Assessment of Water Quality, Sediment Environment and Nutrients Budget of Lake Tega

手賀沼における水質，底質環境および栄養塩収支の解析

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Descriptors
Hyper-eutrophication, nutrient budget, land use, sediment cores, internal loading, ^{210}Pb and ^{137}Cs dating , mass accumulation rate, geo chronology, Lake Tega.

1. Introduction

Lake Tega is a small, shallow and closed lake. It has great importance of recreation, fisheries and agricultural purposes but it has been in an eutropic condition for more than four decades and considered as one of the most polluted lakes in Japan. The biodiversity of lake has been decreased due to the unfavorable water quality. However, the study showed some improvement in water quality, compared to the past.

This research was carried out to i) to study spatiotemporal variation of water quality ii) to quantify the nutrient budget iii) to assess land use pattern and sediment environment and iv) to quantify sedimentation rates using ^{210} Pb and ^{137} Cs dating methods.

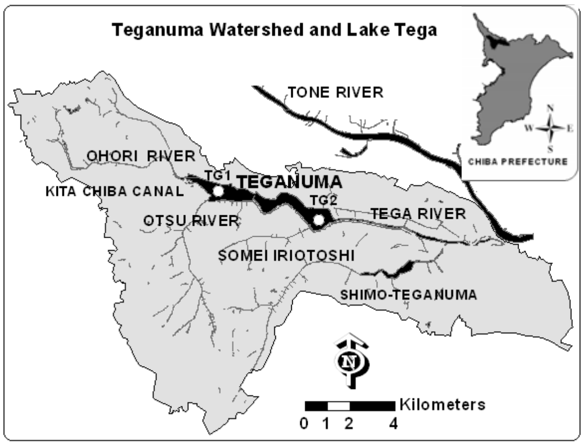

Fig. 1: Teganuma Watershed and Lake Tega

2. Statement of the Study

Research interest in the fresh water lake, accessibility, ideal site in terms of geo- physical and morphometric characteristics and availability of various research aspects such as water quality, sediment and land use are the inspirations to choose lake Tega as the research site.

Table 1: Lake Characteristics

Lake Area: 4.28 km^2
Watershed Area: 163 km^2
Depth: Maximum: 3.8 m, Mean depth: 0.86 m
Length: 7.1 km, Width: 1 km (max)
Shoreline Development Index (DL): 2.37
Retention Time: 5-12 days
Mixing Type: Polymictic

3. Materials and Methods

The sampling points representing the inflowing and out-flowing rivers, shorelines; transect points, the deeper and shallow part and narrow and wide region of the lake were selected. The spatial and vertical variation of various parameters was studied and finally two stations, namely; TG1 and TG2 were finalized for sediment core sampling and water sampling.

The stations represent the western (TG1) and eastern part (TG 2) of Lake Tega.

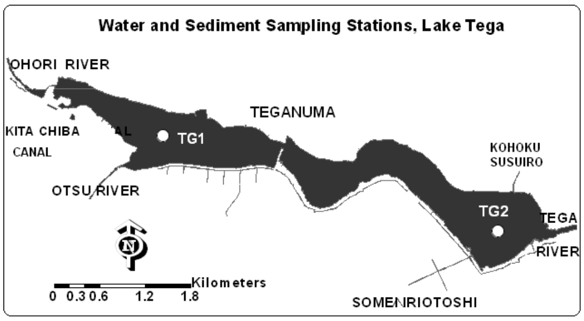

Fig. 2: Water and Sediment Sampling Sites

In- Situ- Measurement and Laboratory analysis were performed to analyze physico-chemical parameters of water, sediment and ^{210} Pb and ^{137} Cs Dating of Sediment by adopting standard instruments and methods. Nutrient release experiment was performed in the laboratory under static, dark and anoxic conditions at 7 ^{0}C, 16 ^{0}C, and 26 ^{0}C. In addition, Chiba Prefecture's Water Quality data were studied to observe the long term trend and variation of water quality.

4.1 Spatial Variation of Water Quality

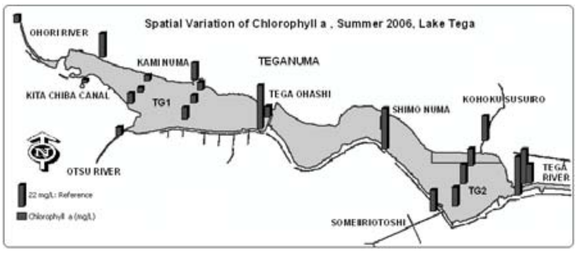

Fig.3: Spatial Variation of Chl a

The concentration chlorophyll *a* showed a gradual increment towards the outlets of the lake indicating the presence of higher biomass of photosynthetically active phytoplanktons (Fig.3). The processes of photosynthesis and respiration caused higher pH in TG2 and similarly the presence of the phytoplanktons and solid particulate matters which reside for a longer period in the water column increased concentration of chlorophyll *a* and turbidity in the TG2 . The less concentration of TN in TG2 may be governed by nitrification and de-nitrification of the nitrogenous compounds as well as absorption by the macrophytes and planktons. Similarly, the dissolved inorganic phosphorus, one of the main constituents of TP, was decreased in the TG2, possibly by absorption by plants and adsorption in suspended solid particles (Fig.4).

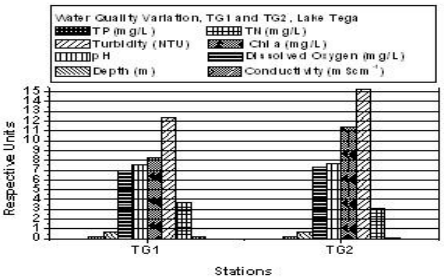

Fig. 4: Variation of Water Quality

4.2 COD Level and Eutrophication

The late 70's and mid 80's was a period in which the lake Tega experienced highest level of COD level. Since 2001, COD level started decreasing sharply (Fig.5).

Similarly, The Trophic State Index (Carlson 1977) TSI (SD), TSI (TP) and TSI (Chl *a*) have been decreased in the recent years, however, the status of lake is still in between hypertrophic and eutrophic condition, more towards hypertrophic state. The TSI for phosphorus and chlorophyll are higher than the TSI for secchi depth which may indicate that inorganic turbidity or color of the water reduces the clarity of the lake. All the indicators are in good agreement from 1998 through 2005 (Fig.6).

4.3 Nutrients Budget and Role of Nutrients Loading

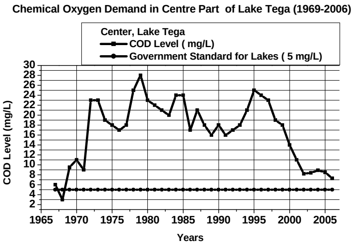

Fig.5: Long Term COD Level

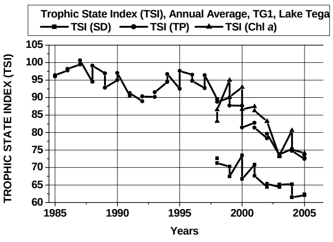

Fig.6 Variation of TSI

The influx of nutrients from the inflowing rivers such as Ohori and Otsu has been decreased in the recent years compared to the past., more specifically after the extension and improvement of the Tega waste water treatment facilities, . In 1985, the coverage was only 42% which is increased to 84% in the year 2005. The Kita Chiba Water Conveyance Channel contributed the highest nutrient loads in the nutrients budget of lake Tega, Other sources are shown in the figure 7. Tega River is the major source of nutrient out-fluxes which discharged 96% of TN and TP. In an average of seven years (1999 to 2005), 900 Tons of TN and 56 Tons of TP were loaded in Lake Tega where as 872 Tons of TN and 59 Tons of TP was out-fluxed from the lake Tega annually. The NH_4 + -N concentration values in sediment pore water were 3 to 13 times higher than in overlying water indicating a marked concentration gradient (Fig.9).

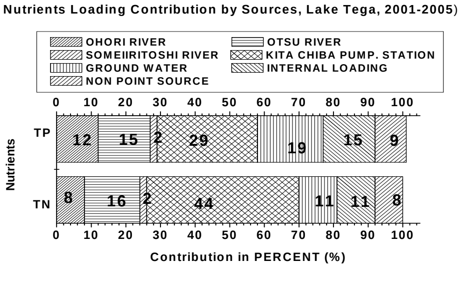

Fig. 7: Nutrients Influx

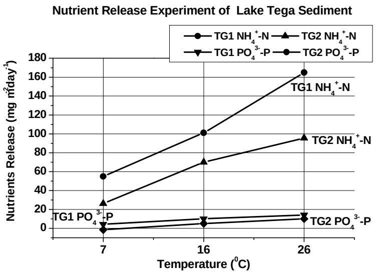

Fig. 8: Internal Loading

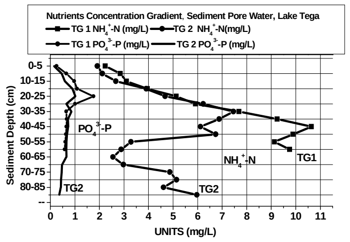

Fig. 9: Pore Water Nutrients

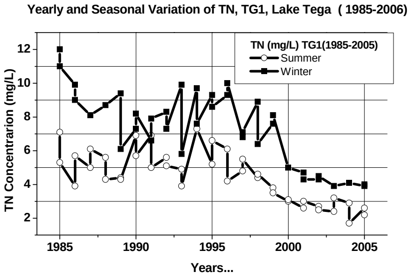

Fig. 10: TN Variation

The general increase in NH_4+ concentration down profile is suggesting that sediments are an important source of nitrogen to the overlying waters. Similarly, the PO_4^{3-}-P concentration values were 3 to 18 times higher than the overlying water in both the stations.. It indicated that the NH_4^+ -N and PO_4^{3-}-P release from the sediment was obvious as there was a significant concentration gradient between overlying water and the sediment water interface. The Nutrient release experiment showed that internal loading contributed in the Nutrient Budget and internal N load was 13 % (113 Tons/year) of the total nutrient loading and similarly the internal P load was 15 % (9 Tons/year) of the total phosphorus loading. Importantly, the nutrient release from the sediment was contributing to the lake water as equal as from the inflowing rivers (Figs. 8 and 7).

4.4 Water Residence Time and Water Quality of Lake Tega

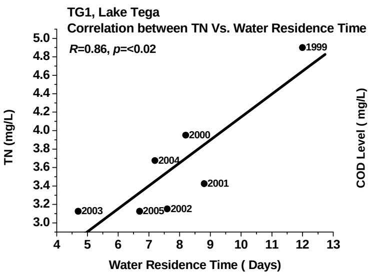

Fig.11: WRT Vs. TN at TG1

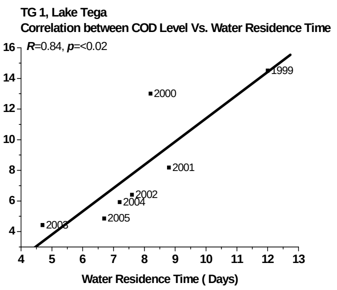

Fig. 12: WRT Vs. COD

The introduction of Tone River water (with annual average TN and TP concentrations 2.7 mg/L and 0.1 mg/L respectively) performed the flushing and dilution in lake Tega which significantly reduced the TN and TP concentration by 34% and 55% respectively (comparing the average values between 1985-1990 and 2001-2005) in TG2 and 50% and 78 % in TG1 in the same period and seasons (*Fig. 10*). The reduction in water residence time (WRT) allows the dilution and flushing out the nutrients before they could be utilized by phytoplanktons to cause a nuisance in the water environment. The reduction in water residence time has significantly reduced the, TN level, COD level and Chl *a*.(Figs. 11 and 12). The algal cells that are produced in water column are washed out faster than they can grow and accumulation. Longer water residence times provide plenty of time for algal biomass to accumulate if sufficient nutrients are present. However, TN has attained a certain concentration and not shown further decrement even the water residence time has been decreased and reached less than 5 days in the year 2003. It can be inferred that even reducing the water residence time less than 6 days, the achievement in reducing TN, mayn't be achieved (Fig. 11).

4.5 Land Use Change in Teganuma Watershed

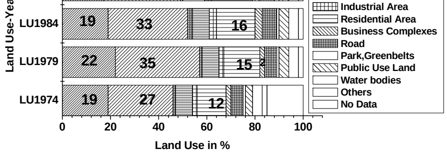

Fig. 13: Land Use Change

Out of 162.88 km^2, the total area of the watershed, the land use ratio (*Fig.13*) showed that the watershed had been headed towards urbanization for last 3.5 decades. The residential, industrial and other development and business activities increased in the watershed by 6% since 1979. In the mean time, the forest cover had decreased by 6% between 1979 and 1994. The land scape which had been covered with forests, occupied by residential and business complexes and the factors that had played a crucial role to reduce the load began to increase instead which disrupted the natural balance. The western part of the lake Tega has more urbanized characteristics with more residential areas, business complexes, shops etc while the eastern and southern part of the lake have more agricultural areas, including paddy fields. The higher nutrients concentration and COD level in the TG1 might have correlation with land use type of the western region. Sand particles are dominant in the upper layer, while the occurrence of clay is higher at the bottom (*Figs. 14 and15*). The value of C/N ratio (*Fig.16*) revealed that the upper layer of sediment which was deposited after 1906s had high carbon containing contaminants. The highest values in both the stations were observed in the upper layer corresponding to the age of sediments accumulated since 1960 to 1980s. However, the decomposition of Organic matter along with the time period is the reason of decrement of C/N ratio along with the sediment depth. The values of C/N ratios suggested high proportion of algal organic matter in the sediment.

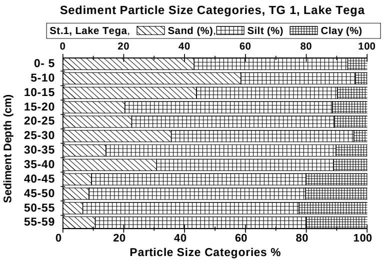

Fig.14: Particles Size TG1

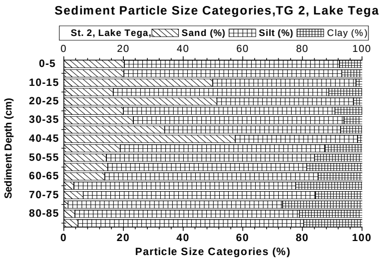

Fig.15: Particles Size TG2

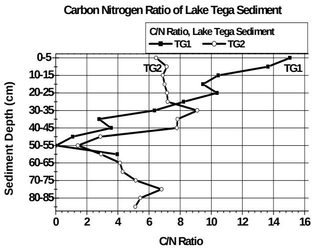

Fig. 16: C/N Ratio

4.5 Sedimentation Rates and Sediment Characterstics

Various factors seem to influence the sedimentation rates as the rates were found not uniform along the sediment depth in the stations TG1 and TG2 as analyzed with ^{210} Pb and ^{137} Cs sediment dating methods based on the radioactivity counts (Figs 17 and 18). The linear sedimentation rates at TG1 were 0.78 cm yr^{-1} , 0.62 cm yr^{-1} and 0.45 cm yr^{-1} at upper, middle and bottom cores respectively .Similarly, the sedimentation rates were 0.56 cm yr^{-1} , 0.62 cm yr^{-1} , 0.42 cm yr^{-1} at TG2 in the same sediment core depth. It can be interpreted that the sedimentation rates were higher in TG1 than in the TG2 (*Fig. 19*).

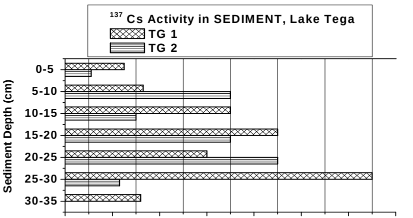

Fig. 17: ^{137} Cs Dating

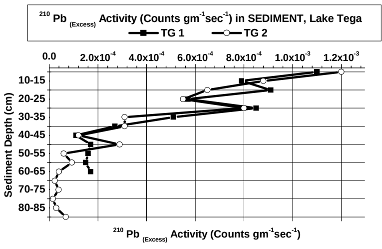

Fig. 18: ^{210} Pb Dating

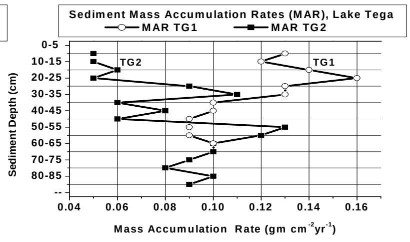

Fig.19: MARs

The high percent of sand in the sediment depth of 5-10 cm was also in the same line of result exhibiting the high sedimentation rate (*Figs. 14 and 15*). The land use change might have the correlation with this sedimentation rates. The decreasing forest covers, increasing residential areas and urbanization could have the impacts on higher sedimentation rates in the periods. To consider the compaction phenomenon of sediment, the mass accumulation rates (MARs) were calculated (*Fig. 19*). The highest MAR (0.16 gm cm $^{-2}$ year $^{-1}$) at TG1 represents the year 1980s to the recent years. According to the geochronology, the MAR was found minimum before the year 1960s. Similarly, in TG2, the MAR reached to the value of 0.13 gm cm $^{-2}$ year $^{-1}$, the highest, in the sediment depth of 40-45 cm and the rate was corresponding to the years before 1960s.

5. Conclusion

The inflowing rivers loaded the lakes with organic waste and nutrients which increased the COD level, TN and TP concentrations. The eastern and western part of the lake showed the variability in water and sediment quality and influence of inflowing rivers was apparent in the western part of lake. Decreased forest cover and increased in urban development activities led to high sedimentation rate, high nutrients and organic waste since 1960s and the peak was around 1980s. Introduction of Tone River water and extension and improvement of waste water facilities have demonstrated little improvement in water quality however; the lake couldn't be categorized as a clean lake. An integrated and sustainable approach of lake conservation has to be identified and implemented.