

Water migration of soil organic carbon in soils and landscapes in humid forests of middle taiga (Arkhangelsk region, Russian Federation).

**German Kust¹, Olga Andreeva²*

¹Moscow Lomonosov State University, Dept. of soil erosion and conservation. 119991. Russia. gkust@yandex.com

²Moscow Lomonosov State University, Dept. of agroinformatics; Russia. andreevala@yandex.ru

Abstract

The aim of the study was to pay particular attention to the high migration potential of the organic carbon (OC) originated from soils in middle and northern taiga. Only part of the organic carbon of the soil origin is fixed directly in the soil, under certain conditions (in the litter or at the calcareous geochemical barrier), and most of the OC migrate almost unchanged from the lateral runoff into local streams. Thus, the OC of the initially soil origin subsequently redistributes within the watershed by lateral and surface runoff. This makes important to consider the soils of taiga not only as one of the carbon sink, but also as a generator of the OC carrying out and reallocating with river waters. Approximate number of OC actively migrating when filtering through soil profile and then by surface flow to the local water catchments is not less than 400 kg/Ha annually for the study area.

Keywords: soil organic carbon, soluble carbon, soil carbon migration

Introduction, scope and main objectives

What is the Soil Organic Carbon? It is usually being considered as carbon content in organic horizons of the topsoil accumulated during soil formation due to the processes of humification of the bioorganic residuals of plants (such as tree waste) and soil biota. It is believed that the soil of natural ecosystems may serve as one of the main long-term deposits of carbon sinks, and the carbon content in the soil can be judged on their role in the carbon balance of the related ecosystems. It involves many carbon balance models considering the organic carbon content in the soil in-situ as one of the key components of this balance.

However, not all of the soil organic matter (SOM) of soil origin accumulates and/or mineralizes directly in soils. It has long been observed that a significant part of SOM is water-soluble and migrate beyond the soil profile with streams. This forms the distinctive brown color of the surface waters, not only in lentic swamps and lakes, but also in running lakes, rivers and streams. Major chromophores of these waters are usually compounds of organic carbon and iron. The rivers and lakes of the humid landscapes can contain up to 100 mg/l of OC of the type of soil humic acids. In this case waters acquire the color of strong tea (e.g. in West Siberia and Amazon areas).

Some scientists consider that in podzolic soils about 35% of SOM, formed in the forest litter is driven out of the soil profile, and that it is podzolic soils in middle taiga subzone with the most favorable conditions for the mobilization of the SOM and its abiogenic migration.

In this study we aimed to assess how and what quantities of the water-soluble SOM get from the soil into water bodies, and how meaningful are the quantitative conversion of the OC concentration in the waters within local watershed.

Methodology

We studied the waters sampled in the Kenozero lake area in the Arkhangelsk region of Russia located in between 61⁰⁵⁷' - 61⁰⁵⁷' N, and 38⁰⁰⁵' - 38⁰³⁵' W (fig.1).

The surface deposits of the area vary of sedimentary and crystalline origin. The rocks of different ages and composition from acidic to basic, from the Archean to Fat Kalinin glaciation come to the surface.

The depth of Quaternary deposits varies from 0 to 3 meters on carbon plateau and up to 186 meters in the depression of Kenozero lake.

The soil cover is represented by combinations of podzolic soils and podzols (including residual-calcareous), acid and leached brown soils, and peat soils. The forests consist mainly of mixed pine and spruce forests with an admixture of birch and aspen. The hydrography includes more than 300 lakes of mainly glacial origin, with the exception of the biggest Kenozero lake itself. The chemical composition of the surface waters varies from soft (mainly atmospheric and snow-fed) to hard (ground power supply), and rarely alkaline (on calcareous rocks and sediments).

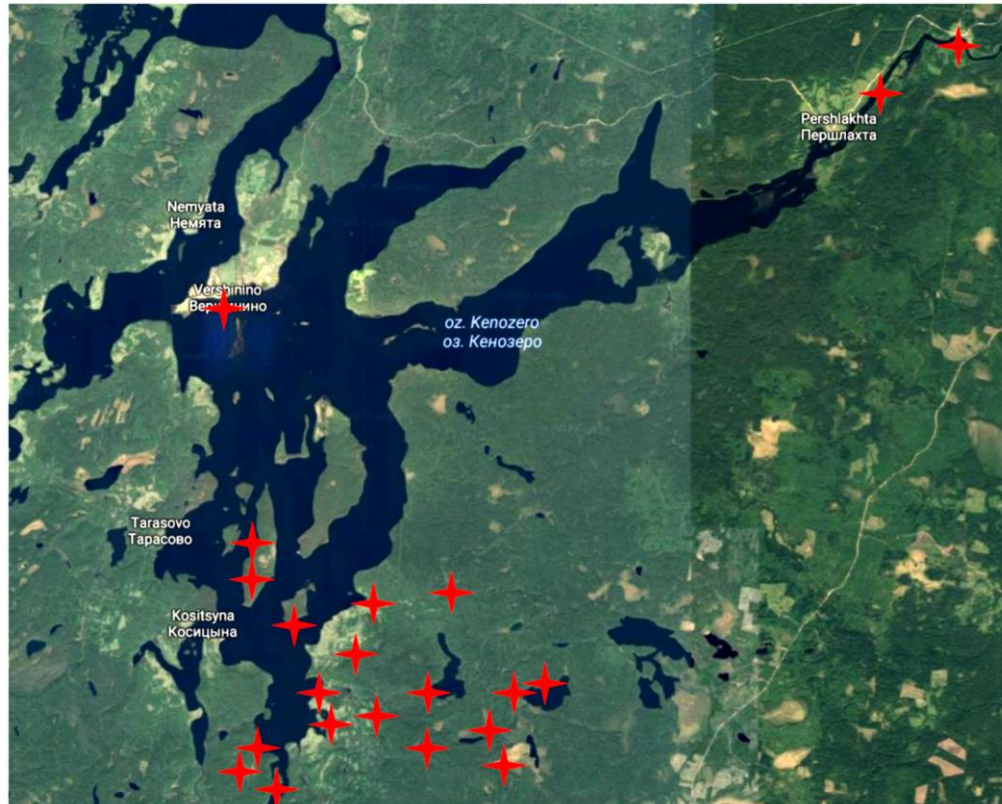


Fig. 1: Location of the testing sites and collecting soil and water samples (based on the Google Earth space imagery scene).

More than 50 water samples were selected and studied from the following sources:

- Soil solution (pressed out) from the surface organic horizons (peat, litter);
- Subsurface water (taken from the vadose or lysimetric vessels installed at 30-40 cm below the illuvial horizon (in the upper part of the horizon C);
- The waters of the surface runoff: streams and small rivers flowing into the Kenozero lake; samples were taken at least 3 times along the stream: near basic soil pits where soil water samples were collected, in the middle reaches, and at the mouth);
- Lake and swamp water: samples were taken close to the shoreline (no more 20 m) at a depth of 1 m to eliminate the influence of precipitation;
- Kena river water flowing out of the Kenozero lake.

Sampling was carried out in July, when the average monthly air temperature of + 17°C.

1 liter of water was taken for each sample and stored in dark glass bottles, conserved with a few drops of toluene. The total organic carbon (TOC) content were tested in the samples filtered through the “blue ribbon” filter (pore diameter = 2-3 micron) to dispose hard and flaky particles. A part of samples were also filtered through membrane filter (pore diameter < 0.45 micron) to determine the content of dissolved organic carbon (DOC).

Samples were concentrated on the bain-marie to the volumes of 20 ml. The OC content was estimated by the wet oxidation method (Tyurin method with the spectrophotometric end).

Results

The TOC content of the mineral topsoil varies from 0.9 to 2.0% (in litter and peat horizons it reaches 40-50%), abruptly decreasing down the profile. Sometimes an additional maximum of the TOC content (0.3-0.5%) is noticeable in the illuvial horizon.

The maximum TOC content was discovered in the soil solutions of pressed from the forest litter, with no relation to the extent of its decomposition, and also in peat: the concentration vary from 180 to 320 mg/l. In the peat maximum values are typical for lowland non-draining locations and relatively low pH values (up to 4.5). For those closely underlined by calcareous rocks and sediments, and pH of the solutions of higher than 5, the TOC concentration in pressed solutions falls sharply (to 30-40 mg/l or less).

The TOC in the samples of lysimetric and vadose waters retain remarkable constancy irrespective of the location of the sampling points and vary in the narrow limits between 94 and 110 mg/l. (The exception is the water samples collected from the damaged ecosystems - in forest cutting and burnt areas. Here, the TOC reaches 150-180 mg/l.) The same range of concentrations as in the lysimetric waters in undisturbed ecosystems is maintained throughout the course of streams and rivers, up to their outfalls in the Kenozero lake, and in the lake itself: from 95 to 107 mg / l. Exceptions are the locations (small lakes and bogs) with the bed underlined by close calcareous rocks and moraines. Here, the TOC concentration falls sometimes to the vanishingly small values. Accordingly, a relatively small TOC content observed in the water sampled at the sources of streams and rivers flowing from such reservoirs, as well as those cutting through calcareous sediments. The water of the Kena river, flowing out of the Kenozero lake, have a lower TOC concentration of about 80 mg/l at the outlet, and less than 70 mg/l downstream.

The DOC concentration in relevant samples is considerably low. In Kenozero lake the DOC content is about 40 mg/l; in vadose and lysimetric water samples it ranges from 10 to 45 mg/l, in streams and small rivers vary from 7 to 35 mg/l. The reason for such large fluctuations of DOC concentrations in comparison with relatively stable concentrations of TOC in the same samples remains unclear, and probably should be concerned with the peculiarities of biochemical processes in soil and water, and with the formation of different ferro-organic complexes in different conditions.

Discussion

These results clearly highlight several groups of water containing organic matter originated from soil:

A. Water with a OC content up to several hundred milligrams per liter. This group includes the water extracted from the forest litter, and the OC concentration in them hardly reflects soil differences associated with the location/formation on the calcareous rocks. We consider this describe the high independence of the soil forming processes in the topsoil from the chemical composition of underlying rocks in humid climate. All water samples have intensive brown color (“strong black tea”).

B. OC content values close to 100 ± 10 mg/l. This is the largest group among the samples studied, including the water of the Kenozero lake, of streams and small rivers, whose catchment area is confined to non-calcareous rocks, as well as all of the samples of soil vadose. It is also easy to see from the data obtained that the OC concentration in the vadose and lysimetric water hardly reflects differences in parent material. All samples are transparent and have a light brown-yellow color.

C. Water with the OC concentration substantially less than 100 mg/l. This group includes surface water of valley and transition peat bogs serving as a local catchment for landscapes and soils located in the watershed containing calcareous rocks and sediments. These samples are colored from light yellow to yellow.

D. Water with negligible OC content. This group is represented by the samples taken from lakes and some bogs formed on the bed of calcareous rocks and sediments. It includes also the water of streams cutting calcareous moraine and fluvio-glacial deposits. These waters are transparent and almost non-colored.

The results obtained describe the following ways of the migration of water-transportable SOM in the test region.

The main source of water-transportable SOM is the forest litter usually overmoistured and having maximum activity of microbiota. The water of the soil vadose (which is the hallmark of the most of the local soils formed on the sediments with binary texture: light sandy loams and loamy sands underlying by heavy loams and clays) and samples from lysimetric pans has less concentration of SOM (about 100 mg/l of TOC). These organic substances can be considered as the most capable for migration. Our study justified that in the absence of geochemical barriers to migration routes of water-transportable SOM, the TOC concentration remains unchanged along all the way from the soil vadose through surface flows until the water entering the final lake catchment of the area.

Accounting the amount of precipitation in the study area during the season of active biochemical conversion of plant residues by soil microorganisms, a first approximation can be given to calculate the amount of SOM runoff into local catchments, and further to the world ocean. When the amount of precipitation is about 400 mm, falling from May to September, we should expect the removal of at least 40 g TOC from each square meter, which is equivalent to 400 kg/ha of soil organic matter annually.

Conclusions

1. Differences in parent rocks and differences in soil location in topography hardly affect the content of OC in the water of forest litter and in vadose. In the study area the OC content in litter water is on the average from 200 to 300 mg/l, and in vadose it is 100 ± 10 mg/l.
2. Differences in the parent rocks chemical composition have a significant impact on the further migration of SOM. The water of lakes and bogs formed in the bed of calcareous rocks and sediments contain vanishingly small amounts of OC. Carcareous rocks and sediments also reduce its concentration in the streams' water. This manifests in the presence of illuvial-humus horizons in soil profile and humus covers and films on the surface of soil peds, and on the faces of chalky and dolomite minerals. If non-calcareous rocks dominating in the catchment area, then the differences in the content of OC in the waters of soil vadose and surface flowing streams and small rivers are not detected.
3. Soils are the main source of organic matter actively migrating when filtering through soil profile and then by surface flows to the local water catchments. Approximate number of TOC is not less than 400 kg/Ha annually for the study area.