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REPRODUCTION OF POTENTIAL SOIL FERTILITY AND THE STATE OF THE ENVIRONMENT AT THE WASTE APPLICATION FROM PIG COMPLEXES

Stanislav Dehodiuk[1], Olena Litvinova[2], Dmytro Litvinov[2*], Yuliia Borko[1]

[1]National Science Center «Institute of Agriculture NAAS Ukraine», 2b Mashynobudivnykiv St., Chabany, 08162, Ukraine; [2]National university of life and environmental sciences of Ukraine. Heroiv Oborony str., 12, bulding 7, Kyiv, 03041, Ukraine

Abstract *The increase of the livestock and waste concentration per unit area of agricultural land determines a qualitatively different nature of the impact on the indicators of potential soil fertility and the state of the environment. Livestock breeding complexes for fattening up to 70 thousand pigs per year are located in the Polissya zone on typical sod-podzolic soils. However, large pig complexes cause an increase in the chemical load on ecosystems in waste disposal sites due to technical and organizational reasons related to the capacity of effluents per unit area. The research aimed to establish the parameters of changes in soil fertility and the ecological state of the environment in the conditions of the intensive waste load of pig complexes. It has established that the use for 25 years of low doses of the solid fraction of effluents from the Agricultural Open Joint-Stock Company «Agrocombinat Kalyta» as well as their combination with straw and green manure in the long-term stationary experiment of the National Science Center «Institute of Agriculture NAAS» caused widespread reproduction of sod-podzolic soil fertility. The highest fertility parameters were achieved by applying the solid fraction of effluents at a dose of N_{75}, where the humus content was 0,28 % higher than control (without fertilizers) and was – 1,17 %. At the norm of the effluents solid fraction of N_{75}, the content of mobile phosphorus in the soil increased to control 1,4 times, and at doses N_{300} – 3,2 times, which caused high soil phosphating. The content of mobile potassium in the soil at the application of the solid fraction of effluents at the dose of $N_{100\text{-}200}$ remained low (70-75 mg/kg), which is required the additional application of potassium fertilizers at the dose $K_{60\text{-}120}$. At the fertilizing of the soil with the pig effluents, the dose of their application should not exceed 200-225 kg/ha in terms of nitrogen has been established. At doses of N_{400} and above, there were a sharp increase in soil acidity, a decrease in the amount of absorbed bases by 1,9 times, an increase in the content of mobile phosphates by 25 times to the natural background, and contamination of groundwater with nitrates. At high effluents loads (N_{400}), nitrogen leaching from nitrates in the soil thickness to 500 cm is increased 14,6 times compared to the control: at the control - 102 kg/ha, at the dose of excess activated sludge N_{225} - 657, dose N_{675} - 1488 kg/ha. At the intensive effluents loads, there was defined the inhibition of the development of mostphysiological groups of soil microorganisms, in particular, actinomycetes and ammonifiers. However, the number of denitrifying and phosphate-mobilizing microorganisms increased 13 and 4 times, respectively, at the increasing intensity of organic matter mineralization. It was significantly affected the processes of nitrate pollution and phosphating of the soil. The use of a solid fraction of livestock effluents in the dose of N_{75} provided crop rotation productivity at the level of 4,10 t/ha of grain units at the dose of $N_{75} + K_{90}$ – 4,57. The highest productivity of crop rotation (5,65 t/ha) was achieved at the application of excess activated sludge at a dose of N_{225}, while a similar indicator at the control was 2,56 t/ha. Further increase of the products doses of biological processing of livestock effluents reduced the payback per unit of fertilizer by 4-5 times and created an environmental hazard in the environment.*

Keywords: *sod-podzolic soil, fertility, waste of pig complexes, environmental protection, soil microorganisms, surface soil water.*

INTRODUCTION

Industrial livestock complexes and poultry farms in Ukraine are in the basins of small rivers. The products of their life create situations of extreme environmental stress, which affects the deterioration of the quality of soil cover, groundwater, and even artesian water. Environmental pollution in areas of industrial livestock is complex, in which there is chemical, biological, bacterial, and helminthic pollution. In world practice, the way out of a complicated environmental situation had found in the regulatory waste application to ensure their quality use [1, 2, 3, 4]. A significant contribution to solving the problem had made by German [5, 6, 7] and European scientists [8, 9] and in Canada and Japan [10, 11].

Ukrainian scientists, in particular O.O. Batsula, E.G. Degodyuk, M.K. Linnik, V.I. Gamalei, have made a significant contribution to the utilization of litter-free manure of large and small livestock complexes [12].

However, the problem of using livestock waste from industrial complexes turned out to be much more complicated. It requires not only utilization but also the transformation of their firm part during bioconversion into digestible forms.

There was the least of all attention to the environmental consequences of systematic stress on the environment at planning large pig complexes. Theoretical issues of ecosystem functioning in such cases were considered even less [13].

Under stress loads of livestock effluents, this balance is disturbed, and decomposition processes do not have time to stabilize with the arrival of new portions of effluents. It sharply inhibits the passage of self-cleaning of the soil, which occurs in the natural environment during one growing season. Thus, in such situations, the production of introduced organic matter exceeds the decomposition, creating favorable conditions for the development of harmful microflora and the preservation of putrefactive processes and diseases. It is known that animal excrement is a source of more than 100 diseases ofboth animals and humans.

Many cases of aggravation of the ecological situation due to ill-considered choice of location of complexes and unsuitability of agricultural land for prompt and uniform application of effluents are in the practice of industrial animal husbandry.

After all, large complexes for fattening up to 100 thousand pigs per year are equated to an industrial center with a population of 400-500 thousand people. In connection with the transition to concentrated feed, which includes various premixes, in the mass of manure pigs content of copper was 1064 kg, zinc 5800 kg, manganese 2600 kg, while in the manure of complexes for 12 thousand heads, respectively, 145; 110 and 340 kg [15]. The liquid flowing from the fattening sites contains 30 times more ammoniacal nitrogen, 4 times more nitrate, and 75 times more phosphorus than in the wastewater from the fields under cultivation. The sewage water of complexes, getting into reservoirs,at a concentration of nitrogen of 0,3 mg/l and phosphorus of 0,2 mg/l, cause rapid development of phytoplankton and death of fish [16].

The ecological danger is posed by the infrastructures of large complexes, which involve the use of large areas under the buildings of treatment facilities and settling ponds, increasing the volume of irreversible water supply (up to 90%), salinization and waterlogging of irrigated fields, phosphating intensively fertilized fields with biological treatment products, reduced yields and deterioration of product quality. And especially it should be noted - increasing the incidence of the population [17].

The area of activity of large livestock complexes is a model of sudden and stressful load on agricultural landscapes, where are including mechanisms of action on nature, which were previously uncharacteristic of it on such a scale.

Livestock effluents are a special type of anthropogenic organic residues. It is uncharacteristic agroecosystems for the entire previous history of civilization [18]. At the same time, it has been established that under conditions of a moderate load of livestock effluents at the complexes with ecologically sound livestock, livestock waste is not harmful to wildlife. And it can play an important role in a balanced cycle of nutrients.

It has been established by many both domestic and foreign scientists [19, 20, 21]. In the last decade in Western Europe, North America, East Asia, violations of norms and standards of hygiene and ecology of the environment by livestock waste products are legally prohibited and strictly controlled by relevant government services, bodies, and public organizations [22].

MATERIALS AND METHODS

A long-term experiment has based in the area of the Left-Bank lowland Polissya (Chornobyl' agro-soil district) on the sod-medium-podzolic sandy soil of the Agricultural Open Joint-Stock Company (AOJSC) "Agrocombinat Kalyta" of the Brovary district of the Kyiv region. The experiment examined the effectiveness of increasing doses of solid fraction (N_{50-400}) of livestock effluents of Kalytyansky pig complex with fattening 70 thousand pigs per year, as well as the efficiency of mineral fertilizers, crop by-products, and green manure in field crop rotation with the following alternation of crops: lupine - winter wheat – corn for silage – winter rye – spring barley – vetch-oats – corn for silage – soybeans. The experiment was deployed in three fields. It had 13 options and 3 repetitions. The sown area of the plot was 120 m^2, accounting – 60 m^2. During field research, we took soil samples at the endof the growing season before harvesting crops to a depth of 0–20 cm and a depth of 1–5 m every 20cm with a soil drill.

In the selected soil samples were determined: the content of total humus according to State Standard of Ukraine (SSU) 4289:2004; pH_{H_2O} and pH_{KCl} - potentiometrically according to SSU ISO 10390:2007; hydrolytic acidity - according to Kappen (SSU 7537: 2014); hydrolyzed nitrogen content - according to Cornfield; the content of mobile phosphorus and mobile potassium (in sod-podzolic soil) - according to Kirsanov (SSU 4405:2005). Yield accounting was carried out in every area by direct combining.

RESULTS AND DISCUSSION

The results of the research have shown that physicochemical parameters of soils have stabilized at a level close to nature at the use of moderate doses of liquid and solid wastes of industrial livestock, as well as their combination with crop by-products and green manures. Based on environmental and economic considerations, the average crop rotation dose of liquid waste and products of their processingin the amount of 150–200 kg of total nitrogen per 1 ha of crop rotation area was determined as one that provides natural reproduction of soil fertility.

In sod-podzolic soil at the once liming in 8-field crop rotation at a dose of 6 t/ha of ameliorant (sugar beet production waste) (60 % $CaCO_3$) and systematic application of biological processing products of livestock effluents, the degree of bases saturation was increased during crop rotation from 46,6 to 53,4 % at the moderate doses of excess activated sludge (N_{50-100}). While at high doses of redundant activated sludge ($N_{450-900}$), it decreased to 10 absolute percent, with a corresponding increase in hydrolytic acidity to 5,16 mg-eq/100g of soil and a shift in the reaction of the soil solution from the values of weakly acidic (pH_{KCl}=5,1) to acidic (pH_{KCl}=4,9).

Optimal physicochemical parameters at the use of products of biological processing of drains have formed at moderate doses (N_{75-150}) with crop by-products and green manures. At the application of increasing doses of the solid fraction of livestock effluents ($N_{200-400}$), there was an increase in hydrolyticacidity from 1,7 to 2,98 mg-eq/100 g of soil.

Humus condition of soils at the bioconversion of livestock waste. The highest content of total humus in sod-podzolic soil at the utilization of products by biological processing in field crop rotation was with the optimal dose of the solid fraction of effluents N_{75} – 1,17 % with an increase to control without fertilizers by 0,28 %. The humus content decreased to 1,05 % at a dose of solid effluent – N_{400}. It is due to the intensification of the processes of organic matter mineralization under high loads of products of biological processing of pig effluents.

The activity of soil microorganisms at the application of livestock effluents. There was a suppression of microbiological activity in sod-podzolic soil at high effluents loads and products of their biological processing (in doses $N_{450-900}$). The number of ammonifiers decreased by 2-3 times, actinomycetes – by 2-4 times. The number of nitrifying bacteria increased – 1,6 times, phosphate-mobilizing microorganisms increased 13 and 4 times, compared with the control without fertilizers and 1.8 times compared with a moderate dose of products of biological effluent processing.

Accumulation of nitrogen compounds in soils at the utilization of livestock effluents of AOJSC "Agrocombinat Kalyta" (excess activated sludge, solid fraction, sediments of vertical settling tanks). In

a long experiment on sod-podzolic sandy soil, we have found that the content of hydrolyzed nitrogen under different crops in the arable (0-20 cm) layer, except for some years, corresponding to the gradation of low supply (57–84 mg/kg), regardless of the amount applied doses of fertilizers. This isdue to the low humus content (1,10 – 1,17 %) and enhanced nitrification and denitrification processes. Compared with the background content of N-NO_3 (156 kg/ha – 1992 and 102 kg/ha – 1994) in the soil thickness of 0-500 cm in the control without fertilizers at the application a double dose of activated sludge (N_{255}) the amount of nitrate-nitrogen per this depth increased in 1992 by 4,8 times, 6 doses of silt – (N_{675}) – by 8 times, in 1994 by 6,4 and 14,5 times, respectively. At the same time, the highest concentrations of nitrate-nitrogen (22-33 %) were concentrated in the upper soil layers and in the underlying rocks, which are close to groundwater – 25-46 % of its total amount. It can lead to a direct threat of nitrate contamination of crop products and groundwater (Fig. 1).

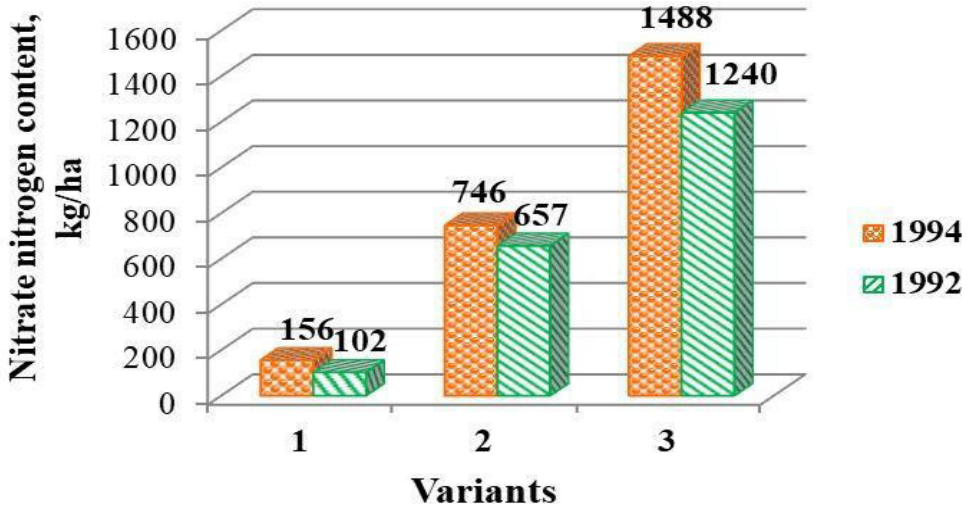

Figure 1. The effect of long-term application of excess activated sludge on the migration of nitrate-nitrogen in the profile of sod-podzolic sandy soil to a depth of 500 cm, AOJSC "Agrocombinat Kalita":
1 – without fertilizers (control); 2 – N_{225} – (2 doses); 3 – N_{675} (6 doses)

According to our calculations, the average load of effluents in the fields of the farm of AOJSC "Agrocombinat Kalyta" reached 700 kg N per 1 ha, which is almost 5 times more than the existing standards. During a full load of pigs livestock (108 thousand), the average content of nitrates in the wells of the village of Kalyta in the early 90s of the twentieth century was 412 mg NO_3 per 1 liter of water, in 1996 - 644 mg/l, which is 8 and 13 times higher than the maximum permission concentrations for drinking water. During the period of inactivity of the complex (1996-2000), the concentration of nitrogen nitrates in the village' wells decreased to 50 mg/l. In 2006 at the fattening 78 thousand pigs mostly exceeded the maximum permission concentrations by 2-4, maximum – 6 times.

Accumulation of phosphorus in soils with the use of livestock waste

At the intensive application of products of biological processing of effluents, due to chemical sorption, there was a noticeable accumulation of mobile forms of phosphorus in the soil, which caused phosphate pollution of the environment. The content of mobile phosphorus in the arable (0-20 cm) layer of sod-podzolic soil was 320 mg of P_2O_5 per 1 kg at the laying of a field experiment in 1978. Between 1990 and 2000, it decreased to 283 mg/kg or 12 %. With the systematic application of moderate and high doses of the solid fraction of livestock effluents, further soil phosphating occurred. With the systematic use of products of natural pig complexes for 20 years with the application of the average dose of solid fraction N_{100} (25 t/ha of physical weight), the content of mobile phosphorus increased by 156 %, and the dose of N_{200} (50 t/ha) – 3,2 times and N_{400} (150 t/ha) 4,9 times compared to the control without fertilizers. In a long-term experiment, the accumulation limit of mobile P_2O_5 was established, which on average reaches 1156 mg/kg. Phosphate pollution had reduced by 30 %

with the combined use of straw and products of biological processing of livestock effluents. According to the materials of the agrochemical survey, the area marked P_2O_5 "elevated, high and very high" accounted for 75 % of the farm's agricultural land. Land areas with low P_2O_5 content did not exceed 2-4 %. Our control agrochemical survey of the farm soil cover showed that the average reserves of mobile P_2O_5 in the field crop rotation reached 2030 kg/ha of soil, which is 25 times higher than the natural background.

Table 1. Change of phosphate regime of soil cover of agricultural lands of AOJSC «Agrocombinat Kalyta»

Surveyed area	Areas, with different provision of movable forms P_2O_5, ha					
	very low	low	medium	increased	high	very high
3728,4	–	71,2	325,9	868,7	1321,7	1140
± until 1985		+01,9	-0,1	+4,1	+21,6	-27,5

The noticeable influence of industrial effluents on the phosphorus content in the well waters of Kalyta village has been determined. The phosphorus content ranged from 0,18 to 3,4 and 7,4 mg/l depending on the distance of wells from fertilizer fields. In surface waters, the phosphorus content was up to 0,32 mg/l at the ecologically safely standard - up to 0,05 mg/l.

Accumulation of mobile potassium in soils

In the products of mechanical and biological processing, potassium passes into the liquid fraction, and, therefore, there is a need to balance this element through the application of mineral fertilizers and by-products of crop production. The ratio of N:P:K in the wastewater of AOJSC "Agrocombinat Kalyta" was 1:0.75:0.3, in the solid fraction – 1:0.24:0.10.

Due to potassium deficit in the soil in the second rotation of field crop rotation, variants with the addition of waste with potassium mineral fertilizers introduced into the experimental scheme. Under moderate loads of excess activated sludge and solid fraction of effluents, the content of mobile potassium in the soil remained at a low level, even with the addition of potassium fertilizers (K_{60-120}). The migration of this form of potassium along the soil profile to a depth of 1 m increased markedly in spring (May) and was 1.3 times higher than the maximum dose of excess activated sludge ($N_{450-900}$),1,6 times higher than the mineral fertilizer system, and 1.6 times higher combination of excess activated sludge and NPK – 3,8 times compared to the control without fertilizers.

Excessive use of effluent of pig complexes in the farm fields, depending on the distance to them, caused an increase in potassium content in well waters of village Kalyta from 1-8 to 500-800 mg/l, in ponds – from 10 to 185 mg/l.

Definition of the nutrient balance in the crop rotation of the experiment on sod-podzolic soil has shown that the intensity of nitrogen balance at high doses of fertilizers increased from 100 to 210 %. The intension of phosphorus balance at moderate backgrounds (N_{75-150}) was 173 %, at high backgrounds ($N_{450-900}$) – 616 %. The intensity of the potassium balance did not exceed 70 %.

Productivity of field crop rotation on sod-podzolic soil at the waste utilization of livestock pig complexes

Under loads of the crop rotation area with excess activated sludge (N_{75-150}), the productivity of the crop rotation unit (fodder beets, oats, vetch-oats, winter rye) was 5.21 t/ha of grain units with an increase of 68 % to control without fertilizers (3,09 t/ha), with a double dose of excess activated sludge (moderate load) – 83 %. Further increase of doses on 1 and 2 intervals ($N_{150-225}$ and $N_{450-900}$) increased crop rotation productivity only by 8 % compared to moderate effluent loading. The addition of K_{90} to an average dose of excess activated sludge provided twice the crop rotation productivity compared to the control without fertilizers. Application of solid fraction of effluents in the fodder crop rotation link (spring barley, corn for silage, winter wheat, lupine) at the dose of N_{75} provided an increase up to 77 % with productivity on control without fertilizers 2,32 t/ha of grain units. Productivity increased by only 3 % at the application of high doses ($N_{150-300} + K_{85}$). At the same time, the payback per unit of the solid fraction by the increase of crop rotation productivity was three times lower compared to the moderate load of crop rotation effluents.

It found that the application of solid fraction of effluents (N_{100} + straw) has provided an increase to control of 37 %, and at an average dose of nitrogen (straw 5 t/ha + N_{50}) – 42 % to control without fertilizers.

CONCLUSIONS AND RECOMMENDATIONS

In AOJSC "Agrocombinat Kalyta" the field experiment for 2 rotations of 8-field crop rotation identified minor changes in physical-chemical parameters at moderate effluents load. We have established the negative impact of high doses of excess activated sludge (N_{675}) on all physicochemical parameters of the soil. At the initial content of total humus of 1,1 % in the arable (0-20 cm) layer of sod-podzolic soil during 2 rotations of crop rotation, its content increased in the control variant without fertilizers to 1,37 % due to the crop rotation factor, and on moderate backgrounds of effluents to 1,43 %, at the application of a high dose of excess activated sludge (N_{675}) – 1,35 %. It has been found that all groups of soil microorganisms developed most steadily under moderate loads of products of biological processing of livestock effluents in doses N_{100}-N_{200}. At high doses (N_{300}-N_{400}), the number of nitrifiers increased sharply, and the number of phosphate-mobilizing microorganisms increased 2,9-4,0 times compared to control without fertilizers.
At the horizontal and vertical migration of nitrate-nitrogen to a depth of 6 m in a long experiment on sod-podzolic soil with gravitational water effluents, there was an accumulation of 533 kg/ha $N\text{-}NO_3$, after 5 years –1088 kg/ha, and on moderate backgrounds of effluents (N_{225}) – 4 times and at high – 18 times more than the control without fertilizers. The content of mobile phosphorus in sod-podzolic soil in the control variant without fertilizers was 235 mg/kg. It increased by 2,6 times at moderate sewage loads and high - by 4.9 times, which indicates its phosphating. The content of mobile potassium in sod-podzolic soil on the control without fertilizers was 52,4 mg/kg, and at the systematic application ($N_{200\text{-}300}$) of the solid fraction – 65 mg/kg of soil, which corresponds to a low level of supply. The use of a solid fraction of livestock effluents in the dose of N_{75} has provided crop rotation productivity – 4,10 t/ha of grain units, at the dose of N_{75} + K_{90} – 4,57 t/ha with exceeding control without fertilizer twice. The highest productivity of crop rotation (5,65 t/ha of grain units) has been achieved at a dose of N_{225} at the application of excess activated sludge, exceeding the control without fertilizers by 2,56 t/ha. Further increase in the doses of biological products of livestock effluents reduced the payback per unit of fertilizer by 4-5 times and created ecological tension in the environment.

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