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Bera Lake water quality, past and present situation

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Abstract

Bera Lake is the largest natural fresh water reservoir in Malaysia. It has vital environmental and ecological importance for human and wild life. Nevertheless, water quality of this lake has been degraded during the last few decades due to land development projects at catchment area. Therefore, a comprehensive water quality assessment of Bera Lake was implemented in order to compare current water quality with the implementation of land development projects. *In situ* water quality surveying was implemented using calibrated full option Hydrolab DS 5. Eleven parameters viz., temperature, depth of sampling, salinity, Turbidity, total dried solid, pH, $NH4^+$, $NO3^-$, Cl^-, saturation percentage of dissolved oxygen, specific conductivity were recorded in fifty one stations at 0.2h, 0.5h, and 0.8h depth. National Water Quality Standards for Malaysia (NWQS) and Water Quality were used to evaluate Bera Lake quality based on previous and resultant data. Vertical water quality analysis revealed a clear stratification in Bera Lake water profile in terms of temperature, dissolved oxygen, chloride (Cl^-), nitrate (NO_3^-), pH and specific conductivity (EC) parameters. Results clearly demonstrate the important role of land use changes since 1972 in the physico-chemical condition of water quality at Bera Lake. Classifications of water quality before and after land development project were calculated as class II and class V, respectively. A long-term and comprehensive monitoring of water quality assessment is recommended in order to reach plan of sustainable water resources use with conservation approach.

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Introduction

Inland fresh water bodies play an important role in human, animals and aquatic lives. These have been recognized as source of drinking water and several activities like fishery, recreation, agriculture, industry and navigation. Bera Lake is the largest natural fresh water reservoir in Malaysia and has vital environmental and ecological importance for human and wild life. However, long-term water quality has not been recorded in Bera Lake Catchment. In addition, few records of water quality by RAMSAR site, available in some cross sections along the Bera Lake have been reported but not published. Evaluation of water quality of Malaysian lakes has been the target of several research contribution (Sharip *et al*., 2014; Ashraf *et al*., 2010; DID, 2009; Shuhaimi-Othman *et al*., 2007). Previous studies mainly have applied the Interim National Water Quality Standard, Malaysia (INWQS) to qualify and classify water quality of lakes. The latest results (Sharip *et al*., 2014) indicat that majority of lakes of Malaysia are classified as Class II

(Clean) water suitable for recreational use. The results of the trophic state assessments, however, indicate that all the lakes are eutrophic, i.e. nutrient-rich, and experience algal blooms or macrophyte problems exhibiting poor water quality. Water quality at the second important natural lakes in Pahang state, Chini Lake was studied by Shahumi-Othman *et al*. (2007). In general, water quality in Chini Lake varied temporally and spatially and the most affected water quality parameters were TSS, turbidity, chlorophyll-a, sulphate, DO, ammonia-N, pH and conductivity. Soil and water interaction is the most important phenomenon in nature, especially in lakes which play considerable role in water quality. Gharibreza *et al*. (2012 and 2013) revealed situation of sediment contaminations in the south, middle and north of Bera Lake. These studies indicate that bottom-dwelling decomposing bacteria begins to die; whereas, leaf litter, dead plant and animal materials are deposited. Aquatic life is threatened by some toxic metals especially As, Fe, and Cr, whose values exceed severe effective levels (SEL).

The most reliable water quality report has been published by Malaysian-Japanese committee prior to land development projects (IBP, 1972). This water quality analysis revealed that the area of open water adjacent to Pos Iskandar at the center of catchment is degraded.

Study area : Bera Lake catchment, which is located in the central part of Peninsular Malaysia, in southwestern Pahang State and northeastern Negeri Sembilan State was selected as study area. The latest physiographic data of this catchment was obtained by Geographical Information System (GIS), digital topographic maps of 1:25,000 scale (Series L8028) and a satellite image (Spot 5, 2009) of spatial resolution 10m. The total catchment area was determined as 593.1 km^2 that covered clear land, rubber and oil palm plantations covering some 340 km^2 and open water involving some 0.54 km^2 (Fig. 1). The remaining area was covered by wetlands and pristine (forest and reed swamps) lowland rain forests (Wüst and Bustin, 2004).

The Bera Lake catchment can be separated into 12 sub-catchments with open water located in its northernmost part and in sub-catchment 3. The overall flow of streams is northwards with sub-catchments 4 to 12 draining into the south end of Bera Lake. Two other streams from sub-catchment 1 (Kelangton stream) and 2, drain into the middle and northern parts of the Lake respectively. Bera Lake drains through an outlet stream in its northern most part into the Bera River which flows northwards into the Pahang River.

Studies on the Bera Lake catchment and its open water started in 1961 owing to its scientific, anthropological and agricultural importance. Bera Lake, being the largest natural lake in Malaysia, has been studied in terms of biological aspects by Merton (1962), Furtado and Moris (1982), Ikusima *et al*. (1982), and Giesen (1998), while its palynological history, and anthropological aspects, have been investigated by Morley (1981) and Surut (1998).

The geological setting and evolution of Bera Lake Basin, as well as deposition of peat and more recent palynological aspects have been studied by Wust and Bustin (1999), Phillips *et al*. (1998) and Wust *et al*. (2001, 2002, 2003, 2004, and 2008). Wust *et al*. (2004) reported that the bedrock of the basin consist of Lower Carboniferous to Triassic marine sedimentary rocks that are unconformably overlain by Jurassic to Cretaceous continental sedimentary rocks and Quaternary alluvium.

The climate of Peninsular Malaysia, including the Bera Lake catchment area, is humid tropical with two monsoon periods. Heavy rainfall is received during the

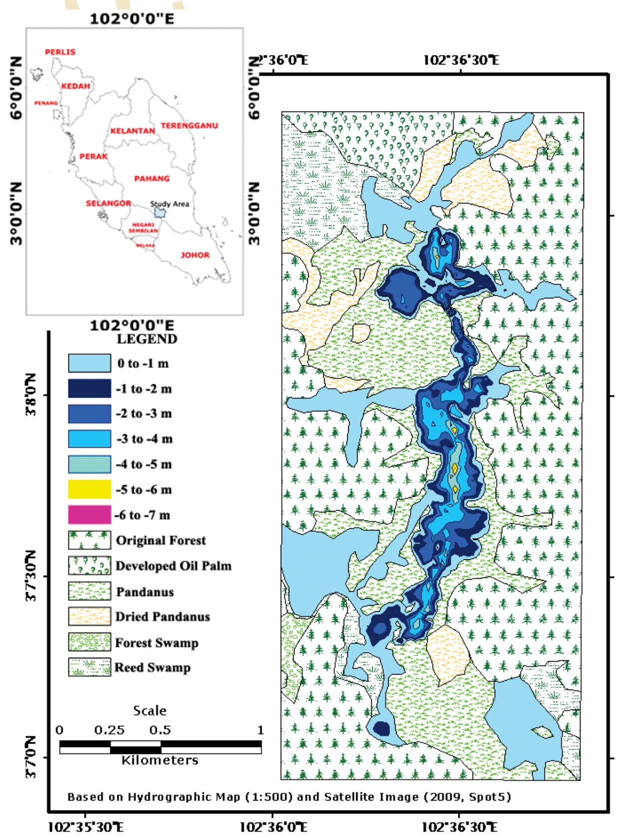

Fig. 1 : Geographical location and morphology of Bera Lake

Northeast (November to March), and Southwest Monsoons (June to August) while in the months of April-May and September-October, less rain is received. Mean annual temperature is approximately 30°C and varies, varying from 25°C to 38°C (Chee, 1998). Rainfall records from 1970 to 2009 at the Fort Iskandar station, which is located at the mid-point of the Bera Lake catchment indicate that minimum and maximum annual rainfall is between 1,000 and 2,602 mm. Field observations and laboratory analyses show the soils of the Bera Lake catchment are Ferralsols. The soils are brownish yellow, yellow and red in colors, overlaying on the Jurassic to Cretaceous continental sedimentary rocks. These Ferrasols have maximum, and average thickness of 1 and 0.2 m, respectively. Organic-rich clays and peat are also found in the central part and along the main channel of Bera Lake. Evaluation of available data about Bera Lake water quality showed that most of the published reports are on water quality published by Malaysian-Japanese committee (IBP, 1972) prior to FELDA land development projects. Presently, the directory of RAMSAR site has been under taken water samples from 5 stations were collected. Several attempts to access the resultant data were not successful. As a result, lack of reliable water quality information, especially previous land development projects have encouraged to conduct Bera Lake water quality assessment comprehensively.

Materials and Methods

Assessment of *in-situ* water quality : The water quality was estimated by fully automated Hydrolab DS 5 USA (Fig. 2). Eleven parameters *viz.* temperature, depth of sampling, salinity, Turbidity, total dried solid, pH, NH_4^+, $NO3^-$, Cl^-, saturation percent of dissolved oxygen, dissolved oxygen, specific conductivity were recorded at three levels of 0.2, 0.5, and 0.8h. *Insitu* water quality was recorded in the 100 x 100 m network, based on the quality of open waters.

Water quality maps : Nine hundred records of water quality parameters at three different depths were categorized and exported into spatial modeling and interpolation techniques (Ordinary Point Kriging) to develop individual map of each parameter. Initial water quality maps were developed by Golden Software Surfer 7.0 and complementary mapping procedure was implemented by ArcGIS 9.2 software.

Results and Discussion

The most reliable water quality report was published by Malaysian-Japanese committee prior to land development projects (IBP, 1972). This water quality analysis revealed that the area of open water adjacent to Pos Iskandar at the center of catchment was degraded. The results are presented in Table 1. According to IBP (1972) the mean TN, NO_3^{2-}, NO_2^{-1}, NH_4^{+1} and organic nitrogen level was 1.12, 0.11, 0.008, 0.33, and 0.58 mg l^{-1}, respectively. The mean PO_4 concentration was 0.021 mg^{-1} (between 0.00 and 0.065). The ratio of reactive to un-reactive phosphorus was 1/21 on the average. The mean value of water quality characters and their graphical distribution of some important parameters are illustrated in Fig. 3 to 7.

Water temperature is one of the climatic effect parameters which significantly affects kinds of aquatic life, regulates maximum DO value of water, and influences the rate of chemical and biological reactions. Seasonal water temperature controls age of organism and life stage and higher biological and chemical reactions are expected in higher water temperature (Brian, 2010). *Insitu* water analyses showed that Bera Lake mean water temperature was less than 5 ºC.

Vertical water quality analysis revealed a clear evidence of stratification in Bera Lake water profile in terms of temperature, DO, Cl^{-1}, NO_3^{2-}, pH and EC (Fig 7). Clear downward reduction of DO in Bera Lake water profile indicated effect of temperature. Maximum coefficient of variation (0.5) was obtained for vertical variation of DO. Dissolved oxygen appeared with different concentration in Bera Lake (Fig. 3) and varied with depth. The lowest DO values were recorded at the south and northeast open waters which probably had a weak water circulation and was partially restricted by some plant species such as *Pandanus*.

Fig. 2 : Surveying of Bera Lake water qualities by Hydrolab DS5 apparatus

Table 1 : Water quality characters of Pos Iskandar open water, IBP, 1972

Depth (m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ph	4.8	4.9	4.7	5.0	4.8	5.0	5.1	5.0	4.8	4.9	4.8	4.8
Transparency (m)	1.2	1.5	1.6	1.7	2.0	1.9	2.1	1.8	2.7	2.5	2.2	2.1
Do (mg l^{-1})	1.1	1.3	1.5	1.3	1.7	2.0	2.4	2.7	2.3	2.3	2.3	1.7

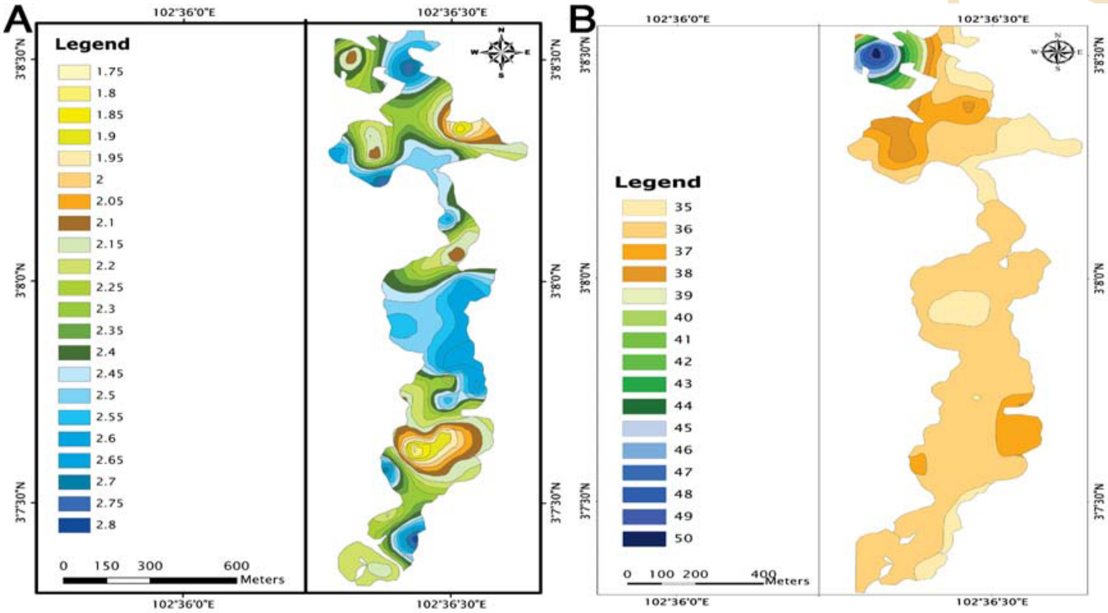

Fig. 3 : Estimation of DO (mg l^{-1}) and EC (mS cm^{-1}) in Bera Lake

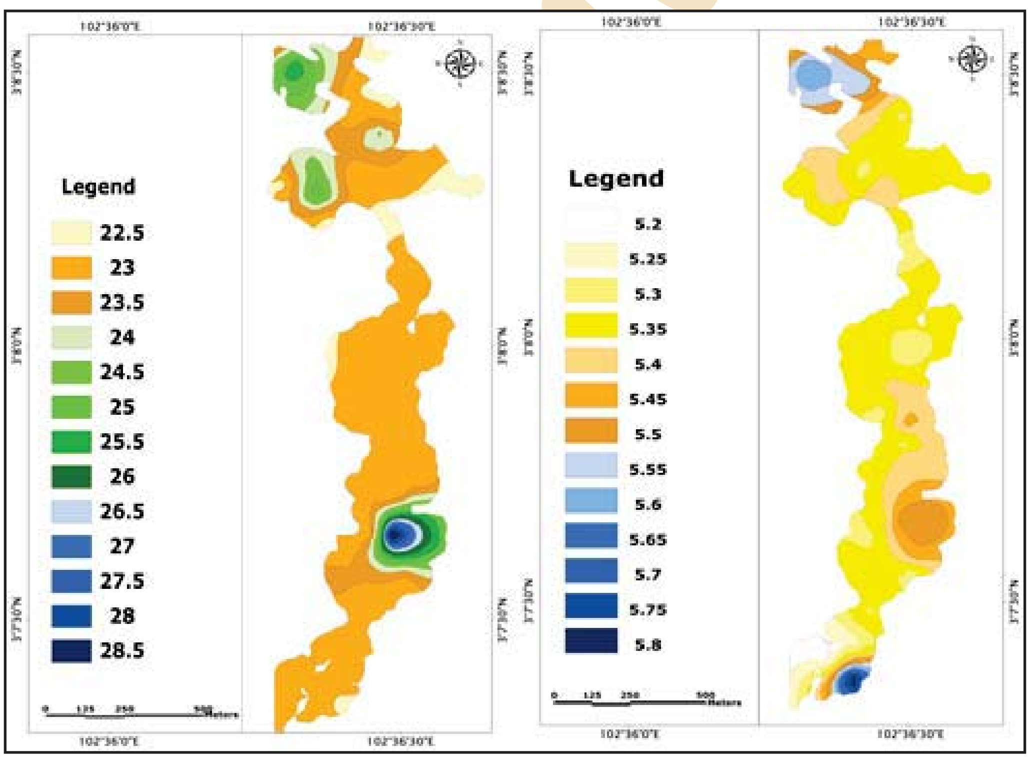

Fig. 4 : TDS (mg l^{-1}) levels and water acidity (pH) in Bera Lake

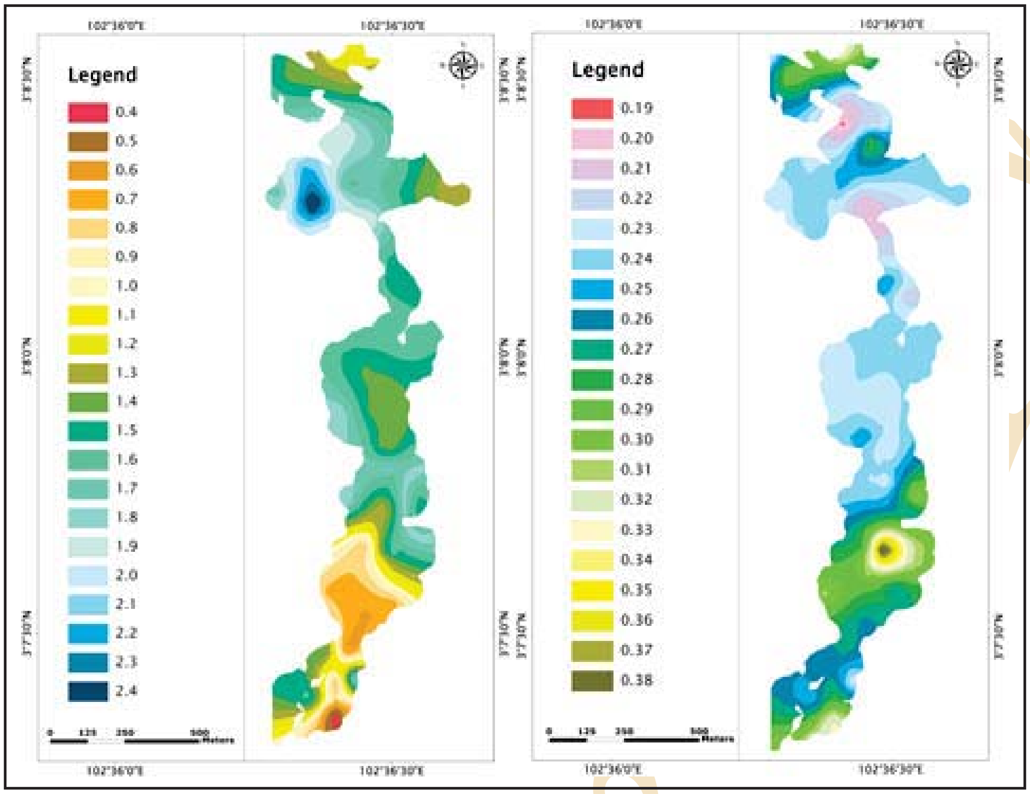

Fig. 5 : NO_3^{2-} (mg l^{-1}) and Ammonia levels in Bera Lake

These areas were recognized unsuitable locations for biological activities. The mean DO value (2.38 mg l^{-1}) recorded may adversely affect the functioning and survival of biological communities. As observed, the microbial activity (respiration) enhanced during degradation of organic and nutrients rich waste water and that resulted in DO values reduction (Chapman, 1996).

Fig. 4 depicts that Bera Lake water was moderately homogenous in terms of electrical conductivity and total dissolved solid except for the northwest part or Kelantong water entry point. A significant correlation between distribution of TDS and EC values was recorded in Bera Lake. Minimum variation in EC and TDS values were recorded in vertical water profile. A dramatic increase in EC and TDS gives an indication of polluted water (Chapman, 1996). In addition, semi-closed open waters and reed swamp at northwest of Bera Lake represent high evaporation and increase in total dissolved solid, as well as electrical conductivity.

The acidity of water depends on strong mineral acids, weak acids such as carbonic, humic and fulvic and hydrolyzing salts of metals (e.g iron, aluminum) as well as strong acids. Bera Lake represents acidic condition with the mean average of 5.39. In such condition bottom-dwelling decomposing bacteria begins to die and leaf litter and dead plant and animal materials are deposited. With regards to heavy metals, the degree to which they are soluble usually determine their toxicity. Lower the pH, more is the toxicity of metal as they are more soluble. Solubility refers to the amount that can be dissolved in water (Chapman, 1996). Slightly downward increase having CV of 0.02 in water acidity was observed at Bera Lake. Distribution of acidity in Bera Lake was uniform except at the southern and northern part and at sediment entry points, while it slightly increased at the eastern part of southern basin. A clear correlation between pH and EC was obtained at the southern part of Bera Lake, which indicate an effluent plum or discharge into the open water. Similar to DO, increase in acidity at surface water was controlled by high temperature and photosynthesis.

Another parameter which represents Bera Lake water quality was NO_3^{2-} (Fig, 5) which is the common form of combined nitrogen found in natural waters. Natural sources of NO_3^{2-} in surface waters includes igneous rocks, land drainage and plant and animal debris. In lakes, concentration of NO_3^{2-} in excess of 0.2 mg l^{-1} NO_3^{2-} tends to stimulate algal growth and indicates possible eutrophic conditions

(Chapman, 1996). The mean average of NO_3^{2-} was 1.49 mg l^{-1} which is an indicator of moderate eutrophication in Bera Lake. Chapman (1996) stated that land clearing and plough for cultivation increased soil aeration resulting in enhancement of nitrifying bacterial action and production of soil NO_3^{2-}. Furthermore, burning of felled trees released a large amount of nitrogen, especially after the first heavy raining to the sink areas (Field, 2000). Both mechanisms happened in BLC since 1972 in which half of the study area was cleared, disturbed and felled trees were burnt. The optimum concentration of NO_3^{2-} (Fig, 5) was recorded at semi-closed open waters in the northwest of Bera Lake. Rest of the lake represents an acceptable range between 0.4-1.9 mg l^{-1}. Bera Lake water column appeared as stratified and upward increasing trend of NO_3^{2-} concentration. According to Chapman (1996), natural occurrence of ammonia in water bodies promote the breakdown of nitrogenous organic and inorganic matter in soil and water, excretion by biota, reduction of nitrogenous gas in water by micro-organisms and exchange of gas with in the atmosphere. The obtained mean average of ammonia was 0.26 mg l^{-1}. Bera Lake water profile represents clear downward reduction in ammonia with a coefficient variation 0.51, in which ammonia value depleted twice with depth. Chapman (1996) stated that ammonia plays an important role in creation of toxic condition for aquatic life and it is detrimental for the ecological balance of open waters at certain pH levels. Higher concentration of ammonia and pH was observed at surface water in the Bera Lake. The mean average value of ammonia content is an indication of organic pollution by agriculture or industrial sewages and fertilizer run-off at BLC area. Chlorine enters surface water with the atmospheric deposition of oceanic aerosols by weathering of some sedimentary rocks (mostly rock salt deposits) and from industrial and sewage effluents and agricultural, as well as road run-off (Chapman, 1996). Minimum Cl^- value was recorded at the southern water entry point and at the departure point of Bera Lake (Fig. 6). Conversely, Cl^- highest value was obtained at the northern open water especially at the end of connection channel. There was a vivid downward increase in Cl^- concentration with coefficient variation of 0.25. Probably, increase of Cl^- and NO_3^{2-} are two active ions in Bera Lake water column, which points out a significant correlation with anoxic condition and lowest DO. National Water Quality Standards for Malaysia (NWQS) (DOE, 2006) and Water Quality Index (Brian, 2010) were used as standards to evaluate Bera Lake quality (Table 2). Overall classification of Bera Lake water quality during and after land development project is classified as IV and V, which is suitable for irrigation only and requires extensive treatment for drinking.

Comprehensive survey of water quality variables in the Bera Lake unveiled the trend of water pollution in the recent decades. Resultant data was properly confirmed capability of methods that was applied in the present study. A clear stratification in Bera Lake water profile in terms of temperature, DO, Cl^{-1}, NO_3^{2-}, pH, and EC parameters, points out weak water circulation and partially water trapping by some plant species such as *Pandanus*. Continues interaction of sediment and water in the study area, provided a situation in which toxic metals are released in water column by seasonal time scale. Aquatic life is threatened by some toxic metals especially As, Fe, and Cr, whose values exceed severe effective levels (SEL). With regards to heavy metals, the degrees to which they are soluble usually determine their toxicity. The low pH value of water column in the Bera Lake indicates the more toxicity due to metals as they are more

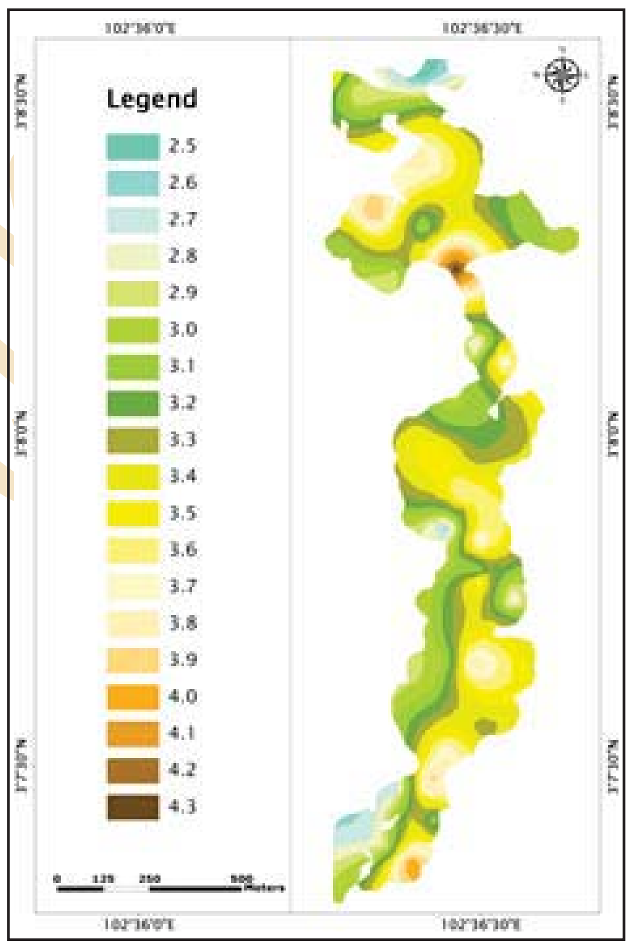

Fig. 6 : Chloride (mg l^{-1}) level in Bera Lake

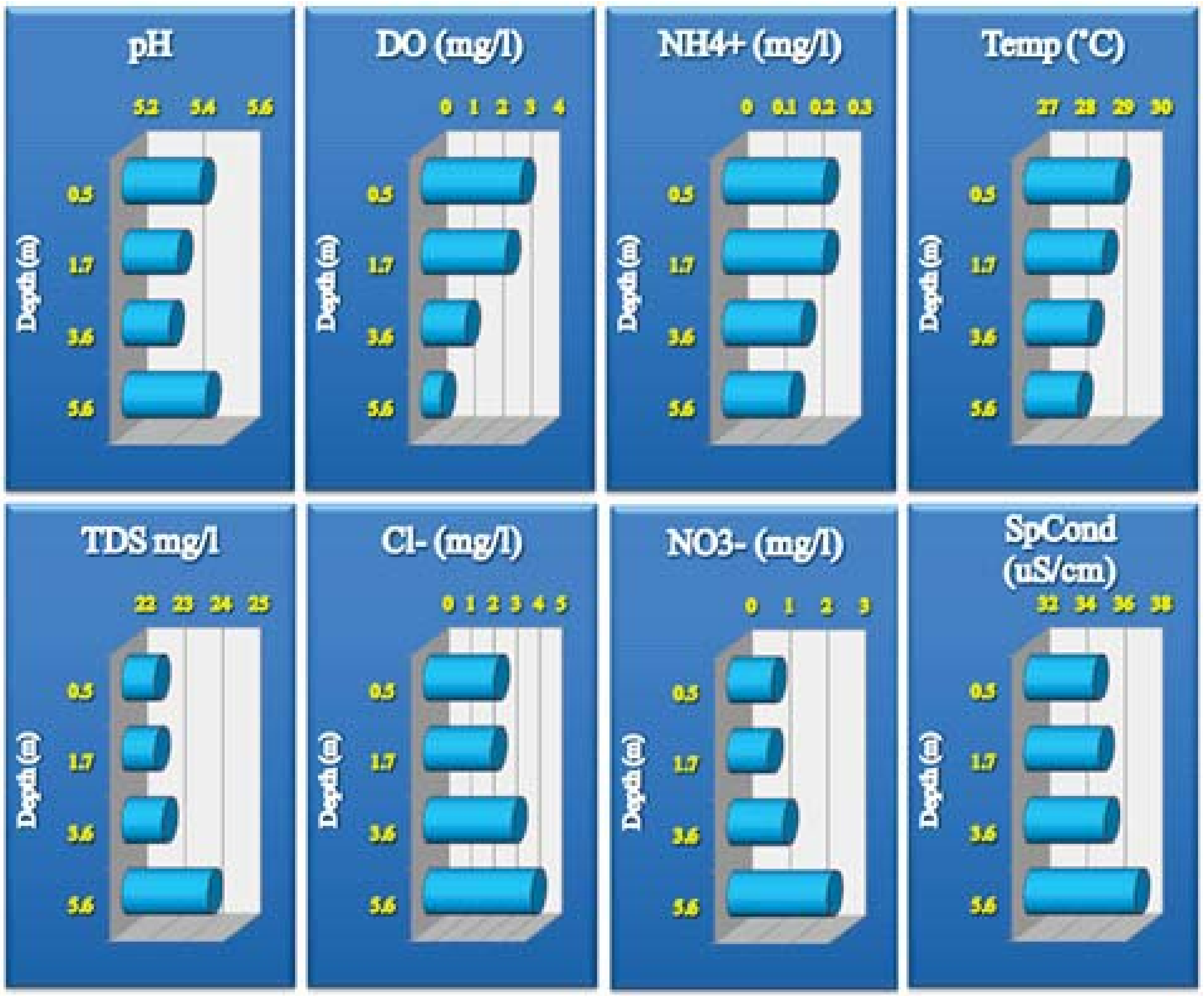

Fig. 7 : Vertical variation of water quality parameters in Bera Lake

Table 2 : Water quality of Bera Lake based on NWQS and WQI guidelines

				Parameter					WQI	
Sampling	**Salinity**	**TDS**	**pH**	**NO_3^-**	**Cl^-**	**DO**	**EC**	**Turbidity**	**Brain 2010**	**DOE 2006**
IBP 1972	-	-	III	V	-	IV	-	II	39	41
Current Study	I	I	IV	V	I	IV	III	IIA	Very Bad	Polluted

soluble. Moderate to considerable eutrophication in the Bera Lake was recognized based on the mean average value of NO_3^{2-} (1.49 mg l^{-1}) and nutrient (TN and TOC) content of the sediments. Clear eutrophication, especially in the north of the basin, indicates that Bera Lake is on the verge of considerable ecological risk. It may be responsible for algal bloom, reduction of dissolved oxygen, high levels of $NO3^{-2}$, and reduction of fish population. Bear Lake water quality can be classified in the era of pre and post-land development project. Five FELDA agricultural land development phases, however, was recognized as the main contributor responsible for the degradation of quality of water and soil resources in the study area. On the basis of available data and result of present study, classification of Bera Lake water quality before and after land development project were categorized into class II and class V, respectively. Finally, this study is firmly recommended for a long-term and catchment scale monitoring of water quality assessment in order to reach sustainable natural resources plan with conservation approach.

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