricultural runoff, or improper waste disposal. Therefore, monitoring for this pathogen is essential and can be conducted through coliform tests, *E. coli* growth tests, and molecular techniques such as PCR to ensure compliance with local health authority standards. Since *E. coli* contamination poses a serious concern, various water treatment methods have been introduced to remove or reduce its presence. Filtration processes can remove particles, bacteria, and other impurities, including *E. coli*, depending on filter media pore size. Reverse osmosis (RO) is another effective method, removing *E. coli* along with other bacteria, viruses, salts, and contaminants [8]. Disinfection methods such as chlorination, chloramination, and ultraviolet (UV) irradiation are widely used to inactivate *E. coli* and other pathogens by damaging cell membranes and disrupting vital cellular functions [9]. Boiling water to 100°C for at least one minute can also kill most pathogens, including *E. coli*. Ozonation, using ozone (O_3), is another powerful oxidizing process that destroys *E. coli* and other microorganisms [10]

Chlorination remains one of the most effective methods for eliminating *E. coli* from drinking water supplies [11]. This disinfection process involves dosing chlorine at concentrations between 1.0 mg/L and 3.0 mg/L into filtered water to kill harmful bacteria without adversely affecting human health. Chlorine acts by disrupting bacterial metabolism and DNA while damaging cell membranes and internal structures [12]. In Malaysia's water treatment systems, chlorine is typically added during the early treatment stage to control algae and oxidize substances such as iron and manganese to facilitate sedimentation [13]. Additional chlorine is added at the end of treatment to inactivate any remaining bacteria and to maintain a residual chlorine concentration in the treated water to protect against recontamination [14]. Secondary chlorination at the main pipeline ensures compliance with the MOH requirement of a minimum free chlorine residual of 0.2 mg/L. Therefore, this paper aims to assess the physical, chemical, and microbiological quality of raw water before treatment, evaluate the treated water quality after chlorination, and compare the pre- and post-treatment results compliance with national guidelines Malaysian Drinking Water Quality Standards (MDWQS). By integrating these objectives, the study provides a comprehensive performance evaluation that encompasses both quantitative and qualitative aspects of water quality, enabling a clear understanding of the treatment process efficiency and its potential to address public health concerns in rural communities such as Kg. Lok Dangkaan.

2. Methodology

2.1 Study Area

This study was conducted at a mini water treatment plant located in Kampung Lok Dangkaan, a small rural fishing village in Pitas, Sabah, Malaysia (Figure 2). The village has an estimated population of approximately 400 residents, the majority of whom rely on small-scale fishing as their primary source of livelihood. Due to its geographical isolation and limited infrastructure, the community previously obtained drinking water through the purchase of bottled or refilled water from nearby towns, while harvested rainwater served as the main source for domestic activities such as cooking, washing, and cleaning. In response to concerns over water safety, reliability, and the economic burden of purchasing drinking water, a mini water treatment plant was established in 2024. The facility incorporates chlorination as the primary disinfection stage, with raw water sourced from pond A and B. This water is pumped into the treatment system, processed on-site, and subsequently distributed to households in the village, allowing the community to use treated water for both drinking and daily domestic purposes.

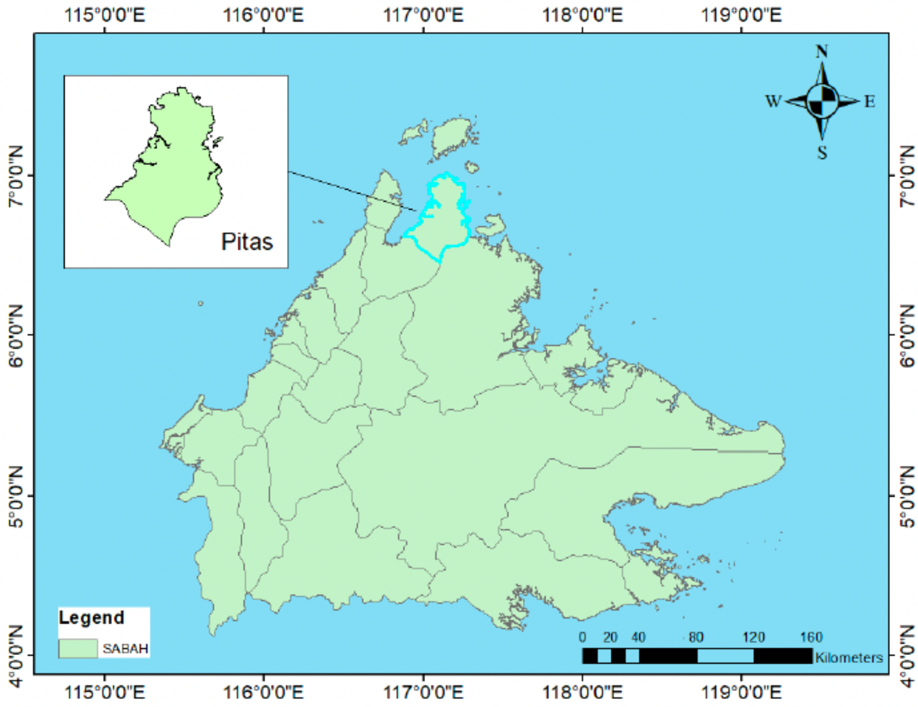

Fig. 2. Map showing the location of the study site, Kampung Lok Dangkaan, situated in the Pitas district of Sabah, Malaysia. The highlighted area in cyan indicates the Pitas district in the northern part of Sabah, while the inset map provides a closer view of its geographical boundary

2.2 Sampling Procedure

Water samples were collected from two sampling points in the treatment system: the first point was before treatment, representing raw water at the inlet of pond A and B and the second was after treatment, representing water discharged in pond A and B following chlorination. For physicochemical analysis, samples were collected in sterile 1-liter high density polyethylene (HDPE) bottles, while microbiological samples were collected in sterile 250 mL glass bottles to maintain microbial integrity [15]. All collected samples were labeled, stored in a portable ice box at approximately 4°C, and transported to the laboratory for analysis within 24 hours to minimize any changes in quality due to environmental exposure [16].

2.3 Chlorination Process

The chlorination process in the mini water treatment plant was conducted in pond A and B. Chlorine was dosed at a concentration of 1–5 mg/L, in accordance with the standard range recommended for conventional water treatment systems in Malaysia, as outlined by the National Water Services Commission (SPAN) and the Ministry of Health (MOH) guidelines [17]. This dosage range is considered sufficient to inactivate pathogenic microorganisms, oxidise certain dissolved metals such as iron and manganese, and maintain an adequate residual chlorine concentration to prevent recontamination in the distribution system [18]. The dosing was carried out using a calibrated metering pump to achieve precise chlorine application. After dosing, the water was held in a contact tank for a retention period of 24 hours to ensure adequate disinfection and to allow for the decay of excess free chlorine to a level acceptable for human consumption. Following the 24-hour contact period, water samples were collected from the outlet for laboratory analysis. Both physical and chemical parameters were measured, with particular attention given to microbiological analysis, including total plate count, total coliform, and Escherichia coli, to evaluate the disinfection performance of the chlorination process

2.4 Physiochemical Analysis

Physicochemical parameters were determined in accordance with the Standard Methods for the Examination of Water and Wastewater [19] . Temperature and pH were measured in situ using a calibrated YSI Professional Plus portable multiparameter water quality meter, with the pH probe calibrated using standard buffer solutions (pH 4.0, 7.0, and 10.0) prior to sampling. Turbidity was determined using a HACH 2100P portable turbidimeter, calibrated with primary standard solutions before measurement. Salinity and conductivity were recorded using the salinity and conductivity probes of the multiparameter meter, with results expressed in parts per thousand (ppt) and microsiemens per centimeter (µS/cm), respectively. Total dissolved solids (TDS) were measured directly with the multiparameter meter and expressed in milligrams per liter (mg/L). Total suspended solids (TSS) were analyzed gravimetrically by filtering a known volume of sample through pre-weighed 0.45 µm glass fiber filters, drying the filters at 105°C to constant weight, and calculating the difference in mass. Dissolved oxygen (DO) was measured in situ using the DO probe of the multiparameter meter, calibrated using the air-saturation method. Biochemical oxygen demand over three days (BOD_3) was determined by incubating the samples in airtight bottles at 20°C in the dark, with the difference between initial and final DO readings used for calculation. Chemical oxygen demand (COD) was determined using the closed reflux colorimetric method with a HACH DR3900 spectrophotometer after digestion with potassium dichromate. Ammonia nitrogen (NH_3-N) was measured using the Nesslerization method, in which ammonia reacts with Nessler reagent to produce a yellow-brown color, quantified spectrophotometrically.

2.5 Microbiological Analysis

Microbiological quality was determined using the Petrifilm method (3M™, USA) for Escherichia coli and total coliform enumeration [20]. Water samples were collected in sterile 250 mL glass bottles, immediately placed in an ice box at approximately 4 °C, and transported to the laboratory for analysis within 24 hours to prevent microbial changes [16], [21]. For each analysis, 1 mL of the water sample was aseptically pipetted onto the center of the Petrifilm plate. The sample was then evenly distributed across the growth area using the manufacturer-supplied plastic spreader, ensuring uniform contact between the inoculum and the nutrient medium. The inoculated Petrifilm plates were incubated in an upright position at 35 ± 1 °C for 24 hours for total coliform enumeration and up to 48 hours for *E. coli* analysis. Blue colonies associated with gas bubbles were recorded as *E. coli,* while red colonies associated with gas bubbles were recorded as coliforms. Results were expressed as colony-forming units per milliliter (cfu/mL) of the sample.

2.6 Data Analysis

All parameters were analyzed in triplicate, and mean values were calculated. The removal efficiency of the treatment plant was determined by comparing pre-treatment and post-treatment values for each parameter. These results were compared against the Malaysian Drinking Water

Quality Standards (MDWQS) to evaluate compliance and to assess the effectiveness of the treatment system in improving water quality for domestic use.

3. Results

3.1 Physical, Chemical, and Microbiological Quality of Raw Water before Treatment

Analysis of raw water from Pond A and Pond B (Table 1) revealed several water quality concerns prior to treatment. Physically, both sources exhibited moderate turbidity levels, with Pond A at 6.2 NTU and Pond B at 13.5 NTU, exceeding the Malaysian Drinking Water Quality Standards (MDWQS) limit of 5 NTU. pH values were slightly alkaline, measuring 8.72 for Pond A and 8.06 for Pond B, within the MDWQS acceptable range of 6.5–9.0. Data on dissolved oxygen (DO) levels was observed relatively high, particularly in Pond B (18.41 mg/L), indicating a good oxygenation but also potential vulnerability to microbial activity [21]. Meanwhile for Total dissolved solids (TDS) and total suspended solids (TSS) the results showed that both ponds were well below the MDWQS limits, suggesting low mineral and particulate loads respectively [22].

Table 1
Mean value of physical, chemical, and microbiological parameters of raw water from pond A and pond B at Kg. Lok Dangkaan before treatment

Water Quality Parameter Analyzed	Before Treatment	
	Pond A	Pond B
Temperature (^{0}C)	26.9	27.1
pH	8.72	8.06
Turbidity (NTU)	6.2	13.5
Salinity (ppt)	0.2	0.24
Conductivity (uS/cm)	451.9	518
Total Dissolved Solid (mg/L)	282.55	325
Total Suspended Solid (mg/L)	14.6	10.6
DO (mg/L)	11.39	18.41
BOD_3 (mg/L)	1	<1
COD (mg/L)	75	13
Ammonia Nitrogen NH_3-N (mg/L)	0.01	0.1
Total plate count (cfu/g)	1400	1080
Coliform count (cfu/g)	466	247
Escherichia coli count (cfu/g)	24	7

Based on the results obtained, Pond A showed a higher COD of 75 mg/L compared to 13 mg/L in Pond B. This can be due to a presence of oxidizable substances in Pond A. For Ammonia nitrogen (NH_3-N) levels, the results was observed low in both ponds with (0.01 mg/L in Pond A and 0.10 mg/L in Pond B). Enumeration of microbiological analysis indicated that contamination occurs in both sources, with total plate counts of 1,400 cfu/mL in Pond A and 1,080 cfu/mL in Pond B. Total coliforms were observed present (466 cfu/mL in Pond A, 247 cfu/mL in Pond B), and Escherichia coli was detected in both sources (24 cfu/mL in Pond A, 7 cfu/mL in Pond B), exceeding the MDWQS requirement of zero detection in 100 mL. These findings confirm that both ponds required effective treatment to meet national water safety standards.

3.2 Post-Treatment Water Quality Following Chlorination

The post-treatment results showed a notable improvements in several parameters, particularly microbiological safety (Table 2). *E. coli* was completely eliminated in both ponds, achieving 100% compliance with MDWQS requirements. Total coliform counts decreased substantially, especially in Pond B (from 247 to 40 cfu/mL), though Pond A retained a relatively higher count (400 cfu/mL), indicating incomplete disinfection or potential post-treatment contamination. Data on Total plate counts were also reduced in both ponds, with Pond B showing a greater reduction (from 1,080 to 400 cfu/mL) compared to Pond A (from 1,400 to 1,100 cfu/mL). Chemically, COD levels improved markedly in Pond A, dropping from 75 mg/L to 16 mg/L, and slightly in Pond B from 13 mg/L to 12 mg/L, reflecting a reduction in organic and inorganic oxidizable material. For Ammonia nitrogen levels, the results was remained low and within the standards, though a slight increase was observed in Pond A (0.01 to 0.05 mg/L), which may be associated with chlorination by-products. For physical parameters, pH levels was recorded in both ponds shifted closer to neutral after treatment with (Pond A: 8.72 to 7.56; Pond B: 8.06 to 7.82), enhancing acceptability for domestic use.

Table 2
Mean value of physical, chemical, and microbiological parameters of raw water from pond A and pond B at Kg. Lok Dangkaan after chlorination treatment

Water Quality Parameter Analyzed	**After Treatment**	
	Pond A	**Pond B**
Temperature (^{0}C)	27.5	27.2
pH	7.56	7.82
Turbidity (NTU)	12.3	18.6
Salinity (ppt)	0.14	0.23
Conductivity (uS/cm)	316.7	499.6
Total Dissolved Solid (mg/L)	196.7	311.1
Total Suspended Solid (mg/L)	6.4	9.8
DO (mg/L)	8.53	6.12
BOD_3 (mg/L)	<1	<1
COD (mg/L)	16	12
Ammonia Nitrogen NH_3-N (mg/L)	0.05	0.08
Total plate count (cfu/g)	1100	400
Coliform count (cfu/g)	400	40
Escherichia coli count (cfu/g)	0	0

Data on TDS values was observed declined in both ponds, with Pond A decreasing from 282.55 mg/L to 196.7 mg/L and Pond B from 325 mg/L to 311.1 mg/L, both pond recorded within the 1,000 mg/L limit. TSS was also observed reduced with (Pond A: 14.6 to 6.4 mg/L; Pond B: 10.6 to 9.8 mg/L), indicating some effectiveness in removing suspended particles. However, turbidity increased in both ponds post-treatment (Pond A: 6.2 to 12.3 NTU; Pond B: 13.5 to 18.6 NTU), exceeding MDWQS limits and suggesting filtration inefficiencies or particle re-suspension during processing. For DO levels, the results showed a decreased in both ponds after treatment, which is expected due to chemical dosing and oxidation processes. Figure 3 shows the physically observation of the water in pond A before and after the treatment process.

(a) (b)

Fig. 3. (a) Physical observation of water from pond A before treatment showing higher turbidity, (b) and after treatment showing visibly clearer water, demonstrating the effectiveness of the treatment process

3.3 Comparison Against MDWQS and Evaluation of Treatment Efficiency

When compared to MDWQS, the mini water treatment plant demonstrated a most significant success with the complete removal of *E. coli*, ensuring microbiological safety in this critical parameter. For parameter pH, TDS, and ammonia nitrogen, the data are remained within permissible ranges after treatment process. Results on COD levels showed substantial improvement, particularly in Pond A, indicating effective reduction of oxidizable contaminants. Nonetheless, there were parameters that failed to meet the MDWQS. Results obtained for turbidity level in both treated water sources exceeded the 5 NTU limit, raising concerns about particulate removal efficiency and the potential for microbial shielding within suspended solids [23]. Additionally, while total coliform counts decreased, Pond A still recorded post-treatment values above the standard of zero detectable coliforms per 100 mL. These results suggest that while chlorination effectively eliminated *E. coli*, further optimisation of filtration and post-treatment handling is required to achieve full compliance [24].

4. Conclusions

In conclusion, the mini water treatment plant has proven capable of significantly improving water quality in Kg. Lok Dangkaan, particularly in eliminating pathogenic bacteria and reducing key chemical contaminants. However, operational adjustments such as improving filter performance, increasing chlorine contact time, and preventing post-treatment contamination are necessary to address residual turbidity and coliform levels. By achieving consistent compliance with MDWQS, these results will enhance public health protection and ensure that the treated water can reliably serve both drinking and domestic needs in the community.

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