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Assessment of drinking water quality for raw water and treated water at Kangar, Perlis, Malaysia

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Abstract. Clean and safe water is vital for human health, whether it is used for drinking purpose, food production or domestic use. The aims of study are to investigate raw water quality parameters and analysed Water Quality Index (WQI) at Timah Tasoh Dam. The research also analyses the treated water quality parameters at Timah Tasoh Water Treatment Plant, Kampung Belukar, Kampung Kechor and Taman Bukit Kaya, then compared to National Standard for Drinking Water Quality (NSDWQ) and World Health Organization (WHO) guidelines. The raw water was analysed for pH, total suspended solids (TSS), chemical oxygen demand (COD), biochemical oxygen demand (BOD), dissolved oxygen (DO) and ammoniacal nitrogen (AN). Treated water was analysed for copper (Cu), iron (Fe) and nickel (Ni). Timah Tasoh Dam is categorized as slightly polluted where its WQI index was 76.94. Sources of pollution related to non-point sources such as fishery activities, agricultural and livestock wastes, and domestic wastes. For treated water parameters, significant results showed at Taman Bukit Kaya which recorded the highest concentrations of Cu, Fe and Ni, at 1.24 mg/L, 0.76 mg/L and 0.01 mg/L respectively. The reason is that Taman Bukit Kaya is the furthest distance from Timah Tasoh Water Treatment Plant, thus the residence time of water in pipe is longer which results in higher concentration of heavy metals. Concentration of Cu and Ni was complied with the guideline values of WHO and only Ni was complied with NSDWQ. Based on the result of treated water analysis at Kangar, Perlis, the drinking water quality is considered as safe for drinking.

1. Introduction

It is the ubiquitous fact that water is important to human life. However, as populations expand and natural habitats decline, maintaining adequate and healthy water sources are becoming increasingly difficult for everyone. According to Uhlenbrook *et al.* [1] in The United Nations World Water Development report, the use of water has risen worldwide by around 1 percent annually since the 1980s. This is due to population growth, socio-economic development and increasing consumption habits. The demand on water is projected to continue to grow at a comparable rate by 2050, reflecting a 20 to 30 percent increase over the present level of water usage.

Apart from the issue of an imminent water shortage, rising water supply contamination is also a concern that needs to be tackled. Water quality degradation is typically due to various sources of organic and inorganic contaminants that come from agricultural, commercial, and domestic activities [2]. This deterioration is generally connected with the release of untreated and treated wastewater into water sources. For example, in Selangor, several water treatments plants have been shut down due to the



presence of ammoniacal nitrogen in the raw water intake, consequently thousands of businesses and households have been affected without water supply. Access to clean and safe water supply has thus become a major obstacle for the water authorities to address.

The maintenance of water piping network systems is very importance in supplying the end user with clean water. The quality of drinking water degrades during processing and storage both at treatment plants and in distribution networks [3]. Upon reaching the household plumbing system, the quality of most water sources deteriorates due to either bacteria or other pollutants. The presence of these pollutants in the piping system may come from developing of bacteria on the wall of pipe or from pipe malfunctions or joint leakages [4]. Consequently, to deliver drinking water of impeccable quality, it is important to assess the water quality in the treatment plant and water distribution system.

This research focuses on assessing the drinking water quality in Kangar, Perlis before it is supplied to consumers.

2. Materials and methods

2.1. Location of sampling points

The sampling locations were divided into two categories, raw water (water from the intake point of Timah Tasoh treatment plant or untreated water) and treated water from treatment plant and distribution system. The raw water source had been chosen is Timah Tasoh Dam because it is the source of water supply to the Timah Tasoh water treatment plant. According to National Standard for Drinking Water Quality (NSDWQ) by Ministry of Health (MOH), Malaysia [5], water samples were taken from water source points which are close to the source as possible. While the treated water samples were taken at the outlet of Timah Tasoh water treatment plant and consumers tap water from residential areas. The residential areas chosen were Kampung Belukar, Kampung Kechor and Taman Bukit Kaya at Kangar, Perlis. Table 1 shows the sampling points location and coordinates. Figure 1 shows the location of Timah Tasoh Dam, Timah Tasoh water treatment plant and residential areas at Kangar, Perlis.

Table 1. Sampling Point Location and Coordinate.

| Division | Location | Coordinate | Distance (km) |
|---------------------------|-----------------------------------|------------------------------|---------------|
| Raw Water | Timah Tasoh Dam | 06°34'42" N 100°12'14" E | 0 |
| Water Treatment Plant | Timah Tasoh Water Treatment Plant | 06°34'31" N 100°12'15 " E | 0.32 |
| | Kampung Belukar | 06°32'09" N 100°12'52" E | 4.89 |
| Water Distribution System | Kampung Kechor | 06°28'58" N 100°12'09" E | 10.92 |
| | Taman Bukit Kaya | 06°26'02" N 100°11'31" E | 16.52 |

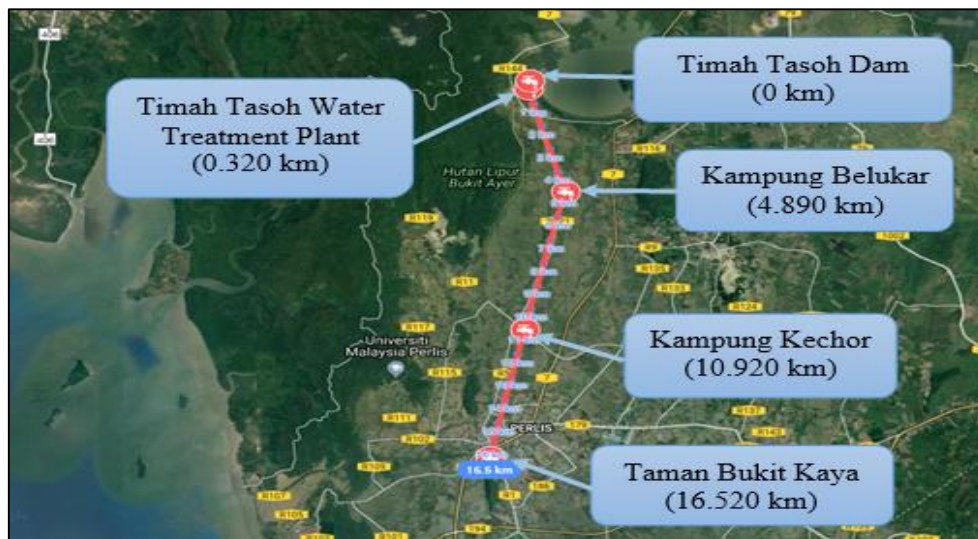


Figure 1. Location and distance of Timah Tasoh Dam, Timah Tasoh Water Treatment Plant and residential areas at Kangar, Perlis.

2.2. Sample collection

About three litres of water samples were obtained from each sampling point for sample analysis. The water samples were stored in the ice box to maintain temperature below 4°C.

2.3. Data analysis

Six parameters that involved to determine the Water Quality Index (WQI) are pH, total suspended solids (TSS), chemical oxygen demand (COD), biochemical oxygen demand (BOD), dissolved oxygen (DO) and ammoniacal nitrogen (AN). Equation 1 shows the WQI calculation and determination. Table 2 shows the best fit equations for the estimation of various sub index values. Then, based on calculated WQI value, the river classification was determined using table 3. The treated water was analysed for concentrations of copper, iron and nickel by Atomic Absorption Spectrophotometry (AAS). Then, the parameters of treated water were compared to acceptable values stated in National Standard for Drinking Water Quality (NSDWQ) and World Health Organization (WHO) guidelines (table 4).

$$WQI = 0.22(SIDO) + 0.19(SIBOD) + 0.16(SICOD) + 0.15(SIAN) + 0.16(SISS) + 0.12(SIpH) \quad (1)$$

Where,

- SIDO = Sub-index DO (% saturation)
- SIBOD = Sub-index BOD
- SICOD = Sub-index COD
- SIAN = Sub-index Ammoniacal Nitrogen
- SISS = Sub-index Suspended Solid
- SIpH = Sub-index pH

Table 2. The best fit equations for the estimation of various sub index values [6].

| Parameter | Sub index | |
|-----------|-------------------|---|
| DO | $X \leq 8$ | SIDO = 0 |
| | $X \geq 92$ | SIDO = 100 |
| | $8 < X < 92$ | $SIDO = -0.395 + 0.03 X^2 - 0.0002 X^3$ |
| BOD | $X \leq 5$ | SIBOD = $100.4 - 4.23 X$ |
| | $X > 5$ | $SIBOD = 108 e^{-0.055 X} - 0.1 X$ |
| COD | $X \leq 20$ | SICOD = $99.1 - 1.33 X$ |
| | $X > 20$ | $SICOD = 103 e^{-0.0157 X} - 0.04 X$ |
| SS | $X \leq 100$ | $SISS = 97.5 e^{-0.00676 X} + 0.05 X$ |
| | $100 < X < 1000$ | $SISS = 71 e^{-0.0016 X} - 0.015 X$ |
| | $X \geq 1000$ | SISS = 0 |
| AN | $X \leq 0.3$ | SIAN = $100.5 - 105 X$ |
| | $0.3 < X < 4$ | $SIAN = 94 e^{-0.573 X} - 5 (X - 2)$ |
| pH | $X < 5.5$ | $SIpH = 17.2 - 17.2 X + 5.02 X^2$ |
| | $5.5 \leq X < 7$ | $SIpH = -242 + 95.5 X - 6.67 X^2$ |
| | $7 \leq X < 8.75$ | $SIpH = -181 + 82.4 X - 6.05 X^2$ |
| | $X \geq 8.75$ | $SIpH = 536 - 77 X + 2.76 X^2$ |

Table 3. DOE water quality index classification [6].

| Parameter | Unit | Classes | | | | |
|-----------|------|---------|-------------|-------------|-------------|--------|
| | | I | II | III | IV | V |
| DO | mg/L | > 7 | 5 - 7 | 3 - 5 | 1 - 3 | < 1 |
| BOD | mg/L | < 1 | 1 - 3 | 3 - 6 | 6 - 12 | > 12 |
| COD | mg/L | < 10 | 10 - 25 | 25 - 50 | 50 - 100 | > 100 |
| TSS | mg/L | < 25 | 25 - 50 | 50 - 150 | 150 - 300 | > 300 |
| AN | mg/L | < 0.1 | 0.1 - 0.3 | 0.3 - 0.9 | 0.9 - 2.7 | > 2.7 |
| pH | - | > 7.0 | 6.0 - 7.0 | 5.0 - 6.0 | < 5.0 | > 5.0 |
| WQI | | > 92.7 | 76.5 - 92.7 | 51.9 - 76.5 | 31.0 - 51.9 | < 31.0 |

Table 4. Guideline values established by National Standard for Drinking Water Quality (NSDWQ), MOH [5] and World Health Organization (WHO) [7].

| Standards | Parameter (mg/L) | | |
|---|------------------|-----------|-------------|
| | Copper (Cu) | Iron (Fe) | Nickel (Ni) |
| World Health Organization (WHO) | 2.0 | *NA | 0.07 |
| National Standard for Drinking Water Quality (NSDWQ), MOH | 1.0 | 0.3 | 0.02 |

*NA = Not applicable

3. Results and discussion

3.1. Water quality index (WQI) for Timah Tasoh Dam

The result of six WQI parameters was depicted in table 5 as well as its respective sub-index and water class. The calculations showed that the WQI for Timah Tasoh Dam was 76.94. According to DOE WQI Classification [6], Timah Tasoh Dam is categorized as slightly polluted where its WQI index within 76.5 to 92.7 and classified in Class II, this means that the water supplies from Timah Tasoh Dam require conventional treatment in order to be used for drinking water purpose. Significant factors that affected the water class of Timah Tasoh Dam were the concentration of TSS and BOD. During storm events, soil particles and debris from streets and residential zone around catchment area can be washed into runoff and flow into water bodies, which ends up in high concentration of TSS at Timah Tasoh Dam. The wastewater from houses around Timah Tasoh Dam contains food residues, human wastes and other solid materials that flow into drains and then to water bodies [8]. High concentrations of BOD showed that there are many activities of microorganisms because pollutants released into the lake will be digested by the microorganisms [9]. From the observation, there are massive fishery activities in Timah Tasoh Dam. Waste disposal such as food waste and fishing bait that were thrown directly into the lake also contributed to the high content of organic matter.

Table 5. Result of Water Quality Index for Timah Tasoh Dam.

| Parameter | Average concentration | Range | Sub-index | Water Class |
|---------------------------|-----------------------|------------------------------|-----------|-------------|
| DO | 7.28 mg/L | For $8\% < x < 92\%$ | 94.78 | Class I |
| BOD | 3.92 mg/L | For $x \leq 5$ | 83.82 | Class III |
| COD | 19.83 mg/L | For $x \leq 20$ | 72.72 | Class II |
| AN | 0.18 mg/L | For $x \leq 0.3$ | 81.95 | Class II |
| TSS | 146.67 mg/L | For $100 < x < 1000$ | 26.82 | Class III |
| pH | 6.94 | For $5.5 \leq x < 7$ | 99.53 | Class II |
| Water Quality Index (WQI) | | 76.94 (Slightly Polluted) | | Class II |

3.2. Treated water quality parameters

Treated water samples were obtained at the Timah Tasoh Water Treatment Plant outlet and consumers tap water from residential areas. The residential areas chosen were Kampung Belukar, Kampung Kechor and Taman Bukit Kaya at Kangar, Perlis.

3.2.1. Copper (Cu). Cu is an importance element with a recommended daily allowance of 2.0 mg/L by WHO [7] and 1.0 mg/L by NSDWQ, MOH [5]. Cu is commonly found in household plumbing system. Thus, the concentration of Cu in tap water was slightly increased compared to the concentration of

existing Cu in water before reaching the water piping system. In this study, the Cu concentration detected in the water samples are 0.60 mg/L at Timah Tasoh Water Treatment Plant and 1.24 mg/L at Taman Bukit Kaya as shown in figure 2. Based on the guideline value of 2.0 mg/L developed by WHO [7], concentrations of Cu in all locations are deemed within acceptable range. However, based on acceptable value of 1.0 mg/L established by MOH [5], only Taman Bukit Kaya exceeds the limit with concentration of 1.24 mg/L. The reason is that Taman Bukit Kaya is the furthest distance from Timah Tasoh Water Treatment Plant, so the residence time of water in pipe is longer which results in higher concentration of Cu [10]. The presence of Cu at such low concentration does not give effect to the taste and colour of water. According to WHO [7] in Drinking Water Quality guidelines, the presence of Cu in the drinking water supply is due to the corrosive action of water which leaching Cu from Cu type pipes material in residential areas. As observed in figure 2, the Cu concentration of treated water flowing from Timah Tasoh Water Treatment Plant to Taman Bukit Kaya posed an increasing trend. That is because the Cu concentration would differ considerably with the time the water was in contact with the pipes [7].

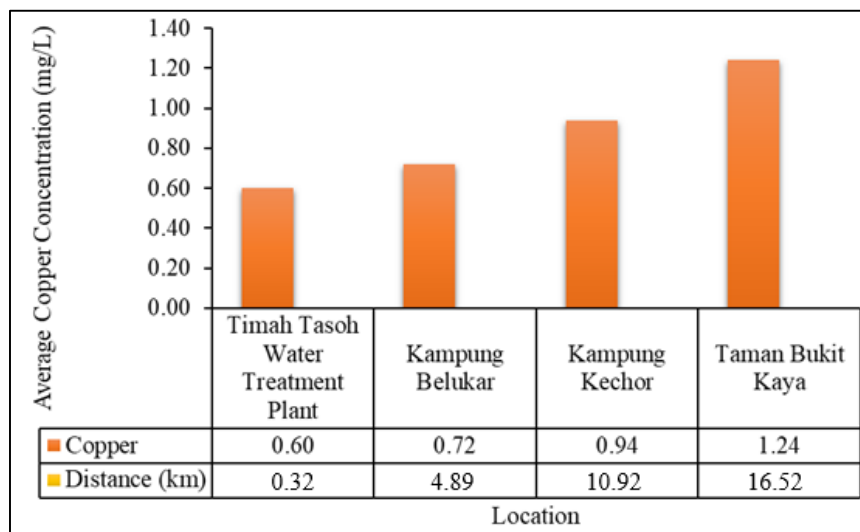


Figure 2. Concentration of copper (Cu) at different locations.

3.2.2. Iron (Fe). Figure 3 shows the Fe concentration in treated water ranged from the lowest of 0.22 mg/L at Kampung Belukar to the highest of 0.76 mg/L at Taman Bukit Kaya. All the tested water samples except Kampung Belukar were surpassed 0.3 mg/L of guideline value established by NSDWQ, MOH [5]. The residence time of water in the distribution system has contributed to high Fe concentration in drinking water at Taman Bukit Kaya. Fe is widely used as material of pipe in water distribution system such as cast iron, steel and galvanized iron [11]. Fluctuation of the concentrations of Fe at different locations as the drinking water flows from Timah Tasoh Water Treatment Plant to Taman Bukit Kaya, may be due to different types of pipe materials. The Fe presence in drinking water may give effect on colour and taste of water and may not be suitable for drinking [12]. Fe is not harmful for human health, but it is considered a secondary or aesthetic contaminant. Fe facilitates to carry oxygen in the human blood, and also vital component for human diet, notably in the iron (II) oxidation state. The recommended daily demand for Fe is in the ranges of 10 to 50 mg/day per person [13].

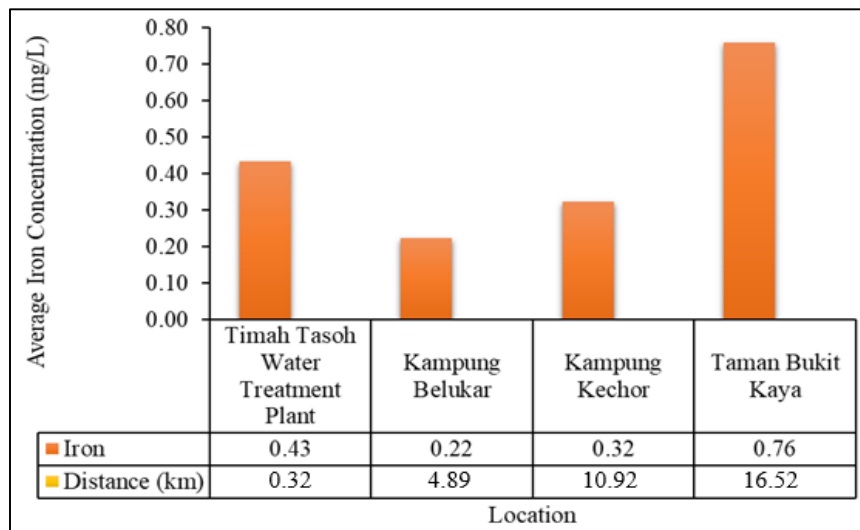


Figure 3. Concentration of iron (Fe) at different locations.

3.2.3. *Nickel (Ni)*. Figure 4 shows the Ni concentration in the treated water samples were below detection limit at Timah Tasoh Water Treatment Plant and Kampung Belukar. It is normal that the concentration of Ni is negligible as there is frequent monitoring of drinking water quality at treatment plant. Kampung Belukar is actually very near to treatment plant, at a distance of 4.890 km. Kampung Kechor possess Ni concentration of 0.003 mg/L while Taman Bukit Kaya has a concentration of 0.010 mg/L. Overall, the water samples have Ni concentration below guideline value of 0.070 mg/L as established by WHO [7] and 0.020 mg/L developed by NSDWQ, MOH [5]. Low concentrations of Ni at Kampung Kechor and Taman Bukit Kaya may arise from stainless steel pipes and fittings [7]. The Ni concentration is very small, and thus Ni contamination in the water piping system can be negligible.

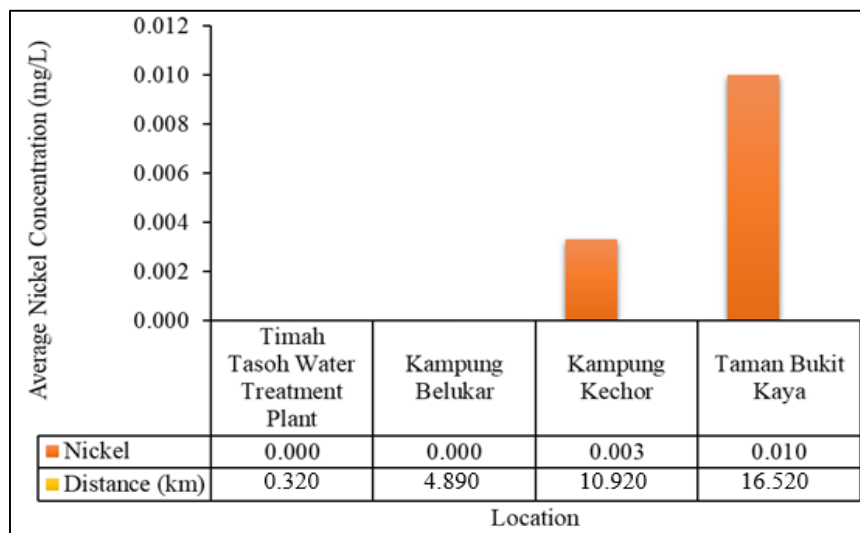


Figure 4. Concentrations of nickel (Ni) at different locations.

4. Conclusion

Water is important to life, and a sufficient supply of clean drinking water is needed to sustain life. Therefore, the monitoring of raw water and treated water quality is importance to be frequently conducted or checked before it is being supplied to consumers. Based on water quality analysis, the

status of raw water that is supplied to Timah Tasoh Water Treatment Plant is slightly polluted with WQI of 76.94. It has been classified as Class II meaning a raw water source require conventional treatment to be used for drinking water purpose. For the analysis of treated water samples from Timah Tasoh Water Treatment Plant and selected three locations of residential areas at Kangar, Perlis, the quality of drinking water is safe for drinking purpose. Amongst of three parameters examined for treated water samples, only Ni concentration obeyed to WHO and NSDWQ, MOH guidelines values. The parameter that obviously exceeded limit was Fe, which exceeded the approved value of 0.30 mg/L at concentrations of 0.43 mg/L (Timah Tasoh Water Treatment Plant), 0.32 mg/L (Kampung Kechor) and 0.76 mg/L (Taman Bukit Kaya). A specific research is suggested to be conducted to examine why Fe concentration is high in the water samples.

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