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AGRONOMIC ASSESSMENT OF THE SUITABILITY OF BOTTOM SEDIMENTS OF PONDS FOR INCREASING SOIL FERTILITY

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Abstract

At the international level one of the main problems are the increase the area of degraded lands and the decrease of soil quality. The development of measures to protect and increase soil fertility, rational management of soil resources is central to achieving the Sustainable Development goals and a zero level of land degradation. One of the possible directions is the use of local raw materials, in particular bottom sediments of fishing ponds. On the example of pilot objectives in the Kharkiv region a study was conducted and the chemical composition of bottom sediments of fishing ponds was analyzed. The assessment of their agronomic value, taking into account the content of organic matter, total carbon, the content of mobile compounds of nitrogen, phosphorus, potassium was performed. It was determined that 90-235 kg of organic matter, 18-48 kg of carbon, 1-7 kg of NPK, 32-63 kg of Ca are introduced into the soil by 1 ton of sediments. Fertilizing efficiency and predicted impact of bottom sediments on soil fertility indicators and crop productivity were evaluated.

***Key words**: agronomic value, bottom sediments, nutrients, organic matter, soil fertility.*

INTRODUCTION

Over the past 40-50 years, there has been a gradual increase in global fish production from aquaculture (Haque et al., 2016; Tran et al., 2017). Aquaculture is predicted to become increasingly important as a source of fish, overtaking fishing as the main fish supplier by 2030. (Tran et al., 2017). According to FAO estimates, global aquaculture production will increase by 32% by 2030 (FAO, 2020).

Ponds for fish breeding have long been quite characteristic elements of agricultural landscapes in many countries of the world (Haque et al., 2016; Tran et al., 2017; Burducea et al. 2022; Dróżdż et al., 2020; Mehmood et al., 2023). And everywhere there is a problem of accumulation of bottom sediments in ponds from aquaculture production.

This significantly reduces the capacity of fish ponds, reduces the content of dissolved oxygen and leads to the release of toxic gases such as H2S and NO2 (Kibria and Haque, 2018; Dróżdż et al., 2020), impairing the efficiency of fish farming.

The removal and disposal of sediment in fish ponds are often practised in an uncontrolled manner, resulting in environmental degradation. Unbalanced and inefficient use of natural resources often causes serious environmental, social and economic problems (FAO, 2021). However, bottom sediments are not waste. The use of renewable natural resources in agricultural production significantly reduces man-made pressure on the natural environment and contributes to the achievement of most of the Sustainable Development Goals (SDGs) by 2030 (Transforming our World, 2015). The possibility of its use at other stages of agricultural production is extremely important (Dróżdż et al., 2020; Matej-Łukowicz et al., 2021; Burducea et al., 2022; Mehmood et al., 2023).

The processing of bottom sediments for soil fertilization corresponds to the policy of the circular (circular) economy and allows the use of micro- and macroelements accumulated in the sediments for soil fertilization. The authors (Dróżdż et al., 2020; Matej-Łukowicz et al., 2021; Burducea et al., 2022) emphasize that considering the potential agricultural use of bottom sediments, the content of valuable elements necessary for plant growth and their ratio should be evaluated.

There are 2,538 fish ponds in the Kharkiv region of Ukraine, and in the pre-war period, there was a trend towards creating new and reconstruction of old fish breeding enterprises (Recommendations, 2023). At the same time, in Ukraine, unproductive, degraded and technogenically polluted soils are widespread, requiring measures to restore their fertility. The development of measures to protect and increase soil fertility, and rational management of soil resources is central to achieving the Sustainable Development goals and a zero level of land degradation. One of the possible ways to increase soil fertility is the use of local raw materials, in particular bottom sediments of fishing ponds as a source of carbon, nitrogen, phosphorus, and potassium.

However, the bottom deposits of ponds differ significantly in chemical composition. Their composition and properties are a reflection of the entire set of biological, chemical and physical processes occurring in the reservoir (Rahman et al., 2004; Dróżdż et al., 2020; Matej-Łukowicz et al., 2021; Burducea et al., 2022; Recommendations, 2023). This makes it necessary to determine the chemical composition and agronomic value of bottom sediments in each pond. So far, no such studies have been conducted in the Kharkiv region.

The overall objective of this study was to investigate the potential of fishpond bottom sediments as a source of valuable nutrients.

Research objectives:

1) Determine the content of carbon and organic matter in bottom sediments;

2) Determine the content of nitrogen, phosphorus and potassium in bottom sediments;

3) Evaluate the effectiveness and predicted impact of bottom sediments on soil fertility indicators and the productivity of cultivated crops.

MATERIALS AND METHODS

The field stage of research was carried out with the selection of samples of bottom sediments and water from fishing reservoirs (research areas) to determine their chemical composition and assess their suitability for use to improve the condition of agricultural land. The site is located in the southern part of the Left-Bank Forest-Steppe of Ukraine, Chuguyivskyi district of Kharkiv region. Sludge samples were taken from 2 ponds (a total of 20 composite samples). Three samples were mixed together in equal proportions, from which the composite sample we obtained. The sampling of bottom sediments was selected by ISO 5667-12:2017 on an irregular grid with GPS referencing. Date of selection of bottom sediment samples - July 24, 2023

Research area № 1 is located in the village of Korobochkine. The pond is used for aquaculture. Characteristics of the pond: the total area is 24.68 hectares, the mirror of the water surface area is 8.55 hectares, the depth is from 1.50 to 3.50 m, and the layer of bottom sediments is from 0.35 to 0.70 m. The bottom sediment sampling scheme is given in Figure 1.

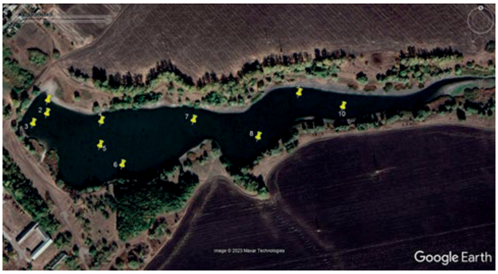

Figure 1. Sampling points of bottom sediments from a pond in the Korobochkine village

Research area № 2 is located in the village of Nova Hnylitsa. The sampling scheme bottom sediments are shown in Figure 2.

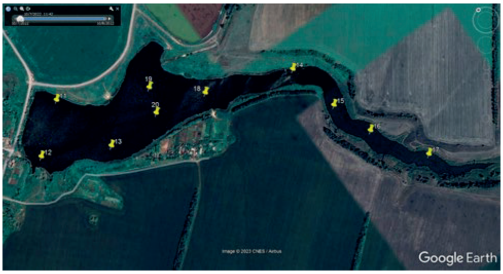

Figure 2. Sampling points of bottom sediments from the pond in the village. Nova Hnylytsia

The pond is also used for aquaculture. Characteristics of the pond: the total area is 50.2 ha, the mirror of the water surface area is 39.8 ha, the depth is from 2.5 m to 7.5 m, and the layer of bottom sediments is from 0.2 m to 0.6 m.
Sampling was carried out with a manual sampling device. The samples were placed in polypropylene vessels in accordance with ISO (ISO 5667-12:2017). A photo of bottom sediments taken from fishponds (research areas №1 and №2) is shown in Figure 3.

Figure 3. Samples of bottom sediments taken from fishing ponds

Storage, transport and stabilization of samples of bottom sediments was carried out in accordance with ISO 5667-15:2009. With samples of bottom sediment that were dried, we behaved similarly with dried soils.
We treated bottom sediment samples that were dried in the same way as dried soils. In dried bottom sediment samples, we determined according to the national standards of Ukraine: mass fraction of ash and mass fraction of organic matter – DSTU 8454:2015 (Organic fertilizers, 2015a); mass fraction of total carbon – DSTU 4289:2004 (Soil quality, 2004a); mass fraction of humic acids – DSTU 7083:2009 (Organic and organo-mineral fertilizers, 2009); mass fraction of total nitrogen – DSTU 7911:2015 (Organic and organo-mineral fertilizers, 2015); mineral nitrogen content – calculation based on the results of determination according to DSTU 4729:2007 (Soil quality, 2007); mass fraction of total phosphorus – MV 31-497058-028:2019 (Methodology .., 2019); the content of mobile phosphorus – DSTU 4114-2002 (Soils, 2002a); mass fraction of total potassium – DSTU 7949:2015 (Organic fertilizers, 2015b); the content of mobile potassium – DSTU 4114-2002 (Soils, 2002b).

RESULTS AND DISCUSSIONS

According to our calculations, from 25 to 60 million m^3 of bottom sediment matter accumulate in fishing ponds of Ukraine per year (Recommendations, 2023). Their total reserves are estimated to be 100 million tons. They can be used in agricultural production to cultivate unproductive and degraded lands, increase soil fertility and structural melioration of sandy and clayey soils, reclamation of soils damaged by war activities.
On the example of research areas in the Kharkiv region, field observations were conducted and the chemical composition of the bottom sediments of fishing ponds was analyzed. Based on the main indicators of their composition, the nutritional value and directions of their possible use in agriculture to improve the condition of the soil and increase the yield of cultivated crops were determined.
According to the reaction of the soil solution, the bottom sediments of the ponds were mainly characterized by a slightly alkaline reaction. The water pH ranged from 7.5 to 8.0 units. According to the content of physical clay, their granulometric composition was classified as medium loam (physical clay 33-43%) and heavy loam (47-58%).
Agronomic value of bottom sediments of research area №1. The agronomic value of bottom sediments and the possibility of using them to increase fertility and improve soil properties were determined based on the content of organic matter, total carbon, and the content of nutrient macroelements (mobile compounds of nitrogen, phosphorus, potassium). The chemical composition of the bottom sediments of pilot pond No. 1 is shown in Table 1. The table shows the fluctuations of indicator values from 10 sampling points of bottom sediments in the pond.
On the basis of the conducted analysis, fluctuations in the values of indicators of the qualitative composition of bottom sediments within one pond were established. This is due to the different depth of the pond in different areas, fluctuations in the strength of sediments, redox and alkaline-acidic conditions, the activity of microorganisms and benthic biota. So, the content of organic matter was from 9 to 23.5%, and total carbon from 1.81 to 4.79%.

The composition of the organic matter of the bottom sediments of this pond was dominated by fulvic acids, their content was 0.65%, and humic acids were 0.14%. The share of humic substances in the bottom sediments was 0.79%.

Table 1. Chemical composition of bottom sediments of research area № 1

Indexes	Actual content per dry matter, %
Mass fraction of ash	76.50-91.00
Mass fraction of organic matter	9.00-23.50
Mass fraction of total carbon, C	1.81-4.79
Mass fraction of humic acids	0.14
Mass fraction of fulvic acids	0.65
Mass fraction of humic substances	0;79
Mass fraction of total nitrogen, N	0.10-0.33
Mineral nitrogen content, N, mg/kg	52.5-111.6
Mass fraction of total phosphorus, P_2O_5	0.10-0.17
The content of mobile phosphorus, P_2O_5, mg/kg	60.5-82.7
Mass fraction of total potassium, K_2O	0.29-0.69
The content of mobile potassium, K_2O, mg/kg	243.4-498.8

We calculated the arrival of organic matter to the soil with the bottom sediments of this pond No. 1 (Table 2). From 90 to 235 kg of organic matter, from 18 to 47 kg of total carbon, 1.4 kg of humic acids, 6.5 kg of fulvic acids (7.9 kg of humic substances) can enter the soil from 1 ton of dry bottom sediments of this pond. Enriching the soil with organic matter will improve its physical and chemical properties, increase fertility and yield of cultivated crops.

Table 2. Agronomic value of bottom sediments (research area №1)

Index	Content in 1 ton of dry bottom sediments, kg	Index	Content in 1 ton of dry bottom sediments, kg
Organic matter	90-235	Total nitrogen	1.0-3.3
Total carbon, C	18-47	Total phosphorus	1.0-1.7
Humic acids	1.4	Total potassium	2.9-6.9
Fulvic acids	6.5		

An important indicator of the agronomic value of bottom sediments is the content of the main macroelements (Table 1). They can be a source of nutrients for the soil and help to improve the quality of the soil. According to the chemical composition, the bottom sediments of the pilot facility No. 1 are characterized by a high content of nutrients. The high content of macronutrients enriches their nutritional value and the possibility of using them as fertilizers. The content of mineral nitrogen (ammonia and nitrate form) was estimated to be very high and ranged from 52.2 to 111.6 mg/kg. Bottom sediments were characterized by a very high content of mobile phosphorus compounds. Their concentration ranged from 60.5 to 82.7 mg/kg. The availability of mobile potassium varied from a gradation of increased content to very high. The actual values of its concentration ranged from 243.4 to 498.8 mg/kg.

We determined the nutritional value of the bottom sediments of the pilot facility No. 1 by the content of macroelements (see Table 2). According to calculations, 1 ton of bottom sediments of object 1 contains from 1 to 3.3 kg of total nitrogen, from 1 to 1.7 kg of total phosphorus, from 2.9 to 6.9 kg of total potassium. The total content of total nitrogen, phosphorus and potassium, which will enter the soil from 1 ton of sediments, is from 4.9 to 11.9 kg. At the same time, the ratio of N: P: K is 1: 0.5-1: 2.9-2.1, and the ratio of carbon to nitrogen (C: N) is 15-18.

We compared the nutritional value of bottom sediments with organic fertilizer - manure. With 1 ton of cattle manure with a moisture content of 75%, 5 kg of total nitrogen, 2.5 kg of phosphorus and 6 kg of potassium are introduced into the soil. Their total content is 13.5 kg, and the N: P: K ratio is 1: 0.5: 1.2. Therefore, the bottom sediments of the object No. 1 are agronomically valuable and can be used as fertilizers.

Norms of organic fertilizers are established, as a rule, on the basis of the need of fertilized crops for nitrogen and its content in fertilizers, since nitrogen has the greatest effect on the size of the harvest. To apply 50 kg of nitrogen per hectare, it is necessary to add from 15 to 50 tons of dry raw material of the bottom sediments of object No. 1 to the soil. The supply of nutrients to the soil with the application of these standards is shown in Table 3.

Table 3. Inflow of nutrients to the soil at different rates of bottom sediments (research area №1)

Index	Arrival to the soil, kg	
	Rate of the bottom sediments 15 t/ha	Rate of the bottom sediments 50 t/ha
Organic matter	1350-3525	4500-11750
Total carbon, C	272-718	906-2393
Humic acids	21	70
Fulvic acids	97	323
Total phosphorus	15-26	50-85
Total potassium	44-104	145-345

Agronomic value of bottom sediments of research area №2. The chemical composition of the bottom sediments from the pond of the research area No. 2 was analyzed. Compared to the previous one, this pond was characterized by a larger area of the water table, greater depth and thickness of the sediment layer. Table 4 shows the chemical composition of sediments from 10 sampling points on the territory of the pond. Compared with the previous object, bottom deposits of object No. 2

Table 4. Chemical composition of bottom sediments of research area № 2

Indexes	Actual content per dry matter, %
Mass fraction of ash	79.00-86.00
Mass fraction of organic matter	14.00-21;00
Mass fraction of total carbon, C	2.59-3.38
Mass fraction of humic acids	0.14
Mass fraction of fulvic acids	0.63
Mass fraction of humic substances	0.77
Mass fraction of total nitrogen, N	0.12-0.41
Mineral nitrogen content, N, mg/kg	54.1-116.5
Mass fraction of total phosphorus, P_2O_5	0.11-0.21
The content of mobile phosphorus, P_2O_5, mg/kg	95.0-119.3
Mass fraction of total potassium, K_2O	0.35-0.58
The content of mobile potassium, K_2O, mg/kg	168.7-306.0

Adding bottom sediments to the soil will ensure its enrichment with organic matter (Table 5). According to calculations, from 140 to 210 kg of organic matter can enter the soil from 1 ton of analyzed dry bottom sediments.

Table 5. Agronomic value of bottom sediments (research area №2)

Index	Content in 1 ton of dry bottom sediments, kg	Index	Content in 1 ton of dry bottom sediments, kg
Organic matter	140-210	Total nitrogen	1.2-4.1
Total carbon, C	26-34	Total phosphorus	1.0-2.1
Humic acids	6.3	Total potassium	3.5-5.8
Fulvic acids	6.3		

With this amount, 26 to 34 kg of total carbon will be added to the soil; 1.4 kg of humic acids, 6.3 kg of fulvic acids (7.7 kg of humic substances), 1.2-4.1 kg of total nitrogen, 1.1-2.1 kg of total phosphorus, 3.5-5.8 of total potassium. The total content of nitrogen, phosphorus and potassium is 5.8-12 kg. The N: P: K ratio was 1: 0.9-0.5: 2.9-1.4.

According to the results of the analysis, the bottom sediments have a very high content of mineral nitrogen (ammonia and nitrate form) - from 54.1 to 116.5 mg/kg (according to DSTU 4362:2004 (Soil quality, 2004b) very high availability - more than 35 mg/kg), a very high content mobile phosphorus compounds - from 95.0 to 119.3 mg/kg (according to DSTU 4362:2004 (Soil quality, 2004b) very high supply - more than 60 mg/kg), from average to high content of exchangeable potassium - from

168.7 to 306.0 mg / kg (according to DSTU 4362:2004 (Soil quality, 2004b) - average availability 101-200 mg/kg, increased - 201-300 mg/kg).

The bottom sediments of object No. 2 are characterized by a slightly higher agronomic value compared to object No. 2. They contain more organic matter, humic acids, nitrogen, phosphorus, and potassium. According to calculations, to apply 50 kg of nitrogen per hectare, it is necessary to apply from 12 to 42 tons of dry raw materials of bottom sediments of the object № 2.

From 1680 to 2520 kg of organic matter, including 311 to 406 kg of total carbon, 17 kg of humic acids, 76 kg of fulvic acids (93 kg of humic substances) will enter the soil from 12 tons of raw materials (Table 6). In addition, from 13.2 to 25.2 kg of total phosphorus, from 42 to 69.6 kg of total potassium will be added. From 42 tons of bottom sediments, from 5880 to 8820 kg of organic matter will enter the soil, including from 1088.5 to 1421 kg of total carbon, 59.5 kg of humic acids, 266 kg of fulvic acids (325.5 kg of humic substances). In addition, from 46.2 to 88.2 kg of total phosphorus, from 147 to 243.6 kg of total potassium will be introduced.

Table 6. Inflow of nutrients to the soil at different rates of bottom sediments (research area №2)

Index	Arrival to the soil, kg	
	Rate of the bottom sediments 12 t/ha	Rate of the bottom sediments 42 t/ha
Organic matter	1680-2520	5880-8820
Total carbon, C	311-406	1089-1421
Humic acids	17	60
Fulvic acids	76	266
Total phosphorus	13-25	46-88
Total potassium	42-70	147-244

The obtained results of the chemical analyzes of the bottom sediments from the pilot fishing ponds show that they have the prospect of being used as soil conditioners from the point of view of soil science, agrochemistry, agronomy and ecology. Of greatest interest is the content of organic matter, carbon, humic acids and fulvic acids in the raw material, enrichment with useful microflora. The introduction of soil-improving mixtures based on bottom sediments will contribute to increasing the fertility of soils, especially light granulometric composition. They improve the water-air regime, increase their moisture capacity, water-holding capacity, and activate microbiological processes. The presence of highly dispersed mineral substances in bottom sediments is very important for creating an organo-mineral complex of soils, increasing their buffering capacity and sorption properties.

Thanks to the sorption capacity of the bottom sediments, the applied nutrients are "fixed" and released gradually. This reduces unproductive losses of nutrients.

Bottom sediments, due to their characteristics and properties, can play the role of an active surface in biocomposting processes of organic materials (manure, bird droppings, etc.). The addition of bottom sediments to the compost mass in certain ratios will contribute to the formation of stable, highly humicized organic matter and will prevent unproductive losses of nutrients and carbon in the composting process.

According to their chemical and physical and chemical characteristics, bottom sediments can be classified as raw materials with a fertilizing and ameliorating effect.

CONCLUSIONS

In the example of research areas, the agronomic value of bottom sediments from fishery reservoirs was learned. Based on the main indicators of their composition, the nutritional value and directions of their possible use in agriculture to improve the condition of the soil and increase the yield of cultivated crops were determined.

Research has established that bottom sediments use will enrich the soil with organic matter, and increase the content of total carbon, mobile compounds of nitrogen, phosphorus, and potassium. Bottom sediments can be used as components of fertilizers, soil conditioners or recultivators.

Their use in agriculture will improve the soil quality. Land reclamation with the bottom sediments of fishing ponds ensures optimization of the water regime, agrophysical and physicochemical properties of soils and nutrients for agricultural crops

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