Organic matter and organic carbon levels in sediments of Lake Maninjau, West Sumatra

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Abstract. The organic matter content of lake sediments provides a variety of indicators, or proxies that can be used to reconstruct paleoenvironments of lakes and their watersheds. Particularly, in this study it will provide information that is important to interpretations of both natural and human-induced changes in lake ecosystems. The abundance of organic matter in sediments is described from the total organic carbon (TOC) because it’s a primary parameter. Moreover, Algae is the main source of organic carbon in the eutrophic lake. Lake Maninjau that located in West Sumatra has been eutrophic due to increasing of lake water utilization for floating fish cages, in recent years Lake Maninjau has faced an algal bloom frequently. Four sediments core were collected in Lake Maninjau from the lowest (near coastal) and deepest part (30 cm long core in average). Total organic matter (TOM) was performed using Lost on Ignition method (LoI) in whole cores, while total organic carbon (TOC) was analyzed using combustion analyzer method in one core that was taken in the deepest part of Lake Maninjau. TOM in Lake Maninjau among the cores varied between 21 to 34% at the surface, then decreased slowly as a depth. The percentage of surface TOM in the near coastal is elevated to the deepest part (21% to 34%). The TOC content in the surface was 9%. According to the Mid-Atlantic Integrated Assessment (MAIA) Estuaries the TOC concentrations in the sediments was in the range of high organic carbon level (>3%). The high value of TOC level in the surface sediment was controlled by algal productivity.

1. Introduction
Lakes are sensitive to varieties of extrinsic and intrinsic forcing variables that regulate the subsequent history of the lake, such as tectonic, volcanic activity, climate, vegetation, aquatic biota, and human activities [1]. The reconstruction of quaternary palaeoenvironment (2.6 mya-present) is being widely applied [2]. One of the most interesting applications of this study today is the exploration of rapid changes in past environmental quality driven by human activities [1]. Moreover, the understanding of palaeoenvironments are not only for past environmental and paleoclimate, but also to provide reference data to aid the assessment of the ecosystem responses to changing climate in the future [2]. Nowadays, there are many proxies that can be used to study paleolimnology one of them is through understanding of organic matter.

The organic matter content of lake sediments provides information that is important to studies of lacustrine palaeoenvironments, the history of climate change, and the effects of humans on local and
regional ecosystems [3]. The organic matter originates from the complex mixture of lipids, carbohydrates, proteins, and other organic matter components produced by organisms that have lived in and around the lake [4][5]. As an accumulation of geochemical fossils, the organic matter content of lake sediments provides information that is important to interpretations of both natural and human-induced changes in local and regional ecosystems [3][6].

Lake Maninjau located in the middle parts of Sumatra Island. Lake Maninjau origin was from volcanic eruptions in late Pleistocene until Holocene that was dated from andesite, tuff, and rhyolitic ash-flow [7]. The lake has 9,997.5 Ha of water surface area and 105 m depth average with 10,226,001,629 m³ volume of water [8]. Lake Maninjau has been experiencing eutrophication due to uncontrolled operation of floating net-cages (aquaculture in lake) by local farmers since 1990. However, anoxic bottom layer has been identified to occurred prior to 1920’s. The aim of this study was to identify sources of organic matter, as a preliminary key findings of anthropogenic activities and natural processes study.

**Geological Setting**

Lake Maninjau is located northwest of the Singgalang -Tandikat strato volcano. The eruption of Maninjau Volcano occurred in in late Pleistocene until Holocene [7]. This area is known as a volcanotectonic depression, similar to the Lake Toba region, in a smaller size. The Maninjau caldera wall has a height of 1,200-1,400 m above sea level. Lake Maninjau is bordered by steep cliffs, especially on the southern wall, which is formed by faults and volcanic eruptions. Most of Maninjau area is occupied by lava deposits and also covered by tuff and pumice that associated with Maninjau caldera eruption products [9].

2. **Methods**

**Study site**

Lake Maninjau is located in central parts of Sumatra Island, West Sumatra Province. Coring site was obtained at the four points from near coastal (cr1;cr2) to the deepest part of the lake (cr3;cr4) (figure 1). The core was taken by gravity corer in September 2018, core long was 30 cm in average.
Figure 1. Coring points map.

**TOC and TOM analysis**
Total 70 samples from the cores that were sliced every 2 cm for total organic matter (TOM) analysis. This analysis was performed using Lost on Ignition method (LoI) [10][11]. Firstly, dried sediment samples at 100°C overnight to counted water loss and furnace at 550°C for 4 hours, then weighted to defined organic matter loss. For total organic carbon (TOC) analysis there were 15 selected samples from core that were taken at the deepest part of Lake Maninjau. The TOC was performed using combustion analyzer method. Sediment preparation prior analysis used Yanaco JMA 1000, then for TOC analysis used Yanaco JM 1000CN.

3. **Results and Discussion**
Lake received their organic matter from both allochthonous and autochthonous sources. Allochthonous sources include terrestrial and anthropogenic sources mainly delivered by rivers, while autochthonous sources of organic matter are mainly from phytoplanktons and macrophytes that live in the lake. TOM in Lake Maninjau among the cores varied between 21% to 34% at the surface, then decreased slowly as a depth. For instance, the surface TOM among cores (cr1; cr2; cr3; cr4) are 21.6%; 24.8%; 29.4% and 34.5% respectively (figure 2). The percentage of TOM in the near coastal smaller than in the deepest part (21% compared to 34%), it can happens because TOM will increase as a sediment grain size decrease [6]. A consequence in the deeper parts of lake basin fine grained sediments size settled down and sink, while at the shallower parts, coarse sediments size rapidly accumulate. During the process of deposition in the lake bottom, organic matter is subject to microbial
reworking, with the result that its original composition becomes altered [3]. Moreover, as shown on the graphs all TOM on the surface have a higher percentage, the anthropogenic activity in Lake Maninjau is very high especially the floating fish cage activity, which is considered enrich the TOM content in the surface sediment of Lake Maninjau.

Figure 2. Total organic matter of four cores (cr1;cr2;cr3 and cr4).

Total organic carbon (TOC) in lacustrine environments occurred from a complex mixture of compounds derived from terrestrial, littoral, planktonic, and bacterial sources [12]. TOC concentration is a bulk value that represents the fraction of organic matter that escaped remineralization during sedimentation. Initial production of biomass and subsequent degree of degradation will effect of TOC concentrations [6]. The abundance of organic matter deposits in lake sediments usually derived from the process of photosynthetic production by phytoplankton in surface waters. Phytoplankton is the dominant source of primary organic matter in most aquatic systems. This biosynthetic process uses energy captured from sunlight by photosensitive pigments to convert dissolved inorganic carbon and nutrients into organic matter [4].
The TOC content in the surface-near surface core was 9% (figure 3). This percentage is high and it is estimated to be originated from algal productivity. The TOC percentage very fluctuated from top to bottom core (figure 3). High TOC percentages were found on the surface or top and around the middle of the core. In addition, from the Pb$^{210}$ dating analysis that has been done in Lake Maninjau at a depth of 14-16 cm the age was ±40 years ago and at that layer the abundance of montmorillonite minerals was high. Montmorillonite is thought to be a weathering product of volcanic ash from volcanic eruptions. However, further research needs to be done to resolve whether volcanic eruption materials enrich the TOC content in Lake Maninjau. Analysis of C/N ratio along with δ13C and δ15N in lacustrine sediments can provide information on the organic matter and nutrient source [13].

According to the Mid-Atlantic Integrated Assessment (MAIA) Estuaries the TOC concentrations in the sediments was in the range of high organic carbon level (>3%). MAIA [14] recommended the following assessment categories for TOC in sediments are: Low impact: ≤ 1%; Intermediate impact: 1 to 3%; High impact: >3% [14]. High percentage of TOC in surface sediments could be an evidence of frequent algal blooms in the overlying lake waters.

4. Conclusion
Organic matter and organic carbon are very useful for paleolimnology study as a basis for determining organic sources in Lake Maninjau. The existing of organic carbon in Lake Maninjau was dominated by the algae origin, which is Lake Maninjau has very often experienced alga bloom recorded since a period of 20 years and the frequency continues to increase.

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