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THE EFFECT OF SEDIMENT GRAIN SIZE ON HEAVY METAL CONTENT*

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Abstract

In the natural surroundings tectonical, climatological, dynamic and physico-chemical conditions of sedimentation are the crucial factors in the process of sediment composition formation. Grain size is one of the most investigated reasons of space and temporary variability in heavy metal concentration. In general, the data on grain size measurement afford to appreciate sorption capacity of sediments and arrange them. The dependence heavy metal content on grain size of sediments has been examined in the enormous amount of research works. The main conclusion is that if grain size decreases, metal content increases.We have carried out sediment grain size measurement of two lakes (Chebachje Lake, Piketnoye Lake) located within the territory of the Tyumen region and Omsk region. To define grain size of these sediments the sorting of samples collected layer-by-layer has been conducted by nest of sieves (from 43 to 1000 μm). Accomplished examinations allow to state that layer-by-layer grain size measurement of sediments has significant importance in reconstruction of paleoecologic peculiarities and also influences organic and inorganic matter concentrating in the sediments in dynamics.

Keywords: Grain size · Sediments · Lakes · Heavy metals · Layer-by-layer analysis

1 INTRODUCTION

Heavy metal pollution, owing to its permanent existence and biological enrichment, has long been an important subject in the field of international environmental science. As a result of complex physical, chemical and biological processes, a major fraction of trace metals is found to be associated with water body sediments. Sediments are multi-phase solids containing silicates, carbonates, hydroxides/oxides, sulfates and organic substances as major components (Zhu, 2006). The essential factors influencing the heavy metal contents in sediments include the physical and chemical properties (grain size, surface to volume ratio, heavy metal contents of the main geochemistry phase), in which grain size is a main control parameters. There is a theory that finer sediments contain more heavy metals than coarser ones. The main reason is that smaller grain-size particles have a larger surface-to-volume ratio (Salomons, 1984; Martincic, 1990). However, some studies have indicated that coarser particles show a similar or even higher heavy metal concentrations than finer ones and the presence of coarser particles are possibly responsible for higher metal content in the coarser size fractions (Tessier, 1982; Singh,1999).

2 MATERIALS AND METHODS

2.1 Sample collection and size fractionation

Sediment samples were collected from Chebachje Lake (Tyumen region) and Piketnoye Lake (Omsk region) in the different depths. The collected sediment samples were packed and sealed in pre-washed polyethylene bags and transferred to the laboratory within a week, where they were dried at room temperature. For determining the relationship between grain size and metal contents, the sediment samples were fractionated into nine sizes by nest of sieves (from 43 to 1000 μm).

2.2 Chemical analysis

The different grain-size fractions were analysed for some heavy metal contents. For determination of metal total concentrations in different grain-size fractions, sediments were digested in glass-carbon open cups with a mixture of aqua regia and HF. The determination of metals was carried out by AAS (ContrAA 700 Analytic Jena).

3 RESULTS AND DISSCUTION

3.1 Grain size

Grain size of sediments can indicate spatial inhomogenuity. Thus, a wide range of heavy metal concentrations can be detected. Some investigations have shown (Jernstrom, 2010) that if grain size varies greatly, the comparison of metal concentrations in different sampling location can be inadequate without accounting grain size. Grain size of sediments from Ghebachje Lake collected layer-by-layer is given in Figure 1.

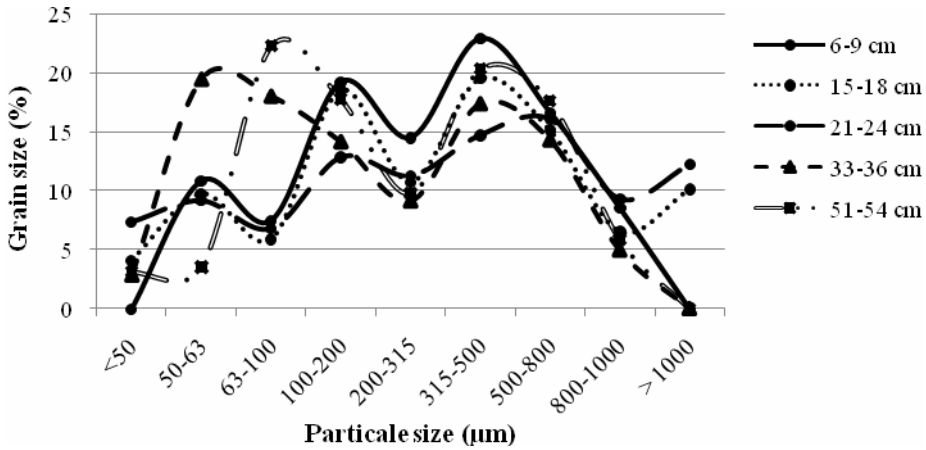


Figure 1. The size distribution of sediments at different depths (Chebachje Lake)

Grain size of the sediments from Chebachje Lake (fig. 1) has a twin-peaked and trimodal character and differs in the various depths. The depth from 6 to 18 cm is characterized by domination of 100-200 µm fraction (about 20 %) and 315-500 µm fraction (above 20 %). According to Lane's classification (Lane, 1947) the sediments are fine sand and medium sand at the depths 6-9 cm, 15-18 cm. The depth 21-24 cm is marked by domination of 315-800 µm (above 30 %) - medium sand and coarse sand. In general the sediments at this depth distinguish more uniform presence of all fractions both most coarse (>1000 µm) and most fine (<50 µm). Prevalence of 50-63 µm can be observed at the depth 33-36 cm (about 20 %) – silt; 63-100 µm is 18 % (very fine sand), 315-500 µm is 17 % (medium sand). The depth 51-54 cm is characterized by domination of 63-100 µm (22 %) and 315-500 µm (20 %).

Thus, the sediments of Chebachje Lake are marked by prevalence of the particles in range of 50-1000 µm not taking into consideration a depth. The presence of the particles in range of 315-800 µm (medium and coarse sand) is discernible with small variation (34,8±4,2 %). The particles (50-100 µm) are presented at the deep layers (33-54 cm). The particles (less 50 µm) are from 3 to 7 % excepting the highest layer where owing to sediment detachment the transition of this fraction in suspension is possible.

Grain size of the sediments from Piketnoye Lake collected layer-by-layer is given in Figure 2.

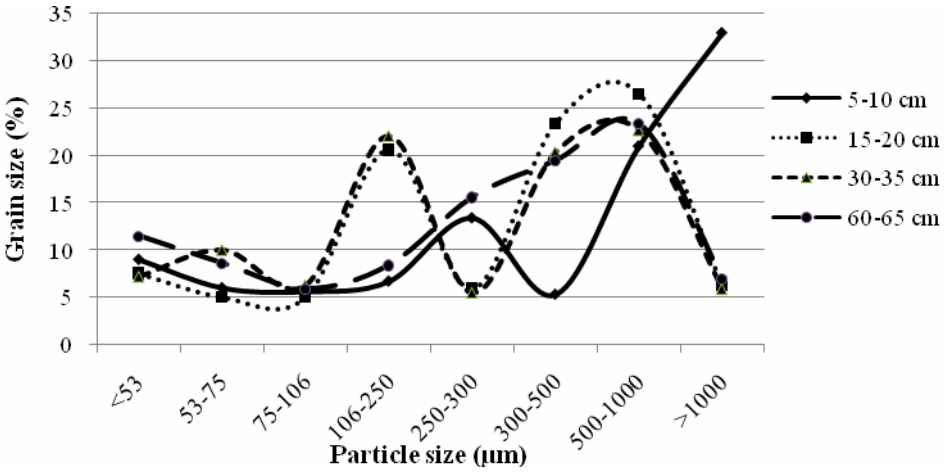


Figure 2. The size distribution of sediments at different depths (Piketnoye Lake)

The sediments of Piketnoye Lake mainly consist of the following fractions: 106-250 μm and 300-1000 μm$ according to Lane's classification they are fine, medium and coarse sand.

3.2. Metal concentration

The heavy metal contents were determined in each size fraction. The distribution character of metals in the examined profile of the sediments from Chebachje Lake in the different size particles is ambiguous. Lead concentration increases with decreasing particle size only at the lower part of the profile (fig. 3 (a)). At the depth of 51-54 cm Pb content tends to increase, but concentration varies slightly except for <53 μm fraction. At the depth of 33-36 cm a slight grow of lead concentration also takes place with decreasing particle size. The particles 200-315 μm in which the metal content is much lower are exception. The depth 21-24 cm is characterized by the increase of metal concentration with increasing particle size, but there is an anomalous high lead content in 63-100 μm fraction at this depth. The horizon of 15-18 cm is characterized by the absence of a pronounced dependence Pb concentration on particle size. The minimum amount of lead contains in 63-100 μm fraction. Pb content is comparable the remaining fractions. In the case of the sediments from Piketnoye Lake there is a uniform dependence of lead content at the depth 5-10 cm and 15-20 cm (fig. 3(b)).

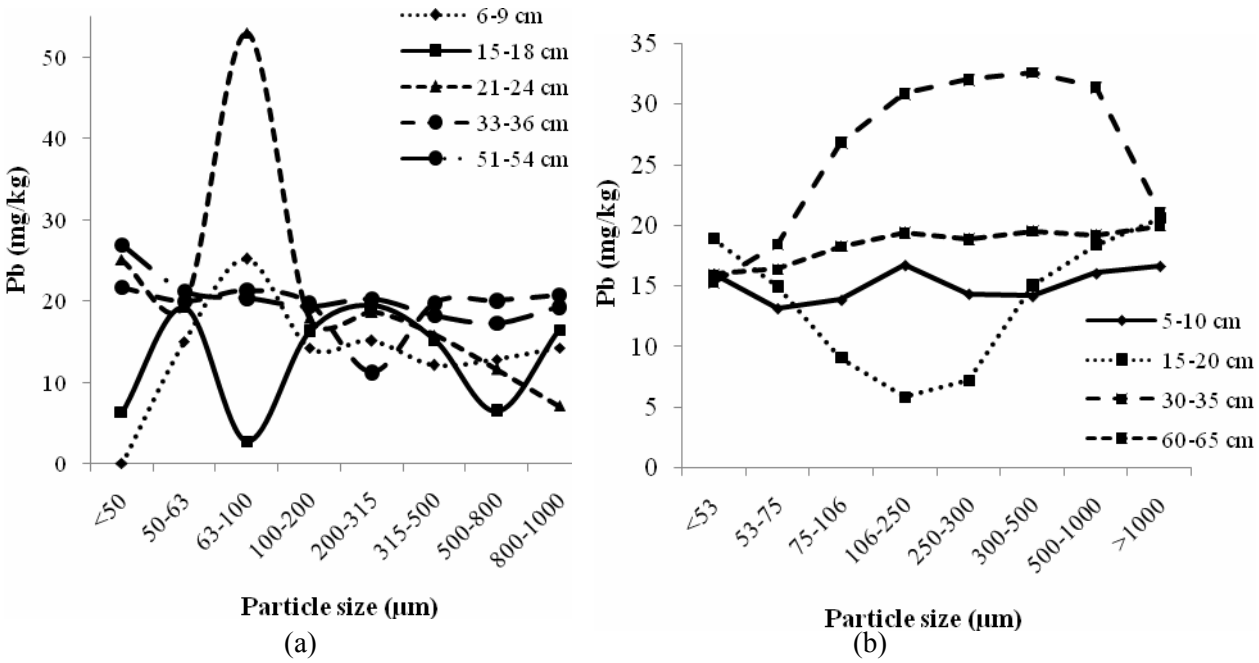
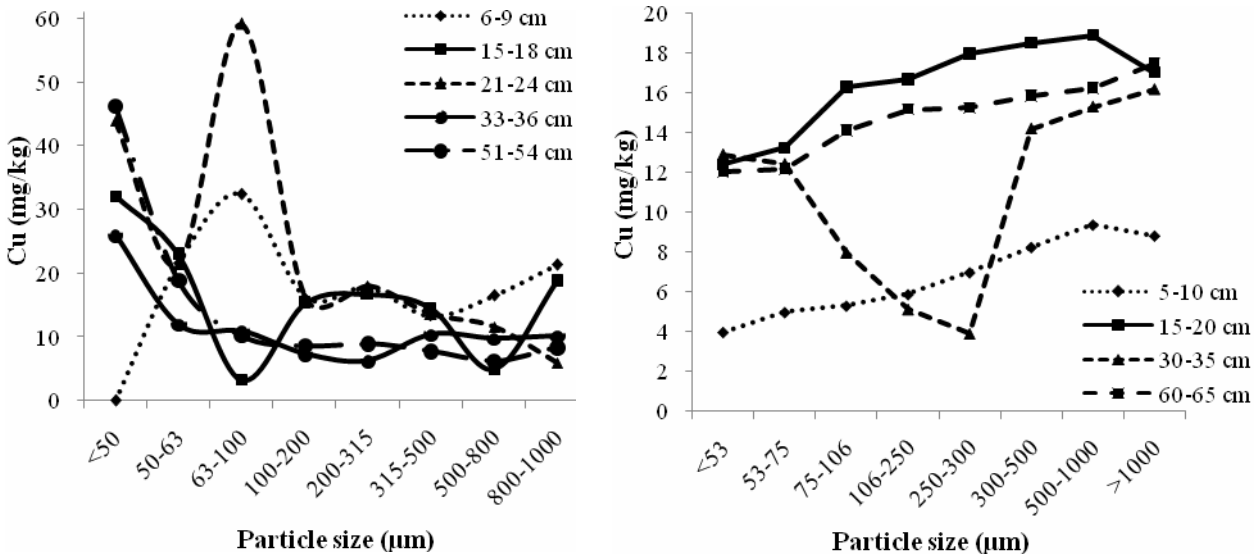


Figure 3. Variation of Pb concentrations against grain size at different depths (a – Ghebachje Lake; b – Piketnoye Lake)

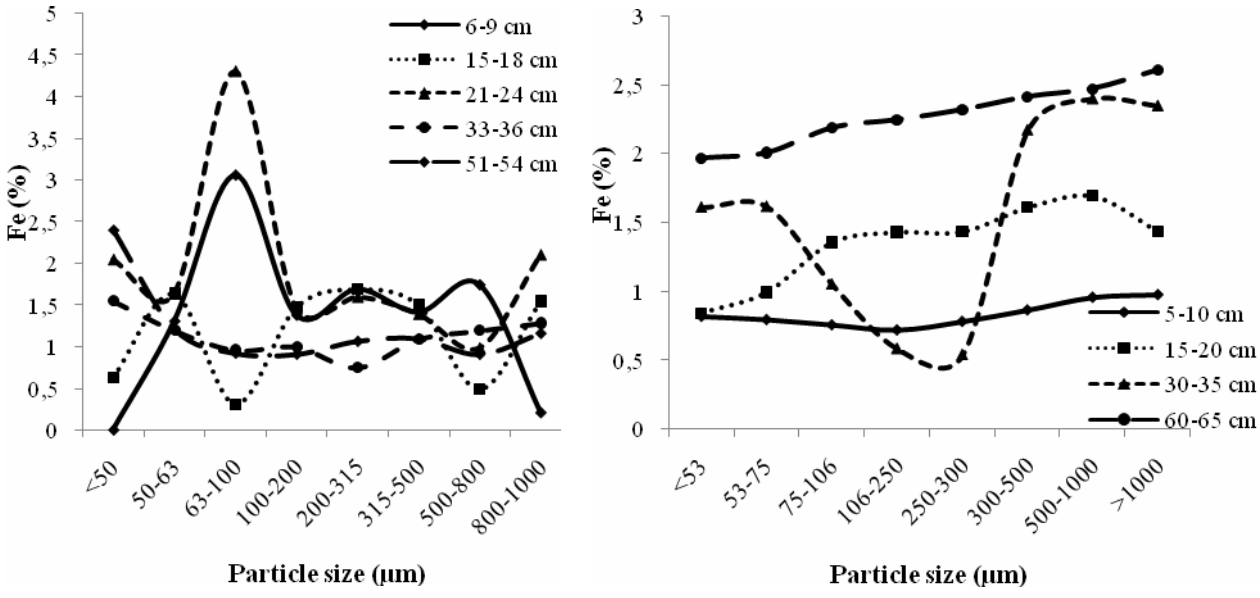
In the case of copper (fig. 4 (a)) there is a tendency of increasing metal content as far as decreasing particle size at the low part of profile (33-36 cm, 51-54 cm). It should be noted that the increase of concentration is essential in the fine fraction. The depth 21-24 cm is characterized by two maximums of Cu concentration in <50 μm and 63-100 μm fraction, though these fractions are not prevail. Copper distribution in surface layer is similar to lead distribution at this depth. In the sediments from Piketnoye Lake (fig. 4 (b)) Cu concentration grows monotonically with increasing particle size except for the layer 30-35 cm where there is a sudden decrease of Cu content for 75-300 μm fraction.



(a) (b)

Figure 4. Variation of Cu concentrations against grain size at different depths (a – Ghebachje Lake; b – Piketnoye Lake)

Iron distribution (fig. 5 (a)) in the sediments of Chebachje Lake in different fractions is similar to lead and copper distribution at all depths excepting the highest layer. Also at this depth the minimal concentration of iron is in <50 μm 800-1000 μm fractions. For the sediments of Piketnoye Lake the decrease of Fe content accompanies the decrease of particle size at three examined layers.

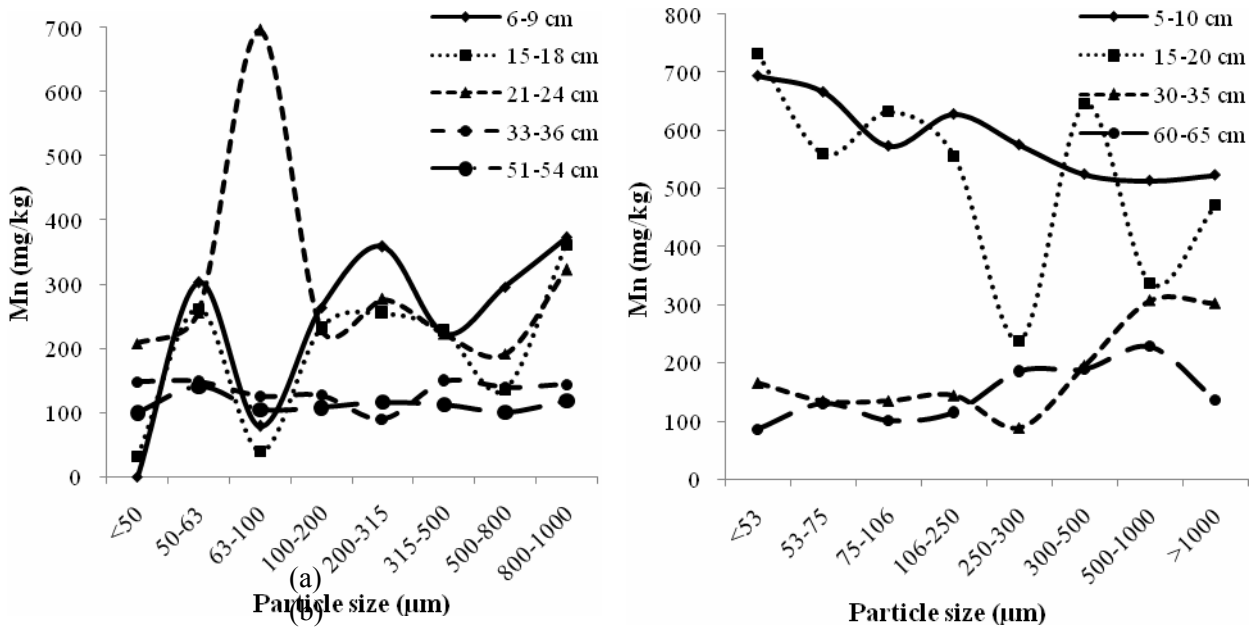


(a) (b)

Figure 5. Variation of Fe concentrations against grain size at different depths (a – Ghebachje Lake; b – Piketnoye Lake)

Mn concentration in two low layers of the sediments from Chebachje Lake does not depend on particle size (fig. 6 (a)). There is no clear tendency at the depth 21-24 cm. It can separate 63-100 μm fraction (it is characteristic for all metals) in which Mn content is high.

Mn concentration in the sediments from Piketnoye Lake (fig. 6 (b)) decreases in the case of increasing particle size at the depths 5-10 cm and 15-20 cm, but increase at the depths 30-35 cm and 60-65 cm. The layer 15-20 cm is characterized by concentration minimum for 250-300 μm as well as by maximum – 300-500 μm.



(a) (b)

(a) (b)

Figure 6. Variation of Mn concentrations against grain size at different depths (a – Ghebachje Lake; b – Piketnoye Lake)

4 CONCLUSION

As a result of heavy metal content determination in different fractions of the sediment collected layer-by-layer from two lakes located in the south of Western Siberia we have discovered the following regularities. In the sediments from Chebachje Lake heavy metals accumulate equally on the particles from 100 to 1000 μm or there is a tendency associated with increasing metal content as far as decreasing particle size. The significant accumulation of heavy metals takes place at coarse fractions in surface layers. Coarse fractions of the sediments from Piketnoye Lake sorb most content of heavy metals.

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