THE INFLUENCE OF MINERAL AND ORGANIC FERTILIZERS ON SOIL, FODDER PLANTS AND QUALITY OF CHICKEN MEAT

(SUMMARY OF Ph.D. THESIS)

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INTRODUCTION

Heavy metals are potential polluters of the environment, with the ability to cause health problems if present in food. Certain metals in small quantities, are essential in the development of metabolic processes, but can become toxic when found in high concentrations. They are given special attention all over the world due to their toxic effects even at very low concentrations. There have been reported some cases of the disorder, disease, organ malformations caused by heavy metals toxicity. Some heavy metals can be disposed of in soil, plants and animals, reaching the human body through the food chain.

An important source of heavy metal pollution is represented by agriculture through the inputs used (chemical fertilizers, organic fertilizers, pesticides, irrigation water). Systematic and continuous use of phosphoric and zinc fertilizers leads to increasing the accumulation of cadmium in soils.

For the third millennium is expected a demographic explosion (over 7 billion people) fact that will raise serious problems regarding the problem of feeding the Earth’s population. Vegetables, grains and meat are essential in human nutrition. These may be contaminated with different kinds of heavy metals.

In this social context, livestock rearing will take on new dimensions, given the importance that products of animal origin have on human food, animal protein represents the basis of a rational nutrition and some of the products obtained from animals are indispensable to most people.

In the top of animal production, a well-defined position has the poultry due to their high nutritional value, but also a lower price that can be acquired compared to other types of meat. Poultry production is ascending, meaning that it increases from one year to another, in recent years it has increased by 60%.

Poultry meat quality, in addition to its properties, is determined by the degree of contamination by heavy metals (Cd, Cu, Fe, Hg, Mg, Ni, Pb, Zn), mycotoxins, growth hormones, antibiotics or other micro-organisms, that can harm human health.

Heavy metal contamination of animals can be made by direct exposure, contaminated water, contaminated grain used to feed the animals, industrial emissions.

According to the national strategy for development of poultry farming, raising broilers in the industrial system will be of great interest, since investment in poultry production in Romania will reach to 384.5 million Euro until 2025, it is estimated to increase around 90%.

In these circumstances, a special attention will be given to the tracing heavy metals in soil, grains and poultry meat to ensure proper food for human population.
Structure of the thesis: the thesis is composed of two main parts, called “State of research on heavy metals in the soil – plant – animal system under the influence of fertilizers” and “Own research”, which includes materials and methods used, results obtained and conclusions.

Part I contains two chapters:

Chapter I. Classification and characteristics of fertilizers, which succinctly describes the characteristics of fertilizers, types of fertilizers, toxic components of fertilizers, the risk of using fertilizers.

Chapter II. Potentially toxic metals in the soil – plant – animal system, contains information on soil pollution with heavy metals (Cd, Pb, Cu, Zn), distribution and effects of heavy metals on the plants and animals, the effects of heavy metals on the human organism.

Part II - includes eight chapters:

Chapter III. The purpose and objectives of the research
Chapter IV. The natural environment where the research is conducted, being described the climate and soil conditions during the conduct of research.

Chapter V. The biological material and research methods used, provides data about vegetal and animal biological material taken into account for study, variants chosen for studied, the analytical methods used in the determination of heavy metals and methods of calculation and interpretation of results.

Chapter VI. Influence of doses and combinations of chemical and organic fertilizers on the concentration of cadmium in soil-plant-animal system, the results obtained are presented in long-term experiences with NPK, NP and NP + farmyard manure, with regard to the concentration of cadmium in the preluvosoi from Oradea, the grains of wheat and maize, respectively chicken meat (breast muscle, leg muscle and liver).

Chapter VII. Influence of doses and combinations of chemical and organic fertilizers on the concentration of lead in soil-plant-animal system which exposes the data obtained with regard to the concentration of lead in soil, wheat grain and maize, respectively chicken chest, leg muscle and liver under the influence of nitrogen, phosphorus, potassium fertilizers and farmyard manure.

Chapter VIII. Influence of doses and combinations of chemical and organic fertilizers on the concentration of copper in the soil-plant-animal system, where the research results are detailed regarding the concentration of copper from the soil fertilized with different doses of NPK, NP and NP + farmyard manure, from the wheat and maize grains harvested from it and different anatomical parts of the chicken.

Chapter IX. Influence of doses and combinations of chemical and organic fertilizers on the concentration of zinc in the soil-plant-animal. The effects of chemical and organic fertilizers applied, the concentration of zinc in soil, grain and maize wheat, respectively chicken meat that is presented in this chapter.

Chapter X. Conclusions and Recommendations, which systematizes the conclusions triggered from three years of research (2010-2012).

The purpose and objectives of the research:

Research is aimed at understanding the traceability of heavy metals and optimizing the relationships from soil – plant – animal system based on the results obtained in long lasting experiments with doses and combinations of mineral and organo-mineral fertilizers in soil-plant and in experiments with broilers, in order to obtain viable production from a toxicological point of view.
Research objectives:
- The study of the influence of doses and combinations of nitrogen, phosphorus and potassium in long-term experience on the concentration of Cd, Pb, Cu and Zn in soil and wheat and maize grains.
- The study of the influence of doses and combinations of nitrogen and phosphorus in long-term experience on the concentration of Cd, Pb, Cu and Zn in soil and wheat and maize grains.
- The study of the influence of doses and combinations of nitrogen, phosphorus and farmyard manure in the long-term experience on the concentration of Cd, Pb, Cu and Zn in soil and wheat and maize grains.
- Establish the influence of using wheat and maize grains in food from the long-term experience with nitrogen, phosphorus and potassium, regarding the concentration with heavy metals (Cd, Pb, Cu and Zn) in different anatomical regions of broilers’ liver.
- Quantifying the influence of using wheat and maize grains in food from the long-term experience with nitrogen and phosphorus, regarding the concentration with heavy metals (Cd, Pb, Cu and Zn) in different anatomical regions of broilers’ liver.
- Determining the influence of using wheat and maize grains in food from the experience with nitrogen, phosphorus and manure, regarding the concentration with heavy metals (Cd, Pb, Cu and Zn) in different anatomical regions and broilers’ liver.
- Modeling the research results in order to develop predictions to obtain viable production from a toxicological point of view.

The natural environment where the research is conducted

From a climate point of view, the research has been conducted in three years totally different in terms of rainfall, in 2010 their amount being 869.0 mm in 2011 was 569.7 mm, and respectively in 2012 were recorded 418.9 mm. The air temperature was almost identical 11.3 °C in 2010 and 2012 and 11.4 °C in 2011. With regard to air humidity, its average was 79% in 2010, 73% in 2011 and 70% in 2012.

Soil reaction on arable horizon is slightly acid. The lack of calcium carbonate in the soil profile is obvious from the data presented. Soil content in mobile aluminum in horizon A can affect the normal growth of some plants. The soil is well supplied with mobile potassium and phosphorus. Humus content in soil is average.

Biological material and research methods used

The vegetal biological material studied was the wheat variety Crişana and hybrid maize Fundulea 376.

Animal biological material used for research was the hybrid chicken for meat Cobb-500.

Variants studied

I. Field Experience
They are based on some of the variants studied in three long-term experiments located at the Agricultural Research and Development Station Oradea.

Experiment 1: V₁ - N₀P₀K₀, V₂ - N₈₀P₄₀K₄₀, V₃ - N₈₀P₈₀K₈₀, V₄ - N₁₆₀P₈₀K₁₂₀
Experiment 2: V₁ - N₀P₀, V₂ - N₄₀P₄₀, V₃ - N₈₀P₈₀, V₄ - N₁₆₀P₁₆₀
Experiment 3: $V_1 - N_0P_0 + 0 \text{ t/ha farmyard manure}$, $V_2 - N_{50}P_0 + 20 \text{ t/ha farmyard manure}$, $V_3 - N_{50}P_{50} + 40 \text{ t/ha farmyard manure}$, $V_4 - N_{100}P_{100} + 60 \text{ t/ha farmyard manure}$.

Of the four experimental parcels of each variant was set an amount of wheat, respectively maize that has been used for feeding broilers.

II. Experiments of feeding broilers

The research was carried out using wheat and maize grains obtained during long-term experiments from the variants described above. Batches of broilers chickens were created made up of 10 broilers which were fed with wheat and maize grains in the form of middlings, with 30% wheat and 70% maize harvested from the studied variants for each long term experiment NPK, NP and NP + manure. Thus resulted a total of 12 batches, 4 for each experiment. The broilers were slaughtered at the age of 56 days, after which the samples were taken out from the breast muscle, leg muscle and liver in order to determine the concentration of Cd, Pb, Cu, Zn.

Analytical methods used in determining the heavy metals

Laboratory investigations were carried out in the “Research Laboratory of risk factors for Agriculture, Forestry and the Environment”, Faculty of Environmental Protection Oradea.

In order to achieve the proposed objectives a series of chemical tests were performed for soil samples, biological vegetal material (wheat, maize), animal biological material (broiler chicken). Analytical methods applied to determine the concentration of heavy metals studied (Cd, Pb, Cu, Zn) are presented in this subchapter.

Mineralization of soil samples in order to determine the metals was done with concentrated strong acids and hydrogen peroxide: HNO$_3$, HCl and H$_2$O$_2$ using the digester MILESTONE.

Mineralization of plant biological material samples in order to determine the metals was done with a mixture of sulfuric and perchloric acids.

Mineralization of animal biological material samples in order to determine the metals was done with concentrated strong acids and hydrogen peroxide: H$_2$SO$_4$, HCl and H$_2$O$_2$.

Dosage of heavy metals (Cd, Pb, Cu, Zn). For the determination of heavy metals under study, samples of soil, vegetal biological material, animal biological material respectively prepared according to the working methods presented above were analyzed by spectrophotometer with atomic absorption SHIMADZU AA-6300.

Calculation methods and interpretation of results. Correlations between doses of mineral fertilizers (N, P, K) – heavy metals (cadmium, lead, copper, zinc) in soil, plant (wheat, maize), animal (broilers, respectively brest, leg muscle, liver) and doses of organo fertilizer – minerals (NP + manure) – heavy metals in soil, plant, animal were calculated using Microsoft Excel; of the 5 types of functions available on the program (linear, exponential, logarithmic, polynomial and power) was chosen the function with the highest value of $R^2$. 
RESULTS AND DISCUSSIONS

Chapter VI. Influence of doses and combinations of chemical and organic fertilizers on the concentration of cadmium in the soil-plant-animal system

6.1. Influence of NPK, NP fertilizers and NP + farmyard manure on the concentration of cadmium preluvosoi l

On average over the three years studied in the control variant (N₀P₀K₀) the concentration of cadmium from preluvosoi l in Oradea was 1.120 mg/kg. In other variants were recorded higher concentrations, but the difference recorded in variant N₈₀P₄₀K₄₀ (14.7%) is not statistically significant, and the differences determined in the other two variants (51.6% and 123.6%) are distinctly significant and very significant statistically.

On average over the period 2010-2012 in the unfertilized control variant the concentration value of cadmium in soil was 0.120 mg/kg. The fertilized variant with N₄₀P₄₀ the cadmium concentration increased by 0.234 mg/kg (20.9%), the difference is statistically significant. The difference registered in the fertilized variant with N₈₀P₈₀ (0.661 mg/kg, 59%) is significantly distinct. Fertilization with N₁₆₀P₁₆₀ resulted in an increase of 160.8% compared to the control variant, the differences were highly significant statistically.

In the control variant the average for the period 2010-2012 of the cadmium concentration in the soil was 1.117 mg/kg. Fertilization N₅₀P₀ + 20 t/ha farmyard manure resulted in an increase of 0.121 mg/kg and 10.8%, the difference was statistically insignificant. In the fertilized variant with N₅₀P₅₀ + 40 t/ha farmyard manure the cadmium recorded value of 1.341 mg/kg, higher then 20% compared to the control variant, and fertilization N₁₀₀P₁₀₀ + 60 t/ha farmyard manure resulted in an increase 31.4%, or 0.350 mg/kg respectively compared to the control variant, the differences are statistically significant.

6.2. Influence of NPK, NP fertilizer and NP + farmyard manure on the concentration of cadmium in wheat grains

On average over the three years studied, in control variant (N₀P₀K₀) cadmium concentration in wheat grains was 0.056 mg/kg. In N₈₀P₄₀K₄₀ variant was registered a higher concentration of 0.068 mg/kg, 21.3% compared to the unfertilized variant, is statistically insignificant. In the fertilized variant with N₈₀P₈₀K₈₀ the wheat grains had a higher cadmium concentration by 48.3% (statistically significant) and with 0.027 mg/kg higher compared to the control variant. The variant N₁₆₀P₈₀K₁₂₀ increased the concentration of cadmium by 81.8% compared to the N₀P₀K₀ version, it is statistically significant.

On average over the three years studied, in variant N₀P₀ the cadmium concentration in wheat grains was 0.056 mg/kg. In case of variant N₄₀P₄₀ a higher concentration of 21.1% (statistically insignificant) was registered, 0.068 mg/kg, compared to the control variant was statistically insignificant. The fertilized variant with N₈₀P₈₀ wheat grains had a higher cadmium concentration higher with 52%, a statistically significant difference (0.085 mg/kg) higher than controls. Concentration determined in variant N₁₆₀P₁₆₀ was 99.4% higher than N₀P₀ variant, the difference is highly statistically significant.

Average concentrations of cadmium in wheat grains in experiment with chemical fertilizers with nitrogen, phosphorus and farmyard manure were 0.056 mg/kg in control variant, 0.059 mg/kg (higher with 6.2% compared to the control) in variant N₅₀P₀ + 20 t/ha farmyard manure, 0.063 mg/kg (higher with 13.4% compared to the control) in the fertilized variant with N₅₀P₅₀ + 40 t/ha farmyard manure, the differences in the two variants are statistically
insignificant, 0.067 mg/kg respectively (higher with 20.5% compared to the unfertilized variant) in variant N\textsubscript{100}P\textsubscript{100} + 60 t/ha farmyard manure, the difference being statistically significant.

6.3. Influence of NPK, NP fertilizer and NP + farmyard manure on the concentration of cadmium in maize grains

On average, during the period studied (2010-2012), in control variant the cadmium concentration in maize grains was 0.041 mg/kg. In variant N\textsubscript{80}P\textsubscript{40}K\textsubscript{40} was registered a higher concentration of 0.050 mg/kg, with 22.4% higher than the unfertilized variant being statistically insignificant. Maize grains in the variant N\textsubscript{80}P\textsubscript{80}K\textsubscript{80} had a higher cadmium concentration with 49.4%, or 0.020 mg/kg, compared to the control variant (N\textsubscript{0}P\textsubscript{0}K\textsubscript{0}). The variant N\textsubscript{160}P\textsubscript{80}K\textsubscript{120} increased the concentration of cadmium at 0.075 mg/kg, 82.9% compared to the N\textsubscript{0}P\textsubscript{0}K\textsubscript{0} variant. Statistical significance was statistically insignificant, statistically significant, respectively distinctly statistically significant.

The average concentration of cadmium in the period under study, in variant N\textsubscript{0}P\textsubscript{0} was 0.041 mg/kg. In case of variant N\textsubscript{40}P\textsubscript{40} was registered a higher concentration, with 22.9%, 0.050 mg/kg, compared to the control variant being statistically insignificant. The fertilized variant with N\textsubscript{80}P\textsubscript{80} maize grains had a higher cadmium concentration with 52.5% (0.063 mg/kg) compared to the control variant, distinctly statistically significant differences. The difference determined in variant N\textsubscript{160}P\textsubscript{160} was 100.3% higher than the control variant, being highly statistically significant.

The average concentration of cadmium in maize grains in the three years studied, the experiments with chemical fertilizers with nitrogen, phosphorus and farmyard manure was 0.040 mg/kg in control variant, 0.043 mg/kg (higher than 8.4% compared to control one) in variant N\textsubscript{50}P\textsubscript{0} + 20 t/ha farmyard manure, 0.046 mg/kg (16% higher compared to the control variant) in the variant fertilized with N\textsubscript{50}P\textsubscript{50} + 40 t/ha farmyard manure, statistically insignificant differences, respectively 0.049 mg/kg (23.3% higher compared to unfertilized variant) in variant N\textsubscript{100}P\textsubscript{100} + 60 t/ha farmyard manure, the difference being statistically significant.

6.4. Influence of NPK, NP fertilizer and NP + farmyard manure on the concentration of cadmium in chicken breast muscle muscle

Average concentration of cadmium in the three years 2010 to 2012 studying the chicken breast muscle muscle fed with maize and wheat from NPK experience, was in control variant of 0.0099 mg/kg, 0.0112 mg/kg in the variant fertilized with N\textsubscript{80}P\textsubscript{40}K\textsubscript{40} (12.4% higher than the control one, difference statistically insignificant), 0.0124 mg/kg in the variant fertilized with N\textsubscript{80}P\textsubscript{80}K\textsubscript{80} (25.2% higher, a statistically significant difference) and 0.0146 mg/kg in the variant N\textsubscript{160}P\textsubscript{160}P\textsubscript{120}, which is 47% higher compared to the control (N\textsubscript{0}P\textsubscript{0}K\textsubscript{0}) being statistically significant.

On average over the period studied (2010 - 2012), the concentration of cadmium in chicken breast muscle muscle fed with maize and wheat from experiments with NP, in control variant was of 0.0099 mg/kg for those fed with grain harvested from fertilized variant with N\textsubscript{40}P\textsubscript{40}, 0.0114 mg/kg, 14.4% higher than the control one, statistically insignificant difference, 0.0130 mg/kg for those fed with the harvest from fertilized variant N\textsubscript{80}P\textsubscript{80} (30.9% higher, statistically significant difference) and respectively 0.0164 mg/kg for those fed with maize and wheat in N\textsubscript{160}P\textsubscript{160} variant, which is 65.4% higher than breast muscle coming from chickens fed with grains harvested from control variant (N\textsubscript{0}P\textsubscript{0}) being distinctly statistically significant.

The average cadmium concentrations (2010 - 2012) of breast muscle chickens fed on maize and wheat harvested from experiment with nitrogen, phosphorus and farmyard manure was in control variant of 0.0099 mg/kg for those fed with grains harvested from variant N\textsubscript{50}P\textsubscript{0} +
20 t/ha, 0.0104 mg/kg, 5.1% higher than the control one, 0.0110 mg/kg for those fed with the harvest from fertilized variant with N\textsubscript{50}P\textsubscript{50} + 40 t/ha farmyard manure (11.1% higher), the differences are not statistically significant, 0.0115 mg/kg respectively, and those fed on maize and wheat from variant N\textsubscript{100}P\textsubscript{100} + 60 t/ha farmyard manure, it was 16.2% higher than the breast muscle coming from chickens fed with grains harvested from control variant (N\textsubscript{0}P\textsubscript{0} + 0 t/ha farmyard manure), being statistically significant.

Fig. 6.1. Correlation between doses of NPK chemical fertilizers and cadmium concentration in chicken breast muscle muscle

Fig. 6.2. Correlation between doses of NP chemical fertilizer and concentration of cadmium in chicken breast muscle muscle

Fig. 6.3. Correlation between doses of NP chemical fertilizers and farmyard manure and concentration of cadmium in chicken breast muscle muscle
6.5. Influence of NPK, NP fertilizer and NP + farmyard manure on the concentration of cadmium in chicken leg muscle

Average concentration of cadmium in the period 2010-2012 from the chickens leg muscle fed with maize and wheat from experiments with nitrogen, phosphorus and potassium was in the control variant of 0.0080 mg/kg, 0.0087 mg/kg in the fertilized variant with N\textsubscript{80}P\textsubscript{40}K\textsubscript{40} (8.8% higher than the control, difference not statistically significant), 0.0096 mg/kg in the variant fertilized with N\textsubscript{80}P\textsubscript{80}K\textsubscript{80} (20.1% higher, difference statistically insignificant) and 0.0111 mg/kg in N\textsubscript{160}P\textsubscript{80}K\textsubscript{120} variant, which is 38.9% higher than the one derived from chickens fed the unfertilized variant, being statistically significant.

On average during the period studied between 2010-2012, the cadmium concentration from the chickens leg muscle fed on grain from experiment with NP, in control variant was of 0.0080 mg/kg for those fed on wheat and maize from fertilized variant with N\textsubscript{40}P\textsubscript{40}, 0.0089 mg/kg, 11.3% higher than in control one, was not statistically significant, 0.0099 mg/kg for those fed with harvest fertilized with N\textsubscript{80}P\textsubscript{80} (23.8% higher, a statistically significant difference) and 0.0121 mg/kg in the case of those fed with maize and wheat N\textsubscript{160}P\textsubscript{160} variant, which is 51.3% higher, distinctly statistically significant compared to chickens leg muscle derived from chickens fed with maize and wheat harvested from unfertilized variant (N\textsubscript{0}P\textsubscript{0}).

During 2010 - 2012, the average concentration of cadmium in the chickens leg muscle fed with maize and wheat harvested from experience with NP and manure was in control variant of 0.0079 mg/kg for those fed with grains harvested from fertilized variant N\textsubscript{50}P\textsubscript{0} + with 20 t/ha, 5% higher, 0.0083 mg/kg, than the control, 0.0087 mg/kg for those fed with grains harvested from fertilized variant N\textsubscript{50}P\textsubscript{50} + 40 t/ha farmyard manure (10.1% higher) and 0.0090 mg/kg for those fed with maize and wheat variant N\textsubscript{100}P\textsubscript{100} + 60 t/ha farmyard manure, which is 13.9% higher than the chickens leg muscle fed with grains harvested from control variant (N\textsubscript{0}P\textsubscript{0} + 0 t/ha farmyard manure), the differences are not statistically significant in all variants studied.

![Graph](image.png)

**Fig. 6.4.** Correlation between doses of NPK chemical fertilizers and cadmium concentration in chicken leg muscle
6.6. The influence of NPK, NP fertilizers and NP + farmyard manure on the concentration of cadmium in chicken liver

On average the concentration of cadmium in the liver of chickens fed on grains harvested from experiments with NPK, in control variant was of 0.0557 mg/kg, for those fed with wheat and maize fertilized with N80P40K40, 0.0657 mg/kg, 18% higher than in the control variant, 0.0727 mg/kg for those fed with harvest fertilized with N80P80K80 (30.5% higher). In both versions the differences were statistically insignificant. The concentration of 0.0860 mg/kg was registered for those fed with maize and wheat with variant N160P80K120, which is 54.5% higher than the liver coming from chickens fed with maize and wheat harvested from unfertilized variant, being statistically significant.

On average over the period studied (2010 - 2012), the concentration of cadmium in the liver of chickens fed with grains from experiments with the NP, in control variant was of 0.0567 mg/kg for those fed with grains harvested from fertilized variant with N40P40, 0.0667 mg/kg, 17.6% higher than the control variant, not statistically significant, 0.0767 mg/kg for those fed with maize and wheat in the fertilized variant with N80P80 (35.3% higher), respectively 0.0943 mg/kg for those fed with harvested variant N160P160, which is 66.5% higher than the liver of chickens fed with grains harvested from N0P0 variant. For the other two variants, the differences were statistically significant, respectively distinctly statistically significant.
The average cadmium concentrations (2010 - 2012) in the liver of chickens fed with maize and wheat harvested from experiments with nitrogen, phosphorus and farmyard manure was in control variant of 0.0567 mg/kg, for those fed with grains harvested from fertilized variant N$_{50}$P$_{0}$ + 20 t/ha farmyard manure, 0.0617 mg/kg, 8.8% higher than the control one, 0.0637 mg/kg for those fed with fertilized harvest with N$_{30}$P$_{50}$ + 40 t/ha farmyard manure (12.4% higher) and 0.0657 mg/kg for those fed with maize and wheat from variant N$_{100}$P$_{100}$ + 60 t/ha farmyard manure, which is 15.9% higher than in the liver of chickens fed with grains harvested from version control (N$_{0}$P$_{0}$ + 0 t/ha farmyard manure), the differences were not statistically significant.

Fig. 6.7. Correlation between doses of NPK chemical fertilizers and cadmium concentration in the chicken liver.

Fig. 6.8. Correlation between doses of NP chemical fertilizer and concentration of cadmium in the chicken liver.

Fig. 6.9. Correlation between doses of NP chemical fertilizers and farmyard manure and concentration of cadmium in chicken liver.
Chapter VII. Influence of doses and combinations of chemical and organic fertilizers on the concentration of lead in the soil-plant-animal system

7.1. Influence of NPK, NP fertilizers and NP + farmyard manure on the concentration of lead in the preluvosoil

The average of the three years studied in the control variant (N₀P₀K₀) concentration of lead in the preluvosoil from Oradea was of 20.204 mg/kg. The other three concentration variants were higher 22.056 mg/kg, 27.819 mg/kg and 32.900 mg/kg, but the difference registered in the variant N₈₀P₄₀K₄₀ (9.2%) is not statistically significant, and the differences determined in the other two variants (37.7% and 62.8%) are statistically significant, respectively distinctly statistically significant.

On average, during the period studied, the concentration of lead in the unfertilized control soil showed a value of 20.192 mg/kg. The fertilized variant with N₄₀P₄₀ the lead concentration increased by 1.930 mg/kg (9.6%). The difference registered in the variant fertilized with N₈₀P₈₀ (38.1%) is statistically significant. Fertilization with N₁₆₀P₁₆₀ resulted in an increase of 62.7% compared to the control being distinctly statistically significant.

7.2. Influence of NPK, NP fertilizer and NP + farmyard manure on lead concentration in wheat grains

On average over the three years studied, in control variant (N₀P₀K₀) the lead concentration in wheat grains was 0.037 mg/kg. In variant N₈₀P₄₀K₄₀ was registered a higher concentration of 0.041 mg/kg, with 9.4% compared to the unfertilized variant. In the variant fertilized with N₈₀P₈₀K₈₀ the wheat grains had a higher lead concentrations by 16.7%, respectively 0.007 mg/kg higher compared to the control. The variant N₁₆₀P₈₀K₁₂₀ lead to an increase of the lead concentration 22.7% compared to the N₀P₀K₀ variant. In variants N₈₀P₄₀K₄₀ and N₈₀P₈₀K₈₀ the differences were not statistically assured and in variant N₁₆₀P₈₀K₁₂₀ the difference was statistically significant.

The average of three years in the study, in variant N₀P₀ the lead concentration of wheat grains was 0.038 mg/kg. In case of variant N₄₀P₄₀ was registered a higher concentration of 9.9%, respectively 0.042 mg/kg, compared to the control. In variant N₈₀P₈₀ the wheat grains had a higher lead concentration by 17.4% (0.045 mg/kg) more than the unfertilized control. The differences registered in the two variants were not statistically significant. The concentration determined in the fertilized variant with N₁₆₀P₁₆₀ was 23.5% higher compared to the control variant N₀P₀ being statistically significant.

The average concentration of lead in wheat grains in the experiment with chemical fertilizers with nitrogen, phosphorus and manure was 0.037 mg/kg in control variant, 0.040 mg/kg (8.8% higher compared to the control, statistically insignificant) in variant N₅₀P₀ + 20 t/ha farmyard manure, 0.043 mg/kg (16.2% higher compared to unfertilized variant, not statistically significant) in the fertilized variant with N₅₀P₅₀ + 40 t/ha farmyard manure, respectively 0.045 mg/kg (21.6% higher compared to the control, statistically significant) in the variant N₁₀₀P₁₀₀ + 60 t/ha farmyard manure.
7.3. Influence of NPK, NP fertilizers and NP + farmyard manure on the concentration of lead in maize grains

On average, over the three years studied, the lead concentration in control variant of maize grains was 0.048 mg/kg. In variant N_80P_40K_40 was registered a higher concentration of 11.2% compared to the unfertilized variant, the 0.053 mg/kg, was not statistically significant. The maize harvested within N_80P_80K_80 variant had higher lead concentration by 19.9% compared to variant N_0P_0K_0. In this variant the difference was not statistically insured. The fertilized variant N_160P_80K_120 led to an increase of lead concentration at 0.059 mg/kg, 24% higher compared to the control variant, being statistically insured.

The average lead concentration in the studied period, in variant N_0P_0 was 0.047 mg/kg. In case of variant N_40P_40 was a higher concentration, 11.8% higher, 0.052 mg/kg compared to unfertilized variant being not statistically significant. In N_80P_80 variant the maize had a higher lead concentration by 21% (0.056 mg/kg) higher than control variant. The concentration determined in N_160P_160 variant was 24.6% higher than N_0P_0 version, the difference being statistically significant.

On average, the lead concentration from maize grains, in the three years studied, the experience with chemical fertilizers with nitrogen, phosphorus and manure was 0.047 mg/kg in control variant, 0.052 mg/kg (10.8% higher compared to control) in variant fertilized with N_50P_0 + 20 t/ha manure, 0.055 mg/kg (18.5% higher compared to the control) in the variant fertilized with N_50P_50 + 40 t/ha of manure, respectively 0.056 mg/kg (20.6% higher compared to unfertilized variant, statistically significant difference) in variant N_100P_100 + 60 t/ha manure.

7.4. Influence of NPK, NP fertilizers and NP + farmyard manure on the concentration of lead from the chicken breast muscle

On average, the lead concentration in the years 2010-2012 in the chicken breast muscle fed with maize and wheat from experiments with nitrogen, phosphorus and potassium was in control variant of 0.0265 mg/kg, 0.0275 mg/kg for variant fertilized with N_80P_40K_40 (3.7% higher than the control), 0.0279 mg/kg in variant N_80P_80K_80 (5% higher), the differences were not statistically insured, respectively 0.0283 mg/kg in variant N_160P_80K_120, which is 6.8% higher than N_0P_0K_0 variant, being statistically significant.

The average for the period under study the concentration of lead in chickens breast muscle fed with maize and wheat from experiment with NP variant N_0P_0 was of 0.0266 mg/kg for those fed with grain harvested from fertilized variant N_40P_40, 3.8% higher - not statistically significant, 0.0277 mg/kg, than the control, 0.0280 mg/kg for those fed with harvest fertilized with N_80P_80 (5.2% higher, difference not statistically significant) and 0.0285 mg/kg for those fed with maize and wheat from N_160P_160 variant, which is 6.9% higher than the breast muscle coming from chickens fed with grains harvested from the control, being statistically significant.

The average concentration of lead over the period studied from the chicken breast muscle fed with maize and wheat harvested from experiment with NP and farmyard manure, was in the variant N_0P_0 + 0 t/ha (control), 0.0266 mg/kg for those fed with maize and wheat harvested from variant N_50P_0 + 20 t/ha farmyard manure, 3.3% higher than the control, 0.0278 mg/kg for those fed with grains harvested from fertilized variant with N_50P_50 + 40 t/ha farmyard manure (4.7% higher) and 0.0278 mg/kg and for those fed with maize and wheat from N_100P_100 + 60 t/ha farmyard manure, it was 5.9 % higher than the breast muscle coming from chickens fed with grains harvested from the control variant, being statistically significant.
7.5. Influence of NPK, NP fertilizers and NP + farmyard manure on the concentration of lead in the chicken leg muscle

On average, the lead concentration over the studied studies, from chicken leg muscle fed with maize and wheat from experiment NPK was in the control variant of 0.0206 mg/kg, 0.0212 mg/kg in the variant fertilized with N$_{80}$P$_{40}$K$_{40}$ (3.1% higher than the control, statistically insignificant), 0.0214 mg/kg in the variant fertilized with N$_{80}$P$_{80}$K$_{80}$ (4% higher, statistically...
uninsured) and 0.0216 mg/kg in variant N_{160}P_{80}K_{120}, which is the 4.9% higher than the one derived from chickens fed from N_{0}P_{0}K_{0} variant (control), being statistically significant.

During the study period studied the average concentration of lead in the chicken leg muscle fed with maize and wheat harvested from experiment with nitrogen and phosphorus was in the unfertilized variant (control) of 0.0209 mg/kg for those fed with grains from fertilized variant N_{40}P_{40}, 0.0216 mg/kg, 3.3% higher than in variant N_{0}P_{0}, 0.0218 mg/kg for those fed with harvest fertilized with N_{80}P_{80} (4.3% higher) and 0.0220 mg/kg for those fed with maize and wheat fertilized with N_{160}P_{160} variant, which is 5.1% higher than leg muscle derived from chickens fed with maize and wheat harvested from control variant (N_{0}P_{0}), being statistically significant.

The average lead concentration for the period 2010 - 2012, from chickens leg muscle fed on grain from experiment with chemical and organic fertilizers, in the unfertilized variant (control) was of 0.0206 mg/kg, for those fed with maize and wheat harvested from fertilized variant N_{50}P_{0} + 20 t/ha farmyard manure, 2.7% higher, 0.0212 mg/kg, than the control variant, 0.0213 mg/kg for those fed with grains harvested from fertilized variant with N_{50}P_{50} + 40 t/ha farmyard manure (3.4% higher) and 0.0214 mg/kg for those fed with maize and wheat from variant N_{100}P_{100} + 60 t/ha farmyard manure, which is 3.9% higher than chicken leg muscle fed with grains harvested from variant N_{0}P_{0} + 0 t/ha farmyard manure, the differences being statistically insignificant in all three variants.

Fig. 7.4. Correlation between doses of NPK chemical fertilizers and the concentration of lead in chicken leg muscle

Fig. 7.5. Correlation between doses of NP chemical fertilizers and concentration of lead in chicken leg muscle
7.6. Influence of NPK, NP fertilizers and NP fertilizer + farmyard manure on the concentration of lead in chicken liver

Chickens liver fed on grain harvested from experiment with NPK had an average lead concentration of 0.0315 mg/kg in the control variant, in the case of chickens fed on wheat and maize on variant N80P40K40, 0.0333 mg/kg, 5.5% higher than the control variant, 0.0342 mg/kg for those fed with harvest fertilized with N80P80K80 (8.4% higher) and 0.0346 mg/kg for those fed with cereals harvested from N160P80K120 variant being 9.7% higher than the liver of chickens fed on maize and wheat harvested from N0P0K0 variant, being statistically significant in this variant of experience with NPK.

On average, during the period studied (2010 - 2012), the concentration of lead in the liver of chickens fed on maize and wheat harvested from experiment NP, in control variant was of 0.0317 mg/kg for those fed with grains harvested from fertilized variant with N40P40, 0.0335 mg/kg, 5.8% higher than the control, 0.0344 mg/kg for those fed with grains harvested from fertilized variant with N80P80 (8.6% higher), respectively 0.0349 mg/kg for those fed with harvested variant N160P160, which is 10% higher than the liver of chickens fed with grains harvested from control variant. The differences registered were statistically insignificant and in variants N40P40 and N80P80, respectively the variant N160P160 was statistically significant.

The average lead concentrations for the studied period from chickens liver fed on maize and wheat harvested from experiment with NP + farmyard manure, in control variant was of 0.0313 mg/kg for those fed with grain harvested from fertilized variant with N50P0 + 20 t/ha farmyard manure, 0.0328 mg/kg, 4.5% higher than the control variant, 0.0334 mg/kg for those fed with harvest fertilized with N50P50 + 40 t/ha of farmyard manure (6.7% higher) and 0.0340 mg/kg for those fed with maize and wheat harvested from fertilized variant with N100P100 + 60 t/ha farmyard manure, which is 8.6% higher than the liver of chickens coming from fed with grains harvested from variant N0P0 + 0 t/ha farmyard manure (control). The differences registered in fertilized variants N50P0 + with 20 t/ha farmyard manure and N50P50 + 40 t/ha farmyard manure were not statistically insured and in variant N100P100 + 60 t/ha farmyard manure the difference was statistically significant.
Fig. 7.7. Correlation between doses of NPK chemical fertilizer and the concentration of lead in chicken liver

![Graph showing correlation between NPK doses and lead concentration]

\[ y = -0.0000x^2 + 0.002x + 0.029 \]
\[ R^2 = 0.800 \]

Fig. 7.8. Correlation between doses of NP chemical fertilizer and concentration of lead in chicken liver

![Graph showing correlation between NP doses and lead concentration]

\[ y = -0.0000x^2 + 0.002x + 0.029 \]
\[ R^2 = 0.807 \]

Fig. 7.9. Correlation between doses of NP chemical fertilizers and farmyard manure and concentrations lead in the chicken liver

![Graph showing correlation between NP and manure doses and lead concentration]

\[ y = 0.031x^{0.58} \]
\[ R^2 = 0.758 \]
Chapter VIII. Influence of doses and combinations of chemical and organic fertilizers on the concentration of copper in the soil-plant-animal system

8.1. Influence of NPK, NP fertilizer and NP fertilizer + farmyard manure on the concentration of copper of preluvosol

On average over the three years studied, the concentration of copper in variant N_0P_0K_0 from preluvosol from Oradea was 22.323 mg/kg, while in other variants the concentrations were higher by 3.4% in variant N_{80}P_{40}K_{40}, 10.5% in variant N_{80}P_{80}K_{80}, respectively 25.8 mg/kg in variant N_{160}P_{80}K_{120}, and reaching values of 23.089 mg/kg, 24.664 mg/kg and respectively 28.087 mg/kg. In variant N_{80}P_{40}K_{40} the difference recorded was not statistically significant, in variant N_{80}P_{40}K_{40} it was statistically significant, respectively in variant N_{160}P_{80}K_{120} was distinctly significant.

Over the period under study, the average concentration of copper in control variant was 22.659 mg/kg. In variant N_{80}P_{40} the concentration of copper increased statistically insignificant by 3.9%, being 23.548 mg/kg. In the fertilized variant with N_{80}P_{80} the difference was 11.1%, not statistically insured. Fertilization N_{160}P_{160} resulted in increase of 29.4% compared to variant N_{0}P_{0} (control), the difference being statistically significant.

On average, during 2010-2012, the concentration of copper in the soil was 20.140 mg/kg in control variant. In fertilized variant N_{50}P_{0} + with 20 t/ha farmyard manure the concentration of copper increased by 2.4% (statistically insignificant), having the value of 22.932 mg/kg. In variant N_{50}P_{50} + 40 t/ha farmyard manure the copper had a concentration of 23.997 mg/kg, 7.2% higher (statistically insignificant) and fertilization with N_{100}P_{100} + 60 t/ha farmyard manure resulted in a increase by 16% (statistically significant) compared to variant N_{0}P_{0} + 0 t/ha farmyard manure reaching a concentration of 25.988 mg/kg.

8.2. Influence of NPK, NP fertilizer and NP + farmyard manure on the concentration of copper in wheat grains

The average copper concentration of the wheat grains during the three years study (2010-2012), in variant version N_{0}P_{0}K_{0} (control) was 1.654 mg/kg. In fertilized variant with N_{80}P_{40}K_{40} there was a higher concentration, 13.8% compared to the control, of 1,883 mg/kg, statistically insignificant. In the variant N_{80}P_{80}K_{80} wheat grains had a higher copper concentration by 23.8% compared to variant N_{0}P_{0}K_{0}, the increase being statistically insured. The variant N_{160}P_{80}K_{120} led to an increase of the copper concentration of 32.2% (2.186 mg/kg) compared to unfertilized variant, the difference being statistically significant.

In variant N_{0}P_{0} (control), the average copper concentration from wheat grains was 1.597 mg/kg. In the variant fertilized with N_{40}P_{40} was a higher concentration of 12.7% (1.801 mg/kg) compared to the control variant being statistically insignificant. Wheat grains harvested from variant N_{80}P_{80} had a copper concentration of 1.926 mg/kg, 20.6% higher compared to the control N_{0}P_{0}, the difference being statistically insured. The concentration determined in the variant fertilized with N_{160}P_{160}, 2.073 mg/kg was 29.8% higher compared to the control, the difference being statistically insured.

Wheat grains harvested from experiment with chemical fertilizers with nitrogen, phosphorus and farmyard manure had an average concentration of copper of 1.640 mg/kg in variant N_{0}P_{0} + 0 t/ha farmyard manure (control), 1.920 mg/kg (17.1% higher compared to control variant) in variant N_{50}P_{0} + 20 t/ha farmyard manure, 2.102 mg/kg (28.2% higher compared to unfertilized variant) in fertilized variant N_{50}P_{50} + 40 t/ha farmyard manure, respectively 2236 mg/kg (36.4% higher compared to the control variant) in variant N_{100}P_{100} + 60...
t/ha farmyard manure. In fertilized variant N\textsubscript{50}P\textsubscript{0} + with 20 t/ha farmyard manure the difference was statistically insignificant, and variants N\textsubscript{50}P\textsubscript{50} + 40 t/ha farmyard manure and N\textsubscript{100}P\textsubscript{100} + 60 t/ha farmyard manure the differences were statistically insured as being “significant”.

8.3. Influence of NPK, NP fertilizer and NP + farmyard manure on the concentration of copper in maize grains

Average copper concentration in maize, for the three years under study (2010-2012) in the control was 2.840 mg/kg. In variant N\textsubscript{80}P\textsubscript{40}K\textsubscript{40} there was a higher concentration of 7.5% compared to unfertilized variant, of 3.052 mg/kg, being statistically insignificant. The maize harvested from the variant fertilized with N\textsubscript{80}P\textsubscript{80}K\textsubscript{80} had a higher copper concentration by 12.9% compared to the control. The fertilized variant N\textsubscript{160}P\textsubscript{80}K\textsubscript{120}increased the concentration of copper of 3.336 mg/kg, 17.5% higher compared to the variant N\textsubscript{0}P\textsubscript{0}K\textsubscript{0} (control), being statistically significant.

In control variant, the average concentration of copper was 2.853 mg/kg. In the fertilized variant with N\textsubscript{40}P\textsubscript{40} there was a concentration of 3.246 mg/kg, 13.8% higher compared to the control being statistically insignificant. In the variant N\textsubscript{80}P\textsubscript{80} the maize had a higher copper concentration of 21.1% (statistically significant) than the version of N\textsubscript{0}P\textsubscript{0} (3.455 mg/kg). The determined concentration in harvested maize from variant N\textsubscript{160}P\textsubscript{160} was 30.6% higher compared to the control, distinctly statistically significant.

In the three years studied, the average concentration of copper in maize grains, the experiments with chemical fertilizers with nitrogen, phosphorus and manure was 2.858 mg/kg for the control variant, 3.322 mg/kg (16.2% higher compared to control) in variant N\textsubscript{40}P\textsubscript{0} + 20 t/ha farmyard manure, 3.479 mg/kg (21.7% higher compared to the control variant) in the fertilized variant with N\textsubscript{50}P\textsubscript{50} + 40 t/ha farmyard manure, respectively 3.935 mg/kg (37.7% higher compared to unfertilized variant) in variant N\textsubscript{100}P\textsubscript{100} + 60 t/ha farmyard manure.

8.4. Influence of NPK, NP fertilizer and NP + farmyard manure on the concentration of copper in the chicken breast muscle

Between 2010-2012, the average concentration of copper in the chicken breast muscle fed on maize and wheat from NPK experiment, in control variant was of 0.1114 mg/kg, 0.1208 mg/kg in the variant fertilized with N\textsubscript{80}P\textsubscript{40}K\textsubscript{40} (8.5% higher than control), 0.1255 mg/kg in variant N\textsubscript{80}P\textsubscript{80}K\textsubscript{80} (12.5% higher) and 0.1310 mg/kg in the variant fertilized with N\textsubscript{160}P\textsubscript{80}K\textsubscript{120}, which is 17.6% higher than N\textsubscript{0}P\textsubscript{0}K\textsubscript{0}variant, being statistically significant.

The average copper concentration (2010-2012) in chicken breast muscle fed on maize and wheat from experiments with nitrogen and phosphorus, in variant N\textsubscript{0}P\textsubscript{0} (control) was of 0.1115 mg/kg, for those fed with grain harvested from fertilized variant with N\textsubscript{40}P\textsubscript{40}, 0.1224 mg/kg, 9.8% higher than control, 0.1269 mg/kg for those fed with maize and wheat from variant N\textsubscript{80}P\textsubscript{80} (13.7% higher) and 0.1343 mg/kg for those fed with grains harvested from N\textsubscript{160}P\textsubscript{160} variant, which is 20.4% higher than the breast muscle coming from chucks fed with maize and wheat harvested from N\textsubscript{0}P\textsubscript{0} variant. The differences between variants N\textsubscript{40}P\textsubscript{40} and N\textsubscript{80}P\textsubscript{80} were not statistically significant, respectively statistically significant in the fertilized variant with N\textsubscript{160}P\textsubscript{160}.

During the period studied (2010-2012), the average concentration of copper in the chicken breast muscle fed with maize and wheat harvested from experiments with NP and farmyard manure, was in the variant N\textsubscript{0}P\textsubscript{0} + 0 t/ha farmyard manure (control), 0.1115 mg/kg for those fed with maize and wheat harvested from variant N\textsubscript{50}P\textsubscript{20} + 20 t/ha farmyard manure, 10.6% higher (0.1234 mg/kg) than the control, in the case of those fed with grains harvested from variant N\textsubscript{50}P\textsubscript{50} + 40 t/ha farmyard manure (18% higher) and 0.1316 mg/kg, the differences being
statistically insignificant. For those fed with maize and wheat harvested from variant $N_{100}P_{100} + 60$ t/ha farmyard manure, this was 28.6% higher than breast muscle coming from chickens fed with grains harvested from control variant (0.1434 mg/kg), the difference being statistically significant.

Fig. 8.1. Correlation between doses of NPK chemical fertilizers and copper concentration in the chicken breast muscle

Fig. 8.2. Correlation between doses of NP chemical fertilizers and concentration of copper in the chicken breast muscle

Fig. 8.3. Correlation between doses of NP chemical fertilizers and farmyard manure and concentration of copper in the chicken breast muscle
8.5. Influence of NPK, NP fertilizer and NP + farmyard manure on the concentration of copper in chicken leg muscle

The average concentration of copper in the period under study (2010-2012), from the chickens leg muscle fed with maize and wheat from experiment with chemical fertilizers (NPK) was in the unfertilized variant of 0.1077 mg/kg, 7.8% higher than \( \text{N}_0\text{P}_0\text{K}_0 \) variant (0.1160 mg/kg) in the variant fertilized with \( \text{N}_{80}\text{P}_{40}\text{K}_{40} \), 4% higher in the variant fertilized with \( \text{N}_{80}\text{P}_{80}\text{K}_{80} \) (0.1204 mg/kg) and higher by 4.9% in \( \text{N}_{160}\text{P}_{80}\text{K}_{120} \) variant (0.1258 mg/kg) compared to that derived from chickens fed from the control variant. The differences were not statistically insured in variants \( \text{N}_{80}\text{P}_{40}\text{K}_{40} \) and \( \text{N}_{80}\text{P}_{80}\text{K}_{80} \), respectively statistically significant in variant \( \text{N}_{160}\text{P}_{80}\text{K}_{120} \).

The average concentration of copper in chickens leg muscle fed on grains harvested from experience with NP was in control variant (\( \text{N}_0\text{P}_0 \)) of 0.1075 mg/kg, for those fed on maize and wheat harvested from \( \text{N}_{40}\text{P}_{40} \) variant, 0.1155 mg/kg, higher by 7.4% than in the control, 0.1192 mg/kg for those fed with harvest from variant \( \text{N}_{80}\text{P}_{80} \) (10.9% higher, not statistically significant) and 0.1256 mg/kg in the case of those fed with maize and wheat harvested from variant \( \text{N}_{160}\text{P}_{160} \), which is 16.9% higher than the leg muscle taken from chickens fed on grains from variant \( \text{N}_0\text{P}_0 \), being statistically significant.

The average copper concentration in the chickens leg muscle fed with maize and wheat harvested from experience with NP and farmyard manure was in control variant (\( \text{N}_0\text{P}_0 + 0 \text{ t/ha farmyard manure} \)) of 0.1077 mg/kg, in the case of those fed on grain from variant \( \text{N}_{50}\text{P}_0 + 20 \text{ t/ha farmyard manure} \), 9% higher (0.1174 mg/kg), than the control variant, 0.1238 mg/kg for those fed with grains harvested from fertilized with \( \text{N}_{50}\text{P}_{50} + 40 \text{ t/ha farmyard manure} \) (15% higher) and 0.1345 mg/kg for those fed with maize and wheat harvested from variant \( \text{N}_{100}\text{P}_{100} + 60 \text{ t/ha farmyard manure} \), being 24.9% higher than chickens leg muscle fed with grains harvested from control variant. The differences registered in variants \( \text{N}_{50}\text{P}_0 + 20 \text{ t/ha farmyard manure} \) and \( \text{N}_{50}\text{P}_{50} + 40 \text{ t/ha farmyard manure} \) were statistically insignificant, respectively statistically significant in variant \( \text{N}_{100}\text{P}_{100} + 60 \text{ t/ha manure} \).

![Fig. 8.4. Correlation between doses of NPK fertilizers and copper concentration in the chicken leg muscle](image-url)
Fig. 8.5. Correlation between doses of NP fertilizer and concentration of copper in the chicken leg muscle

Fig. 8.6. Correlation between doses of NP chemical fertilizers and farmyard manure and concentration of copper in the chicken leg muscle

8.6. **Influence of NPK, NP fertilizer and NP + farmyard manure on the concentration of copper in the chickens liver**

The chickens liver fed on maize and wheat harvested from experiment with NPK, taken during the study, had an average copper concentration of 0.3816 mg/kg in N<sub>0</sub>P<sub>0</sub>K<sub>0</sub> variant (control), in the case of those chickens fed on wheat and maize fertilized with N<sub>80</sub>P<sub>40</sub>K<sub>40</sub>, 9.6% higher (statistically uninsured) than in the control, 0.4183 mg/kg, 0.4378 mg/kg for those fed on grain from N<sub>80</sub>P<sub>80</sub>K<sub>80</sub> variant (14.7% higher - not statistically significant) and 0.4578 mg/kg for those fed on maize and wheat harvested from N<sub>160</sub>P<sub>80</sub>K<sub>120</sub> variant, which is 20% higher than the liver from chickens fed on maize and wheat harvested from control variant, being statistically significant.

During the period under study (2010 - 2012), the concentration of copper in the liver of chickens fed on maize and wheat harvested from experiments with nitrogen and phosphorus, in the control variant was (control) of 0.3818 mg/kg for those fed on maize and wheat harvested from variant N<sub>40</sub>P<sub>40</sub>, 10.8% higher than the control (0.4229 mg/kg), 14.8% higher in the case of those fed with grains harvested from fertilized variant N<sub>80</sub>P<sub>80</sub> (0.4384 mg/kg) and higher by 22% in the case of those fed with grains from variant N<sub>160</sub>P<sub>160</sub> versus the liver of chickens fed with grains from variant N<sub>60</sub>P<sub>0</sub> (0.4657 mg/kg), the differences being statistically insignificant for variants N<sub>40</sub>P<sub>40</sub> and N<sub>80</sub>P<sub>80</sub> and statistically significant in variant N<sub>160</sub>P<sub>160</sub>. 

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The average concentration of copper in the period 2010-2012 in liver of chickens fed on maize and wheat harvested from experience with NP + farmyard manure, in control variant was of 0.3820 mg/kg for those fed with grains harvested from variant N_{50}P_{0} + 20 t/ha farmyard manure, 11% higher than the control variant (difference statistically uninsured), 0.4239 mg/kg, 0.4583 mg/kg for those fed on harvest from variant N_{50}P_{50} + 40 t/ha farmyard manure (20% higher - not statistically significant) and 0.4965 mg/kg for those fed with maize and wheat harvested from fertilized variant with N_{100}P_{100} + 60 t/ha farmyard manure, which is 30% higher (the difference insured statistically “significant”) from liver of chickens fed on grains from the control variant, being statistically significant.

Fig. 8.7. Correlation between doses of NPK fertilizers and copper concentration in the chickens liver

Fig. 8.8. Correlation between doses of NP fertilizer and concentration of copper in the chickens liver
Fig. 8.9. Correlation between doses of NP chemical fertilizers and farmyard manure and concentration of copper in the chickens liver

Chapter IX. Influence of doses and combinations of chemical and organic fertilizers on the concentration of zinc in the soil-plant-animal system

9.1. Influence of NPK, NP fertilizers and NP + farmyard manure on the concentration of zinc of the preluvosoil

The average concentrations of zinc in the three years studied (2010-2012), in control variant (N₀P₀K₀) from the soil was 50.797 mg/kg, in variant N₈₀P₄₀K₄₀ 51.481 mg/kg (1.3% higher than the control version), in variant N₈₀P₈₀K₈₀ 51.322 mg/kg (1% higher than the unfertilized variant) respectively 51.967 mg/kg in variant N₁₆₀P₈₀K₁₂₀ (2.3% higher than N₀P₀K₀ version), the differences being statistically insured.

In the control variant, the average concentration of zinc was 50.685 mg/kg. In the fertilized variant N₄₀P₄₀ the zinc concentration increased by 0.9%, being 51.158 mg/kg. In variant N₈₀P₈₀ difference was higher by 0.7% (51.024 mg/kg), was not statistically significant and in variant N₁₆₀P₁₆₀ 0.2% higher compared to the control variant (50.794 mg/kg), not statistically insured.

The experience with fertilizers NP and farmyard manure, during the period studied, the average concentration of zinc in the soil was 50.697 mg/kg in variant N₀P₀ + 0 t/ha farmyard manure. In variant N₅₀P₀ + 20 t/ha farmyard manure the zinc concentration increased by 7.1% in value of 54.294 mg/kg. In case of fertilized variant N₅₀P₅₀ + 40 t/ha farmyard manure the zinc had a concentration of 54.575 mg/kg, 7.6% higher compared to the control and variant N₁₀₀P₁₀₀ + 60 t/ha farmyard manure the concentration of was 55.033 mg/kg, 8.6% higher than the control variant, the differences were not statistically insured.

9.2. Influence of NPK, NP fertilizers and NP + farmyard manure on the concentration of zinc in the wheat grains

The average concentration of zinc in wheat grains, for the three years studied, 2010-2012, in control variant (N₀P₀K₀) was 11.843 mg/kg. In case of variant N₈₀P₄₀K₄₀ a concentration of 12.866 mg/kg was registered, 8.6% higher compared to N₀P₀K₀ variant, the differences are not statistically significant. In the variant N₈₀P₈₀K₈₀ the wheat grains had a higher zinc concentration of 14.4% (not statistically significant) compared to the control, of 13.553 mg/kg. In fertilized variant N₁₆₀P₈₀K₁₂₀ the increase of the zinc concentration was 19.6% (statistically significant) than the unfertilized variant, 14.161 mg/kg.
The wheat grains collected from the variant \( N_0P_0 \) (control) had an average concentration of zinc 11.826 mg/kg. In case of variant \( N_{40}P_{40} \) there was a higher concentration of zinc in wheat, 4.4%, 12.351 mg/kg than \( N_0P_0 \) variant being statistically insignificant. The wheat grains harvested in the variant fertilized with \( N_{80}P_{80} \) had a zinc concentration of 12.686 mg/kg, 7.3% higher compared to the control, the difference was not statistically significant. The concentration of zinc in wheat grains harvested from \( N_{160}P_{160} \) version, was 7.9% higher compared to unfertilized variant, not statistically insured, registering the value 12.757 mg/kg.

The average concentration of zinc in the wheat grains harvested from variant \( N_0P_0 + 0 \) t/ha of farmyard manure (control) was 11.825 mg/kg. In variant \( N_{50}P_0 + 20 \) t/ha farmyard manure was 9.8% higher (12.988 mg/kg), in variant \( N_{50}P_{50} + 40 \) t/ha farmyard manure, 13.595 mg/kg (15% higher compared to the control) and the variant \( N_{100}P_{100} + 60 \) t/ha farmyard manure 14.163 mg/kg, 19.8% higher compared to the control variant. The differences compared to the control, in the studied variants of experiments with nitrogen, phosphorus and manure were insignificant in the fertilized version \( N_{50}P_0 + 20 \) t/ha farmyard manure and \( N_{50}P_{50} + 40 \) t/ha farmyard manure, respectively statistically significant in the fertilized version \( N_{100}P_{100} + 60 \) t/ha manure.

9.3. The influence of the NPK, NP fertilizers and NP + farmyard manure on the concentration of zinc in maize grains

The maize harvested from experiment with NPK had an average zinc concentration over the three years studied (2010-2012), in control variant of 5.353 mg/kg. In the fertilized variant with \( N_{80}P_{40}K_{40} \) was registered a concentration of 5.713 mg/kg, 6.7% higher compared to the \( N_0P_0K_0 \) variant (control) is not statistically significant. The maize harvested from variant \( N_{80}P_{80}K_{80} \) had a higher zinc concentration by 7.1% compared to the control variant. \( N_{160}P_{80}K_{120} \) fertilization increased the concentration of zinc in maize at 5.908 mg/kg, 10.4% higher than the control, the difference being statistically insured.

In the control variant, the average concentration of zinc was 5.348 mg/kg. In variant \( N_{40}P_{40} \) there was a concentration equal to that of the control variant, of 5.348 mg/kg. The variant fertilized with maize \( N_{80}P_{80} \) had a lower zinc concentration of 2.4% compared to \( N_0P_0 \) version of 5.221 mg/kg. The concentration determined in maize harvested from fertilized variant with \( N_{160}P_{160} \) was 5.093 mg/kg, 4.8% lower than the control variant. In \( N_{80}P_{80} \) and \( N_{160}P_{160} \) variants the negative differences compared to control are explained by the fact that during the growing season of maize there was a more serious drought than during the wheat growing season, as a result the phosphorus doses blocked the zinc in soil and its translocation to the grains was very reduced.

The average concentration of zinc in maize grains in the three years studied (2010-2012), the experiments with chemical and organic fertilizers was of 5.353 mg/kg in control variant, 5.679 mg/kg (6.1% higher than the control variant) for variant \( N_{50}P_0 + 20 \) t/ha farmyard manure, 5.767 mg/kg (7.7% higher compared to the control) in the variant fertilized with \( N_{50}P_{50} + 40 \) t/ha farmyard manure, respectively 5.856 mg/kg (9.4% higher compared to variant \( N_0P_0 + 0 \) t/ha farmyard manure) in variant \( N_{100}P_{100} + 60 \) t/ha farmyard manure, the differences were not statistically insured.
9.4. Influence of NPK, NP fertilizers and NP + farmyard manure on the concentration of zinc in chicken breast muscle

The average concentration of zinc, in 2010-2012, from the chicken breast muscle fed on maize and wheat from experiment with nitrogen, phosphorus and potassium, in variant N₀P₀K₀ (control) was of 1.1210 mg/kg, 1.1723 mg/kg in case of variant N₈₀P₄₀K₄₀ (4.6% higher than the control variant), 1.1871 mg/kg in the variant fertilized with N₈₀P₈₀K₈₀ (5.9% higher) and respectively 1.2045 mg/kg in case of N₁₆₀P₈₀K₁₂₀ variant, which is 7.4% higher than N₀P₀K₀ version, the differences being statistically insignificant.

In the chickens breast muscle fed on maize and wheat from experiments with NP, the average concentration of zinc in control variant was of 1.1214 mg/kg for those fed with grains harvested from N₄₀P₄₀ version, 1.1342 mg/kg, 1.1% higher than the control variant, 1.1408 mg/kg for those fed with maize and wheat from N₈₀P₈₀ version (1.7% higher) and respectively 1.1446 mg/kg for those fed with cereals harvested from fertilized variant N₁₆₀P₁₆₀, which is 2.1% higher than the breast muscle coming from chickens fed with maize and wheat harvested from N₀P₀ version, the differences being statistically insignificant.

The average concentration of zinc in chickens breast muscle fed with maize and wheat harvested from experiment with chemical fertilizers and farmyard manure in variant N₀P₀ + 0 t/ha (control), was of 1.1218 mg/kg for those fed with maize and wheat harvested from fertilized variant with N₅₀P₀ + 20 t/ha farmyard manure, 1.1889 mg/kg, 6% higher (statistically not assured) than the control variant. In the case of those fed with harvested grain from variant N₅₀P₅₀ + 40 t/ha farmyard manure, the concentration of zinc in the breast muscle was 7.3 % higher, which is statistically insignificant, registering the value 1.2040 mg/kg, and for those fed with maize and wheat harvested from variant N₁₀₀P₁₀₀ + 60 t/ha farmyard manure, it was 10.7% higher than chest coming from chickens fed with grains harvested from the control variant, 1.2420 mg/kg, the difference not being statistically insured.

![Graph showing correlation between NPK fertilizer doses and zinc concentration in chicken breast muscle](image-url)
9.5. Influence of NPK, NP fertilizers and NP + farmyard manure on the concentration of zinc in chicken leg muscle

Chickens leg muscle fed on maize and wheat from NPK experiments had an average concentration of zinc in the control variant of 1.1186 mg/kg. In variant N_{80}P_{40}K_{40} it was 3.8% higher than the control variant (1.1616 mg/kg). In case of variant N_{80}P_{80}K_{80}, the zinc concentration was 1.1756 mg/kg, 5.1% higher compared to the control and in variant N_{160}P_{80}K_{120} of 1.1959 mg/kg, 6.9% higher compared to that derived from chickens fed in the unfertilized variant, the differences were not statistically insured.

The average concentration of zinc in chicken leg muscle fed on grains harvested from experiment with nitrogen and phosphorus, in variant N_{0}P_{0} was of 1.1214 mg/kg, for those fed with maize and wheat harvested from N_{40}P_{40} variant, 1.1 % higher than in the control, 1.1342 mg/kg, 1.7% in higher for those fed with harvest N_{80}P_{80} variant, 1.1408 mg/kg, with 2.1% in the case of those fed with maize and wheat harvested from N_{160}P_{160} variant, registering 1.1446 mg/kg, the differences being statistically insignificant.

The average zinc concentration in the years 2010 - 2012, from chickens leg muscle fed with maize and wheat harvested from experiment with nitrogen, phosphorus and farmyard manure, was in variant N_{0}P_{0} + 0 t/ha farmyard manure was of 1.1195 mg/kg, in the case of those fed on grains harvested from fertilized variant N_{50}P_{0} with 20 t/ha farmyard manure, 5.4%
higher, 1.1797 mg/kg, compared to the control, the difference being statistically insured. In case of those fed with grain harvested from variant N\(_{50}\)P\(_{50}\) + 40 t/ha farmyard manure the zinc concentration was 6.1% higher and for those fed with maize and wheat harvested from fertilized variant with N\(_{100}\)P\(_{100}\) + 60 t/ha farmyard manure, it was 9.5% higher than the chickens leg muscle fed with grains harvested from the control variant, registering 1.2260 mg/kg, the differences being statistically insignificant.

Fig. 9.4. Correlation between doses of NPK fertilizer and the concentration of zinc in chicken leg muscle

Fig. 9.5. Correlation between doses of NP fertilizer and concentration of zinc in chicken leg muscle

Fig. 9.6. Correlation between doses of NP chemical fertilizers and farmyard manure and concentration of zinc in chicken leg muscle
9.6. Influence of NPK, NP fertilizer and NP + farmyard manure on the concentration of zinc in chicken liver

The average concentration of zinc in the chickens liver fed on maize and wheat harvested from NPK experiment, was of 1.5482 mg/kg in variant N₀P₀K₀, in the case of grain fed from N₈₀P₄₀K₄₀ variant, 6.2% higher (not statistically significant) than in the control, respectively 1.6441 mg/kg. In the case of chickens fed with maize and wheat harvested from N₈₀P₈₀K₈₀ version, the zinc concentration was higher by 8% (not statistically significant), taking the value of 1.6728 mg/kg. Chickens fed with maize and wheat harvested from variant N₁₆₀P₈₀K₁₂₀ had zinc concentration of 1.6963 mg/kg, 9.6% higher that the liver of chickens fed on grains from unfertilized variant, statistically insignificant.

During the study period, 2010 - 2012, the concentration of zinc in the chickens liver fed with maize and wheat harvested with NP experiment, in control variant (N₀P₀) was of 1.5482 mg/kg for those fed with maize and wheat harvested from N₄₀P₄₀ variant, 1.8% higher than the control (1.5756 mg/kg), 2.5% higher in the case of those fed with grains harvested from N₈₀P₈₀ variant (1.5870 mg/kg) and respectively 3% higher for those fed with grain from N₁₆₀P₁₆₀ version, versus the chickens liver fed with grains harvested from fertilized variants (1.5951 mg/kg), the differences being statistically insured.

The chickens liver fed on maize and wheat harvested from NP experiment and farmyard manure had an average concentration of zinc in the period 2010-2012, 1.5485 mg/kg in the control variant. In the case of chickens fed on grain from fertilized variant N₅₀P₀ + 20 t/ha farmyard manure, the zinc concentration was 7.7% higher than the control variant. Grains harvested from version N₅₀P₅₀ + 40 t/ha farmyard manure led to a concentration of zinc in the chickens liver of 1.6805 mg/kg, 8.5% higher compared to the control. The concentration of zinc in the liver of chickens fed with maize and wheat harvested from version N₁₀₀P₁₀₀ + 60 t/ha farmyard manure was 11.6% higher than the liver of chickens fed on grain from unfertilized variant, being statistically significant.

Fig. 9.7. Correlation between doses of NPK fertilizers and the concentration of zinc in chicken liver
Chapter X. Conclusions and Recommendations

Conclusions on the concentration of cadmium in the soil – plant – animal system

1. The concentration of cadmium in preluvosol from long experiments with NPK, NP, doses of farmyard manure – mineral fertilization is influenced by the dose of fertilizer used. On average during 2010 - 2012, in the NPK experiment the concentration of cadmium in the soil compared to the unfertilized control variant (1.120 mg/kg) increased significantly (51.6%) in variant N80P80K80 reaching 1.698 mg/kg and very significant statistically (123.6%) in variant N160P80K120 (2.504 mg/kg); in case of the fertilized variant with N80P40K40 the difference compared to the control is statistically insignificant, with a concentration of 1.284 mg/kg. The NP experiment, in all three variants studied, the differences compared to the control (1.120 mg/kg) are statistically insured, the biggest difference, 160.8%, highly statistically significant, resulting in the fertilized variant N160P160, the concentration of cadmium was 2.921 mg/kg. The increase of farmyard manure doses determined an increase of the cadmium concentration at 1.468 mg/kg in variant N100P100 + 60 t/ha farmyard manure, but the relative differences from the control are smaller than the differences obtained from experiments with NPK and NP variants.
2. The cadmium concentration of the grains of wheat and maize increased together with the increase of doses of NPK fertilizers having values of 0.068 mg/kg, 0.083 mg/kg, 0.102 mg/kg in the case of wheat, respectively 0.050 mg/kg, 0.061 mg/kg, 0.075 mg/kg in the case of maize. In the NP experiment the highest concentration in the solution was registered in variant N$_{160}$P$_{160}$ 0.112 mg/kg in wheat grains and 0.082 mg/kg in maize grains. The farmyard manure doses applied led to increases in wheat grains from 0.056 mg/kg in control variant to 0.067 mg/kg in variant N$_{100}$P$_{100}$ + 60 t/ha farmyard manure, the difference being statistically insured, respectively in maize grains, the difference recorded was 23.3% higher (0.049 mg/kg).

3. Concentration of cadmium in anatomical areas taken for studies (breast muscle and leg muscle) and chicken liver increased with increasing doses of fertilizers used. The biggest differences compared to the control, were made in the NP experiment in variant N$_{160}$P$_{160}$, 65.4% for pectoral muscles (0.0164 mg/kg) for the leg muscle 51.3% (0.0121 mg/kg), and respectively 66.5% in the case of liver (0.0943 mg/kg).

4. Between the fertilizers doses studied for the wheat and maize and the concentration of cadmium in the chest, leg muscle and chicken liver, a direct correlation was quantified, of the 5 types of regression functions tested (linear, polynomial, logarithmic, exponential and power) the polynomial function had the largest regression coefficient.

5. The concentration of cadmium in soil, plant (wheat, maize) and animal (breast muscle, leg muscle, liver) is below the maximum limits allowed by current standards.

Conclusions on the concentration of lead in the soil – plant – animal system

1. The soil from the 3 long term experiments was modified under the influence of doses and fertilizer combinations with NPK, NP, doses of farmyard manure + NP regarding the concentration of lead. On average over the period studied in the experiment with NPK only in variants N$_{80}$P$_{80}$K$_{80}$ (27.819 mg/kg) and N$_{160}$P$_{80}$K$_{120}$ (32.900 mg/kg) were obtained differences statistically insured, significant and distinctly statistically significant. The same differences were recorded in the NP experiment and experiment with doses of farmyard manure and NP doses.

2. The concentration of lead in the wheat and maize grains from the mineral or organo-mineral fertilized variants increased compared to the unfertilized control, but the differences are statistically significant only in the variants with the highest doses of mineral and organic-mineral fertilizers, so for wheat variants N$_{160}$P$_{80}$K$_{120}$, N$_{160}$P$_{160}$, respectively N$_{100}$P$_{100}$ + 60 t/ha of farmyard manure the registered concentrations were 0.046 mg/kg, 0.047 mg/kg, 0.045 mg/kg, and in the case of maize the concentrations were 0.059 mg/kg, 0.058 mg/kg and 0.056 mg/kg.

3. The concentration of lead in the chicken breast muscle increased together with increasing the doses of fertilizers used for crop fertilization, but only the difference in the version with the highest dose of mineral fertilizer, but also in the organo-mineral fertilized variant, 6.8% in N$_{160}$P$_{80}$K$_{120}$ variant, 6.9% in N$_{160}$P$_{160}$ variant, respectively 5.9% in N$_{100}$P$_{100}$ variant + 60 t/ha farmyard manure. The same was observed in the lead concentration from chicken leg muscle increases being in 4.9%, 5.1% and 3.9%.

4. In the chicken liver was determined a higher concentration of lead compared to the lead concentration determined in breast muscle, respectively chicken leg muscle in all the variants studied. Only in the variants with the highest doses of mineral and organic-mineral fertilizers were differences insured statistically with the degree of “significant”, 9.7% for variant N$_{160}$P$_{80}$K$_{120}$, 10.0% for variant N$_{160}$P$_{160}$ and 8.6% for variant N$_{100}$P$_{100}$ 6% + 60 t/ha farmyard manure.
5. Also in the case of lead, the link between doses of NPK, NP, NP fertilizers + farmyard manure and its concentration in breast muscle, leg muscle, respectively chicken liver was quantified a direct link; in most cases polynomial function had the highest regression coefficient.

6. In all components of the soil – plant – animal system the lead concentration was below the maximum permissible value.

**Conclusions on the concentration of copper in the soil – plant – animal system**

1. On average for the three years under study it was noticed an increase of copper concentration in the soil in all the studied variants for the 3 experiments with mineral or organo-mineral fertilizer. The differences compared to the unfertilized variant were statistically significant in variant N\textsubscript{80}P\textsubscript{80}K\textsubscript{80} (24.664 mg/kg) and distinctly statistically significant in variant N\textsubscript{160}P\textsubscript{80}K\textsubscript{120} (28.087 mg/kg). In the organo-mineral fertilized variants, only the version with the highest doses (N\textsubscript{100}P\textsubscript{100}+60 t/ha farmyard manure) the difference compared to the unfertilized control was statistically insured, the difference being “significant” 25.988 mg/kg, being 16% higher than the control variant.

2. The concentration changes of copper in the soil caused by the use of different doses and combinations of fertilizers have resulted in a different translocation of copper in wheat and maize grains. Compared to the unfertilized control in all the studied variants the copper concentration from wheat grains increased; on average over the period studied they were “statistically significant”. Only in the variants with the highest doses of mineral and organic-mineral fertilizers, 32% in variant N\textsubscript{160}P\textsubscript{80}K\textsubscript{120}, 29.8% for variant N\textsubscript{160}P\textsubscript{160}, respectively 36.4% in fertilized variant N\textsubscript{100}P\textsubscript{100}+60 t/ha farmyard manure. For maize there were differences insured statistically in the last but one dose studied N\textsubscript{80}P\textsubscript{80}K\textsubscript{80}, N\textsubscript{80}P\textsubscript{80} and N\textsubscript{50}P\textsubscript{50} + 40 t/ha farmyard manure, being 23.8%, 20.6%, 28.2% higher compared to the control, recording concentrations of 2.048 mg/kg 1.926 mg/kg and 2.102 mg/kg.

3. The concentration of copper in the chicken breast muscle, leg muscle and liver increased compared to the control, but the differences are statistically insured as significant only for variants with higher doses. In case of the chicken breast muscle, leg muscle and liver the highest difference from the control was determined in the experiment with organo-mineral fertilizers in fertilized variant N\textsubscript{100}P\textsubscript{100}+60 t/ha farmyard manure, 28.6%, 24.9% and 30%. All values measured were below the maximum permissible standards in vigour.

4. The correlation between doses of mineral and organo-mineral fertilizers and the copper concentration determined by the broilers breast muscle, leg muscle and liver studied is a straightforward one, the polynomial function quantified best in this connection.

**Conclusions on the concentration of zinc in the soil – plant – animal system**

1. The concentration of zinc of preluvosol from the long term experiments with NPK, NP, doses of farmyard manure – mineral fertilization increased together with the dose of fertilizer used. On average during 2010 - 2012 in all three experiments with NPK, NP, NP + farmyard manure, zinc concentration from the soil, compared to unfertilized control increased, but the differences are not statistically insured.

2. The zinc concentration of wheat and maize grains increased together with increasing the doses of NPK, NP fertilizer, respectively doses of farmyard manure + chemical
fertilizer, the differences being statistically insured in the variants with the highest doses, taking the values in the case of wheat of 14.161 mg/kg in variant N\textsubscript{160}P\textsubscript{80}K\textsubscript{120}, 12.757 mg/kg in the variant fertilized N\textsubscript{160}P\textsubscript{160} and 14.163 mg/kg in variant N\textsubscript{100}P\textsubscript{100} + 60 t/ha farmyard manure, respectively for maize 5.908 mg/kg in variant N\textsubscript{160}P\textsubscript{80}K\textsubscript{120}, 5.093 mg/kg in the fertilized variant N\textsubscript{160}P\textsubscript{160} and 5.856 mg/kg for variant N\textsubscript{100}P\textsubscript{100} + 60 t/ha farmyard manure. It is noted that the NP experiment showed it was registered the lowest concentration of Zn compared to other experiments, this fact being explained by the fact that due to the lack of rainfall, the amount of phosphorus remaining in the soil was higher resulting in immobilization of zinc by plants.

3. The concentration of zinc in different anatomic zones (breast muscle and leg muscle) and chicken liver increased together with increasing the doses of fertilizers used. So in the variant N\textsubscript{160}P\textsubscript{80}K\textsubscript{120} the zinc recorded a concentration in breast muscle of 1.2045 mg/kg (7.4% higher compared to control) in variant N\textsubscript{160}P\textsubscript{160} 1.1446 mg/kg (2.1% higher) respectively 1.2420 mg/kg (10.7% higher) in variant N\textsubscript{100}P\textsubscript{100} + 60 t/ha farmyard manure. In the case of chicken liver the concentrations were 9.6% higher compared to the control (N\textsubscript{160}P\textsubscript{80}K\textsubscript{120}), 3% (N\textsubscript{160}P\textsubscript{160}) and 11.6% (N\textsubscript{100}P\textsubscript{100} + 60 t/ha farmyard manure).

4. Between the studied doses of fertilizers for the wheat and maize harvest and zinc concentration in breast muscle, leg muscle and chicken liver a direct correlation was quantified, of the 5 types of regression functions tested (linear, polynomial, logarithmic, exponential and power) the polynomial function had the highest regression coefficient.

5. The concentration of zinc in the soil, plant (wheat, maize) and animal (breast muscle, leg muscle, liver) is below the maximum allowed limits by current standards.

✓ In addition to the above we can say that mineral fertilization with different doses and combinations of NP and NPK and organic-mineral fertilization with different doses of farmyard manure and NP did not cause an increase in the concentration of heavy metals (Cd, Pb, Cu, Zn) which exceeds the maximum permissible components of soil – plant – animal system. This demonstrates the importance and necessity of using mineral fertilization and especially the organo-mineral one to ensure sustainable production performance without negative impact on soil, plant and animal products.
✓ It is clear that increasing the doses of fertilizers, especially those with phosphorus, leads to increased levels of cadmium in soil, plants and animal.
✓ Application of farmyard manure leads to cadmium inhibition and to an increase of essential metals concentration (Cu, Zn) in the soil-plant-animal.

Recommendations

- Accumulation of heavy metals in soil – plant – animal system may be reduced by applying the fertilizer in moderate doses and low concentrations of heavy metals, particularly cadmium
- Applying manure at least once every four years, would significantly reduce the cadmium concentration in soil
- Regular control of heavy metals concentrations in chemical fertilizers