Lake Sapropel: a Valuable Resource and Indicator of Lake Development

KARINA STANKEVICA, MARIS KLAVINS, LIGA RUTINA, AIJA CERINA
Department of Environmental Science
University of Latvia
Raiņa Blvd 19, LV 1586, Riga,
LATVIA
karina.stankevica@lu.lv

Abstract: - organic rich lake sediments – sapropel can found wide use in agriculture, livestock farming, balneology and veterinary and such application options has been widely studied in 20th century in the Baltic countries, Ukraine and Russia. Within this study sapropel of three lakes in Latvia – Padelis, Pilcenes and Pilvelu - were studied for a full profiles of the entire sediment layer, which allowed to determine the variability of sapropel properties depending on the development of the lake over time. Sapropel properties can be correlated with macrofossils present in the sediments and the study of the sedimentary profiles can help to study the lake development process. Both previous, both this study proves high application potential of sapropel and also lake remediation options after removal of lake sapropel.

Key-Words: -sapropel, organic-rich sediments, macrofossil

1 Introduction

Sediments are accumulating during the lake existence period and they are formed from remains of organisms living in the lake and its surroundings, and mineral material supplied to the lake from catchment area and atmosphere. In the freshwater bodies located in the temperate forested areas usually are formed sediments with high organic matter content (over 15%) [1], formed from aquatic plants, plankton and benthic organisms and transformed under influence of bacteria, and mixed with mineral components. Sapropel has finely dispersed and colloidal structure and can range from light pink to dark brown colour [2].

Sapropel is valuable resource and can be used in many fields. In Russia, Belorussia and Ukraine sapropel is already used as a raw material for balneology, livestock farming, agriculture, cosmetic applications and other fields. Amongst other applications sapropel use in highly profitable intensification of thermal processing of oil-shale for increasing the tar and gas yields are demonstrated [3]. It has been found that alkali treated organic sapropel can be used as coagulant, but is prospective also as binder additive for fiber board manufacturing from wood grain and agricultural waste. Moreover the technical sapropel characteristics meet requirements of thermal insulation materials [4]. Sapropel also can be used as environmentally friendly substance for development of building and insulation materials made from wood chips, fine peat and other similar materials. Sapropel-based materials are a mixture of wood chips, peat and sapropel and called sapropel-concrete. Economic analysis has shown that sapropel-concrete maybe one of the cheapest, environmentally friendly and affordable materials for wide application in construction industry. Sapropel with low ash content and high NaOH content is used as additive for the brick manufacturing. Sapropel additions increase the glass-phase content during the potting and prevent the color loose on the brick's surface [3]. Sapropel mixtures can be used as livestock feed additives as far as they improve the animal's liver and stomach conditions, blood formation and circulation, increase resistance against diseases and increase the animal's resistance to adverse environmental conditions [4]. The most valuable sapropel for such applications contains a lot of proteins, vitamins, enzymes and other biologically active substances and actually all sapropel types could be used as livestock feed additives. Nowadays the sapropelic humus additives (such as sodium humate) for livestock are becoming popular. These agents enhance the oxidation processes in the body – help to increase and accumulate proteins in the blood, increase the red blood cell production in the red bones marrow, improve vitamin A and other vitamin synthesis, normalizes metabolism and is effective in

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the toxicosis treatment. Sapropel can be used as a cheap fuel – to produce the granules or briquettes for heating of residential houses and auxiliary buildings. Russian scientists offered completely replace the coal-fired aglopyrit (heat insulation material) production by sapropelic product – heat-saving construction and light concrete [5].

Sapropel has wide application potential in medicine. Already in the end of 19th century it has appeared been first publications where has been described the sapropel beneficial effect in the rheumatism treatment and periosteal inflammation [6]. Sapropel thermal capacity provides a long and deep tissue heating and normalizes blood pressure assisting the treatment in joints, peripheral nervous system, skin and inflammation of female genitals. Sapropel high adsorption capacity stimulates the conglutination of wet lacerations. Sapropelic antibiotics and anti-oxidants contribute to the early termination of inflammatory processes; treat eczema, dermatitis and burns. The heated sapropel applications successfully treat phlegmons (diffuse inflammation of cellular fat pus formation), mastitis, furunculus, chronic gastritis, gastric ulcer and duodenum diseases, because these applications stimulate the phagocytes (cells that can destroy the foreign bodies and bacteria) activity, and as result is intensive tissue regeneration [5].

Alike as in medicine the sapropel is widely used also in veterinary medicine to treat the external and internal tissue inflammation diseases: metritis (inflammation of genitourinary tract), mastitis (breast inflammation), bursitis (articular inflammation) phlegmons, tendovaginitis (tendon sheath inflammation), various types of abscesses and etc., there also is treatment of chronic form of many diseases [6].

Scientists, who had studied the sapropel chemical processing, argued that sapropel with high degree of mineralization due to deep chemical transformation is not suitable for application in the medicine but can be used in agriculture as fertilizer, because it contains all necessary natural plant nutriens and mineral elements [5, 6]. Nowadays for fertilizers are used all types sapropels, which can be divided in three groups [6]:

1. group – the sapropel has organic matter content above 50%. This sort of sapropel can be used as organic mineral fertilizer and there is no need to add various organic substances (peat and etc.);

2. group - the sapropel has organic matter content from 10 to 50%. This is a complex mineral fertilizer, rich with a lime, phosphoric acid, nitrogen and organic matter;

3. group – mineral sediments with organic matter content up to 10% and mainly used to improve the soil structure. If the sediment has a high concentration of CaO that soil acidity will be reduced after adding such sediment.

The purpose of this work is to study full sapropel profiles in details in three Latvian lakes to assess sapropel possibilities for practical application and determine of stages of lake development.

2 Materials and Methods

Full sediment profiles from three lakes in Latvia were used in this study. The lakes– Padelis, Pilcenes and Pilvelu – are located in Rēzekne district, Latgale region (Fig.1).

All the lakes are inter-hilly water bodies and in origin belong to the glacial type. The water surface area of each lake does not exceed 10 hectares, and the sediment fills the lakes' trench for more than 80%.

Sampling points were selected by the lakes' characteristics and preliminary data for sapropel layers in the given location.

After sampling the specimens were cut into 10 cm layers and stored in frozen condition at -20°C before analyses.

Loss on ignition (LOI) method was applied in order to estimate moisture, organic matter andcarbonate matter content in the sediments [7].

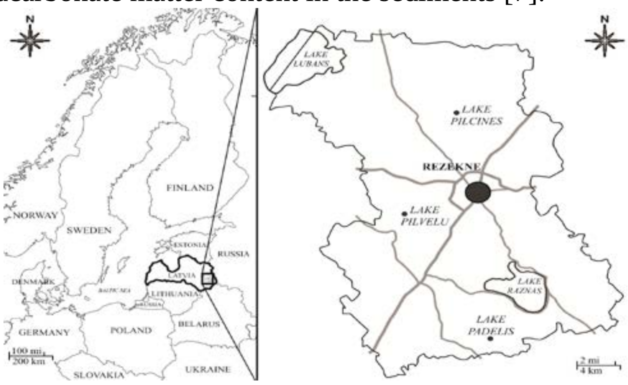

Fig. 1Map of the sampling area

Atfirst, the moisture of sediments was determined after drying at 105°C. The content of organic and carbonate matter was analyzed by ashing samples sequentially at 550°C for 4 h and at 900°C for 2 h.

Carbon, hydrogen, nitrogen and sulphur concentrations in sapropel samples (elemental analysis of C, H, N, S) were carried out using an Elemental Analyzer Model EA-1108 (Carlo Erba Instruments) by combustion-gas chromatography technique. The instrument was calibrated using cystine (Sigma – Aldrich Inc.), and all the sapropel samples were analyzed in duplicate. Ash content was measured after heating 50 mg of each sapropel sample at 750°C for 8 h. Elemental composition was corrected considering the ash content, but the oxygen amount was calculated as a difference.

Samples for macrofossils analyze (approximately 50cm^3) were washed through sieves with a gentle spray of water. The residue was washed gently off the sieve into a container and kept cold until analyzed. Small quantities of the residue were suspended in 2 – 3 mm of water in a shallow dish (e.g., Petri dish) and examined systematically under a stereomicroscope at about 40 magnifications until the whole sample had been examined. Remains of interest were picked out and sorted, identified, counted, and tabulated [8]. The graphic pictures were made using Tilia 1.17.6. program.

Several samples containing material suitable for radiocarbon dating were selected and packed separately directly in the field. The identified specimens were sent to the Institute of Geology at Tallinn University of Technology, Estonia. In total, 9 horizons were dated. The dates were calibrated, and an ageedepth model was built with Clam 2.1 out model [9].

3 Results and Discussion

Sediments with organic matter content of more than 15% are “sapropel”. They formed on the bottom of freshwater body. One of the significant parameters in sapropel value and application potential is ash content. More valuable is sapropel with high organic matter content. Digestion of sapropel sample at different temperatures provides information on mass losses – moisture, ash and carbonate content.

In the elemental composition of sapropel of the lakes the percentage of the carbonate, hydrogen, nitrogen and sulphur content has been analysed.

The elemental composition analysis of sapropel provides information about distribution of elements (C, H, N, O, S) in organic material, as well as gives indirect evidences of sedimentary materials origin and its characteristics.

Composition of phyto- and zoo-plankton, benthic orgsms and insects have protein content with a large amount of nitrogen, but macrophytes are mainly composed of carbohydrates. It is assumed that zoo-plankton and benthic organisms form nitrogen rich sediments and sediments with low nitrogen content were formed by highest coastal plants, algae and, in part, by the humic substances from the catchment areas [4].

Paleovegetation studies of lake development using macrofossils analysis can provide significant information about evolution of lakes and indirect data about change of water level, run-off changes and geochemical processes in catchment area of the lake [9].

In Pilvelu Lake (Fig.2) is clearly separable four sapropel layers.

Layer I. (200-390 cm) 5709-9980 cal. yr BP inthe lake was formed organic sapropel, which cover the low layer of limnic clay.Ash content is 13.84%. Carbonate quantityis increased in the deposit depth. C/N ratio is 13.36 that indicate N increasing in theorganic mass deposit where the source wasfrom common algae. In the depth from 230 to330 cm (6317-8533 cal. yr BP) are dominatedthe remains of aquatic plants –*Characeae gen.*, *Potamogeton pussilus, Najas flexilis,* theremains of animals - *Briozoa*, the remains oftrees - *Betula sect. Albae*.

Layer II. (133-200 cm) 4100-5709 cal. yr BP inthe lake was formed silicate sapropel withash low content 30.2% on average. Sapropel moisture in this depth is lower than in theorganic sapropel and consists 91.95% onaverage. C/N ratio decreased to 16.9 onaverage. From aquatic plants are found only*Characeae gen.* and *Typha sp.* Below 30 cmthe animal number is reduced, but above 30 cmthe number is average and *Daphnia* dominates,in small number is found *Briozoa* too.

Layer III. (120-133 cm) About 4000-4100 cal. yr organic deposits where are clearly visible thecostal plants remains. C/H ratio is 17.9, theconcentration elements C,H,N are decreasedand oxygen is increased. There is a lot of*Daphnia* remains. The blowout of moss leavesnumber indicates about marshy cost in theexplored site, which shows the water levelreduction in the lake during this period.

Layer IV. (0-120 cm) 3739 cal. yr BP to the presenttime the balance in the lake ecosystem is in the stable condition. Sapropel ash is virtuallyunchanged – 9.07% on average (6.37-12.2%), moisture is 92.66% on average. Mass of organicmatter increases in the upper layer.The high concentration of hydrogen and lowconcentration of oxygen indicate that sapropelorganic mass consists from small-separatedremains, consisting from humic substancesand costal plants (on average C/N>18). Theremains of water plants with floating leaves onthe surface (*Potamogeton natans, Nymphaea alba*) dominate in macrofossil. *Dapnia* and*Briozoa* are preserved in a small quantity,number of which decreases from lower to theupper layers. Throughout of depth layer werefound the remains of trees *Betula*, in the depth

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of layer 80-120 cm is dominated the remainsof *Picea*.

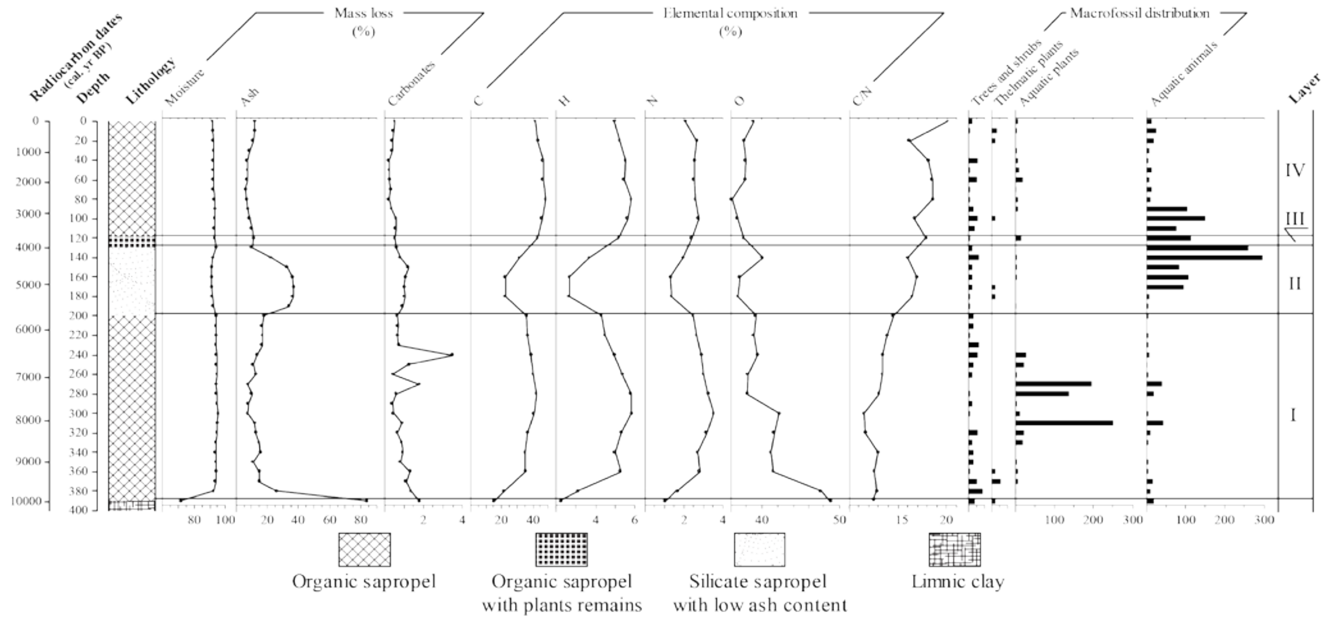

Fig. 2 Mass loss results, elemental composition and macrofossil distribution in the sapropel samples of PilveļuLake

In Padelis Lake (Fig.3) is separable three organic rich sediments layers.

Layer I. (60-281 cm) 6634 – 11405 cal. yr BP in the Padelis lake is formed silicate – carbonatic sapropel (ash content is up 85%) as a foliated lake sediments with a high level of ash (ash > 85%) where the ash content reaches 88.81% and carbonate content is 33% on average. In this sediment stage the moisture decreaseupto80.43%onaverage. In macrofossil dominate trees-*Betula sec. Albae*,thelmaticplants–*Carex spp.*, aquatic plants – *Characeae gen.*, *Najas marina*, aquatic animals – *Briozoa.* From 210 cm depth the mollusca shells occur in small number, but from 130 to 180 cm its a lot. In the range of 150 – 160 cm surface of *Chara* remains cover thin calcium carbonate crust. Perhaps, the lake level was slightly decreased, as well as water temperature was increased.

Layer II. (10 – 60 cm) 4841 – 6634 cal. yr BP in the lake is formed the organic sapropel. In thosetime the sapropel ash was not exceeding 8.16%, had small carbonate content – 3.77% onaverage, C/N ratio 13 that indicates about organic matter formation in sapropel fromwater plants and algae. There also is observed macro-fossil where from trees dominate*Pinus sylvestris* and *Betula sect. Albae*.Most likely they carried into the lake from coast, but they did notgrow in the immediate vicinity. As the drill site is located in south-west of lake coastwhere under the influence of north-east winds is observed the ripple, then there the organicsubstances could be washed into the lake from the coast especially during floods. There ismet the thelmatic plants as *Carex gen.* and *Galium sp.*, but mostly is water plants – *Najas marina, Najas flexilis, Characeae gen., Nymphae alba* and *Menyanthes trifoliata*.Insignificant quantities were found *Bryozoa* remains. Zone of low border is very sharp andshows a rapid sedimentation condition change.

Layer III. (0 – 10 cm) about 4841 cal. yr BP to nowadays in the Padelis lake on the sampling sitewere sharp environmental condition changes. Thefigure shows only 10 cm from one meterthickness layer of peat that has accumulated in the lake and covering the organic sapropelunderlying layer. From macro-fossil are dominated *Betula sect., Albae, Carex spp.*, in thedetritus are a lot of hipnum moss that can be explained by decline of water level as resultof plants overgrowing.

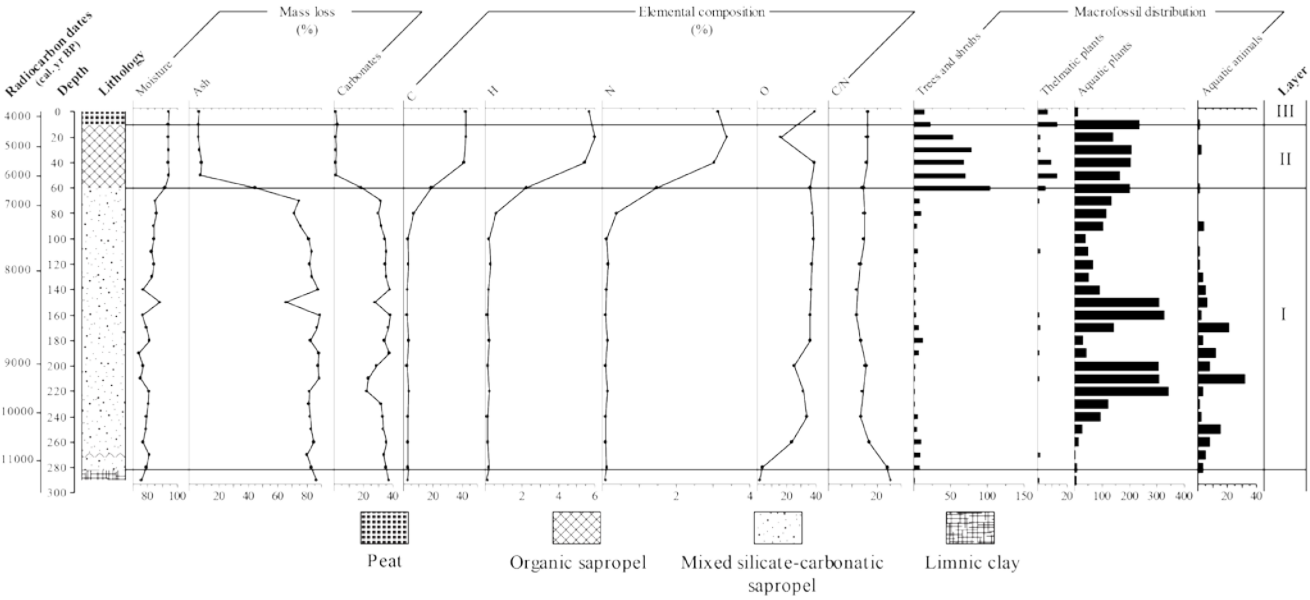

Fig. 3Mass loss results, elemental composition and macrofossil distribution in the sapropel samples of Padelis Lake

In Pilcines Lake (Fig.4) is separable two sapropel layers.

Layer I (180 –228 cm) 5263- 6782 cal. yr BP stage when in the lake were not stabile conditions. In this time in the lake was formed silicate sapropel as with high ash content as with low ash content. During this time the ash accumulation in the sediment was unstable and varies from 45.68 up to 72.42%, carbonate is decreased down to depth and consists 1.59% on average. In the depth from 1.80 m to 2.20m the macrofossils are very few. From animals are found *Bryozoa* and *Hydroptilida*; from water plants and coastal plants practically are nothing, from trees is *Betula sect. Albae*. In the layer from 2.20 m to 2.60 m are more trees remains, where are found *Picea abies* and *Betula sect.Albae*and also a lot of *Bryozoa* and *Hydroptilida*.

Layer II. (0–180 cm) from 5263 cal. yr BPto

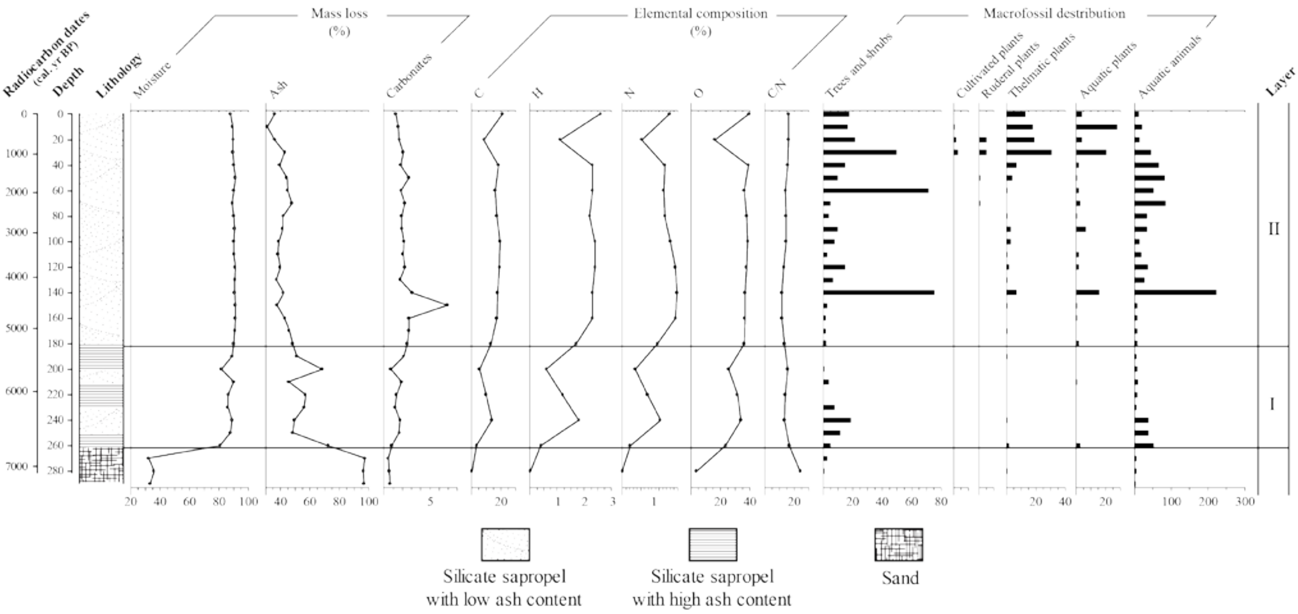

Fig. 4Mass loss results, elemental composition and macrofossil distribution in the sapropel samples of PilcinesLake

nowadays in the sampling site of lake is formed the silicate sapropel with low ash content 31.02 – 47.75%, 40.45% on average. The ash content in the sapropel is increased from upper layer to lower layer. Moisture oscillation is not big and there is 90.27 % on average. Carbonate is 2.39% on average is decreased from bottom layer to upper layer, but in the depth 145- 155 cm (4454 – 4699 years ago) is observed the rapid increasing of carbonate up to 6.91%, not big decreasing ash content and macro-remains of coastal plants - *Betulasect. Albea, Carexspp. Trapa natans*and*Bryozoa, Hydroptilidae* that shows the abatement of water level, which had caused the close approach of shore on the sampling site.

In all three lakes sediments the correlation between quantity of ash and its moisture is observed – then more ash content then less sapropel moisture. This is due to colloidal structure of sapropel organic matter and the ability of organic matter to bind water [11].

This study have shown that about 6500 cal. yr BP in the Padelis un Pilcenes lakes and 10 000 cal. yr BP in the Pilvelu lake started accumulate a large amount of sapropel matter depositedin the lake bottom that was unable to fully mineralize. Currently the lakebeds are filled by more than 80 % with sediment and, taking into account the acceleration of eutrophication, they soon will achieve their old age stage and turn into swamps.

4 Conclusion

Organic rich lake sediments – sapropel can be considered as a valuable resource with wide application possibilities in agriculture, livestock farming, balneology and veterinary. At the same time sapropel extraction can be considered as an environmental remediation action supporting major improvement of lake quality. Studied full sapropel profiles of three lakes in Latvia (Padelis, Pilcenes and Pilvelu) demonstrate abundance of this resource and composition as well as variability of sapropel properties depending on the development of the lake over time. Sapropel properties are correlated with macrofossils present in the sediments and the study of the sedimentary profiles can help to study the lake development process. Both previous, both this study proves high application potential of sapropel and also lake remediation options after removal of lake sapropel

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