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Water quality monitoring: A comparative case study of municipal and Curtin Sarawak's lake samples

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Abstract. In this study, particle size distribution and zeta potential of the suspended particles in municipal water and lake surface water of Curtin Sarawak's lake were compared and the samples were analysed using dynamic light scattering method. High concentration of suspended particles affects the water quality as well as suppresses the aquatic photosynthetic systems. A new approach has been carried out in the current work to determine the particle size distribution and zeta potential of the suspended particles present in the water samples. The results for the lake samples showed that the particle size ranges from 180nm to 1345nm and the zeta potential values ranges from -8.58 mV to -26.1 mV. High zeta potential value was observed in the surface water samples of Curtin Sarawak's lake compared to the municipal water. The zeta potential values represent that the suspended particles are stable and chances of agglomeration is lower in lake water samples. Moreover, the effects of physico-chemical parameters on zeta potential of the water samples were also discussed.

1. Introduction

Surface water and ground water are important components in the environment for the fresh water resources. Photosynthetic activity of phytoplankton's and other primary producers in the aquatic environment commonly occurs in the surface water bodies [1, 2]. These planktons are the main source of food for aquatic organisms [3]. Increased in the human activities such as urban development, deforestation and discharge of industrial effluents and domestic waste into lakes from cities or villages has a profound influence in the quality of surface water bodies such as lakes and reservoirs [4, 5]. Due to the anthropogenic activities, increase in the level of suspended particles in the surface water bodies is expected [6]. The presence of suspended particles will suppress the aquatic photosynthetic system [7] and affects the aquatic food chain [8]. The term suspended particles refers to the mass or concentration of inorganic and organic particles such as trace metals [9] and carbonates [10] respectively that is present in the stream, river or lake water column by turbulence [11]. The increase



of suspended particles in water bodies lead to physical and chemical alterations such as limited penetration of light which resulted in delayed photosynthesis process; temperature changes [12]; increased in eutrophication [13] and release of heavy metal contamination [14, 15] and nutrients such as phosphorus [16]. Moreover, in-situ decomposition of suspended particle with high organic content can depletes dissolved oxygen levels in water. This process will lead to a critical oxygen shortage in surface water bodies that will affect the life of aquatic organisms [17]. High level of suspended particles can also causes damage in the exposed respiratory organs of aquatic invertebrates [18] and delicate gill structures of fishes [19, 20]. Overall, the suspended particles analysis plays a major role in establishing water quality guidelines to improve and protect quality of water and aquatic ecosystems. In the present study, particle size distribution and zeta potential of the suspended particles in municipal water and surface water of Curtin Lake, Miri, East Malaysia was compared and analyzed using dynamic light scattering technique. In addition, the effect of physico-chemical parameters on zeta potential of the water samples was also analyzed.

2. Study area

The lake surface water was collected from Curtin Lake which is located in Curtin University, Sarawak campus, Miri, East Malaysia. Miri city is located in northern Sarawak, in the Borneo Island. The city is dotted by numerous industries such as palm oil, timber processing plants, ship building industries and offshore oil platforms. The surface water is available throughout the year and is utilized for domestic purposes. The Sarawak state receives more annual rainfall of about 3000-4000 mm through the northeast and southwest monsoons. Most of the rainfall is received during October to March through northeast monsoon. The south west monsoon is the dry period of Sarawak. The average temperature is 26 °C throughout the year and the state experiences higher humidity level (80%) due to high evaporation rate [21]. The burning of bushes and its aftermath contributes to the presence of major suspended particles in surface water bodies in and around Miri city. A total of 10 water samples from the surface of Curtin Lake (S1 to S10) were collected for analysis as mentioned in Figure 1. The tap water and the drinking water samples were also collected inside university campus. The tap water was supplied by local municipal authority and the drinking water was purified by Curtin University water treatment facility.

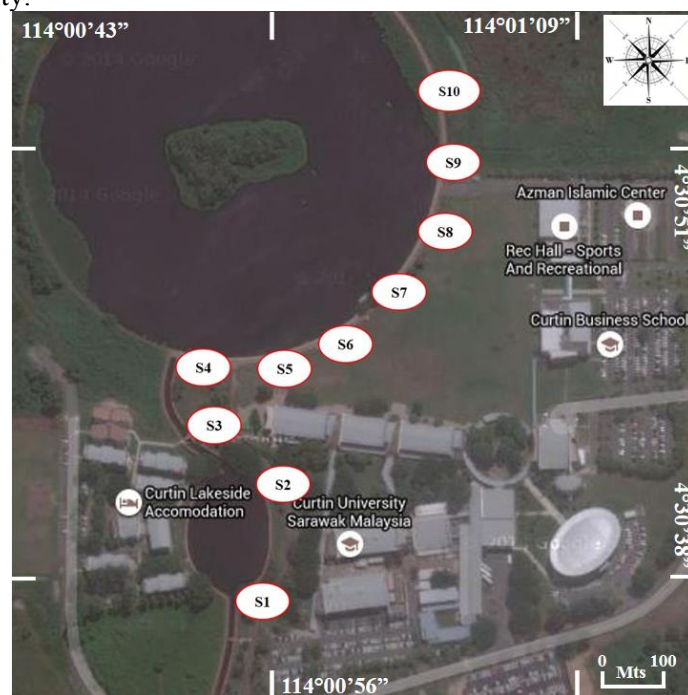


Figure 1. Location of sampling sites in the Curtin University, Sarawak Campus.

3. Materials and methods

Prior to the collection of samples the storage bottles was thoroughly acid washed with diluted Nitric acid (20%) and rinsed with distilled water. General physico-chemical parameters such as conductivity, pH, resistivity, salinity, TDS, ORP and temperature measurements of the water samples was measured in situ with portable water quality analyzer. The collected water samples were filtered using a Whatman No: 1 filter paper for further analysis. The filtered samples were taken in disposable folded capillary cells and measured by using Non-Invasive Backscatter optics (NIBS). The particle size distribution and zeta potential was analyzed using Zetasizer Nano ZS (Malvern Instruments Ltd). This instrument can able to measure the size ranging from 0.3nm o 10 microns (diameter). The accuracy and precision of the instrument was checked by using the standard reference material NIST SRM 1980 [22].

4. Materials and methods

Measured values of physico – chemical parameters, zeta potential values and particle sizes are summarized in Table 1. The range and mean values of physico-chemical parameters was represented in Table 2. The pH was found to be slightly acidic for the surface water. Electrical conductivity was observed more in the lake water samples compared to the municipal waters. Higher concentration of total dissolved solids was observed in the sampling site S1 and the minimum values was noticed in the municipal waters. Salinity of the water samples was in the range of 0.3 to 0.4 ppt. Zeta potential is a convenient way to study the suspended particle and its interactions in surface water bodies [23]. The interaction of suspended particles in aqueous media is dependent on its zeta (electro-kinetic) potential which is controlled by the surface charge of the suspended particles and the aqueous medium [24-26]. According to electric potential of colloidal particles, zeta potential from 0 to ± 5 mV leads to agglomeration, ± 10 to ± 30 mV indicates incipient stability, ± 30 to ± 40 mV leads to moderate stability and excellent stability can be obtained from ± 40 to ± 60 mV [27, 28]. The sign and the level of zeta potential will act as a deciding factor to determine the range of physical and chemical processes on the particle surface [29, 30]. Zeta potential of all the water samples was found to be negative which denotes the surface charge of the suspended particles [31, 32] and it is represented in the figure 2. For distilled water, the pH is 6.82, the average size is 1345 nm and zeta –potential is -8.58. Compared with the physico-chemical parameters and Z-potential in all the samples (Table 1), it is clear that the presence of suspended particles are very low in the distilled water and it shows the lower Z-potential and larger size which will lead to agglomeration and settlement of the suspended particle [33, 34]. Similarly, compared to tap water, drinking water consists of larger size suspended particles (831nm) with lower z-potential (-12.1mV) which show there is no micro-level contaminants present in both samples. The pH of the lake samples are in the range of 5.8 and 6.8, the particle size varied from 180.3 nm to 386.6 nm and the zeta potential value varies between -13.7mV to -26.1mV.

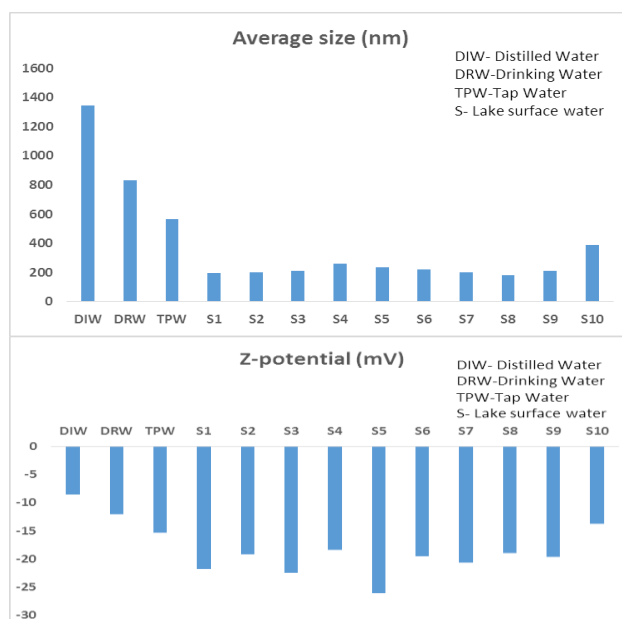


Figure 2. Chart showing zeta potential and average size of all the water samples

Table 1. Physico-chemical parameters of water samples collected from Curtin university, Sarawak Campus

| Sample ID | pH | Conductivity (µs/cm) | Salinity (ppt) | Resistivity (MΩ-cm) | TDS (mg/l) | ORP (Rmv) | Temperature °C | PDI | Average size (nm) | Z-potential (mV) |
|------------|------|----------------------|----------------|---------------------|------------|-----------|----------------|-------|-------------------|------------------|
| DIW | 6.82 | 1.47 | 0.0 | 0.681 | 1 | 46.8 | 26 | 0.998 | 1345 | -8.58 |
| DRW | 6.47 | 138.8 | 0.0 | 0.0072 | 68 | 42.7 | 28 | 0.667 | 831 | -12.1 |
| TPW | 6.6 | 138.5 | 0.0 | 0.0072 | 68 | 34.3 | 27.7 | 0.537 | 567 | -15.3 |
| S1 | 6.61 | 850 | 0.4 | 0.0012 | 417 | 55.2 | 31.3 | 0.351 | 198 | -21.8 |
| S2 | 6.34 | 679 | 0.3 | 0.0015 | 333 | 49.7 | 30.6 | 0.345 | 198.4 | -19.2 |
| S3 | 6.25 | 632 | 0.3 | 0.0016 | 310 | 55.2 | 32.2 | 0.398 | 208.3 | -22.5 |
| S4 | 6.14 | 639 | 0.3 | 0.0016 | 313 | 61.7 | 31.8 | 0.423 | 258.2 | -18.4 |
| S5 | 6.13 | 660 | 0.3 | 0.0015 | 323 | 62.8 | 32 | 0.54 | 236.5 | -26.1 |
| S6 | 6.1 | 690 | 0.3 | 0.0014 | 338 | 64.1 | 31.5 | 0.339 | 218 | -19.5 |
| S7 | 6.21 | 631 | 0.3 | 0.0016 | 309 | 58 | 32.4 | 0.416 | 200.6 | -20.7 |
| S8 | 6.16 | 635 | 0.3 | 0.0016 | 311 | 60.9 | 32.5 | 0.391 | 180.3 | -19 |
| S9 | 6.15 | 629 | 0.3 | 0.0016 | 308 | 61.3 | 33 | 0.462 | 211.3 | -19.6 |
| S10 | 5.93 | 646 | 0.3 | 0.0015 | 317 | 74.3 | 31 | 0.852 | 386.6 | -13.7 |

Table 2. Descriptive analysis of water samples

| Parameters | Range | Minimum | Maximum | Mean | Std. Deviation |
|---------------------|---------|---------|---------|--------|----------------|
| pH | 0.89 | 5.93 | 6.82 | 6.30 | 0.25 |
| Conductivity | 848.53 | 1.47 | 850.00 | 536.13 | 261.25 |
| Salinity | 0.40 | 0.00 | 0.40 | 0.24 | 0.14 |
| Resistivity | 0.68 | 0.00 | 0.68 | 0.05 | 0.19 |
| TDS | 416.00 | 1.00 | 417.00 | 262.77 | 127.98 |
| ORP | 40.00 | 34.30 | 74.30 | 55.92 | 10.44 |
| Temperature | 7.00 | 26.00 | 33.00 | 30.77 | 2.16 |
| Average Size | 1164.70 | 180.30 | 1345.00 | 387.63 | 344.80 |
| Z potential | 17.52 | -26.10 | -8.58 | -18.19 | 4.67 |

Significant difference was observed between the zeta-potential value of sample site S5 (-26.1mV) and S10 (-13.1 mV). Similar significant difference was observed between S8 (180.3nm) and S10 (386.6nm). For sample site 8, the observed z-potential is -19mV with 180.3 nm as average size which reveals that the sample contains smaller suspended particles with less chance of agglomeration. Its polydispersity index is 0.391 indicating that the sample consists of monodispersed particles [22, 35, 36]. In the sampling location 10, as represented in Figure 2, the observed z-potential is -13.7mV with an average particle size of 386.6 nm signifies the ability of the suspended particles for agglomeration and settlement. From the result, it is evident that the surface lake water samples consist of suspended particles with size smaller than 300nm and with incipient stability. As the surface charge is negative based on z-potential results, chances for heavy metal to be the suspended particles are higher due to the atmospheric deposition and leaching process in the lake [30, 37, 38].

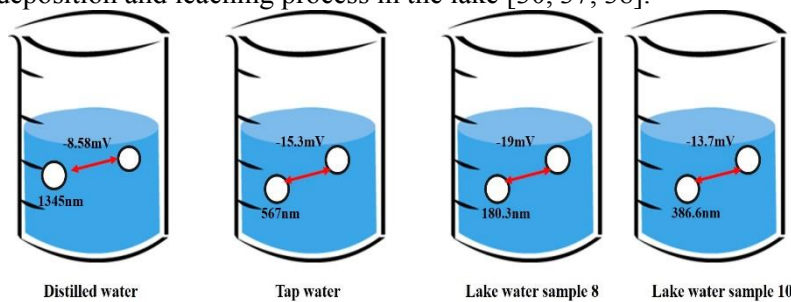


Figure 3. Zeta potential and average size of suspended particles in selected samples.

From the results, we propose that zeta potential can be used for the identification of suspended particle presence in water samples. The particle size distribution along with z-potential will reveal the presence of suspended particles and its ability to agglomerate [39-41]. As the suspended particles are smaller in size, they can easily discharge during the sedimentation and filtration processes which makes them difficult to remove during water treatment [42]. If agglomeration occurs, the size of the particle will increase and eased the filtering process. Figure 3 shows the zeta potential of suspended particles in water samples based on the observed results. From the figure, it is evident that zeta potential plays an important role in the suspended particle analysis and its measurement is believed to be helpful in the water quality monitoring. Moreover, particle size distribution will also contribute in the prediction of larger size particles formation due to agglomeration process.

5. Conclusion

- The presence of suspended particles, its average size and zeta potential was analysed using dynamic light scattering method
- Distilled water was used as reference sample (blank) and the observed results reveals that the higher level of suspended particles in tap water than in drinking water.
- The lake water samples contain smaller suspended particles (lower than 300nm) and their zeta potential discloses that the suspended particles have less chances of agglomeration.
- Thus, it is evident that the suspended particles are smaller in size and free floating in lake water that can affect the aquatic organisms particularly the filter feeding organism.
- Furthermore, we suspect that the negative potential of the suspended particles are due to the presence of heavy metals in the water samples. This can be proved with evidence by heavy metal analysis using atomic absorption spectroscopy which is intended to be performed as future work.

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