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CHEMICAL POLLUTION OF SOIL AND WATER ON PIG-BREEDING FARMS

ZANIECZYSZCZENIA CHEMICZNE GLEBY I WODY W OBEJŚCIU FERM TRZODY CHLEWNEJ

Abstract: Farmyards of pig producing farms are a specific source of pollution of the natural environment. In Poland pigs are mainly breed on farms of low animal concentration, which has a minimal negative effect on the environment. The greatest danger for the environment is created by factory pig-breeding farms, whose functioning is particularly troublesome for the residents of the surrounding areas. The places which create the greatest risk for soil contamination are piggeries, areas where natural fertilisers are stored and animal yards. High concentration of animals makes waste management difficult, especially the management of liquid manure. Inappropriate storing of liquid manure and using it as a natural fertilizer may bring about soil devastation and ground and surface water pollution. The following are treated as the chemical indicators of the sanitary condition of soil, specifying its pollution with an organic substance and characterizing the processes of decomposition and mineralization of this substance: the organic nitrogen content and the final products of decomposition of protein substances, that is ammonium and nitrates, organic carbon, and sometimes also some macroelements (P, K, Na, Ca, Mg, S) and microelements (Fe, Mn, Cu, Zn, Mo, Cl, Co).

Keywords: chemical pollution, soil, water, pig, farm

The problem of environment pollution caused by intensive animal breeding is a multi-aspect problem. Hygienic, sanitary and ecological aspects constitute a very important part of this problem, and concern both intensive and extensive pig production.

In recent years, the environment and its impact on human and animal health has been the object of particular interest. One of the conditions of ecological production is keeping the surrounding area clean, that is not exceeding the admissible concentration of harmful substances polluting the air, soil and water. The farmyards of pig farms are sources of contamination of the above enumerated components of the natural environment. The very problem is quite vital since in Poland there are over 600 thousand pig-breeding farms, and the total livestock population of these animals is estimated at about 18 million. In Poland pigs are mainly bred on farms with a low concentration of

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animals, which does not have such a negative impact on the environment. The biggest danger for the environment is posed by factory pig-breeding farms, and their functioning is particularly troublesome for residents of the neighbouring areas [1]. Negative ecological effects, such as: natural environment degradation, contamination of soil and rivers and drinking water intakes are among the negative consequences of the excessive concentration of flocks and unfavourable scale of production [2, 3].

Most research conducted so far has been concerned with the influence of animal waste (manure, liquid manure and slurry) on the contamination of arable land. There are not so much detailed research concerning the problem of soil contamination on pig farms, whereas on pig farms and around them there are people and animals, and this contamination may have immediate negative effect on their health and well-being. Farmsteads and their surroundings, as integral parts of farms, are in villages sources of area contamination of an agricultural origin. The areas which are particularly risky as regards soil pollution are piggeries, places where natural fertilizers are stored, and animal yards [3, 4]. Farm animals influence the natural environment directly and indirectly. The natural environment is polluted by dusting and gas pollution of the air, introducing to many organic compounds, mainly nitrogen ones, to soil and water [1, 5], and by microbiological contamination [6–8], including contamination with pathogenic microorganisms. The main source of the natural environment pollution is animal waste, such as manure, liquid manure and slurry [3, 9, 10], which are stored on farms. Very often, inadequate utilization of the existing equipment for manure, liquid manure and slurry management additionally intensifies the degradation of the natural environment in the farmers' residential area and in the surrounding areas, in which food is produced. A high concentration of animals creates problems with waste management, especially slurry management, and its inadequate storing and using as natural fertilizer may cause soil devastation, and ground and surface water pollution [11]. It is understandable that this situation creates some fears for hygienists, sanitary engineers and ecologists, whose concern is protection of human and animal health, production of "healthy" food, and shaping and protection of the environment in village areas [12].

Many authors [13–18] emphasise that the natural environment is more endangered by livestock farm waste than by domestic sewage. In 1980 in Poland the number of substances potentially harmful for the environment included in slurry was 51.3 thousand tons (Mg) of nitrogen and 10.9 thousand tons (Mg) of phosphorus. A ratio between the amount of contamination included in domestic sewage and animal waste for an average community is: 1–41 for nitrogen, 1–37 for phosphorus and 1–60 for potassium [12]. The values given above indicate that the problem of environment pollution caused by the concentration of livestock farms is really big. One of the components of the natural environment which is polluted as a result of unreasonable management of animal waste is soil. A constant contact of people and animals through food and animal feed with soil on which it is produced influences people and animals, their health and productivity. The influence is different depending on the mechanical, physical, chemical and biological properties of soil [19].

A lack of control and inappropriate disposal and neutralization of waste may cause excessive pollution of soil, water and air, which worsens the hygienic conditions and

causes a huge epidemiological danger for the surrounding areas. Thus, issues connected with the disposal and neutralization of waste are of primary importance for soil hygiene. In order to maintain its adequate sanitary state, the bacteriological, helmintological and chemical protection is necessary. The sanitary and epidemiological tests are usually carried out together with microbiological, helmintological and chemical tests. Thanks to them it is possible to define the intensity of soil pollution; they can also indicate the source of contamination and approximately define the date when the soil was polluted [13].

The most important chemical indicators of the sanitary condition of soil specifying its contamination with an organic substance and characterising the processes of this substance decomposition and mineralization, are: the content of organic nitrogen and the final products of the decomposition of protein substances, that is ammonia and nitrates, organic carbon, and sometimes also some macroelements (P, K, Na, Ca, Mg, S) and microelements (Fe, Mn, Cu, Zn, Mo, Cl, Co) [13, 20].

Contamination with nitrogen compounds

In agricultural production the main source of nitrogen is animal waste, accumulated, stored and used on most farms as a natural fertilizer in the form of manure, liquid manure and, less commonly, in the form of slurry. Now in Poland the annual production of manure, liquid manure and slurry is about 130 million tons (Mg), which corresponds to the following doses of fertilizer components:

– 35 kg/ha N, which gives 650 thousand tons (Mg) of N a year;
– 9 kg/ha P, which gives 170 thousand tons (Mg) of P a year;
– 35 kg/ha K, which gives 650 thousand tons (Mg) of K a year [5].

The losses of nitrogen during the production of natural fertilizers can be decreased by accumulating all animal waste and storing it better. The state of natural fertilizers management so far significantly restricts the productive functions of natural fertilizers and contributes to the devastation of the environment, especially of the soil environment [3, 5, 11, 12, 16]. Natural fertilisers should be stored in such a way so as to maximally restrict the loss of all the nutritional elements taking place during fermentation [21]. There may be various reasons for losses in manure, liquid manure and slurry. Water may mainly rinse out soluble compounds, such as nitrogen compounds: nitrates, ammonium, amino acids and amides. They are the most valuable compounds, available for plants or quickly becoming available. Therefore, in the water of most wells situated close to dunghills, a harmful content of nitrates has been found: 20–160 mg/dm^3 NO_3^- [22–25]. The protection against the losses caused by rinsing is easy, and the losses may by totally eliminated while storing animal waste such as manure in leakproof spaces or on a layer of absorptive materials, and liquid manure or slurry in leakproof containers securing the inside against water from the outside [5].

When manure is not stored appropriately, the losses of nitrogen may even exceed 50 %, and when it is stored adequately only 10 %, in relation to the initial amount. It means that about 20 kg of nitrogen is saved annually from 1 LU [10, 23]. The

possibility to restrict the losses of nitrogen in animal waste management, apart from economic effects (increased cropping), also has a good impact on the environment.

Nitrogen compounds, especially nitrates, which are produced in the process of nitrification, may have a negative impact on the environment. The pollution of water and air takes place when these compounds leave the soil-plant system [5]. Nitrogen in soil is only present in its organic or mineral form, in the amount of 0.1 %. Mineral nitrogen is mainly composed of nitrogen in the ammonium form (NH_4^+) and in the nitrate form (NO_3^-) [20]. The ammonium form of nitrogen gets into soil with rainfall and causes its acidification as a result of nitrification. The processes of nitrification proceed also in manure heaps, and the produced nitrates are either rinsed out or denitrified. As a result of rinsing out nitrates from manure not stored appropriately and from manure water, groundwater and water in village wells become polluted [26]. When there is a lot of ammonium in soil, it means that it is highly contaminated with organic substances of animal origin. With faecal contamination, the number of ammonium ions increases even by ten times. Whereas, if nitrates are present in soil (the final product of the process of nitrification) it means that the process of pollution took place long time ago. In the surface stratum of soil (0–20 cm) close to a piggery, it was found that the amount of mineral, mainly ammonium, nitrogen was about 150 kg N/ha, which corresponds to quite a big amount of nitrogen used in fertilization. The majority of this form of nitrogen resulted from the reduction conditions and the lack of oxygen in the soil which was strongly affected by animal waste [3]. In other tests of soil at different livestock farm objects, the dominant form of nitrogen was nitrate nitrogen in both the surface stratum and deeper strata of the soil profile. The biggest mean amount of nitrate nitrogen was found in soil 10 m from the dunging gutter (111.52 mg $\cdot$ kg^{-1}). The content of nitrate nitrogen depended greatly ($P < 0.01$) on the object from which the samples were taken, the soil stratum, and the interaction between the two factors. Ammonium nitrogen showed a tendency to accumulate in the deeper strata of the soil profile. This phenomenon was the most visible at the manure site. In the soil profiles of the yard and around the dunging gutter, a significant increase in the amount of $N\text{-}NH_4^+$ was found, in the 60–80 cm stratum and in the 40–150 cm stratum, respectively. As regards the dunging gutter, the concentration of the analysed component was increasing gradually until it reached the value of 109.68 mg $\cdot$ kg^{-1} at the depth of 100–150 cm. The content of ammonium nitrogen in the soil on the analysed farms depended significantly on the object ($P < 0.01$), the depth of the soil profile and the interaction between the factors.

Drinking water contamination is very often connected with the fact that the dunghill is not leakproof, and nitrogen compounds leak into the soil, especially at the manure heaps on the field. Most evidence for nitrogen contamination is provided by water analyses in wells situated close to dunghills or containers for liquid manure. Tests [3] have shown that about 50 % of water in wells on village farms contain over 10 mg $N\text{-}NO_3 \cdot dm^{-3}$, and 16 % over 40 mg $N\text{-}NO_3 \cdot dm^{-3}$. The Polish norm is 10 mg $N\text{-}NO_3 \cdot dm^{-3}$. That is why collecting all the animal waste and storing it in leakproof containers, controlled every year and sealed if necessary, creates a chance for full protection of the soil water environment against nitrate contamination [10].

Contamination with phosphorus compounds

Phosphorus is a chemical element whose excess is also unfavourable and causes degradation of the environment. It is an important, biologically active, component of all living organisms. It is present in soil, natural waters and precipitation. The content of general phosphorus in soil ranges from 0.01 to 0.2 % [20]. In municipal and agricultural sewage, mainly in slurry, the concentration of phosphorus is getting higher and higher. It is connected with the form in which this chemical element is present in animal feed. In grains and in products from processed grains, about 70 % of phosphorus is present in organic connections, mainly in the form of phytic acid and its salts – phytates. Utilisation of phytic phosphorus depends on the presence of phytase enzyme, releasing it from inaccessible organic connections. Phytase is produced by plants, intestinal epithelium of animals and microorganisms existing in the digestive tract. On the whole, the amount of this enzyme is not enough, which significantly restricts the utilization of phytates. Thus, availability of phytic phosphorus is not great, for example in pigs it is about 30 %. Insufficient utilization of phytic phosphorus is a serious ecological problem, because in animal waste there are big amounts of undigested phosphorus. It is estimated that in Poland only cattle and pigs produce annually about 10 thousand tons (Mg) of P_2O_5. The natural environment is endangered in the places where a lot of animal waste is produced, so in the areas with a high concentration of animals [4, 14, 27]. In the tests of soil taken from pig farm areas, 80 kg of dissoluble phosphorus ($P\text{-}PO_4$) per 1 ha [3] were found. The soil at the fattening house and in the yard contained the greatest amounts of phosphorus. This chemical element showed a tendency to accumulate in the deeper strata of soil (100–120 cm), which creates a potential danger for groundwater [4].

Animal waste is utilised as a fertiliser. Plants dynamically absorb phosphorus, maximally up to 1 % of dry matter. The rest of phosphorus, susceptible to soaking, gets into surface and ground waters. Waters are particularly endangered by liquid manure, not only because it flows easily and because of excessive doses of phosphorus, but also because the phosphorus included in it is labile [24]. Pollution of ground and surface waters and open water regions with phosphorus is a serious problem. For example, in Denmark, 8 % of private water intakes do not fulfil the purity standards, and in German as much as 50 %. In Poland it is even worse – in the year of 1987 66 % of household wells provided excessively polluted water. Containers of lentic water are most endangered when there are animal farms in the area. Also sewage pollutes flowing water. It is estimated that about 70 % of the total amount of phosphorus in the Vistula river comes from sewage. The rest gets into waters through rinsing out. Violent rains or thaw contribute to great amounts of phosphorus [27]. That is why special attention must be drawn to the appropriate storing and timely utilization of liquid manure. It is also necessary to appropriately shape the components of the landscape, such as trees, meadows, small water reservoirs, marshland, etc. It will restrict the spread of pollution, cause waste neutralization, and as a result will fasten the regeneration of soil [19].

Other chemical pollution

Greater concentrations of potassium, caused by pollution from animal waste, are present in the surface stratum of soil, whose thickness is about 60 cm, in shallow ground waters and in shallow wells [18]. The total content of potassium in mineral soils in Poland ranges from 0.8–2.1 % [20]. Potassium cation is strongly absorbed both by living organisms and by soil. It can also move together with soaking rainwater into soil water and groundwater. Soil tests soil at different farm objects showed a substantially increased content of potassium in comparison to the reference points, which indicates that animal waste is polluting [3, 4]. Chemical analyses of groundwater from under the enclosure, water from the well and surface water adjacent to the enclosure showed potassium contamination. The presence of high concentration of potassium in groundwater at the level close to, or exceeding, 1000 mg K/m^3 concerns most farms in Poland conducting intensive animal production [3].

Many authors recommend introducing the monitoring of the quality of water and soil from the areas of household enclosures in order to check the content of nitrogen, dissoluble phosphorus and potassium [4, 28].

Sulfate sulphur is an indicator of the anthropogenic pollution of soil. Estimation of the content of sulphur in soil is necessary due to its influence both on the mobility of heavy metals and on the worsening of the chemical properties of soil, and above all on activating aluminium and losses of magnesium. These phenomena create serious ecological dangers [20].

The author's research [29] concerning the content of general sulphur and sulphate sulphur in the soil from pig farms did not found its high concentrations. The highest content of general sulphur was found in the surface stratum of soil (0–20 cm) on the sow yard (68.42 mg · 100 g^{-1}) and at the fattening house (53.08 mg · 100 g^{-1}). Also the soil from the sow yard contained the greatest amounts of sulphate sulphur (12.83 mg · 100 g^{-1}). The phenomenon of accumulating sulphur at the depth of 40–69 cm was observed. In one of the analysed farms, about 42 % of samples were characterized by the 4th grade of sulphate sulphur content in soil.

Heavy metals are found not only in the highly industrialised regions, but also in natural ecosystems, used agriculturally. The harmfulness of heavy metals results from their biological and biochemical properties. One such property is the susceptibility to bioaccumulation from the soil environment [13, 25]. The soil from farmyards may be the source of animal contamination with heavy metals, especially in the farmyards situated close to public roads [30]. Heavy metals are introduced into the agricultural ecosystem (soil and water) through rainfall and animal waste. Pig waste, both liquid and solid, may contain heavy metals such as: Pb, Zn, Cu, Ni, Cr and others [31].

The author's own research [32] concerning the content of selected heavy metals (Pb, Zn and Mn) in soil at various farm objects found that permissible norms for the chemical elements tested had not been exceeded. It was noted that there was a difference in the content of heavy metals, depending on where the samples had been taken. The highest values of the analysed elements were found in the soil from the animal yard. The results of our research [4, 29, 32] confirm Pawlak's statement [33] that keeping pigs in yards was connected with increasing the risk of chemical pollution and

microbiological pollution of soil and water, as compared with keeping animals in closed spaces.

Summary and recommendations

So far, the ecological danger connected with pig production in Poland has not been big thanks to the small sizes of the farms. However, recently, the concentration of production may be observed, which poses more danger for the natural environment. The impact of pig production on the natural environment concerns all its elements: water, soil and air. Thus, it is important that the quality of water and soil from farm enclosures be inspected with regard to the nitrogen, dissoluble phosphorus and potassium content.

A pig farm and its surrounding area in village areas is the source of area pollution of agricultural origin. The areas which are most dangerous are: piggeries, animal yards, dunging gutters and manure and liquid manure containers. Farm objects for storing animal waste, depending on their kind, technical condition and capacity, create the greatest risk for soil and water pollution with nitrogen, phosphorus and potassium compounds.

In order to prevent losses of fertiliser components and to protect the environment against pollution, animal waste should be stored appropriately and used rationally in agriculture.

It is important to undertake some action to decrease the danger for the natural environment by increasing supervision to make sure that in the farms with high concentration of animals technological regimes are abided by, as well as the requirements enforced by the Code of Good Agricultural Practice. Education is an effective method to improve the soil and water quality on a farm. That is why farmers and agricultural services workers should be trained continuously on the modern systems of animal breeding to limit its negative impact on the environment.

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ZANIECZYSZCZENIA CHEMICZNE GLEBY I WODY W OBEJŚCIU FERM TRZODY CHLEWNEJ

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Abstrakt: Obejścia gospodarstw nastawionych na produkcję świń są swojego rodzaju źródłami zanieczyszczenia środowiska naturalnego. W Polsce dominuje chów trzody chlewnej w gospodarstwach o niskiej koncentracji zwierząt, który w minimalnym stopniu ujemnie wpływa na środowisko. Największe zagrożenie dla

środowiska stanowią wielkoprzemysłowe fermy świń, których funkcjonowanie jest szczególnie uciążliwe dla mieszkańców okolicznych terenów. Miejscami stwarzającymi największe ryzyko zanieczyszczenia gleby w są chlewnie, miejsca składowania nawozów naturalnych, okólniki dla zwierząt. Duża koncentracja zwierząt stwarza trudności z zagospodarowaniem odpadów, zwłaszcza gnojowicy, a niewłaściwe jej przechowywanie i stosowanie jako nawozu naturalnego może powodować dewastację gleby, zanieczyszczenie wód powierzchniowych i podziemnych. Za najważniejsze wskaźniki chemiczne stanu sanitarnego gleby, określające zanieczyszczenie jej substancją organiczną i charakteryzujące procesy rozkładu i mineralizacji tej substancji przyjmuje się: zawartość azotu organicznego oraz końcowych produktów rozkładu substancji białkowych, tj. amoniaku i azotanów, a także węgla organicznego, a niekiedy również niektórych makro- (P, K, Na, Ca, Mg, S) i mikroelementów (Fe, Mn, Cu, Zn, Mo, Cl, Co).

Słowa kluczowe: zanieczyszczenia chemiczne, gleba, woda, świnie, ferma