Session 4
Urban sludge as fertilizer for fruit trees

key-speaker: **Prof. Dr. Mihail Dumitru**

UTILIZATION OF LABELLED ISOTOPS TO EVALUATE THE CONDITIONS OF USING THE SEWAGE SLUDGE AND MANURE FOR FERTILIZATION OF OATS

Mihai Dumitru*, Eugenia Gamenț*, D.M. Motelică*, Nicoleta Vrînceanu*, Ioana Prodan**
* National Research and Development Institute for Soil Science, Agrochemistry and Environment – ICPA Bucharest, Romania
** Teleorman Agricultural Research and Development Station, Romania

Abstract

The experiments have been organized with Phaeozems in the Teleorman Research-Development Agricultural Station and included treatments with urban sludge and manure at rates equivalents of 0; 100; 200; 300 and 400 kg N/ha and mineral fertilizers (N_{100}). To evaluate the amounts of nitrogen derived from residual products of the achieved nitrogen balance, an experiment was treated with ^{15}N at a rate of 20 kg N/ha coming from ammonium sulphate (^{15}N. 10% atom excess). The experiment was built up according to the method of randomized blocks with three replicates. On average, the characteristics of residual products used in experiments are as follows:
- Manure: pH – 8.93, N – 1.66%, C – 16.8%, P – 0.54%, K – 1.96%, Na- 0.12%, Ca – 0.48%, Mg – 0.77%, organic matter – 41.9%, Cu – 18.0 mg/kg, Zn – 58.5 mg/kg, Pb – 27.4 mg/kg, Ca – 12.5 mg/kg, Ni – 31.9 mg/kg, Mn – 5.61 mg/kg, Cd – 1.44 mg/kg.
- Urban sludge: pH – 6.76, N – 3.68%, C – 27.8%, P – 0.79%, K – 0.85%, Na - 0.06%, Ca – 2.09%, Mg – 0.28%, organic matter – 64.4%, Cu – 102 mg/kg, Zn – 505 mg/kg, Pb – 90 mg/kg, Co – 9.7 mg/kg, Ni – 41.8 mg/kg, Mn – 406 mg/kg, Cd –2.94 mg/kg.

Mineral fertilization ensured a yield increase of 8%, while manure fertilization led to yield increases of 18-35% (depending on rate), while the sludge fertilization to 13-46%. The organic fertilization led to the soil content increase in organic carbon, total nitrogen, mobile phosphorus and potassium. The paper presents data regarding the content of nitrogen, phosphorus, potassium, calcium, magnesium and heavy metals (Cu, Zn, Pb, Co, Ni, Mn and Cd) in stems, leaves and grains of oats. Indices of nitrogen uptake from sewage sludge and manure are similar. So, the nitrogen in the oats straw, coming from the sewage sludge varied between 12.0 and 41%, and that coming from the manure varied between 18.1 and 44.6%. The nitrogen in the oats grains, derived from the urban sludge, reached values between 12.7 and 28.2%, and that coming from manure reached values between 2.8 and 38 %. Overall, the nitrogen derived from the sewage sludge varied between 12.4 and 32.3%, and that derived from the manure varied between 8.7% and 40.5%. The recovering degree of nitrogen in urban sludge varied between 10.0% and 13.5%, and that from manure varied between 9.5 and 16.8%.

Keywords: **organic carbon, total nitrogen, mobile phosphorus and potassium, heavy metals**

1.Introduction

The European Community has taken measures concerning nitrogen pollution in waters for over twenty years. According to the Nitrate Directive (91/676/EEC), the Romanian soils and groundwater bodies need to be protected against nitrate pollution originating from agriculture. To design action plans for monitoring and protecting the soils and groundwater bodies, Nitrate Vulnerable Zones and Potential Nitrite Vulnerable Zones were identified. Based on the assessed vulnerability, fertilization norms should be introduced and codes of good agricultural practice should be implemented, such as regulations related to nutrient balance, manure storage and spreading the manure as well as other organic nitrogen source (sewage sludge) maximum 210 kg $N_{organic}$/ha/yr. in the first 4 years and maximum 170 kg $N_{organic}$/ha/yr after.

The inventory, carried out under the framework of the National Soil Quality Monitoring System, shows that about 12 million ha of Agricultural land of which 7, 5 million ha of arable land are more or less affected by one or several limitations.
The influence of these limitations deteriorates the characteristics of soil functions, that is, it affects the soil bio-productive capacity as well as the yield quality and food security with severe consequences on the soil quality.

The main restrictive factors are: 7.1 million hectares – frequently affected by the drought, 3.781 thousands hectares – periodic excess of waterlogging, 6.3 million hectares – water soil erosion, 378 thousands hectares – wind soil erosion, 702 thousands hectares – landslides, 614 thousands hectares – salinity, 3.424 million hectares – moderate and strong acidity, 7.485 million hectares – low and very low humus content, 6.330 million hectares – low and very low available phosphorus content, 5.110 million hectares – low nitrogen content, 781 thousands hectares – low available potassium content, 1.5 million hectares – zinc deficiency, 900 thousands hectares – chemical soil pollution (*Dumitru, 2005*). Low content of organic matter and nutrients in soil imperatively determine the agricultural efficient use of the entire organic matter source, especially manure and sewage sludge.

At the end of 2006 year, in Romania there were 2,934 thousand cattle, 6,815 thousand pigs, 7,675 thousand sheep, 727 thousand goats, 805 thousand horses and 84,990 thousand poultry.

The agricultural land area included 14,731 thousand ha, of which 9,434.6 thousand ha arable land. Consumption of chemical fertilizers was of 363 thousand t (252 thousand t nitrogen, 94 thousand t phosphorus, and 17 thousand t potassium). Production of organic fertilizers was of 14,900 thousand t. On average, in 2006, Romanian agriculture used 24.6 kg NPK per hectare of agricultural land or 38.4 kg NPK per hectare of arable land, and 1.1 t manure per hectare of agricultural land or 1.5 t manure per hectare of arable land.

The collected wet sewage sludge in the municipal waste water treatment plants included 1,408,990 t/y primary sludge, 357,524 t/y secondary sludge, 0.24 t/y chemical sludge and 1,314,757 t/y mixed sludge. A quantity of 89,538 t primary sludge, 2011 t secondary sludge and 49741 t mixed sludge is in stocks. About 9.33% (7,901 t) primary sludge, 28.51% (3,922 t) of secondary sludge and 8.59% (9,845 t) mixed sludge are applied to agricultural lands (MMGA, 2004).

To avoid the groundwater pollution with nitrates coming from the application on the agricultural lands of manure and sewage sludge, it is necessary to estimate as much as precise the efficient use indices of nitrogen coming from the two sources.

In view to comply with the rules of the newly issued legal framework, it is imperative to know:

- The characteristics of the two residue products;
- The limitative factors of using them on the agricultural lands (pollution with pathogenic agents, heavy metals, organic pollutants);
- Evolution of soil quality and agricultural production;
- Rate, time and method of the application on the land to avoid environmental pollution;
- Structure and rotation of crops;
- Nitrogen balance sheet in the treated parcels with sewage sludge and manure (*Barrow et al., 1980; Davies, 1983; McGrath et al., 1994; Alcock et al., 1995; Baraldi et al., 1997; Dumitru et al., 1997*).

In zones which are vulnerable and potentially vulnerable to pollution with nitrates, it is imperatively necessary to institute a system for monitoring the soil and groundwater quality, and to apply a plan for the management of nutrients at the farm level.
The research, of which results are presented in this paper, had as an objective the establishment of utilization degree of nitrogen coming from the manure and sewage sludge and of influence of these fertilizers on the soil quality and oats yield level and quality.

2.Material and methods

A field experiment with sewage sludge and manure on Phaeozems, at the Teleorman Agricultural Research and Development Station, using oats as a test crop, was organized.

The field experiment was designed according to a complete randomized block including 10 treatments (4 replicates):

- T_1: 100 kg N/ha of ^{15}N labelled fertilizer, 1% a. e.;
- T_2: 20 kg N/ha of ^{15}N labelled fertilizer, 10% a. e.;
- $T_3 - T_6$: sewage sludge with rates equivalent to 100, 200, 300 and 400 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a. e.;
- $T_7 - T_{10}$: manure with rates equivalent to 100, 200, 300 and 400 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a. e.

Ammonium sulphate with 10% ^{15}N abundance and simple ammonium sulphate with 21% nitrogen were used as nitrogen source for isotopic dilution.

The sewage sludge used in the experiments was taken from the waste water treatment plant in Pitești. The manure was taken from cattle farm in the Teleorman Agricultural and Development Research Station.

To ensure the needed water to plants, two watering have been applied, each of them supplying 600 m^3/ha. The showed results have been obtained in the third experiment year.

The chemical characteristics of sewage sludge and manure are showed in the **Table 1**.

Table 1. Chemical characteristics of manure and sewage sludge used in the experiment

Characteristic		Manure		Sewage sludge		MAL*
		Range	*Average*	*Range*	*Average*	
$pH(H_2O)$		8.58 – 9.38	8.93	6.49 – 7.32	6.76	
Nitrogen content	(%)	1.26 – 1.75	1.66	2.97 – 4.47	3.68	
Carbon content	(%)	16.1 – 17.7	16.8	25.9 – 29.6	27.8	
Phosphorus content	(%)	0.38 – 0.69	0.54	0.66 – 1.09	0.79	
Potassium content	(%)	1.40 – 2.51	1.96	0.36 – 1.54	0.85	
Sodium content	(%)	0.08 – 0.16	0.12	0.04 – 0.07	0.06	
Calcium content	(%)	0.29 – 0.58	0.48	0.70 – 3.72	2.09	
Magnesium content	(%)	0.57 – 0.99	0.77	0.24 – 0.34	0.28	
OM content	(%)	40.1 – 45.2	41.9	63.5 – 65.4	64.4	
Copper content	(mg/kg)	14.5 – 20.2	18.0	88 – 137	102	500
Zinc content	(mg/kg)	48 – 79	58.5	482 – 524	505	2000
Lead content	(mg/kg)	26 – 30	27.4	50 – 132	90	300
Cobalt content	(mg/kg)	11 – 14	12.5	8.5 – 11.5	9.7	50
Nickel content	(mg/kg)	25.0 – 41.5	31.9	27 – 60	41.8	100
Manganese content	(mg/kg)	517 – 631	561	269 – 615	406	—
Cadmium content	(mg/kg)	1.20 – 1.60	1.44	1.80 – 5.10	2.94	10

* Maximum allowable content of heavy metal in sewage sludge applied on agricultural lands

Results and discussions

Influence of fertilization system on oats yield

Influence of fertilization system on oats yield is showed in **Table 2**, which shows significant differences between experiment treatments depending on both the organic fertilizer type used and the calculated nitrogen rate that should be ensured by their application.

So the application of 100 kg N/ha a. i. in the mineral fertilizer ensured a yield increase of 8% as compared to the control treatment (T_2). In the case of treatments that have received the T_3, T_4, T_5 and T_6 treatments where the applied equivalent sewage sludge quantities were equivalent to the rates of 100, 200, 300 and 400 kg/ha N a. i. respectively, usable yield recorded an increase of 18 - 35%. In absolute values, the yield reached 540 kg/ha with T_3 treatment and 1033 kg/ha with treatment having an applied maximum rate of sewage sludge.

As compared to the sewage sludge, applied manure to T_7, T_8, T_9 and T_{10} treatments with progressive rates so calculated to supply from 100 to 400 kg N/ha ensured a better supply of plants with nitrogen, fact also proved by the highest yield increases. These varied between 13%, in the case of the treatment fertilized with the equivalent of 100 kg N/ha, and 46% in the case of treatment fertilized with the equivalent of 400 kg/ha N supplied by manure. In absolute values, the maximum yield increase has been obtained with 1363 kg/ha.

The by-product including straw and husks recorded higher yields as compared to the yield of grains. The recorded increase varied between 1453 and 3133 kg/ha in the case of treatments receiving sewage sludge and between 2087 and 3550 kg/ha in the case of treatments receiving manure. Also, as in the case of usable yield, the recorded by-product increases were higher in the case of manure application as compared to the treatments that received sewage sludge.

Influence of sewage sludge and manure fertilization on chemical characteristics of Haplic Phaeozems and on chemical composition of oat plants in S.C.D. A. Teleorman

Soil samples have been collected in three replicates on the depth of 0-20 cm from topsoil of Phaeozems in the Teleorman S.C. A., cultivated with oats.

Table 3 shows the data regarding the effects of fertilization with manure and sewage sludge on soil pH and soil content of carbon organic, total nitrogen and mobile phosphorus and potassium. It can be observed that as the rates of sewage sludge increase, the soil pH value decreases, and in the case of treatments with manure the reaction value is higher. This is mainly due to the high alkalinity of manure and due to the higher content of nitrogen sewage sludge, which, by decomposition, can have acidifying effects on soil. From the statistical viewpoint, the change of pH values due to the application of the two organic residual products is statistically ensured.

Both residual products have a benefic effect on the organic carbon content in soil, the absolute values being higher as compared to the control with sewage sludge treatments, but even higher and statistically ensured with manure treatments.

Both in the case of sewage sludge treatment and in that of manure treatment, distinctly significant increases in total nitrogen soil content have been observed, as the rate of applied residual product increases. The values of total nitrogen soil content were higher within manure treatments.

Mobile phosphorus contents as well as the mobile potassium contents distinctly significant increased, absolute values being higher for both chemical indices in manure treatments.

Table 4 shows the sewage sludge and manure fertilization effects on nitrogen content in plants of oats (straw, husk, grain). Concerning the straw and husk, distinctly significant total nitrogen content increases were observed, while in the case of grains, non significant increases were found with both treatments (sewage sludge and manure). The same total nitrogen situation occurred also in the phosphorus content case (**Table 5**).

Data in **Table 6** emphasizes the aspects of potassium content increases which are distinctly significant in straw, significant in husks and not significant in grains.

Fertilization with sewage sludge or manure did not lead to significant changes of content of calcium in straw, but it determined significant increases of calcium content in husk and grain (**Table 7).**

The increase of magnesium content was significant in straw, distinctly significant in husk and not significant in grain (**Table 8**).

Tabel 2 The effects of sewage sludge application and manure on oat yield obtained on Haplic Phaeozem from SCDA Teleorman

	Treatment	Grain yield	Secondary production
		--------------------- kg / ha	----------------------
1.	100 kg N/ha of ^{15}N labelled fertilizer, 1% a.e.	3172 ab	5060 a
2.	20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	2937 a*	4800 a
3.	Sewage sludge, equivalent to 100 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	3477 bcd	6253 b
4.	Sewage sludge, equivalent to 200 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	3640 cde	7433 d
5.	Sewage sludge, equivalent to 300 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	3777 de	7400 d
6.	Sewage sludge, equivalent to 400 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	3970 ef	7933 ef
7.	Manure, equivalent to 100 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	3330 abc	6887 c
8.	Manure, equivalent to 200 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	3510 bcd	7667 de
9.	Manure, equivalent to 300 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	3857 de	8580 g
10.	Manure, equivalent to 400 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	4300 f	8350 fg
	HSD 5% (test Tukey)	*416*	*462*

* means within a column followed by the same letter are not significantly different at the p=0.05 level (Tukey's honestly significant difference procedure)

Tabel 3 The effects of sewage sludge and manure application on some chemical characteristics of the Haplic Phaeozem cultivated with oat from SCDA Teleorman

Treatment	pH (H_2O)	C organic	N total	P mobile	K mobile
		%	%	mg/kg	mg/kg
1. 100 kg N/ha of ^{15}N labelled fertilizer, 1% a.e.	6.17 cd	2.47 ab	0.212 a	34 a	159 a
2. 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	6.33 de	2.21 a	0.212 a	39 ab	164 a
3. Sewage sludge, equivalent to 100 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	6.10 cd	2.54 ab	0.238 ab	50 abc	178 a
4. Sewage sludge, equivalent to 200 kg N/ha + 20 kg N/ha of 15N labelled fertilizer, 10% a.e.	5.96 bc	2.57 ab	0.248 ab	57 abcd	173 a
5. Sewage sludge, equivalent to 300 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	5.81 ab	2.64 abc	0.238 ab	65 abcd	168 a
6. Sewage sludge, equivalent to 400 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	5.69 a	2.71 abc	0.251 ab	66 abcd	164 a
7. Manure, equivalent to 100 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	6.32 de	3.09 bcd	0.269 bc	72 bcd	235 ab
8. Manure, equivalent to 200 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	6.47 ef	3.49 cde	0.302 cd	83 cde	358 b
9. Manure, equivalent to 300 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	6.49 ef	3.60 de	0.327 d	86 de	398 b
10. Manure, equivalent to 400 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	6.64 f	3.97 e	0.377 e	115 e	635 c
HSD 5% (test Tukey)	0.23	*0.86*	*0.045*	*34*	*171*

* means within a column followed by the same letter are not significantly different at the p=0.05 level (Tukey's honestly significant difference procedure)

Table 4 The effects of sewage sludge and manure application on nitrogen content in oat plant

Treatment	N in oat plant		
	straw	husk	grain
	------------------------ %------------------------		
1. 100 kg N/ha of ^{15}N labelled fertilizer, 1% a.e.	0.56 ab*	0.87 a	2.24 a
2. 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.55 ab	1.00 ab	2.58 a
3. Sewage sludge, equivalent to 100 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.48 a	1.14 ab	2.20 a
4. Sewage sludge, equivalent to 200 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.52 ab	1.07 abc	2.36 a
5. Sewage sludge, equivalent to 300 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.55 ab	1.26 bc	2.46 a
6. Sewage sludge, equivalent to 400 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.63 ab	1.36 c	3.08 a
7. Manure, equivalent to 100 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.58 ab	1.02 abc	2.25 a
8. Manure, equivalent to 200 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.62 ab	1.19 abc	2.39 a
9. Manure, equivalent to 300 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.72 b	1.20 abc	2.86 a
10. Manure, equivalent to 400 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.74 b	1.18 abc	2.82 a
HSD 5% (Tukey test)	*0.22*	*0.34*	*1.02*

* means within a column followed by the same letter are not significantly different at the p=0.05 level (Tukey's honestly significant difference procedure)

Table 5 The effects of sewage sludge and manure application on phosphorus content in oat plant

Treatment	P in oat plant		
	straw	husk	grain
	------------------------ %------------------------		
1. 100 kg N/ha of ^{15}N labelled fertilizer, 1% a.e.	0.08 a*	0.103 a	0.333 a
2. 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.10 a	0.120 ab	0.343 a
3. Sewage sludge, equivalent to 100 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.15 ab	0.133 ab	0.360 a
4. Sewage sludge, equivalent to 200 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.12 ab	0.143 ab	0.337 a
5. Sewage sludge, equivalent to 300 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.12 ab	0.133 ab	0.427 a
6. Sewage sludge, equivalent to 400 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.13 ab	0.123 ab	0.423 a
7. Manure, equivalent to 100 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.19 b	0.147 ab	0.433 a
8. Manure, equivalent to 200 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.19 b	0.180 b	0.443 a
9. Manure, equivalent to 300 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.19 b	0.177 b	0.413 a
10. Manure, equivalent to 400 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.19 b	0.173 b	0.400 a
HSD 5% (Tukey test)	*0.07*	*0.06*	*0.170*

* means within a column followed by the same letter are not significantly different at the p=0.05 level (Tukey's honestly significant difference procedure)

Table 6 The effects of sewage sludge and manure application on potassium content in oat plant

Treatment	K in oat plant		
	straw	husk	grain
	------------------------ %-------------------------		
1. 100 kg N/ha of ^{15}N labelled fertilizer, 1% a.e.	2.43 ab*	0.98 a	0.68 a
2. 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	2.11 ab	0.99 a	0.69 a
3. Sewage sludge, equivalent to 100 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	2.22 ab	1.07 a	0.68 a
4. Sewage sludge, equivalent to 200 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	1.97 ab	0.88 a	0.66 a
5. Sewage sludge, equivalent to 300 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	2.00 ab	0.90 a	0.73 a
6. Sewage sludge, equivalent to 400 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	1.93 a	0.88 a	0.69 a
7. Manure, equivalent to 100 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	2.54 ab	0.97 a	0.75 a
8. Manure, equivalent to 200 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	2.69 ab	0.96 a	0.76 a
9. Manure, equivalent to 300 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	2.72 b	1.01 a	0.68 a
10. Manure, equivalent to 400 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	2.73 b	1.07 a	0.70 a
HSD 5% (Tukey Test)	*0.78*	*0.20*	*0.17*

* means within a column followed by the same letter are not significantly different at the p=0.05 level (Tukey's honestly significant difference procedure)

Table 7 The effects of sewage sludge and manure application on calcium content in oat plant

Tratament	Ca in oat plant		
	straw	husk	grain
	------------------------	%-------------------------	
1. 100 kg N/ha of ^{15}N labelled fertilizer, 1% a.e.	0.62 a*	0.99 ab	0.09 ab
2. 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.70 a	.092 ab	0.09 ab
3. Sewage sludge, equivalent to 100 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.79 a	1.20 ab	0.07 a
4. Sewage sludge, equivalent to 200 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.63 a	1.03 ab	0.13 b
5. Sewage sludge, equivalent to 300 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.76 a	1.07 ab	0.09 ab
6. Sewage sludge, equivalent to 400 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.68 a	1.33 b	0.10 ab
7. Manure, equivalent to 100 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.71 a	1.06 ab	0.08 ab
8. Manure, equivalent to 200 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.63 a	0.68 a	0.09 ab
9. Manure, equivalent to 300 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.76 a	1.27 b	0.09 ab
10. Manure, equivalent to 400 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.79 a	0.94 ab	0.13 b
HSD 5% (Tukey test)	*0.30*	*0.57*	*0,05*

* means within a column followed by the same letter are not significantly different at the p=0.05 level (Tukey's honestly significant difference procedure)

Table 8 The effects of sewage sludge and manure application on magnesium content in oat plant

Treatment	Mg in oat plant		
	straw	husk	grain
	------------------------ %------------------------		
1. 100 kg N/ha of ^{15}N labelled fertilizer, 1% a.e.	0.15 a*	0.18 a	0.15 a
2. 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.15 a	0.20 ab	0.15 a
3. Sewage sludge, equivalent to 100 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.15 a	0.24 ab	0.15 a
4. Sewage sludge, equivalent to 200 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.15 a	0.24 ab	0.15 a
5. Sewage sludge, equivalent to 300 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.18 ab	0.25 b	0.16 a
6. Sewage sludge, equivalent to 400 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.18 ab	0.25 b	0.16 a
7. Manure, equivalent to 100 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.15 a	0.21 ab	0.16 a
8. Manure, equivalent to 200 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.15 a	0.23 ab	0.15 a
9. Manure, equivalent to 300 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.16 ab	0.26 b	0.16 a
10. Manure, equivalent to 400 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.20 b	0.26 b	0.16 a
HSD 5% (Tukey test)	*0.04*	*0.07*	*0.02*

* means within a column followed by the same letter are not significantly different at the p=0.05 level (Tukey's honestly significant difference procedure)

The applied treatments did not determine statistically significant changes of total copper content in sol, but they changed distinctly significant the soluble copper values in sol (**Table 9**). Different values are not observed between the sewage sludge treatments and the manure treatments, while the copper values in the two residual products are quite different. Presence of higher mobile copper content in soil creates premises to a better plant supply with this microelement. As concerns the copper accumulation in oats plant, straw and grain, this is not significant, and in husk it is distinctly significant. Copper values in plant are normal for a good supply with this element.

In Romania, the maximum allowable concentrations for heavy metals in soils are: 100 mg/kg Cu, 300 mg/kg Zn, 100 mg/kg Pb, 50 mg/kg Co, 50 mg/kg Ni, 1500 mg/kg Mn, 100 mg/kg Cr and 3 mg/kg Cd (*Dumitru et al., 1997*). These limits correspond to those recommended by the European Union (1-3 mg/kg Cd, 100-150 mg/kg Cr, 50-140 mg/kg Cu, 50-300 mg/kg Pb, 30-75 mg/kg Ni and 150-300 mg/kg Zn (*McGrath et al., 1994*).

Data in the literature assess as normal level in plants the values less than 0.5 mg/kg Cd, 8 mg/kg Cu, 3 mg/kg Pb, 40 mg/kg Zn, warning at the same time, that these values can be much different from one plant to another, plant genotype being an important factor that may induce high differences between plants as compared to that limits (*Davies and Carlton-Smith, 1980*).

Table 10 shows the effects of sewage sludge and manure fertilization on zinc contents in sol and plants of oats. Total zinc content reached a distinctly significant increase; the same distinctly significant change was also observed for the soluble zinc content in Na_2EDTA. With the maximum rates of residual products, equivalent to 400 kg N/ ha, soluble zinc content increased almost 7 times higher as compared to the control.

While the sewage sludge had a zinc loading that was much higher as compared to the manure, no high differences were noted either with the total zinc contents or with soluble zinc contents, between the parcels fertilized with sewage sludge and those fertilized with manure. The straw did not present statistically significant changes in the zinc content as a result of fertilizer application; on the contrary, a distinctly significant increase in husk and grain was recorded. The phytotoxic levels of heavy metals are appreciated at values of 8 mg/kg Cd, 20 mg/kg Cu, 35 mg/kg Pb and 200 mg/kg Zn, and zootoxic levels at values of 1 mg/kg Cd, 30 mg/kg Cu, 5 mg/kg Pb and 500 mg/kg Zn. Compared to these levels, the zinc values in plants of oats can be ranked in the normal limits (*Davies and Carlton –Smith, 1980*).

Data in **Table 11** are referring to the effect of mineral and organic (sewage sludge and manure) fertilization on the lead content in soil, plants of oats. These data reveal that the values of total lead content in soil do not suffer statistically ensured changes; on the contrary, the values of soluble lead content significantly increases with the sewage sludge treatments and decreases with the manure treatment. The values of the total lead content do not present differences between those with sewage sludge treatments and those with manure treatments. The values of lead content in straw did not statistically significantly change, they significantly increased in husks and had a distinctly significant increase in grain. The applied treatments do not present a risk of a lead accumulation in soil and plants of oats.

Data presented in **Table 12** reflect the effect of the sewage sludge and manure fertilization on the cadmium content in soil and plants of oats. Accentuated (almost twice) increase in soluble cadmium content values in soil creates premises of its accumulation in plant and leaching. The present values of total and soluble cadmium do not put problems on soil quality and risk for agricultural production. As concerns the accumulation in plants of oats, not significant cadmium changes in straw are observed, but distinctly significant increases in husks and significant increases in grain are observed. These accumulations in husks and grains represent no risk for the quality of these products.

Table 9 The effects of sewage sludge and manure application on copper content in soil and oat plant

Treatment	Cu in soil		Cu in oat plant		
	total	soluble	straw	husk	grain
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
1. 100 kg N/ha of ^{15}N labelled fertilizer, 1% a.e.	21 a*	5.8 a	5.2 a	3.5 a	4.6 a
2. 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	22 a	5.7 a	4.1 a	3.4 a	4.7 a
3. Sewage sludge, equivalent to 100 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	22 a	5.9 ab	3.7 a	3.9 ab	5.2 a
4. Sewage sludge, equivalent to 200 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	22 a	6.4 bcd	3.9 a	3.9 ab	4.8 a
5. Sewage sludge, equivalent to 300 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	24 a	6.5 cd	4.7 a	4.1 ab	5.1 a
6. Sewage sludge, equivalent to 400 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	25 a	6.7 d	4.8 a	4.1 ab	5.5 a
7. Manure, equivalent to 100 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	23 a	6.1 abc	5.2 a	3.9 ab	4.8 a
8. Manure, equivalent to 200 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	22 a	6.1 ab	4.7 a	3.7 a	5.7 a
9. Manure, equivalent to 300 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	24 a	6.4 bcd	3.7 a	4.4 ab	4.5 a
10. Manure, equivalent to 400 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	23 a	6.5 cd	4.3 a	5.1 b	4.8 a
HSD 5% (Tukey test)	*4*	*0.4*	*4.7*	*1.2*	*2.6*

* means within a column followed by the same letter are not significantly different at the p=0.05 level (Tukey's honestly significant difference procedure)

Table 10 The effects of sewage sludge and manure application on zinc content in soil and oat plant

Treatment	Zn in soil		Zn in oat plant		
	total	soluble	straw	husk	grain
	mg/kg	mg/kg	---------------- mg/kg -------------		
1. 100 kg N/ha of ^{15}N labelled fertilizer, 1% a.e.	36 a*	1.6 a	15 a	17 a	27 a
2. 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	38 ab	1.6 a	15 a	15 a	28 a
3. Sewage sludge, equivalent to 100 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	41 ab	4.4 ab	15 a	19 ab	32 ab
4. Sewage sludge, equivalent to 200 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	42 ab	7.2 bcd	19 a	23 ab	35 ab
5. Sewage sludge, equivalent to 300 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	60 c	9.0 cd	26 a	25 ab	44 b
6. Sewage sludge, equivalent to 400 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	47 abc	10.6 d	22 a	28 b	45 b
7. Manure, equivalent to 100 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	48 abc	5.4 abc	18 a	17 a	30 a
8. Manure, equivalent to 200 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	43 ab	5.5 abc	11 a	15 a	30 a
9. Manure, equivalent to 300 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	44 ab	8.6 bcd	15 a	18 ab	29 a
10. Manure, equivalent to 400 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	51 bc	11.4 d	22 a	25 ab	34 ab
HSD 5% (Tukey test)	*13*	*4.4*	*27*	*10*	*13*

* means within a column followed by the same letter are not significantly different at the p=0.05 level (Tukey's honestly significant difference procedure)

Table 11 The effects of sewage sludge and manure application on lead content in soil and oat plant

Treatment	Pb in soil		Pb in oat plant		
	total	soluble	straw	husk	grain
	mg/kg	mg/kg	---------------------- mg/kg		------------------
1. 100 kg N/ha of ^{15}N labelled fertilizer, 1% a.e.	34 a*	8.1 bc	1.42 a	1.71 a	0.53 a
2. 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	34 a	8.1 bc	1.09 a	1.97 ab	1.58 bcd
3. Sewage sludge, equivalent to 100 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	30 a	8.1 bc	1.20 a	1.54 a	1.45 abcd
4. Sewage sludge, equivalent to 200 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	33 a	8.6 bc	1.71 a	2.21 ab	1.04 abc
5. Sewage sludge, equivalent to 300 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	33 a	8.8 c	1.86 a	1.86 ab	1.71 bcd
6. Sewage sludge, equivalent to 400 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	33 a	9.0 c	1.61 a	2.23 ab	0.86 a
7. Manure, equivalent to 100 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	37 a	8.3 b	2.32 a	2.70 ab	1.39 abcd
8. Manure, equivalent to 200 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	31 a	8.1 b	1.54 a	1.93 ab	2.05 d
9. Manure, equivalent to 300 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	33 a	7.8 b	2.00 a	3.21 ab	1.90 cd
10. Manure, equivalent to 400 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	34 a	6.8 a	2.06 a	3.87 b	1.92 cd
HSD 5% (Tukey test)	*18*	*0.9*	*1.70*	*2.04*	*0.97*

* means within a column followed by the same letter are not significantly different at the p=0.05 level (Tukey's honestly significant difference procedure)

Table 12 The effects of sewage sludge and manure application on cadmium contents in soil and oat plant

Treatment	Cd in soil		Cd in oat plant		
	total	soluble	straw	husk	grain
	mg/kg	mg/kg	--------------------- µg/kg	------------------	
1. 100 kg N/ha of ^{15}N labelled fertilizer, 1% a.e.	1.1 ab*	0.15 a	140 a	163 ab	88 a
2. 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	1.2 abc	0.16 a	162 a	116 a	146 ab
3. Sewage sludge, equivalent to 100 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	1.0 ab	0.20 ab	184 a	183 abc	90 a
4. Sewage sludge, equivalent to 200 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.9 a	0.25 bcd	259 a	238 bc	102 ab
5. Sewage sludge, equivalent to 300 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	1.3 abc	0.28 bcd	277 a	235 bc	137 ab
6. Sewage sludge, equivalent to 400 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	1.5 bc	0.31 d	227 a	235 bc	203 b
7. Manure, equivalent to 100 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	1.1 abc	0.23 abcd	260 a	137 ab	136 ab
8. Manure, equivalent to 200 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	1.3 abc	0.22 abc	178 a	153 ab	145 ab
9. Manure, equivalent to 300 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	1.3 abc	0.29 cd	191 a	239 bc	135 ab
10. Manure, equivalent to 400 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	1.6 c	0.28 bcd	231 a	292 c	135 ab
HSD 5% (Tukey test)	*0.5*	*0,08*	*175*	*115*	*107*

* means within a column followed by the same letter are not significantly different at the p=0.05 level (Tukey's honestly significant difference procedure)

Table 13 The effects of sewage sludge and manure application on nickel contents in soil and oat plant

Treatment	Ni in soil		Ni in oat plant		
	total	soluble	straw	husk	grain
	mg/kg	mg/kg	------------------- mg/kg		------------------
1. 100 kg N/ha of ^{15}N labelled fertilizer, 1% a.e.	47 a*	9.4 ab	0.64 a	1.2 a	4.7 ab
2. 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	49 a	9.5 b	0.65 a	1.2 a	4.5 a
3. Sewage sludge, equivalent to 100 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	49 a	9.3 ab	0.83 ab	1.8 a	4.8 ab
4. Sewage sludge, equivalent to 200 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	48 a	9.2 ab	0.97 ab	2.3 ab	5.1 ab
5. Sewage sludge, equivalent to 300 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	50 a	9.1 ab	0.87 ab	1.9 a	6.0 ab
6. Sewage sludge, equivalent to 400 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	46 a	9.3 ab	1.15 b	2.0 ab	6.3 b
7. Manure, equivalent to 100 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	44 a	9.2 ab	0.54 a	1.3 a	4.8 ab
8. Manure, equivalent to 200 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	47 a	9.0 ab	0.84 ab	1.5 a	5.3 ab
9. Manure, equivalent to 300 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	48 a	9.0 ab	0.83 ab	2.0 ab	5.5 ab
10. Manure, equivalent to 400 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	46 a	8.7 a	0.84 ab	3.1 b	6.2 b
HSD 5% (test Tukey)	*10*	*0.6*	*0.46*	*1.1*	*1.6*

* means within a column followed by the same letter are not significantly different at the p=0.05 level (Tukey's honestly significant difference procedure)

Table 14 The effects of sewage sludge and manure application on manganese contents in soil and oat plant

Treatment	Mn in soil		Mn in oat plant		
	total	soluble	straw	husk	grain
	mg/kg	mg/kg	mg/kg		
1. 100 kg N/ha of ^{15}N labelled fertilizer, 1% a.e.	988 a	638 a	79 b	216 c	53 a
2. 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	958 a	651 a	65 ab	190 bc	56 a
3. Sewage sludge, equivalent to 100 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	988 a	437 a	74 ab	192 bc	48 a
4. Sewage sludge, equivalent to 200 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	963 a	641 a	63 ab	172 abc	48 a
5. Sewage sludge, equivalent to 300 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	940 a	625 a	50 ab	156 ab	51 a
6. Sewage sludge, equivalent to 400 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	915 a	627 a	55 ab	140 a	51 a
7. Manure, equivalent to 100 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	957 a	625 a	59 ab	134 a	49 a
8. Manure, equivalent to 200 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	867 a	601 a	46 a	129 a	51 a
9. Manure, equivalent to 300 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	900 a	598 a	51 ab	130 a	44 a
10. Manure, equivalent to 400 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	866 a	573 a	51 ab	134 a	45 a
HSD 5% (Tukey test)	*179*	*293*	*31*	*47*	*13*

* means within a column followed by the same letter are not significantly different at the p=0.05 level (Tukey's honestly significant difference procedure)

Effects of fertilization with organic residual products on nickel content in soil and plants of oats are presented in **Table 13**. While total and soluble nickel contents did not changed from a statistical viewpoint, a significant increase in this element in the plants of oats is observed; this phenomenon should be deeper analyzed and explained.

Data presented in **Table 14** reflect the effects of sewage sludge and manure fertilization on the manganese contents in soil and oats plants. The obtained data do not emphasize statistically significant changes, under the influence of the applied treatments, on the total and soluble manganese content. Contents in plants are within the range of normal values.

In **Table 15,** the Fisher test significances obtained by analyzing the effects of the fertilization system on the content of elements in plants of oats are shown.

Table 15 Influence of fertilization system on content of different elements in oats plants harvested in the Teleorman SCDA field experiment

Characteristic	Significant test F (Fisher)		
	Straw	Husk	Grains
N content	**	**	ns
P content	**	**	ns
K content	**	*	ns
Ca content	ns	*	*
Mg content	*	**	ns
Cu content	ns	**	ns
Zn content	ns	**	**
Pb content	ns	*	**
Cd content	ns	**	*
Ni content	**	**	**
Mn content	*	**	ns

Note: * - statistically significant, **-distinctly significant, ns – non significant.

Nitrogen balance sheet in parcels treated with organic residues

Every year, a part of organic nitrogen form in soil is mineralized and other part of mineral nitrogen is immobilized as organic form; a part is taken up by plants and other part returns in soil with vegetal residues; a part is lost in the atmosphere and other part is returned into the soil; a part can be lost by erosion or accumulated by storage in clay minerals or in synthesized organic form (humus, microorganisms).

A long period of time, the utilization degree of nitrogen fertilizers was determined only on the basis of the simple differentiation between the extracted nitrogen from the non fertilized soil and the fertilized one with different nitrogen fertilizers.

Researchers have not paid attention to the effect of nitrogen fertilizers on the heterotrophic bacteria activity to decompose the organic matter, when nitrogen reserves in soil are easier available for plants. The way how the nitrogen fertilizers influenced the use of nitrogen reserves in soil was also unknown.

With the help of ^{15}N isotopes, many problems suspected to be unexplainable have been clarified. For example, the nitrogen quantity used by plants only from the soil reserve and the quantity of available nitrogen from fertilizer, the transformation in organic nitrogen of a mineral nitrogen part applied by fertilizer have been established. It was also observed that the nitrogen fertilizers, under the presence of phosphorus fertilizers, stimulate much more the nitrogen assimilation from the soil reserves than where the nitrogen is applied alone.

I. Nitrogen balance sheet in agriculture is fulfilled on the basis of two components:

1. Nitrogen inputs:

- nitrogen fertilizers
- symbiotically fixed nitrogen
- non symbiotically nitrogen

– manure nitrogen (residue nitrogen, ex: sewage sludge)
– roots and stubble
– in precipitation

2. Nitrogen outputs (exportation):

– incorporated in yield
– losses by erosion
– nitrogen leaching from the soil
– nitrogen leaching from the fertilizers
– denitrification.

Nitrogen quantity specifically necessary to some particular experiments depends on the crop requirements, available nitrogen in soil and lost nitrogen by volatilization, leaching, denitrification and washings.

Some crops require higher nitrogen quantities in soil than others to produce optimum yields. The available nitrogen quantity in soil before certain residual products application can be estimated by sol testing. Percentage of nitrogen easily available for plants varies for every soil and only a little percent is available for crops during the growing season. The interval is from 0% to at most 10% per year, but in most of the soils, the available nitrogen interval is from 1% to 6% of total nitrogen. The nitrogen quantity lost by volatilization is affected by the application method of residues.

Denitrification varies according to the management type, precipitation (or irrigation) and organic matter in soil for a given texture.

The multiplication factors to adjust the quantities of residues applied on soil in relation with the nitrogen losses by volatilization and denitrification are showed in ***Table 16***.

Balance sheet of nitrogen in parcels treated with residues (sewage sludge) depends on the crop structure and rotation, application of organic fertilizers and used soil management (irrigation or rainfed). A cereal-cereal rotation always provides a negative balance sheet for nitrogen.

Table 16. Multiplication factors used to adjust the quantities of residues applied on soil in relation with the nitrogen losses by volatilization and denitrification (Gilbertson et al. 1979)

Soil groups	***Residue application management***	
	Broadcast application	*Incorporated into the soil*
A (sandy soils)	1.33	1.05
B (sandy/silty loam soils)	1.33	1.18
C (relatively heavy soils)	1.33	1.33
D (clayey soils)	1.33	1.67

The effects on the nitrogen input achieved by the application of sewage sludge and of manure obtained with oats straw are showed in the **Table 17.**

Data emphasize statistically ensured increased nitrogen contents under the influence of fertilization with mineral nitrogen or with nitrogen coming from the residual. Indices of nitrogen taken up from the sewage sludge and from manure are similar. So, the nitrogen in the oats straw coming from the sewage sludge varied between 12.0 and 41.0%, and that coming from the manure varied between 18.1 and 44.6%.

However, the most quantity of nitrogen in straw of oats is taken up from the soil (67%) in the case of mineral fertilization applying 100 kg N/ ha, as compared to 54.3 - 81% in the case of sewage sludge fertilization applying 100 - 400 kg/ ha N equivalent, and 51.0 – 75.4% in the case of manure fertilization with 100 - 400 kg/ ha N.

The effects of sewage sludge and manure application on the quantities of nitrogen taken up by oats grains are shown in **Table 18**. Under the influence of the applied treatments, statistically significant total nitrogen contents in grains of oats did not occur. Nitrogen derived from mineral fertilizer represented 35% and that from the soil represented 65%. Also in grains of oats, nitrogen derived from sewage sludge had values between 12.7 and 28.2, and that derived from manure had values between 2.8 and 38%. The largest part o nitrogen content in grains of oats comes from the soil with values between 57.8 and 81.3%. High values of nitrogen taken up from sewage sludge and manure show the possibility to efficiently use these residual products to increase agricultural production and to protect the environment.

The influence of soil and of fertilization with mineral fertilizers and residual products on the quantities of nitrogen taken up by the plants of oats (grains and straw) is shown in **Table 19**. Per total, the nitrogen derived from sewage sludge varied between 12.4% and 32.3% and that derived from manure between 8.7 and 40.5%. The recovering degree of nitrogen coming from sewage sludge varied between 10.0% and 13.5%, and that from manure between 9.5 and 16.8%.

In another experiment organized on the same soil, the data show that for oats % of nitrogen derived from sewage sludge or manure (Ndfss) increased with time, and had values between 12 and 32 % for non-irradiated sewage sludge, and 8.7 - 41 % for irradiated sewage sludge. For maize, in the last (third) year of experimentation, Ndfss had values of 4.0 to 27 % for non-irradiated sewage sludge and 7.4 to 22 % for irradiated sewage sludge. Recovery values for sewage sludge N were low: 10 to 14 % for non-irradiated sewage sludge, 9.5 to 17 % for irradiated sewage sludge applied to oats, and 9.3 to 20% for non-irradiated sludge and 11 to 19 % for irradiated sewage sludge (*Dumitru et al., 2002*).

Concluding, the discussed data show that, concerning the establishment of rates of nitrogen coming from organic residual products, rates of 2 - 3 times higher than those used for mineral fertilizers can be recommended without affecting the environmental quality.

Table 17 The effects of sewage sludge and manure application on the amounts of nitrogen taken up by oat straw

Treatment	Total N	^{15}N abundance	Ndff	Ndfss	Ndfs
	%	%	%	%	%
1. 100 kg N/ha of ^{15}N labelled fertilizer, 1% a.e.	0.56 ab*	0.33 a	33.0		67.0
2. 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.55 ab	0.83 e	8.0		92.0
3. Sewage sludge, equivalent to 100 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.48 a	0.73 de	7.0	12.0	81.0
4. Sewage sludge, equivalent to 200 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.52 ab	0.65 cd	6.3	21.7	72.0
5. Sewage sludge, equivalent to 300 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.55 ab	0.60 bcd	5.8	27.7	66.5
6. Sewage sludge, equivalent to 400 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.63 ab	0.49 abc	4.7	41.0	54.3
7. Manure, equivalent to 100 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.58 ab	0.68 de	6.5	18.1	75.4
8. Manure, equivalent to 200 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.62 ab	0.64 cd	6.2	22.9	70.9
9. Manure, equivalent to 300 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.72 b	0.57 bcd	5.5	31.3	63.2
10. Manure, equivalent to 400 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	0.74 b	0.46 ab	4.4	44.6	51.0
HSD 5% (Tukey test)	*0.22*	*0.16*			

* means within a column followed by the same letter are not significantly different at the p=0.05 level (Tukey's honestly significant difference procedure)
Ndff - nitrogen derived from fertilizer
Ndfss - nitrogen derived from sewage sludge or manure
Ndfs - nitrogen derived from soil

Table 18 The effects of sewage sludge and manure application on the amounts of nitrogen taken up by oat grain

Treatment	Total N	^{15}N abundance	Ndff	Ndfss	Ndfs
	%	%	%	%	%
1. 100 kg N/ha of ^{15}N labelled fertilizer, 1% a.e.	2.24 a*	0.35 a	35.0		65.0
2. 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	2.58 a	0.71 b	6.8		93.2
3. Sewage sludge, equivalent to 100 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	2.20 a	0.62 ab	6.0	12.7	81.3
4. Sewage sludge, equivalent to 200 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	2.36 a	0.60 ab	5.8	15.5	78.7
5. Sewage sludge, equivalent to 300 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	2.46 a	0.57 ab	5.5	19.7	74.8
6. Sewage sludge, equivalent to 400 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	3.08 a	0.51 ab	4.9	28.2	66.9
7. Manure, equivalent to 100 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	2.25 a	0.69 b	6.6	2.8	90.6
8. Manure, equivalent to 200 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	2.39 a	0.62 ab	6.0	12.7	81.3
9. Manure, equivalent to 300 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	2.86 a	0.56 ab	5.4	21.2	73.5
10. Manure, equivalent to 400 kg N/ha + 20 kg N/ha of ^{15}N labelled fertilizer, 10% a.e.	2.82 a	0.44 ab	4.2	38.0	57.8
HSD 5% (Tukey test)	*1.02*	*0.28*			

* means within a column followed by the same letter are not significantly different at the p=0.05 level (Tukey's honestly significant difference procedure)
Ndff - nitrogen derived from fertilizer
Ndfss - nitrogen derived from sewage sludge or manure
Ndfs - nitrogen derived from soil

Table 19 Effects of mineral fertilization and organic residual products application on the amounts of nitrogen taken up by oat plants

Characteristic		**Mean values**									
		T_1	**T_2^***	**T_3**	**T_4**	**T_5**	**T_6**	**T_7**	**T_8**	**T_9**	**T_{10}**
Ndfs - Nitrogen derived from soil	%	65.8	92.7	81.3	76.4	71.9	62.9	84.8	77.3	69.7	55.2
Soil N yield	kg/ha	64.3	81.1	86.3	91.3	96.5	105.4	92.6	94.3	103.7	91.6
Ndff - Nitrogen derived from mineral fertilizer	%	34.2	7.3	6.3	5.9	5.7	4.8	6.5	6.1	5.4	4.3
Mineral fertilizer N yield	kg/ha	33.4	6.4	6.7	7.1	7.6	8.1	7.1	7.5	8.0	7.1
Ndfss - Nitrogen derived from sewage sludge or manure	%			12.4	17.7	22.4	32.3	8.7	16.6	24.9	40.5
Sewage sludge or manure N yield	kg/ha			13.2	21.1	30.1	54.1	9.5	20.3	37.0	67.2
Recovery of Sewage sludge/manure N	%			13.2	10.6	10.0	13.5	9.5	10.2	12.3	16.8

* reference for treatments T_3 - T_{10}.

References

Alcock R. E., et. al., 1995 - *The influence of multiple sewage sludge amendments on PCB content of an agricultural soil over time*, Environ. Toxicol. Chem.14, 553-560

Baraldi D. et. al. 1997 - *Sewage sludge disinfection by irradiation -. Sewage Sludge and Wastewater for Use in Agriculture*. IAEA-TECDOC-971.Vienna, 83-90.

Barrow M. L., et al., 1980 - *Trace elements in contaminated soils and associated crops*, Research seminar on crop trials, Water Technical Division, Department of the Environment, London.

Davies R.D. and Carlton –Smith C., 1980 - *Crops as indicators of the significance of contamination of soil by heavy metals*, Swindon Water Research Centre, Fibowa 44.

Davies R. D., 1983 - *Summary of the seminar at Upsala*, June 7-8.

Dumitru M., Motelică D. M., Alexandrescu Ariadna, Plaxienco Doina, Gamenț Eugenia, Dumitru Elisabeta, Calciu I., Vrînceanu Nicoleta, 1997 - *Agricultural use of sewage sludge*, Lucrările celei de a XV -a Conferință Națională de Știința Solului, vol. 29 B, p. 221-240.

Dumitru M., Motelică D. M., Alexandrescu Ariadna, Plaxienco Doina, Gamenț Eugenia, Dumitru Elisabeta, Calciu I., Vrînceanu Nicoleta, Prodan Ioana 2002 - *Use of nuclear techniques for evaluating agricultural use of sewage sludge* - IAEA –TDCDOC-1317, Irradiated sewage sludge for application to cropland.

Dumitru Mihail, 2005 - *Development of potash fertilizer input and the consequences for soil fertility and crop production in Romania*,. In Lucrările Simpozionului CIEC din 30-31 octombrie 2003, Bacău''Diversificarea sortimentului de îngrăşăminte şi îmbunătățirea calității acestora în raport cu cerințele agriculturii durabile''. Editori M. Dumitru, A. Dorneanu şi O. Popa, Bucureşti, p.17-104.

Gilbertson C. B. et al., 1979 - *Animal waste utilization on cropland and pastureland*. A *manual for evaluating agronomic and environmental effects*. US Department of Agriculture, EPA 600/2-79-059

McGrath S. P. et al. 1994 - *Land application of sewage sludge: scientific perspectives of heavy metal loading limits in Europe and the United States*, Environ. Rev. 2., 108-118.

MMGA, 2004 - *Raport privind nămolurilor provenite de la stațiile de epurare din Romania*.