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Assessment of Water Quality of Inle Lake and Four Main Streams Flowing into Inle Lake,in Myanmar

Ei Wai Phyo[1*], Cho Cho Thin Kyi[1], Win Win Zin[1]

[1*,1] Department of Civil Engineering, Yangon Technological University,
Gyogone, Insein Road Yangon 11011, Myanmar
Author Email: eiwaiphyo38@gmail.comTel: +9595342343

Robbert De Lange[2*],Thom Bogaard[2]

[2*,2] Department of Civil Engineering Water Management, Delft University of Technology,The Netherlands

Kristin Peters[3*], Nicola Fohrer[3]

[3*,3] Department of Hydrology and Water Resources Management, Kiel University, Germany

1 INTRODUCTION

Freshwater resources provide a large number of ecosystem services constituting a valuable natural resource for humans and biodiversity (Dudgeon et al., 2006; Oki & Kanae, 2006). Yet rivers and lakes are threatened by multiple anthropogenic stressors, such as climate change, salinization, hydro morphological changes, and pollution from various sources (Reid et al., 2019). Worldwide nearly 80% of the population are threatened by reduced access to freshwater (Vörösmarty et al., 2010), which especially applies to the country of Myanmar. Since the economy and people's income largely depend on agriculture with more than 65% living in rural areas, the access to water resources is crucial (Taft & Evers, 2016). However, the country has faced major political and economic changes in the past and it is assumed that current and future socio-economic developments will further pressure the water resources (Kattelus et al., 2014). Furthermore, Myanmar is the second most affected country by climate change over the past two decades (Eckstein et al., 2021) and extreme events such as floods and droughts are predicted to mainly influence the coastal areas and the central dry zone (Taft & Evers, 2016).
The Inle Lake is reported to have faced a serious decline in open water surface area and water quality reduction in the recent years (Furuichi & Wasson, 2011; Michalon et al., 2019; Sidle et al., 2007). The lake is well known for its floating gardens; and the traditional stilt housing and one leg rowing technique of the *Intha* used to attract large numbers of domestic and international tourists (Michalon et al., 2019). Another economic sector at the lake is textile production in a traditional small scale for tourists, but also industrialized factories for export of fabric are present. The direct input of fertilizers and pesticides on the floating gardens, as well as wastewater and solid waste from households, hotels and restaurants and the input of other industrial wastewater is assumed to have degraded the water quality of the Inle Lake (Aung et al., 2019; May, 2007; Re et al., 2018; Swe, 2013; Thin et al., 2020). Nevertheless, there is a lack of sufficient monitoring and data about the current status of the lake's water quality and the main sources of the pollution. This study therefore aims to assess the water quality in the lake and its four main streams considering the spatial variation and socio-economic conditions. The analysis can help to identify the main sources of pollution and serve as a basis for measures against the contamination of the freshwater resources to preserve biodiversity and secure access to clean water for the population at the Inle Lake.

2 MATERIALS AND METHODS

2.1 Study Area

It is located within 96°46́ - 97°.09´ E longitude and 20°05´- 21°17´N latitude in WGS 84 coordinate system. Inle Lake area is surrounded by hilly region of elevation (about 900 to 1800 masl). It is a part of Shan Plateau which has main limestone formation and is situated between Sagaing Active Fault and faults along the Shan scarp. This area has a humid subtropical climate with subtropical highland climate. and is located in the Balu Chaung Valley (884 masl) between the Sindaung (east) and

Letmaunggwe, Thandaung and Udaung mountain ranges. The lake surface is 116km2, however, varying between 150km2 in the rainy season and 100km2 in the dry season. It is a shallow lake, where maximum depth varies between approximately 4m in the dry season and 5-6m in the rainy season. The average depth is approximately 1.5m in the dry season. In 2014-2015 a maximum depth of 3.7m was recorded. The volume of the lake is 790x106m3, with a total water inflow of 1,132x106m3 per year, the retention time can be estimated to be 0.3 years (NIWR2017, referring to IID 2012).

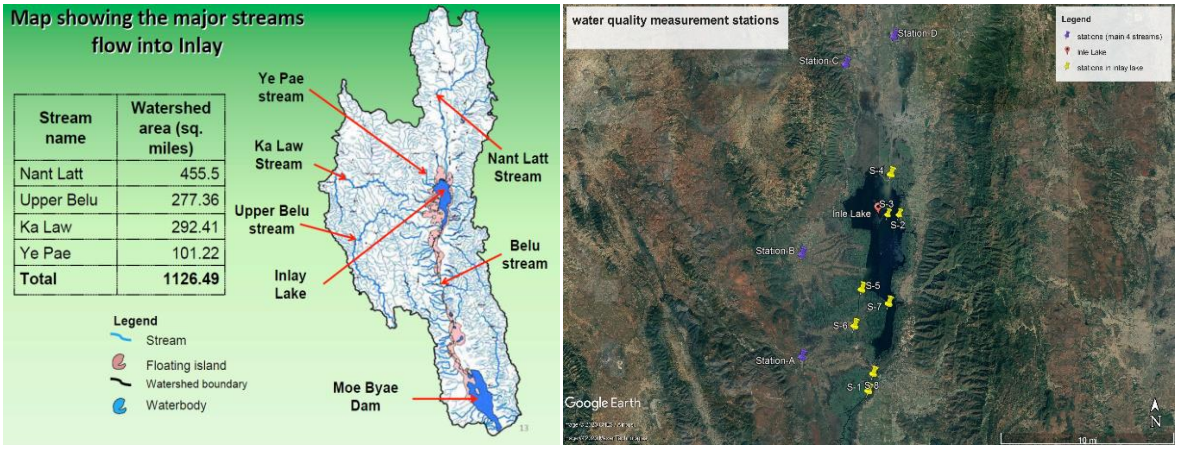


Figure.1. Location of study area, Shan State, Myanmar (MOECAF2014): Figure.2. Location of water quality measurement stations

There are 35 villages within Nyaung Shwe township: 17 of these lie within the lake and 5 lie partly in the lake and partly on land. The remaining 13 villages are situated on land around the lake surroundings. The population was about 160000 and increased about 60 percent within 25 years (source: Department of Rural Development, Shan State Development Committee,2019). In total four major streams drain into the lake: *Nan Lat* from the North, *Ye Pae* from the North-West, *Kalaw* from the West and *Belu* from the South-West. The outflow (*Belu* stream) connects to the downstream *Saga* lake, Moe Byaedam and serves the hydroelectric power plant of *Lawpita* which is a prominent water resource for huge amount of hydropower in country.

2.2 Materials and Methods

Based on environmental survey, there are eight stations in the lake and four main streams stations. To consider the comprehensive measures, a total of three water quality measurements in the lake were undertaken in 3-4 December 2019(the first) ,11-13 February 2020 (the second) and 15-16 March (the third). At second and third time, water samples were collected at four main streams stations to compare with lake water quality status. The water samples were collected for three time and all samples transported to Alarm Ecological Laboratory (Yangon) during 24 hours for analysis. There are 18 water quality parameters measured (Physical characteristic: temperature, turbidity, TDS, TSS, TS, conductivity, color, Chemical characteristics: pH, total hardness, DO, COD, BOD, nitrate-nitrogen, total alkalinity, manganese, arsenic, phosphorous, Biological Characteristic: total coliform). During the field survey, some physicochemical parameters (pH, temperature, TDS, conductivity and DO) were measured in situ by using Hawkeye Sonar, CDT diver and cup, GMH3400 meter [69], the multimeter instrument (Senso Direct150), etc. At second time, spatial water quality measurement was made around 8 stations by Rt4 bait boat equipped with measuring devices (source: Robbert De Lange 2020).[In this study, the lab water sample results are compared with WHO standard for drinking water(2011),US EPA drinking water standard 2018,proposed national drinking water standards, Ministry of Health ,(sep,2014)and National Environmental Quality (Emission)Guidelines, order No(61/2015)(MOECAF,29dec2015) and Malaysia water quality standard for surface water (Class IIA, Class IV).]

Table 1. Location of Stations in Inle Lake and Four Main Streams

No.	Locations	Latitude (N)	Longitude (E)	Reasons
S-1	Maing-Pyo Village	20.4327	96.8996	near outflow
S-2	b/w Sky lake &Paradise Hotel	20.5773	96.9272	b/w two floating hotels
S-3	Rest House	20.57738	96.9271	center of lake
S-4	Nyaung Shwe's Canal	20.6092	96.9196	Inflow
S-5	Nga- Phe -Chaung	20.5162	96.8936	chemical free zone
S-6	Ywar Ma Village	20.4857	96.8873	gold /silver smith
S-7	Kay La Village	20.5040	96.9177	floating garden
S-8	Inn Paw Khone Village	20.4467	96.9039	weaving village
S-A	Indein Weir	20.4601	96.8403	inflow of Inle lake
S-B	Kalaw stream	20.5438	96.8402	inflow of Inle lake
S-C	Yay Pel Stream	20.6985	96.8402	inflow of Inle lake
S-D	Nant latt Stream	20.712	96.9222	inflow of Inle lake

3 RESULTS AND DISCUSSION

Water Depth and Colour

The average water depth at 8 stations of the first, second and third survey was 1.2m,1.6m,2.3m,1.5m,1.13m,1.2,1.6m and1.3m respectively (dry season). Water colour of the lake is noticeable different because of water depth and sedimentation. Colour ranges from 5to 1160 HU in lake and from 0 to 73HU at streams.

Water Temperature

The study area has a humid subtropical highland climate and lake water temperature ranges 19-33˚ ℃.

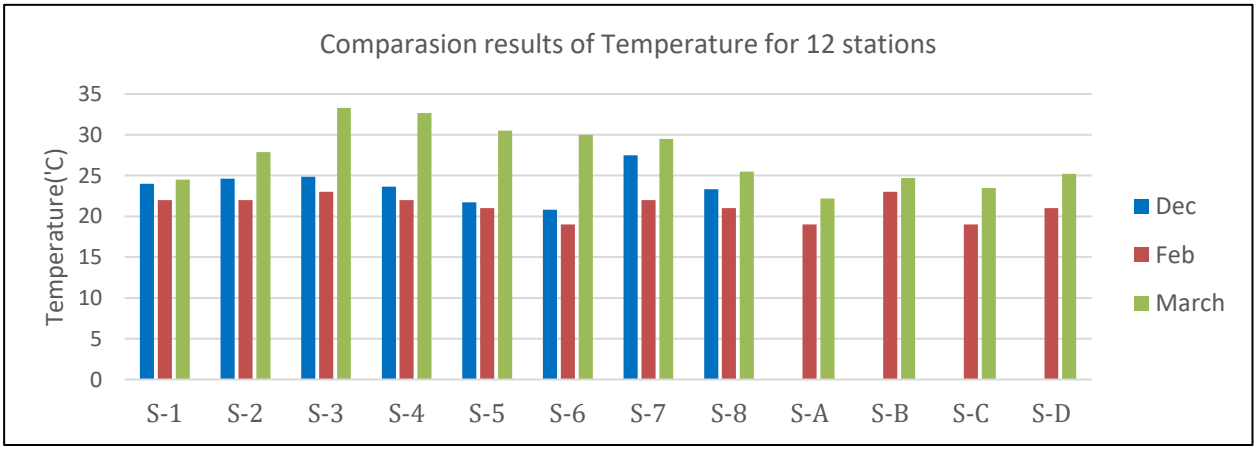


Figure.3. Comparison results of temperature for 12 stations

pH

pH is an important parameter which determine the stability of water for various purpose. The value of pH in water samples of all station is over 7. The results are acceptable by comparing with the permissible limit.

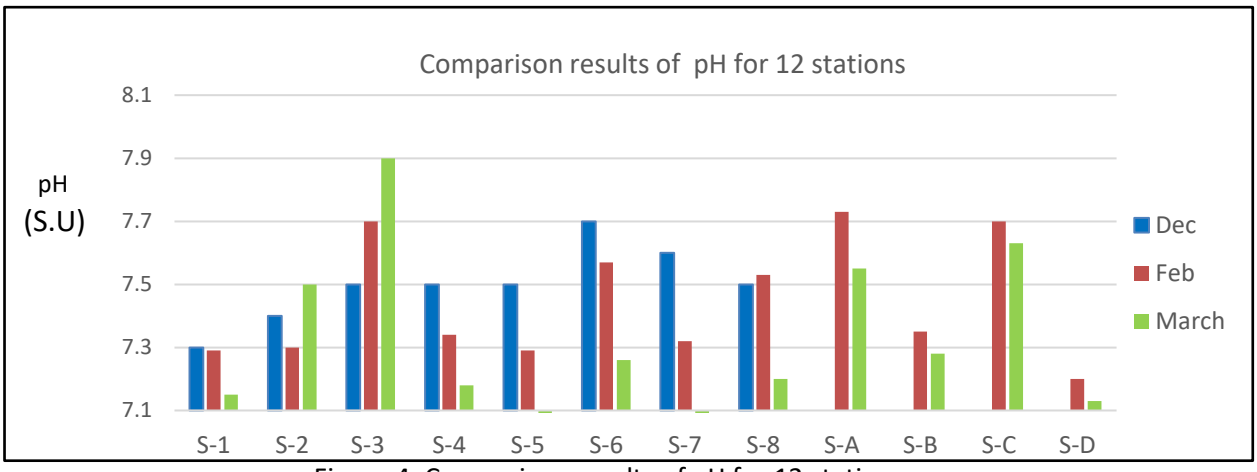


Figure.4. Comparison results of pH for 12 stations

Turbidity

The result of Turbidity values ranges from 5 to 241FAU. Thus, most of the result are higher than the permissible limit expect station 2,3,7 and A.

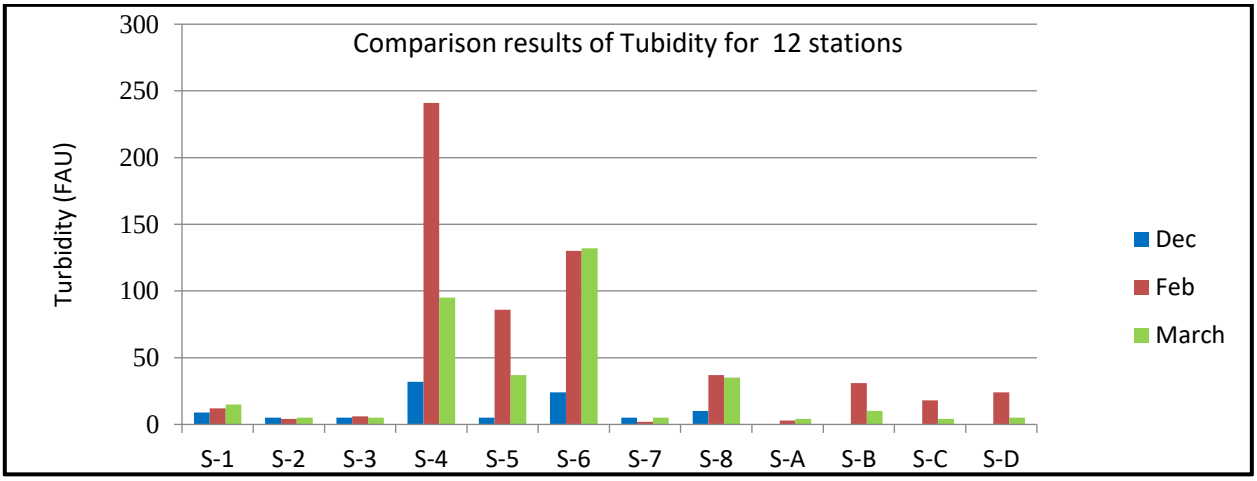


Figure.5. Comparison results of Turbidity for 12 stations

Hardness and Alkalinity

Hardness of Inle lake is high because it is a part of Shan Plateau which has main limestone formation. It ranges from 140 ton363 mg/l. Alkalinity ranges from 185 to 840mg/l.

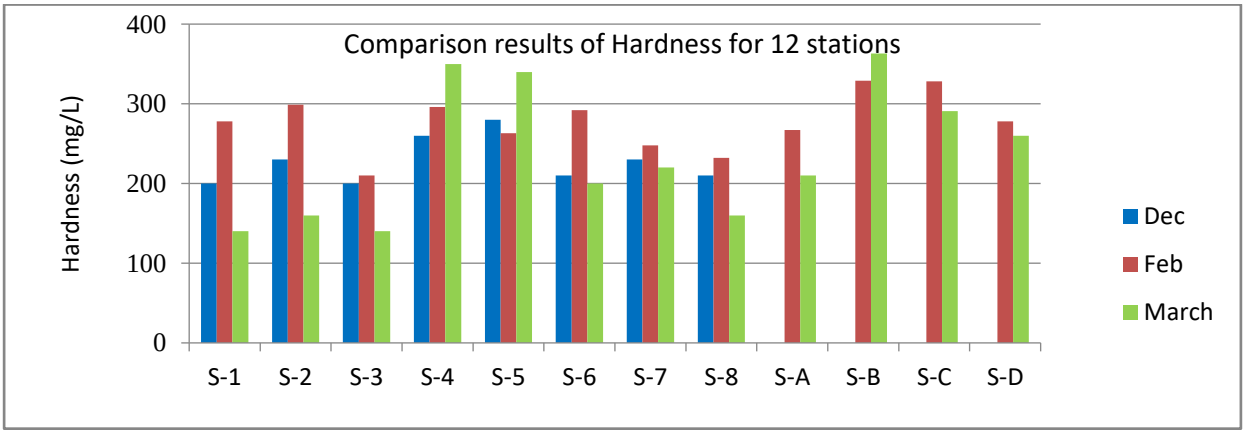


Figure.6. Comparison results of Hardness for 12 stations

Total Dissolved Solid, Total Suspended Solid, Total Solid

TDS represents the total concentration of dissolved substances in water. Result of total dissolved solid in all stations are lower than the standard limit. TSS ranges from 0 to 129 m/l and TS ranges from 172 to 409 mg/l.

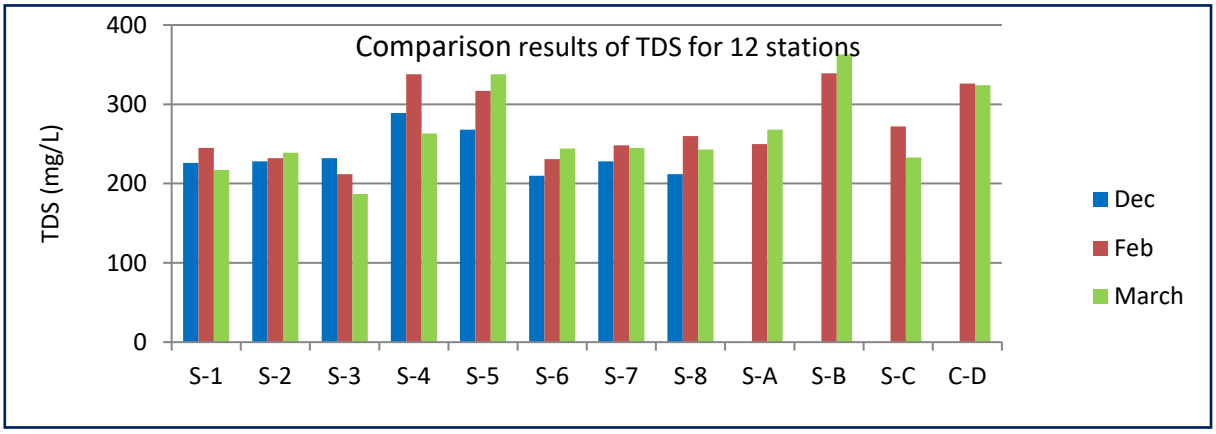


Figure.7. Comparison results of TDS for 12 stations

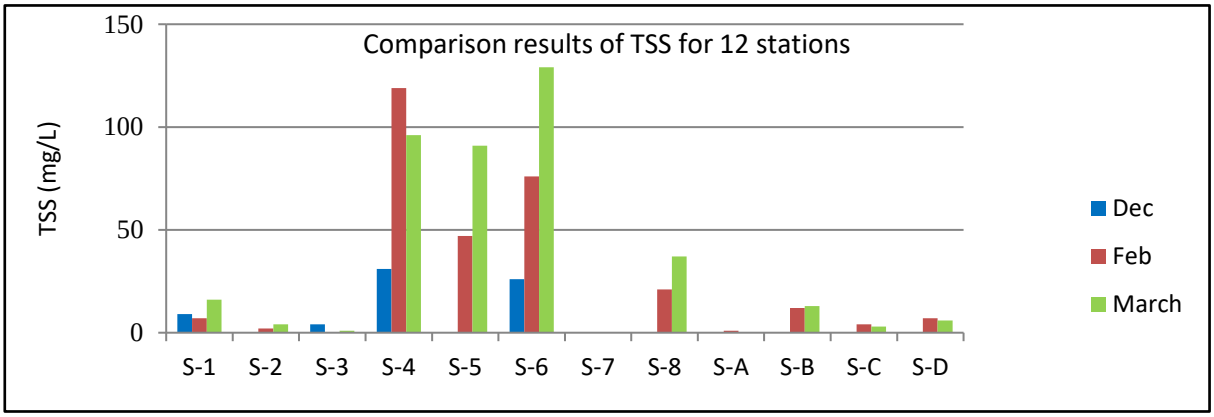


Figure.8. Comparison results of TSS for 12 stations

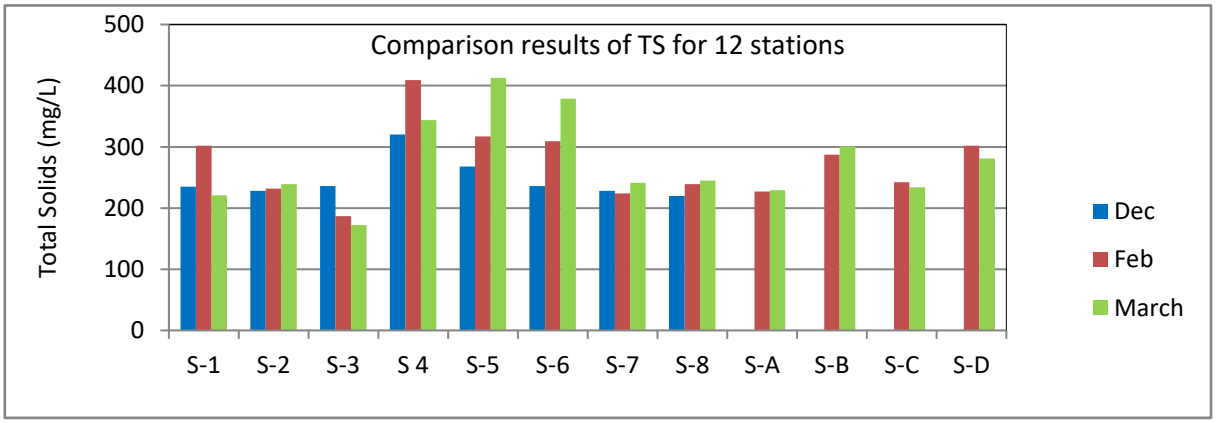
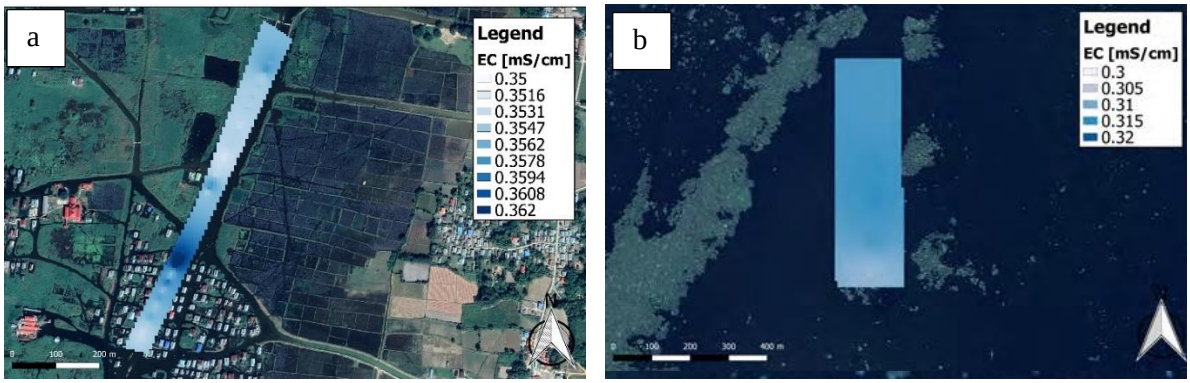


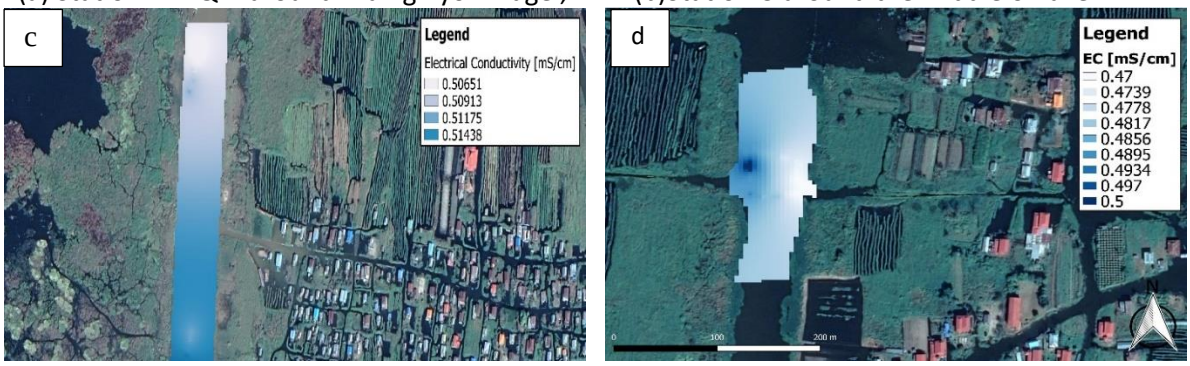
Figure.9. Comparison results of TS for 12 stations

Electrical Conductivity

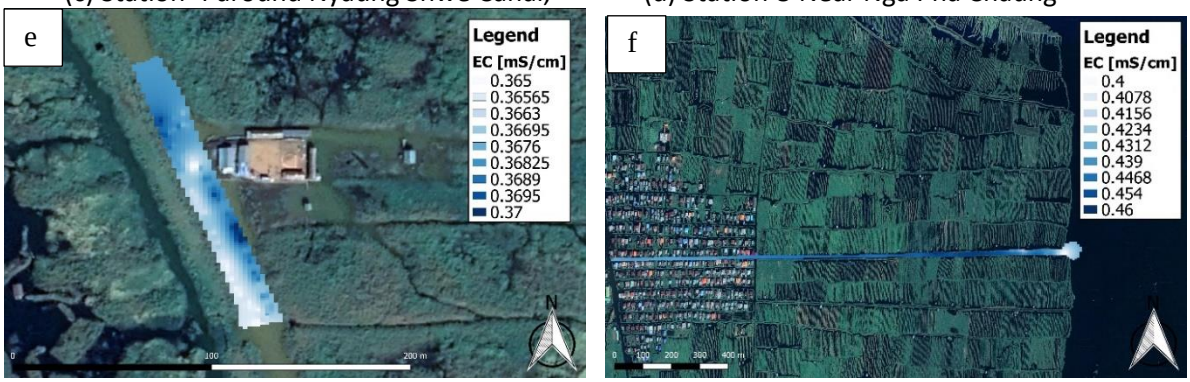
Electrical Conductivity (EC) measures the water's ability to conduct electricity, which provides a measure of what is dissolved in water and a higher conductivity value indicates that there are more chemicals dissolved in the water. It ranges from 0.3 to 0.5 mS/cm at 12 stations.



(a) Station-1 WQM around Maing Pyo Village , (b)Station-3 around the middle of lake



(c) Station-4 around Nyaung Shwe Canal, (d) Station-5 Near Nga Pha Chaung



(e) Station-6 Near Yoma Village, (f) Station-7 along Kela Village

Figure.10. Water Quality Measurement (Source: Robbert De Lange report)

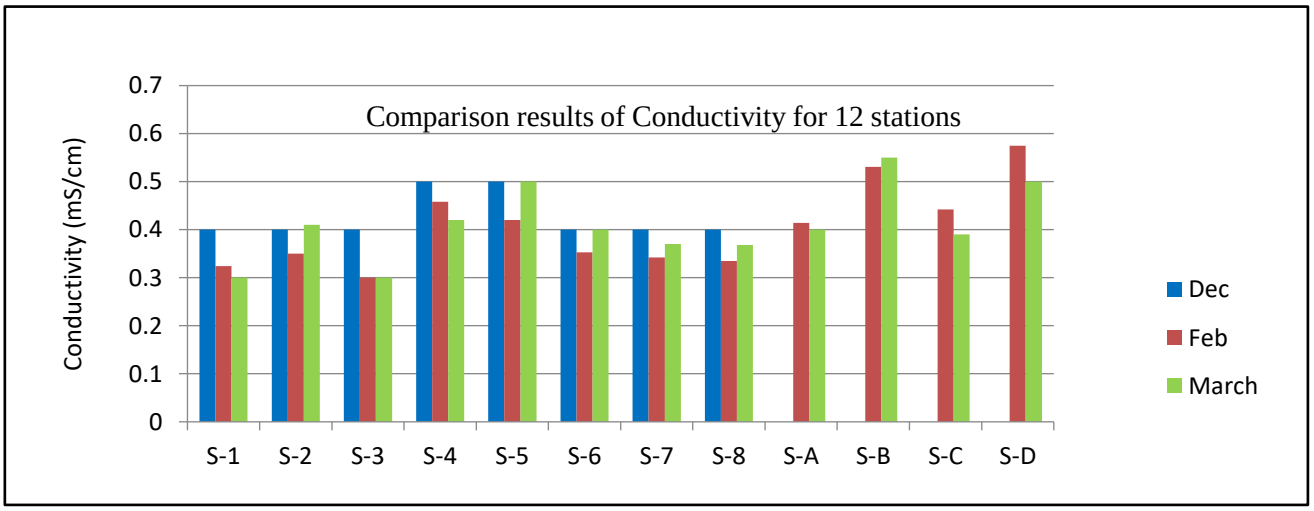
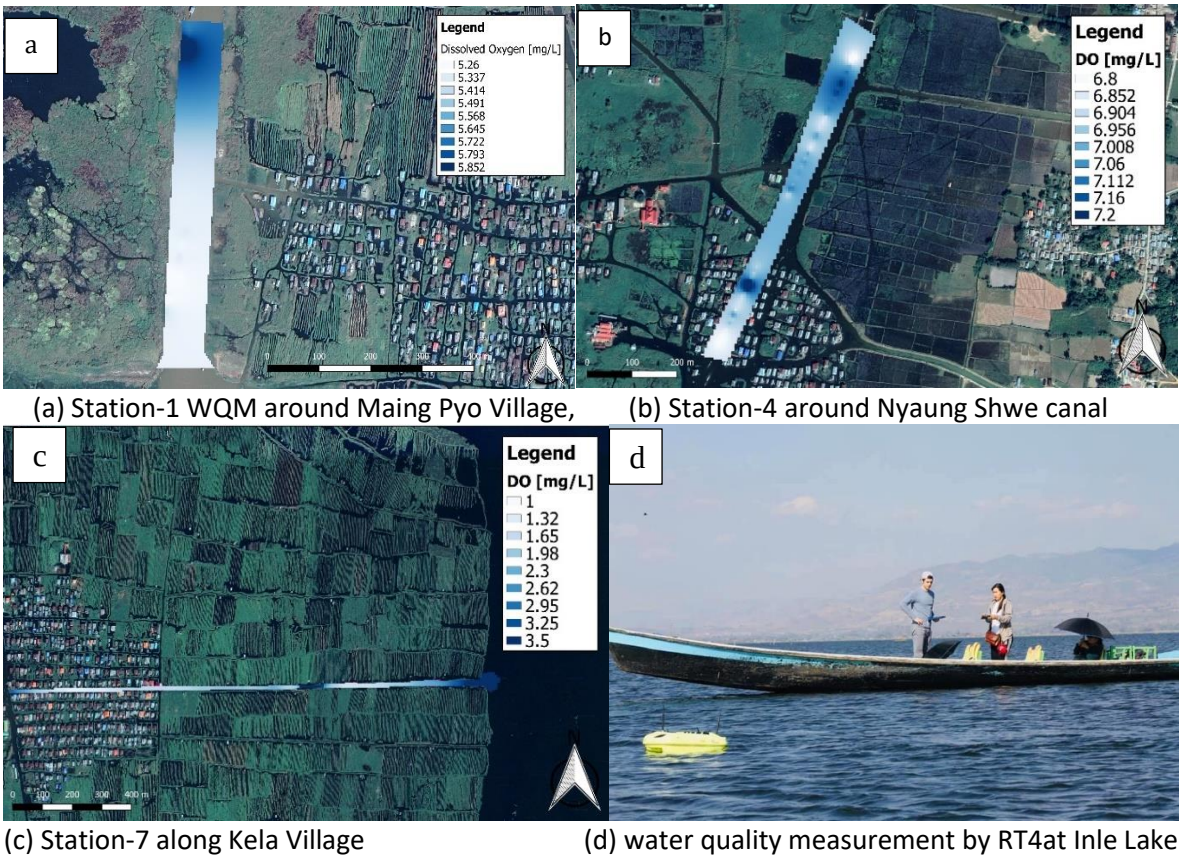


Figure.11. Comparison results of Electrical Conductivity for 12 stations

Dissolved Oxygen (mg/l),Electrical Conductivity(µs/cm) ,Chlorophll-A(µg/L) and Cyanobatetria (µg/L) were measured with Rt4.From Rt4 boat survey result, EC ranges from 2.9 to 3.15 µs/cm around Maing Pyo village (Station 1), from 0.3 to 0.32 µs/cm around the middle of the lake(station 3),from 0.5 to 0.52 µs/cm along Naung shwe canal (station 4),from 0.47 to 0.49 µs/cm near Nge Phae Chaung(Station 5),from 0.365 to 0.37 µs/cm near Yoma Village(Station 6) and from 0.4to0.45 between Kela village and floating garden (Station 7).(Source: Robbert De Lange report)

Dissolved Oxygen

The presence of dissolved oxygen is essential to maintain the higher forms of biological life and to keep proper balance of various pollutions thus making the water bodies healthy.DO ranges 5 to 21.2 mg/l. From Rt4 boat survey result, DO ranges from 6.8to 7.2 µs/cm around Maing Pyo village (Station 1), from 7.5 to 9 µs/cm around the middle of the lake(station 3),from 5.26 to 5.852µs/cm along Naung shwe canal (station 4),from 4.2to 4.65 µs/cm near Nge Phae Chaung(Station 5),from 5.9 to 6.65 µs/cm near Yoma Village(Station 6) and from 1to3.5 µs/cm between Kela village and floating garden and from 2.9 to 3.2 µs/cm within floating garden (Station 7).(Source: Robbert De Lange report)



(a) Station-1 WQM around Maing Pyo Village, (b) Station-4 around Nyaung Shwe canal

(c) Station-7 along Kela Village (d) water quality measurement by RT4at Inle Lake

Figure.12. Water Quality Measurement (Source: Robbert De Lange report)

COD

COD is the total concentration of chemical determination in water bodies and the result of most stations less than 30mg/l but station 4 is 39mg/l at second time; station 5 is 31 mg/l and station 6 is 32 at third time.

BOD

Most of BOD results (from 3 to 7.5mg/L) are higher than the standard limit of Class II. The higher the BOD, the higher the amount of organic matter or 'food' available for oxygen consuming bacteria.

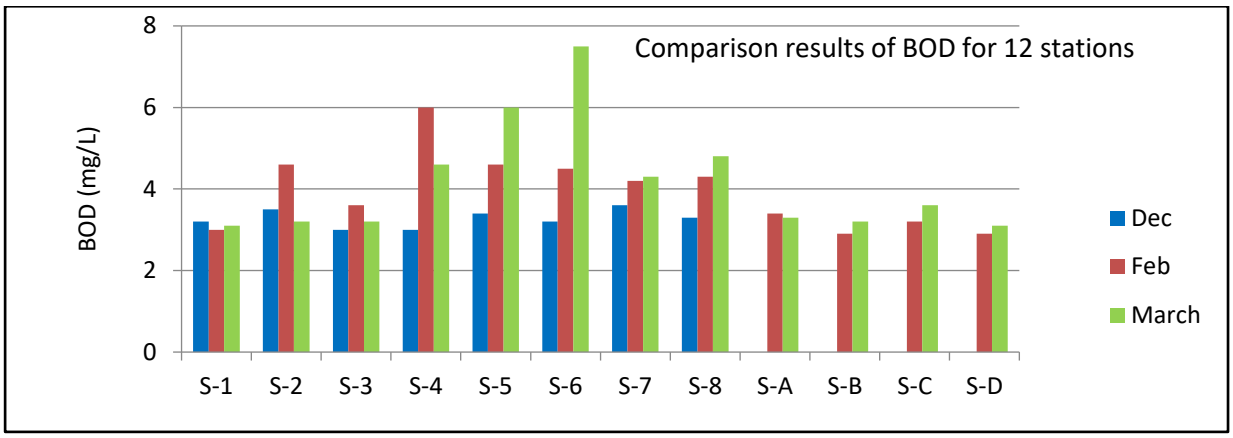


Figure.13. Comparison results of BOD for 12 stations

Phosphorus, Arsenic and Manganese, Nitrate-Nitrogen, Total Coliform

Phosphorus has a direct effect on plant and algae growth in lakes. The more phosphorus is available, the more plants and algae are in the lake.The results of Phosphors ranges 3.3 to 6.8 mg/l at 8 stations .But second and third time results are less than 0.2 mg/l First time result of Arsenic at station 3 and 8 are 0.05mg/l over the standard limit and second and third results of all station is below the limit. Second time and third result of Manganese at station 4 and 8 are 0.46 and 0.42mg/l and first and third results of station 6 are 0.5 mg/l over the standard limit. Other stations are below the limit.In this study, the results of nitrate nitrogen are between 0.02mg/L and 11 mg/l in lake and less than 2.6 mg/L at the main stream stations . Total Coliform is primary indicator of suitability for consumption of drinking water. The result of most of station in lake are greater than 1100 MPL/100ML expect station2.

4 CONCLUSIONS

The study area is one of the most valuable existences in Myanmar and it is therefore important to monitor and manage the water quality. From field surveys and water quality results, the levels of arsenic, manganese and phosphorus were above the permissible limit at some stations. According to the water level measuring records, the water depths of the lake are lowering over time and it increases the turbidity of the water. This raises the main point to consider the question on how to control sedimentation in the lake. Another observation is that most villages had sanitary waste water systems (bio-tech), but some villages had poor sanitary waste water systems. At the most stations in lake, total coliform count was found more than 1100 MPN/100 mL. The immediate attention should also be paid on the problems of the construction and management of floating gardens if the open lake area and water quality are to be preserved . Due to many factors the water quality of Inle Lake is changing and it should be checked seasonally and spatially. Concluding, the continuous monitoring of the Inle Lake is required in the district to protect the water quality in the future from any possible contamination due to population growth, increasing industrialization and agricultural practices, etc. Water quality of Inle lake are one of the primary issues to be considered in the long-term integrated water management system for the Inle basin.

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