Recycling of Biological Sludge for the Fertilizing of Soils Cultivated with *Lolium perenne*

Florica Morariu[1], Smaranda Mâşu[2], Adina Horablaga[1], Anca Andreea Marin[1], Dumitru Popescu[1], Gheorghe Ciobanu[3]

[1]*Banat's University of Agricultural Sciences and Veterinary Medicine "King Michael I of Romania" from Timisoara, 300645, Timisoara, Calea Aradului 119, Timis, Romania*
[2]*National R & D Institute for Industrial Ecology, Branch of Timisoara, 300431, Timisoara, Bujorilor 115, Timis, Romania*
[3]*National Sanitary Veterinary Authority and Food Safety, Branch of Arad, 310414, Arad, Liviu Rebreanu 98C, Arad, Romania*

Abstract

The present study has been elaborated with the aim of justifying the high efficiency of in-situ slaughterhouse sludge recycling and its usage in *Lolium perenne* cultures. Stabilized slaughterhouse sludge was used to complete the high deficiency in nutrients of the poor terrains. Slaughterhouse sludge represents an excessive, final by product from a meat-processing unit in Western Romania. It contains 59.78-90.77% easily bio-degradable organic substances. Moreover, it has compounds containing nitrogen and phosphorus, total N=1.922-3.318%, total P=1107-1126mg•kg^{-1}D.M. The experimental variants have been prepared, having the following characteristics: control variants of non-fertilized soils and variants of soils fertilized with slaughterhouse sludge, 50t•ha^{-1}. The experimental variants used were arranged in a completely randomized block design, with three replicates each. The efficiency of fertilization with slaughterhouse sludge was a 30-35% rise in the quantity of grass harvested *vs.* the quantities harvested from the control variants. The quantity of Cd and Pb has been determined from the aerial parts of the harvested plants and they were below the maximum limit admitted by the sanitary regulations in Romania. Cr didn't bio-accumulate in plants at a detection limit. The quantity of other metals determined from the aerial parts of the plants was low: *i.e.* <10mg•kg^{-1}D.M. for Cu or Ni <50mg•kg^{-1}D.M. for Zn, <150mg•kg^{-1}D.M.for Mn. Green feed harvested from fields fertilized with slaughterhouse sludge can be part of animal nutrition.

Keywords: fertilization efficiency, grass harvested, metal bioaccumulation, slaughterhouse sludge recycling.

1. Introduction

Due to the dynamics of the population rise, respectively the insurance of its suitable food, the elaboration of measures necessary for the development of these areas was required, alongside estimations of the livestock and agricultural potential. Based on these considerations, the research and practice need studies conducted *in- situ,* using new resources of nutrients for the soil which can ensure the basics of a healthy nutrition for animals. The manure, liquid dejections, chicken manure, sludge from pig farms, etc. can be used in a fresh state or stabilized. Fermented sludge is most frequently used. Out of the by-products obtained from various industries, biological sludge has raised interest and it is regarded as a valuable fertilizer because it has an important content of nutrients for cereals and feed-cultures, based on carbon, nitrogen and phosphorus. This sludge can be recycled in agriculture in the shape of fertilizers. They can be dispersed on field in autumn in doses

* Corresponding author: Florica Morariu, +40256277206, Fax +40256277110, florica.morariu@animalsci-tm.ro

of 25-50t•ha^{-1}. The option of using the sewage sludge is limited because it contains, besides nutrients and considerable quantities of heavy metals, which might produce important accumulations in some cultures [1-3]. The aim of this study was to use stabilized sludge from slaughterhouses for the fertilizing of meadows made of Gramineae such as *Lolium spp.* The study proved the efficiency of fertilizing on the harvest quantity. Moreover, the quality of the harvested biomass has been assessed using the bio-accumulation of heavy metals in the aerial parts of the plants.

2. Materials and methods

The experiment has been conducted in the experimental block of Banat's University of Agricultural Sciences and Veterinary Medicine "King Michael I of Romania" from Timisoara, Department for Experimental Science, at +45° 47'3.33"N and +21° 12'54.01"E. The precipitation level in the studied culture year was 573 mm. The experimental variants, with the following characteristics, have been prepared: control variants of non-fertilized soils and variants of fertilized soils with 50t•ha^{-1} slaughterhouse sludge. Each experimental variant occupied 15 m^2. The experimental variants which were used were arranged in a completely randomized block design with three replicates. The nutritional characteristics of stabilised slaughterhouse sludge used for fertilising are presented in Table 1.

Table 1. Content of nutrients in the fertilising agents

No	Fertilizer type	Content of nutrients in the fertilising agents [min.-max.]				
		pH	Humidity [%]	Organics [%]	N total [%]	P total [mg·kg^{-1}D.M.]
1	Slaughterhouse sludge	7.17-7.83	80.8-86.6	59.78-90.77	2.922-3.318	1107.2-2537.1

The slaughterhouse sludge used is part of the mostly-organic sludge category and has presented a high quantity of organic matter 59.78-90.77%. The slaughterhouse sludge had a total Nitrogen content of 2.922-3.318%. The total quantity of Phosphorus was P total = 1107.2-2537.1 mg·kg^{-1} D.M. The metal quantities determined from the slaughterhouse sludge which was used for the experimental fertilizing are presented in Table 2. The sludge contains various quantities of heavy metals. The analysed metals do not surpass the maximum concentration according to the Order 344/708/2004 [4] completed by OMMGA 27/2007-regarding the approval of the technical regulations for environmental protection, and especially, of the soil, when the sludge from wastewater treatment plants is used in agriculture.

Table 2. The quantities of metal determined in stabilized slaughterhouse sludge for the treatment of experimental variants

No.	Fertilizer type	Heavy metal content of used slaughterhouse sludge [mg·kg^{-1}D.M.] min.-max.							
		Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
1.	slaughterhouse sludge	0.7-0.8	28.1-35.6	14.6-19.5	408.0-630.9	571.5-620.7-	13.0-17.2	17.3-32.3	325.0-433.6
2.	OM 344/2004	10	500	500	-	-	100	300	2000

Experimental variants have been conducted throughout the year on cultures of *Lolium perenne* species. This species is regarded as a feed plant which goes into the composition of meadows and in cultures which stand at the base of a feed production. The cultures are valued through grazing, harvesting or both. It is a species with a high economical value having a large participation in the meadows flora. This participation share is owed to its special ecological plasticity which allows it to adapt to various environmental conditions. The *Lollium perenne* forms small rahis nodes at a 4-5 cm depth in the soil. From this level, the sprouts situated in a sharp angle towards the main sprout start to develop. The sprouts developed from the rahis node form a rare bush with the aspect of a bowl. The quantity of sowed plants was 30 kg·ha^{-1}. The study was performed in two variants on an experimental farming land. Each randomized block design had three replicates. A 1m space was left free between the experimental variants so that each culture would be personalized and in order to avoid possible contamination of the soil with micro fauna and leached micro and macro-nutrients. The experimental variants were prepared as follows: non-fertilized control variants (P) and variants fertilized with 50 $t{\cdot}ha^{-1}$ slaughterhouse sludge (P1). The experimental topsoil was prepared in February. The fertilized soils were put aside for geo-chemical stabilization, for 60 days. The incorporation of the fertilizer was done using specific agricultural methods for crops, at a 30cm depth. The sowing of the *Lollium perenne* seeds, the maintenance of the experimental culture, the harvesting and the estimating of the crop yield was done according to the agricultural methods specific for this type of plant [5]. In this study, measurements were done for selected plant growth variables: quantity of harvest and quality characteristics. The amount of heavy metals in the harvest and topsoil extracts was determined [6] and compared to the Romanian standards. Analysis was done using an Atomic Absorption Spectrophotometer GBC Avanta AAS, GBC Scientific Equipment Ltd. Company. The detection limit of the device for Cd is of 0.02 $mg{\cdot}L^{-1}$, Cr, Cu, Fe, Mn, and Zn is of 0.05 $mg{\cdot}L^{-1}$, for Ni is of 0.10 $mg{\cdot}L^{-1}$and for Pb is of 0.2 $mg{\cdot}L^{-1}$.

3. Results and discussion

Soil characterisation. The characteristics of the non-fertilized/fertilized soils, stabilized with slaughterhouse sludge that was used in the experimental variants cultivated with *Lollium perenne* species are presented in Table 3.

Table 3. The quantity of metals in non-fertilized/fertilized experimental variants with stabilized slaughterhouse sludge fertilizer to *Lollium perenne* culture

No	Experiment variant	Soil pH	*The content of heavy metals from the topsoil [$mg{\cdot}kg^{-1}$ D.M.]							
			Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
1	P	6.5 ±0.2	0.8 ±0.2	28.0 ±0.7	30.6 ±0.3	864.0 ±14.0	147.0 ±3.1	31.0 ±2.3	8.7 ±1.3	35.0 ±3.2
2	P1	6.8 ±0.01	0.9 ±0.2	33.8 ±0.3	27.8 ±0.2	701.5 ±15.5	177.6 ±6.2	39.7 ±3.3	12.6 ±1.2	38.7 ±4.0
**Romanian Decree MAPPM 796/1997			1	30	20	-	900	20	20	100

*Values are means of three replicates ±SE
**MAC maximum allowable concentration in Romanian Decree, MAPPM 796/1997 in normal soil [7]

The characterisation of plants. Two consecutive harvests were collected from the studied variants. The total harvest resulted from the fertilized and stabilized with slaughterhouse sludge variants was 30-35% higher than the herbaceous plants harvested from the non-fertilized variants. Moreover, after the first harvest, the *Lolium perenne* developed from the rahis node during the first three months formed bushes on the fertilized soil which covered the sowed soil in a high level of 75-95%, fact that corresponds with Level 5 (coverage>3/4)(see Table 4 by Braun Blanquet) [8].

Table 4. The coverage degree of the cultivated variants with *Lolium perenne* species (compared to the Braun-Blanquet scale)

No.	Experimental variant	*Lolium perenne* cover [%]	Coverage according to Braun Blanquet	
			Level	Coverage [%]
1	P	60-70	Level 4 (½-3/4 Coverage)	50-75
2	P1	75-95	Level 5 (>3/4 Coverage)	78-100

The plants present various degrees of access of the metals in their tissues. Metals may accumulate in different parts such as the roots, the aerial parts or the seeds. A high quantity of accumulated metals in the tissues represents a high risk for the consumers, in this case, the animals. In literature, there are examples regarding the percolation degree of the metals from fertilizers into the soil and consequently, the accumulation of metals from the soil in different parts of the plants [9-11]. Metals such as Cd and Pb which are considered to be especially dangerous have been determined from stabilized slaughterhouse sludge which was used as a fertilising agent. The quantity of metals found in the harvest (aerial parts of the plants) collected from the fertilized with stabilized slaughterhouse sludge and non-fertilized experimental variants is presented in Table 5.

Table 5. The quantity of metals found in the harvest collected from the non-fertilized and fertilized with stabilized slaughterhouse sludge experimental variants

No	Variant	*Heavy metals content from *Lolium perenne* harvest [$mg \cdot kg^{-1}$ D.M.]							
		Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
1.	P 1	0.6 ±0.2	u.d.l.	7.4 ±0.8	297.1 ±15.0	124.2 ±20.1	3.2 ±0.3	9.3 ±0.3	39.8 ±5.1
2.	P	u.d.l.	u.d.l.	4.5 ±0.2	275.3 ±18.5	52.5 ±8.2	1.8 ±0.7	5.6 ±1.2	40.7 ±6.0
Rules		**1 mg/kg at humidity 12%	-	-	-	-	-	**30 mg/kg at humidity 12%	-

*values are means of three replicates ±SE

**order regarding the approval of Sanitary and Veterinary Norms from Food Safety concerning certain contaminants from animal and plant origin food, part I nr. 1056/26.10.2005 (M.O. of Romania) [12], u.d.l. - under detection limit

From the presented data we can see minimal changes in the bioaccumulation of heavy metals in the aerial parts of the plant. Cd has risen but it remained below the maximum limit admitted by the regulations in exercise. Although Cr was found in the soil, it has not been accessed by the plants harvested on the studied variants (non-fertilized and fertilized with slaughterhouse sludge). Accumulated Cu was below 10 $mg \cdot \cdot kg^{-1}$D.M.]. Ni and Fe bio-accumulated in the two harvests collected from non-fertilized and fertilized soil were similar. The Mn quantity in the harvest resulted from the fertilized soil grew from to 53.2 $mg \cdot kg^{-1}$D.M. la124.3 $mg \cdot \cdot kg^{-1}$D.M.The bio-accumulated Pb was comprised between 2.3-2.6 values much lower than the maximum limits admitted by the national regulations of 30 mg/kg in a mass with 12% humidity.

4. Conclusions

The formation of an enriched layer with nutritive organic substances, carbon compounds, nitrogen and phosphorus on drained soils from an agricultural point of view has been done using recycled materials. The layer enriched with nutritive substances offered by the stabilized slaughterhouse sludge has determined the total of grass harvests from the fertilized soil variants to be 30-35% higher than the herbaceous plants harvested from the non-fertilized variant. In addition, following the first harvest, the *Lolium perenne* sprouts which developed from the rahis node during the first three months of vegetation formed bushes on the surface of the sowed soil, covering it in proportion of 75-95%, fact which corresponds to Level 5 (3/4 coverage according to Braun Blanquet). The monitoring of the bio-accumulation degree of metals in the aerial tissues of the plants in the presence of stabilized slaughterhouse sludge has shown that the accumulation of metals in different parts of the tissue are in the limits imposed by the Sanitary and Veterinary Norms from Food Safety concerning certain contaminants from animal and plant foods.

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