SLUDGE TECHNOLOGICAL ECOLOGICAL PROGRESS
increasing the quality and reuse of sewage sludge

Increasing the quality and reuse of sewage sludge- Programme INTERREG South Baltic 2014-2020

Ecological sewage sludge management: an international project STEP

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V FOŚ 15-16 KWIETNIA 2019

Warszawa

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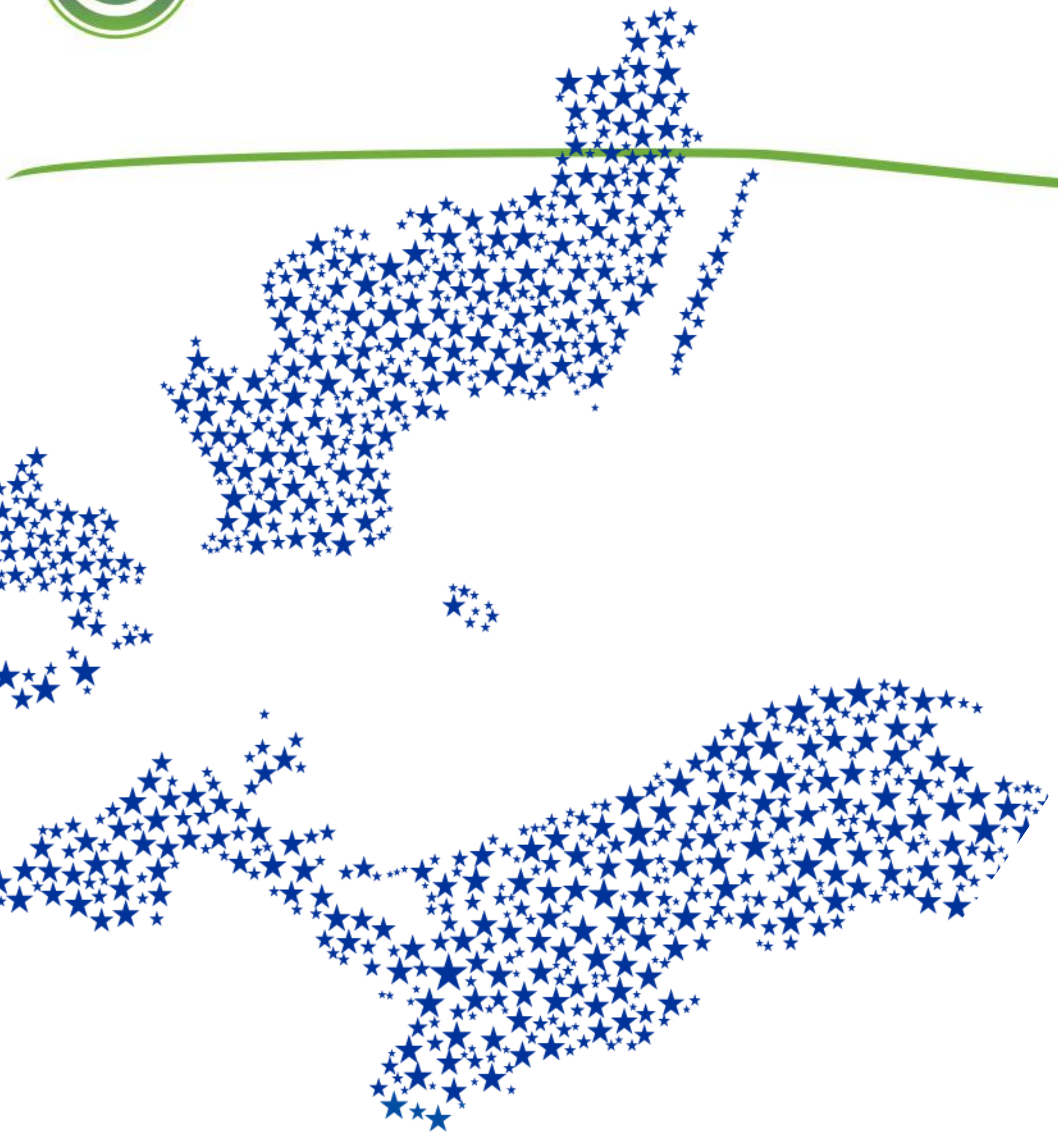

The Interreg South Baltic Program aims to unleash the potential of the South Baltic's in terms of blue and green growth trough cross-border cooperation between local and regional entities from Denmark, Germany, Lithuania, Poland and Sweden. Based on the maritime nature of the program, „blue growth" refers to the Baltic Sea's economic potential for economic growth and job creation on the shores of the South Baltic. „ Green growth" underlines the need to continue economic growth in balance with the environment, in particular through the use of the rich natural and cultural heritage of the South Baltic in a sustainable way.

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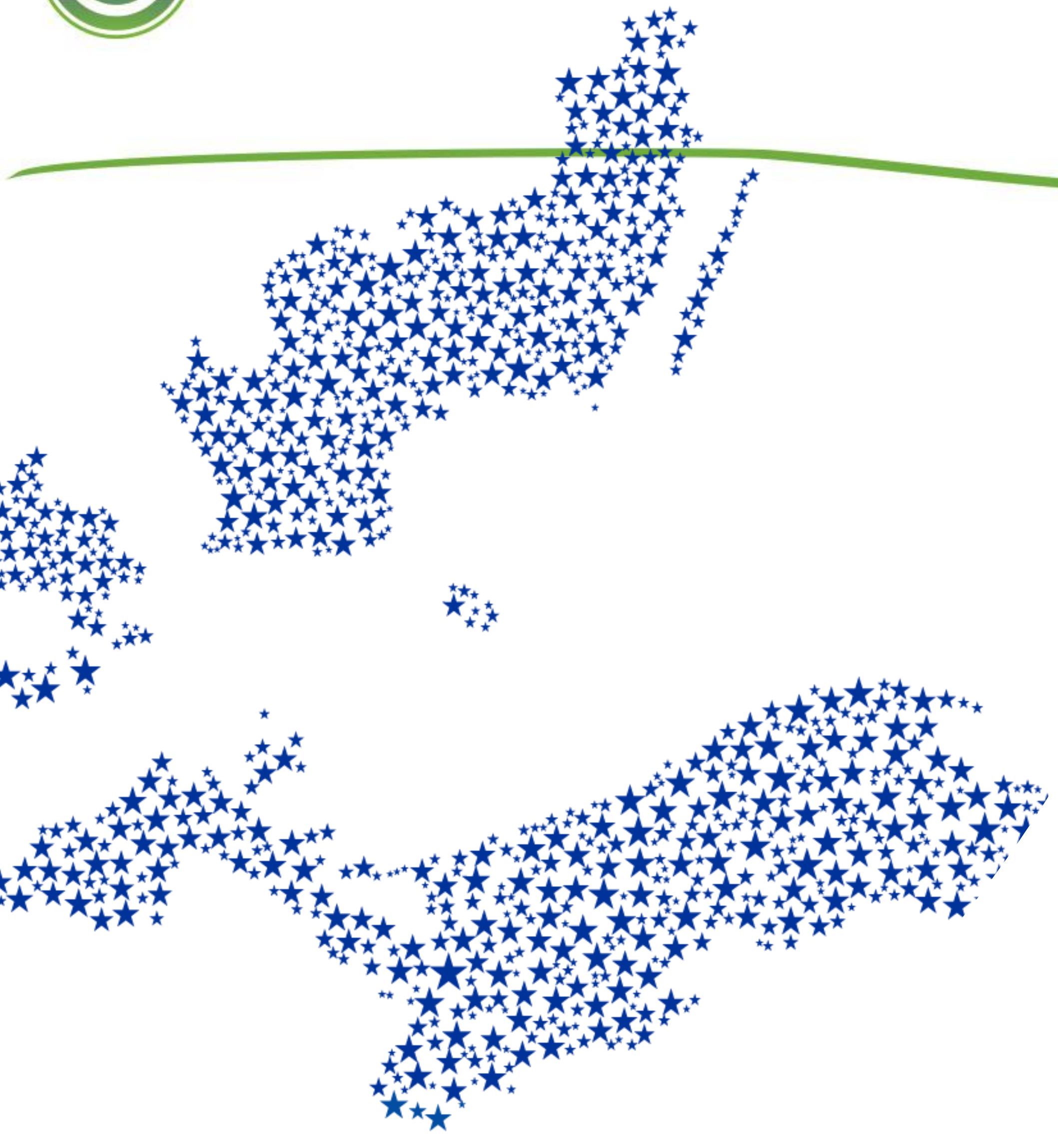
KRONOBERGS LÄN
BLEKINGE LÄN
SKÅNE LÄN
DK
ØSTSJÆLLAND
VEST-OG
SYDSJÆLLAND
BORNHOLM
Baltic Sea
TELŠIŲ
APSKRITIS
LT
KLAIPĖDOS
APSKRITIS
TAURAGĖS
APSKRITIS
STADT
ROSTOCK
VORPOMMERN-
RÜGEN
ROSTOCK
NORDWESTMECKLENBURG
VORPOMMERN-
GREIFSWALD
SZCZECIŃSKI
MIASTO
SZCZECIN
SZCZECINECKO-
PYRZYCKI
KOSZALIŃSKI
SŁUPSKI
GDAŃSKI
TRÓJMIEJSKI
CHOJNICKI
STAROGARDZKI
ELBLĄSKI
DE
PL



Priority Axis 2: Exploiting the environmental and cultural potential of the South Baltic area for blue and green growth.

Specific objective 2.1 : Increased development of natural and cultural heritage resources of the South Baltic area in sustainable tourist destination.

Specific objective 2.2 : Increased use of green technologies to reduce pollutant discharges in South Baltic area

Partnership and work packages in the Step Project

Höör Municipality, partner

mittskåne vatten

Bornholm, partner

BORNHOLMS ENERGI & FORSYNING

Klaipėda partner

Goleniów, partner

Goleniowskie Wodociągi i Kanalizacja

Szczecin, lead partner

Zachodniopomorski Uniwersytet Technologiczny w Szczecinie

EUROPEAN UNION Interreg South Baltic

Zachodniopomorski Uniwersytet Technologiczny w Szczecinie

Goleniowskie Wodociągi i Kanalizacja

Project budget

Partner	Budget [EUR]	%
Univeristy of Technology- Szczecin	251 580	22
Bornholm	207 700	18
Municipality Höör	199 125	17
Goleniów	309 850	27
Klaipeda	191 400	17
SUM	1 159 655	100

Refinancing for partners from Poland: 85%

Construction of project budget (expenses)

BL1	• Staff costs
BL2	• Office and administration
BL3	• Travel and accommodation
BL4	• External expertise and services
BL5	• Equipment
BL6	• Infrastructure and works

WP3 – Clean sludge

1. Analysis of the impact of sewage quality on sludge composition.
2. Comparison of sludge management regulations.
3. The use of sludge in agriculture.

WP4 – Energetic efficiency

1. Sludge as biofuel in sewage treatment plants
2. Energy- efficient composting

WP5 – Reusing nutriens

1. Guidelines on composting technology
2. Analysis of modern deodorization technologies
3. Database of sludge use and management technologies.

WP6 – Knowledge transfer

1. Sludge management guide.
2. Cases study.
3. Staff exchange program.

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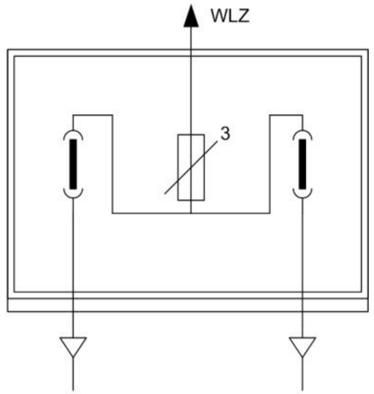
Pilot installations



- Intallation of optimization and deodorization of the composting process– optimization of nutrient content, proces hermetization and a modern system base on a non-thermal plasma reactor for exhaust air deodorization, the deodorization system will be made available to other interested entities.
- Pilot installation for drainage and sludge management from external suppliers (home sewage treatment plants)- technological and economic assessment of the possibility of sludge managing (use as biofuel) from external partners and the impact of the installation on the local community- the possibility of sludge management from individual customers.

STEP – Pilot instalation for drainage and sludge management from external suppliers (home sewage treatments plants)

STEP – Pilot installation for deodorizing process air from composting

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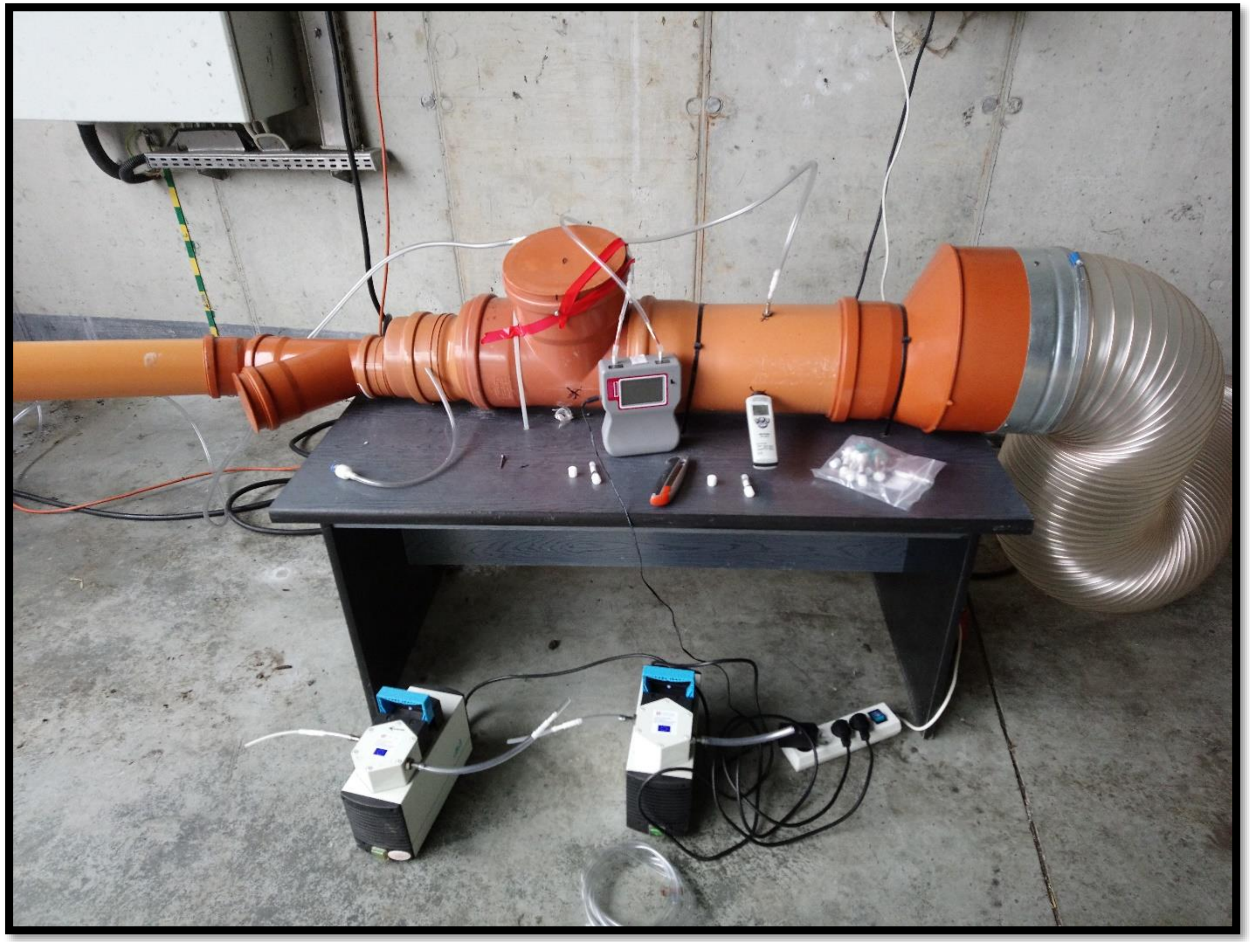
Goleniowskie Wodociągi i Kanalizacja

STEP – Pilot installation for deodorizing process air from composting



STEP – Pilot installation for deodorizing process air from composting

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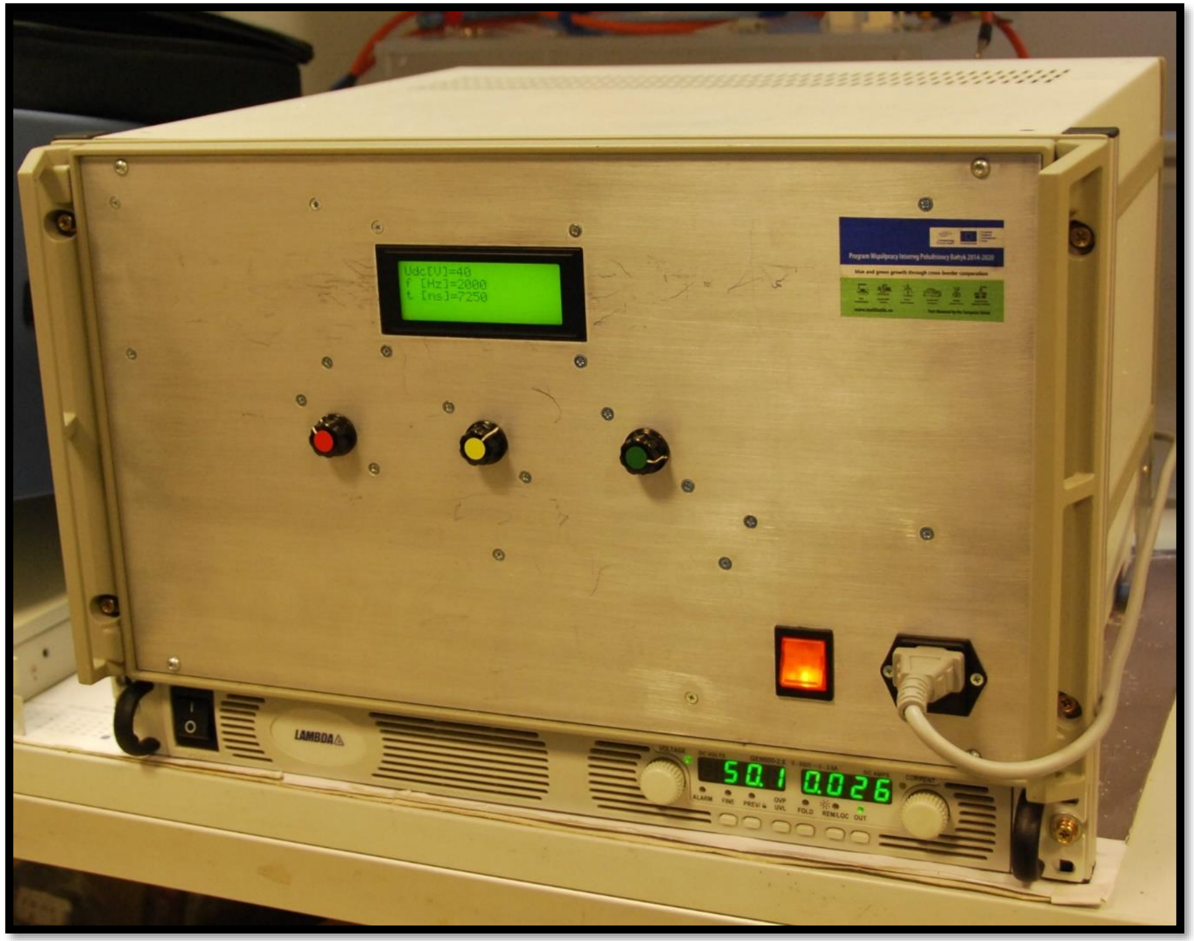
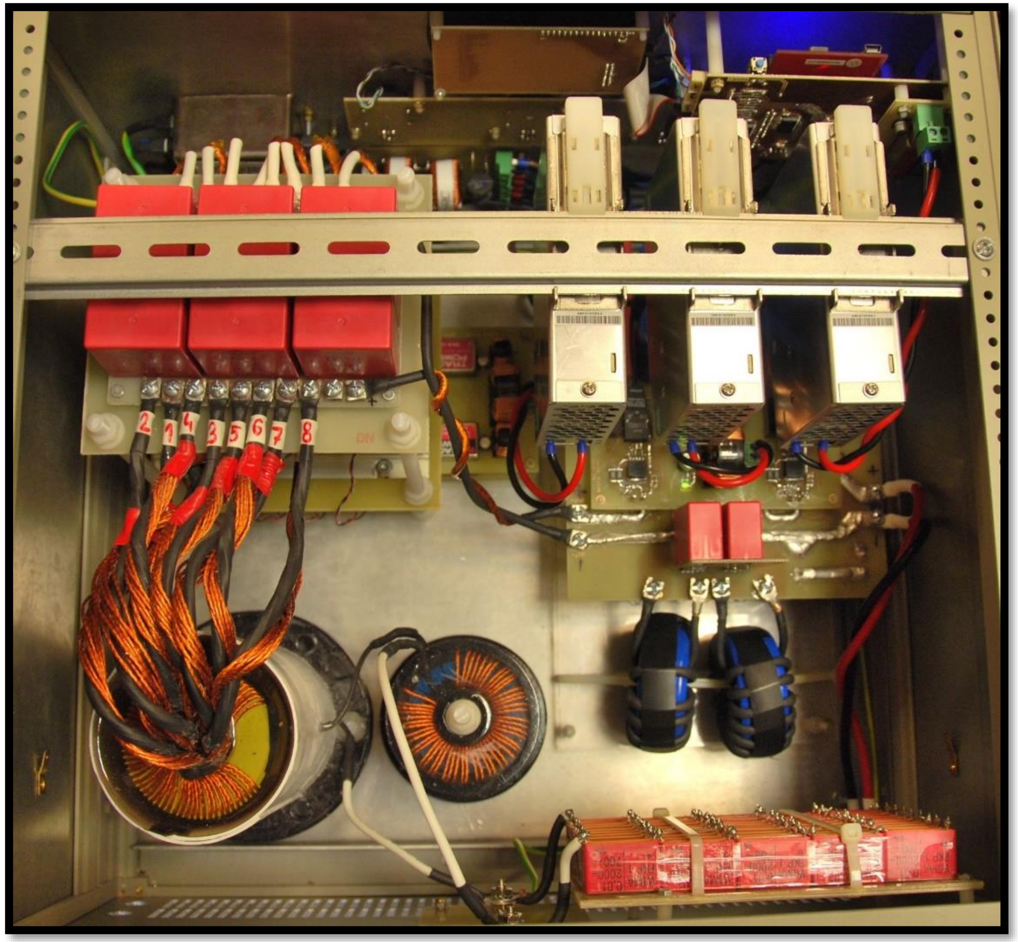
STEP – Pilot installation for deodorizing process air from composting





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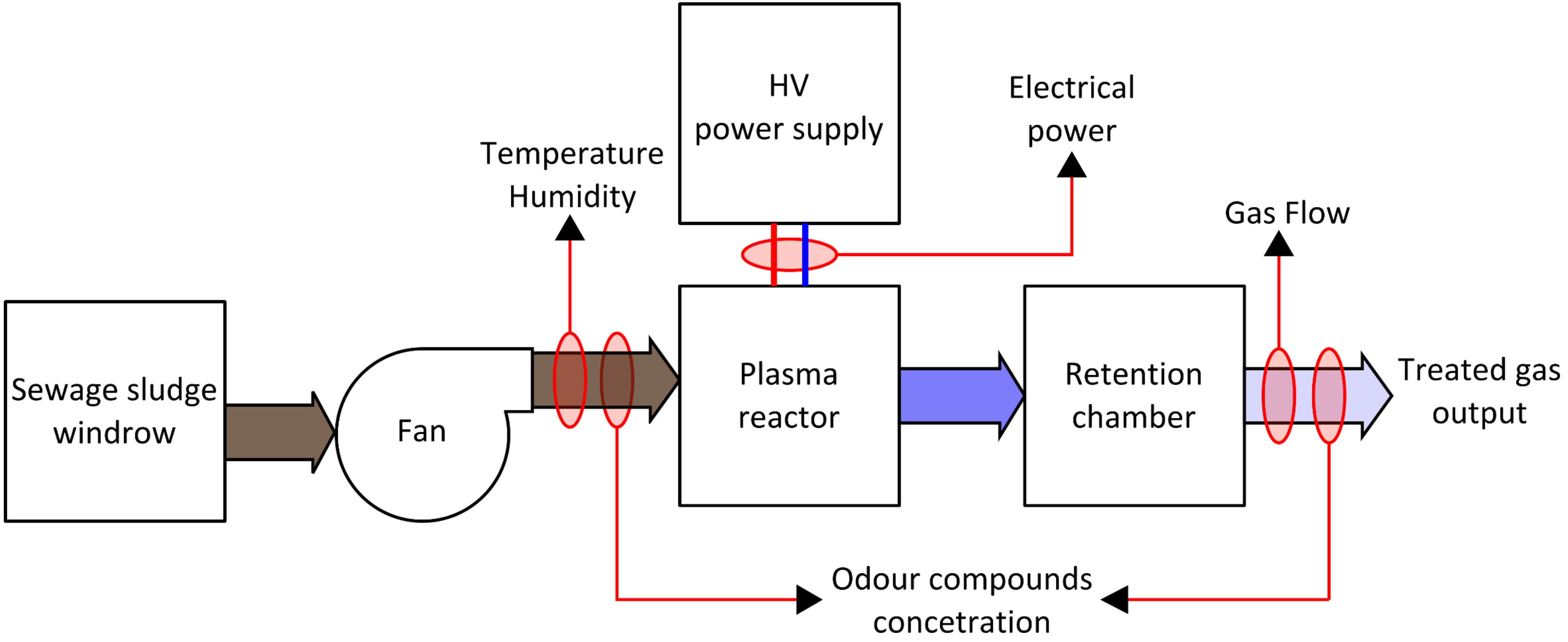
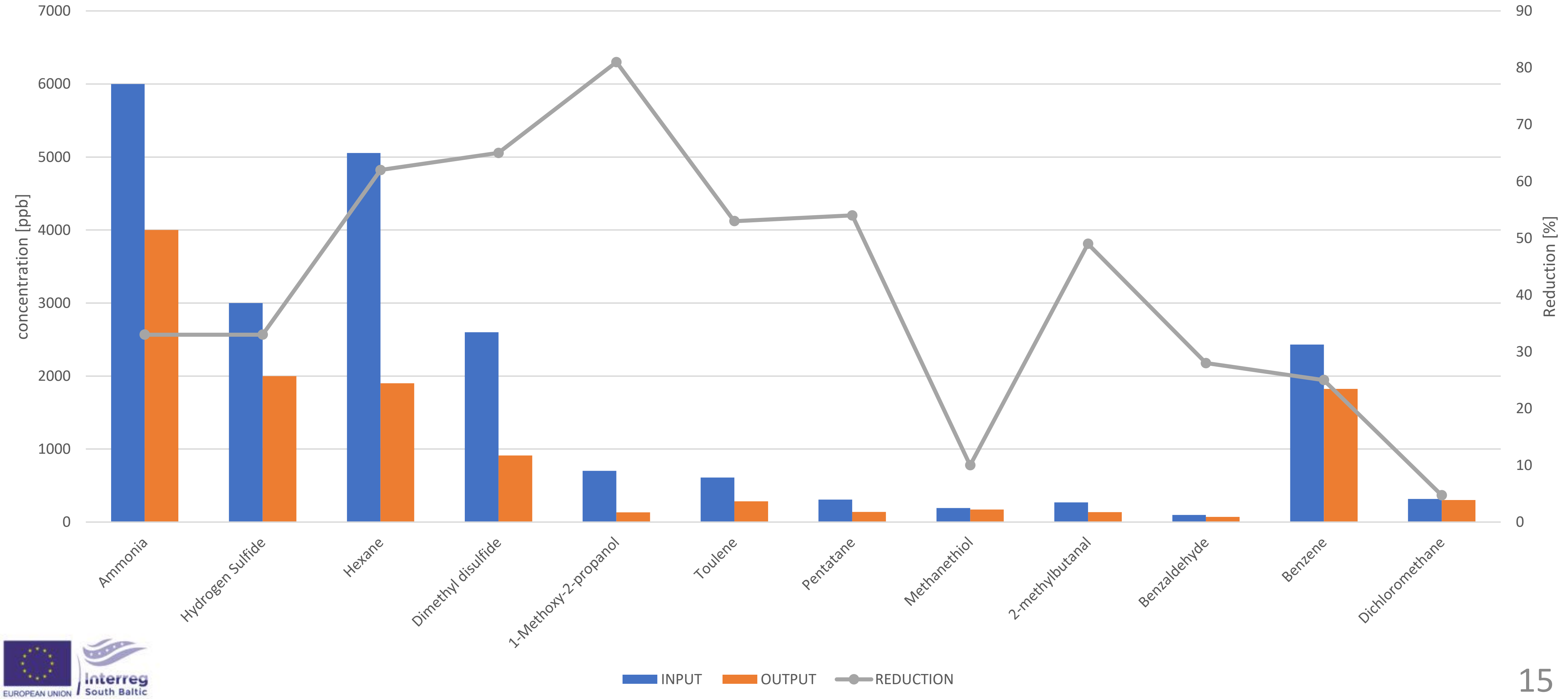
STEP – Pilot installation for deodorizing process air from composting



Average reduction of malodourous substances– 41%



STEP – mobile sampler

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STEP – composting process at the sewage treatment plant in Goleniów

STEP – – composting process at the sewage treatment plant in Goleniów

STEP – – composting process at the sewage treatment plant in Goleniów

Zachodniopomorski Uniwersytet Technologiczny w Szczecinie

Goleniowskie Wodociągi i Kanalizacja

STEP – studies on the impact of the composition of a mixture of various organic raw materials on the composting process of dewatered sewage sludge

Harmonogram badań, etap I

2018 r.																								
Maj				Czerwiec				Lipiec				Sierpień				Wrzesień				Październik				
	p	p	p	p		p		p		p			p			p				p				pryzma nr.1
	p	p	p	p		p		p		p			p			p				p				pryzma nr.2

- faza przygotowania pryzmy
- faza gorąca, 1- 2 miesiące
- faza dojrzewania, 3- 4 miesięcy

- składniki (proporcja masowa)

odwodnione osady ściekowe	słoma	zrębki	inoculum (kompost dojrzały)		
4	1	0.5	0.5	(4:1:1)	pryzma nr. 1
8	1	1	1	(8:1:2)	pryzma nr. 2

STEP – studies on the impact of the composition of a mixture of various organic raw materials on the composting process of dewatered sewage sludge

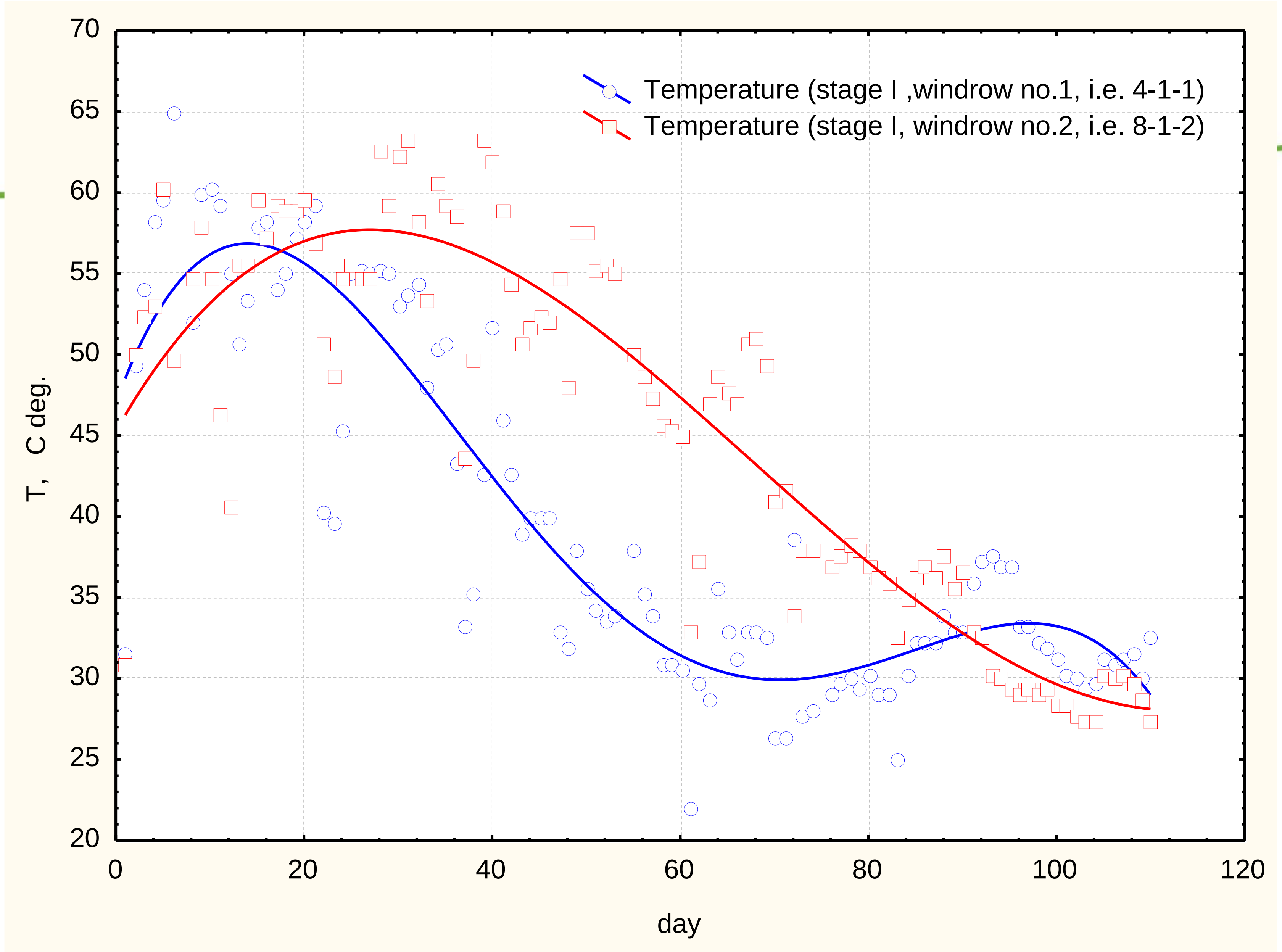
<table>
<tr><th rowspan="4">parameters</th><th rowspan="4">scope of analysis</th><th rowspan="4">method</th><th colspan="7">number of samples</th></tr>
<tr><th colspan="3" rowspan="2">raw materials</th><th colspan="4">compost</th></tr>
<tr><th colspan="2">stage no. I</th><th colspan="2">stage no. II</th></tr>
<tr><th>sludge</th><th>barley straw</th><th>chips</th><th>no.1</th><th>no.2</th><th>no.1</th><th>no.2</th></tr>
<tr><td rowspan="5">physical and chemical</td><td>dry mass (d.m.)</td><td>PN-R-04006</td><td>4</td><td>4</td><td>4</td><td>10</td><td>10</td><td>11</td><td>11</td></tr>
<tr><td>organic matter (o.m.)</td><td>PN-Z-15011-3</td><td>4</td><td>4</td><td>4</td><td>10</td><td>10</td><td>11</td><td>11</td></tr>
<tr><td>C org.</td><td>PN-Z-15011-1,3</td><td>4</td><td>4</td><td>4</td><td>10</td><td>10</td><td>11</td><td>11</td></tr>
<tr><td>N tot.</td><td>PN-R-04006</td><td>4</td><td>4</td><td>4</td><td>10</td><td>10</td><td>11</td><td>11</td></tr>
<tr><td>P tot.</td><td>PN-Z-15011-3</td><td>4</td><td>4</td><td>4</td><td>10</td><td>10</td><td>11</td><td>11</td></tr>
<tr><td rowspan="5">heavy metals</td><td>Cr</td><td rowspan="5">(AAS)</td><td>4</td><td>-</td><td>-</td><td>10</td><td>10</td><td>11</td><td>11</td></tr>
<tr><td>Cd</td><td>4</td><td>-</td><td>-</td><td>10</td><td>10</td><td>11</td><td>11</td></tr>
<tr><td>Ni</td><td>4</td><td>-</td><td>-</td><td>10</td><td>10</td><td>11</td><td>11</td></tr>
<tr><td>Pb</td><td>4</td><td>-</td><td>-</td><td>10</td><td>10</td><td>11</td><td>11</td></tr>
<tr><td>Hg</td><td>4</td><td>-</td><td>-</td><td>10</td><td>10</td><td>11</td><td>11</td></tr>
</table>

STEP – studies on the impact of the composition of a mixture of various organic raw materials on the composting process of dewatered sewage sludge

speciation analysis	Zn- fr.I	according with Tessier's method	4	-	-	10	10	11	11
	Zn- fr.II		4	-	-	10	10	11	11
	Zn- fr.III		4	-	-	10	10	11	11
	Zn- fr.IV		4	-	-	10	10	11	11
	Zn- fr.V		4	-	-	10	10	11	11
	Cu- fr.I		4	-	-	10	10	11	11
	Cu- fr.II		4	-	-	10	10	11	11
	Cu- fr.III		4	-	-	10	10	11	11
	Cu- fr.IV		4	-	-	10	10	11	11
	Cu- fr.V		4	-	-	10	10	11	11
	Ni- fr.I		4	-	-	10	10	11	11
	Ni- fr.II		4	-	-	10	10	11	11
	Ni- fr.III		4	-	-	10	10	11	11
	Ni- fr.IV		4	-	-	10	10	11	11
	Ni- fr.V		4	-	-	10	10	11	11
humic substance	FA	according with IHSS method	4	-	-	10	10	11	11
	HA		4	-	-	10	10	11	11

STEP – studies on the impact of the composition of a mixture of various organic raw materials on the composting process of dewatered sewage sludge

parameters	scope of analysis	method	number of samples						
			raw materials			compost			
						stage no. I		stage no. II	
			sludge	barley straw	chips	no.1	no.2	no.1	no.2
sum			108	20	20	270	270	297	297
total			1282						



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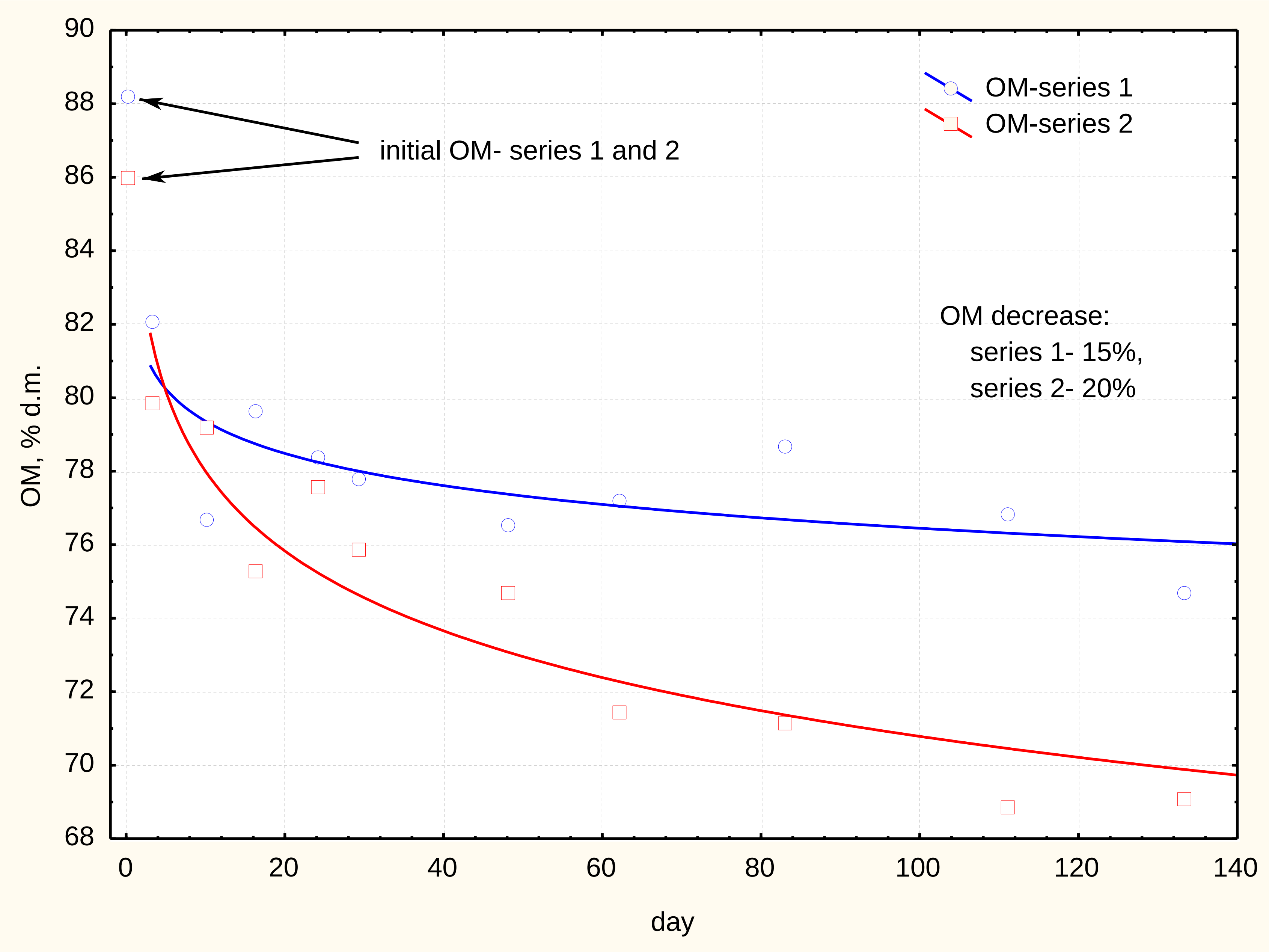

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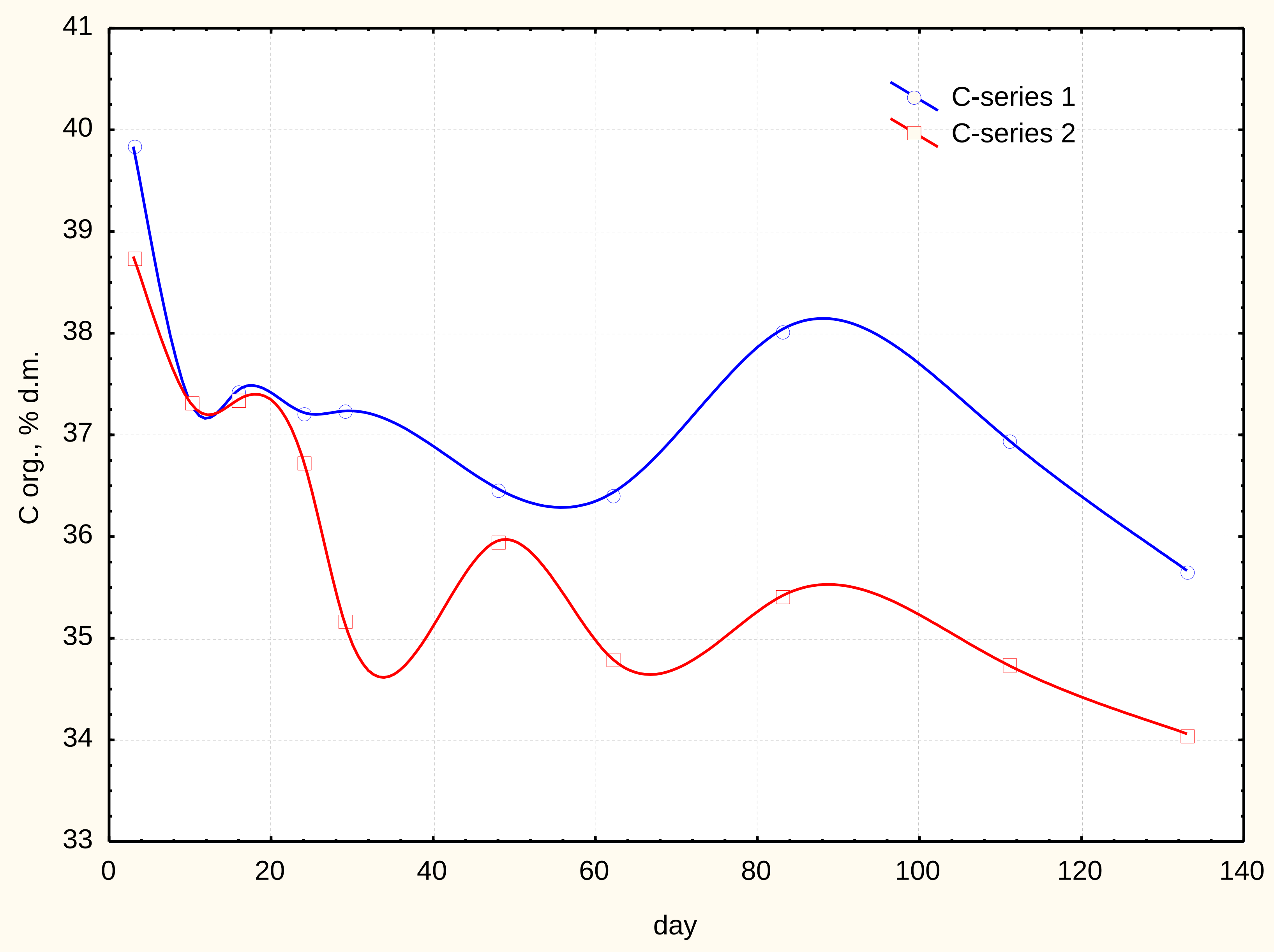
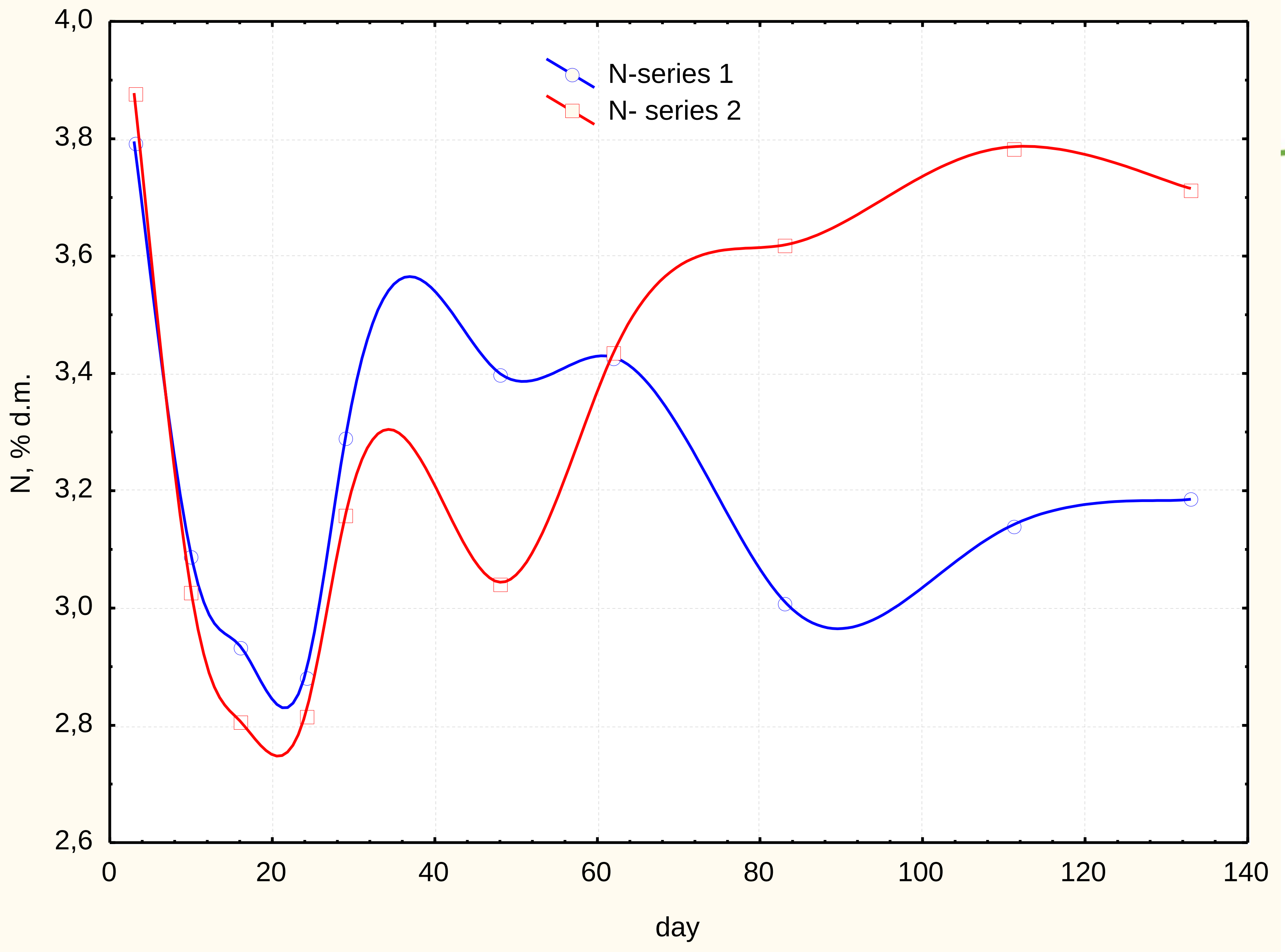


C org., % d.m.
day
C-series 1
C-series 2
41
40
39
38
37
36
35
34
33
0
20
40
60
80
100
120
140



N-series 1
N- series 2
4,0
3,8
3,6
3,4
3,2
3,0
2,8
2,6
N, % d.m.
0
20
40
60
80
100
120
140
day

COUNCIL DIRECTIVE

of 12 June 1986

on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture

(86/278/EEC)

Regulation of the Minister of the Environment

of 6 February 2015

on the municipal sewage sludge

Zachodniopomorski Uniwersytet Technologiczny w Szczecinie

Goleniowskie Wodociągi i Kanalizacja

STAGE I, series 1	the sample identification	Zn, mg/kg d.m.	Cu, mg/kg d.m..	Cr, mg/kg d.m..	Cd, mg/kg d.m.	Pb, mg/kg d.m.	Ni, mg/kg d.m.	Hg, mg/kg d.m..
compost (4-1-1)	I/1/1	405,50 ± 4,24	182,50 ± 4,95	34,75 ± 0,35	1,00 ± 0,00	29,25 ± 1,06	12,75 ± 1,06	0,420±0,066
	I/1/2	431,75 ± 22,98	202,50 ± 2,83	35,75 ± 0,35	1,00 ± 0,00	29,50 ± 0,71	13,00 ± 0,00	0,382±0,045
	I/1/3	439,00 ± 27,58	192,75 ± 1,06	37,75 ± 0,35	0,75 ± 0,35	36,75 ± 0,35	13,75 ± 0,35	0,379±0,021
	I/1/4	378,50 ± 21,92	170,00 ± 8,49	54,00 ± 2,83	1,00 ± 0,00	27,75 ± 2,47	19,25 ± 1,06	0,312±0,033
	I/1/5	423,25 ± 15,20	193,75 ± 6,72	57,75 ± 6,72	1,00 ± 0,00	32,00 ± 0,71	20,50 ± 0,71	0,375±0,034
	I/1/6	393,75 ± 30,05	175,50 ± 0,71	22,50 ± 2,12	0,75 ± 0,35	29,75 ± 0,35	8,25 ± 0,35	0,325±0,016
	I/1/7	400,25 ± 20,86	179,50 ± 2,12	50,75 ± 1,06	0,50 ± 0,00	31,00 ± 0,71	16,50 ± 0,00	0,364±0,025
	I/1/8	421,00±8,48	184,25±0,35	33,50 ± 0,71	1,25 ± 0,35	29,75±0,35	13,25±0,35	0,347±0,020
	I/1/9	429,00±1,41	190,25±1,06	45,00 ± 2,12	1,00 ± 0,71	32,50±0,707	15,75±0,35	0,377±0,020
	I/1/10	453,50±12,02	201,25±1,06	47,75 ± 0,35	1,25 ± 0,35	32,25±1,06	17,00±0,71	0,371±0,003
sewage sludge		551,75±3,18	225,25±2,47	26,25±1,06	0,50±0,00	48,50±0,00	10,50±0,71	0,551±0,075
86/278/EEC		2500÷4000	1000÷1700	-	20÷40	750÷1200	300÷400	16÷25
Dz.U. poz.257, 2015 r.		2500	1000	500	20	750	300	16

STAGE I, series 2	the sample identification	Zn, mg/kg d.m.	Cu, mg/kg d.m..	Cr, mg/kg d.m..	Cd, mg/kg d.m.	Pb, mg/kg d.m.	Ni, mg/kg d.m.	Hg, mg/kg d.m..
compost (8-1-2)	I/2/1	441,50±4,95	189,00±3,53	37,75 ± 2,47	0,05 ± 0,00	33,75±0,35	13,50±0,71	0,386±0,064
	I/2/2	475,25±1,77	204,25±0,35	53,25 ± 1,77	0,05 ± 0,71	34,50±0,71	18,25±0,35	0,508±0,054
	I/2/3	482,75±16,61	208,75±1,77	46,00 ± 1,41	0,05 ± 0,35	36,50±2,12	16,25±0,35	0,466±0,076
	I/2/4	484,50±19,80	212,25±2,47	48,00 ± 2,83	1,00 ± 0,71	37,00±1,41	16,50±1,41	0,428±0,042
	I/2/5	509,31±18,12	219,08±2,94	71,34 ± 4,72	0,79 ± 0,30	40,13±3,71	22,47±2,08	0,448±0,035
	I/2/6	532,50±18,38	238,95±5,59	72,25 ± 3,89	1,25 ± 0,35	41,0±0,00	24,25±0,35	0,449±0,014
	I/2/7	548,71±2,53	235,50±0,71	35,68 ± 0,25	1,01 ± 0,01	41,71±1,00	14,07±0,81	0,491±0,064
	I/2/8	533,50 ± 44,55	245,75 ± 1,77	43,75 ± 1,77	1,00 ± 0,00	40,50 ± 0,00	16,00 ± 1,41	0,531±0,033
	I/2/9	562,00 ± 30,41	255,25 ± 2,47	40,50 ± 1,41	0,25 ± 0,35	41,75 ± 0,35	15,25 ± 0,35	0,513±0,033
	I/2/10	555,00 ± 31,11	253,50 ± 4,95	58,75 ± 7,42	0,50 ± 0,00	41,25 ± 0,35	22,00 ± 2,12	0,548±0,050
86/278/EEC		2500÷4000	1000÷1700	-	20÷40	750÷1200	300÷400	16÷25
Dz.U. poz.257, 2015 r.		2500	1000	500	20	750	300	16

COMMISSION DECISION

of 28 August 2001

establishing ecological criteria for the award of the Community eco-label to soil improvers and growing media

(notified under document number C(2001) 2597)

(Text with EEA relevance)

(2001/688/EC)

Regulation of the Minister of Agricultre and Rural Development

of 18 June 2008

on the implementation of certain provisions of the Act on Fertilizers and Fertilization

STEP – studies on the impact of the composition of a mixture of various organic raw materials on the composting process of dewatered sewage sludge

elements, mg/kg d.m.	acording with:		compost after 133 days - Goleniów	
	Polish regulations	EU regulations	series no. 1 (4-1-1)	series no. 2 (8-1-2)
Cr	100	100	48	58
Cd	5	1	1,3	0,5
Ni	60	50	17	22
Pb	140	100	32	41
Hg	2	1	0,37	0,55
Zn	-	300	**453**	**555**
Cu	-	100	**201**	**253**

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Goleniowskie Wodociągi i Kanalizacja

Sequential extraction conditions according to Tessier methodology

stage	fraction	extractant	conditions	
			time	temperature
FI	replaceable	10 cm^3 1M CH_3COONH_4 ; pH=7	1h	ca 20°C
FII	carbonate	20 cm^3 1M CH_3COONa with H_3COOH; pH=2	5h	ca 20°C
FIII	Associated with Fe/Mn oxides	20 cm^3 0,4 M $NH_2OH{\cdot}HCl$ w 25% (v/v) CH_3COOH	5h	95°C
FIV	Associated with a humic substance	a) 5cm^3 0,02 M HNO_3 + 5cm^3 30% H_2O_2 , pH=2 b) 5cm^3 30% H_2O_2 , pH=2 c) 10 cm^3 3,2M CH_3COONH_4 in 20% (v/v) HNO_3	a) 2h b) 3h c) 0,5h	a) 85°C, b) 85°C, c) ca 20°C
FV	remained	Marked as the difference between the total concentration and the sum of the fractions FI, FII, FIII, FIV		

Average Zn content in fractions according to Tessier methodology (stage I)

series 1	average Zn content in fractions, [mg/kg s.m.]					
	fr. I	fr. II	fr. III	fr. IV	fr. V	total
1/1	16,58	117,00	160,00	62,88	49,05	405,50
2/1	10,28	90,75	181,88	101,75	47,10	431,75
3/1	13,58	102,00	177,13	85,50	60,80	439,00
4/1	14,40	82,00	152,63	85,88	43,60	378,50
5/1	14,10	88,50	186,88	94,25	39,53	423,25
6/1	16,20	68,50	148,50	105,50	55,05	393,75
7/1	13,50	63,75	169,88	112,63	40,50	400,25
8/1	8,85	69,50	162,75	120,50	59,40	421,00
9/1	9,30	67,00	157,00	141,00	54,70	429,00
10/1	10,80	71,63	148,25	145,50	77,33	453,50
sludge	28,95	146,63	253,25	91,13	31,80	551,75

Fr (I + II + III)= 230,7

Fr (IV + V)= 228,8

conclusion: the sum of bioavailable Zn form is 230,7 mg/kg s.m. and is less than the allowable value- 300 mg/kg s.m.

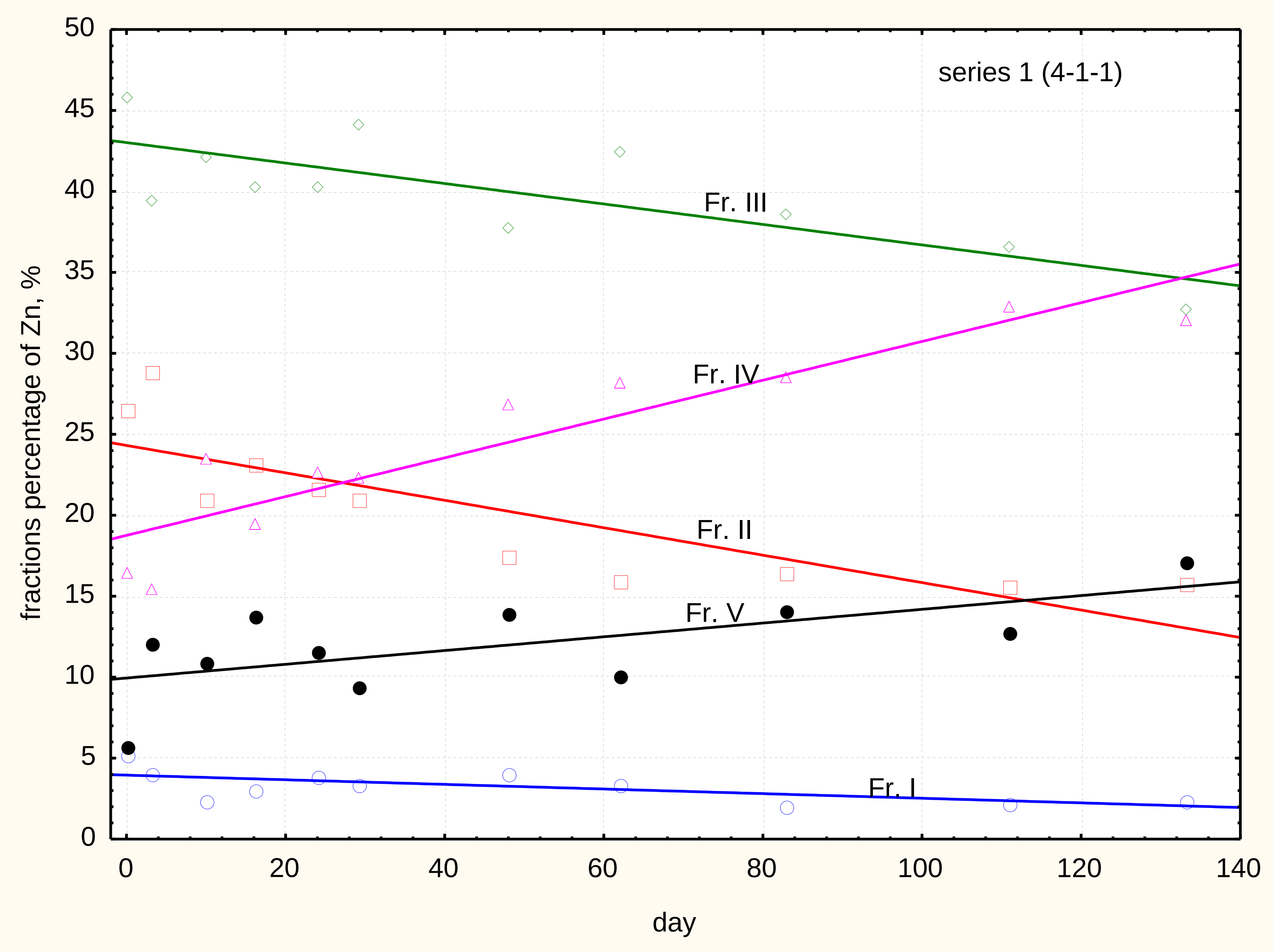
Average Cu content in fractions according to Tessier methodology (stage I)

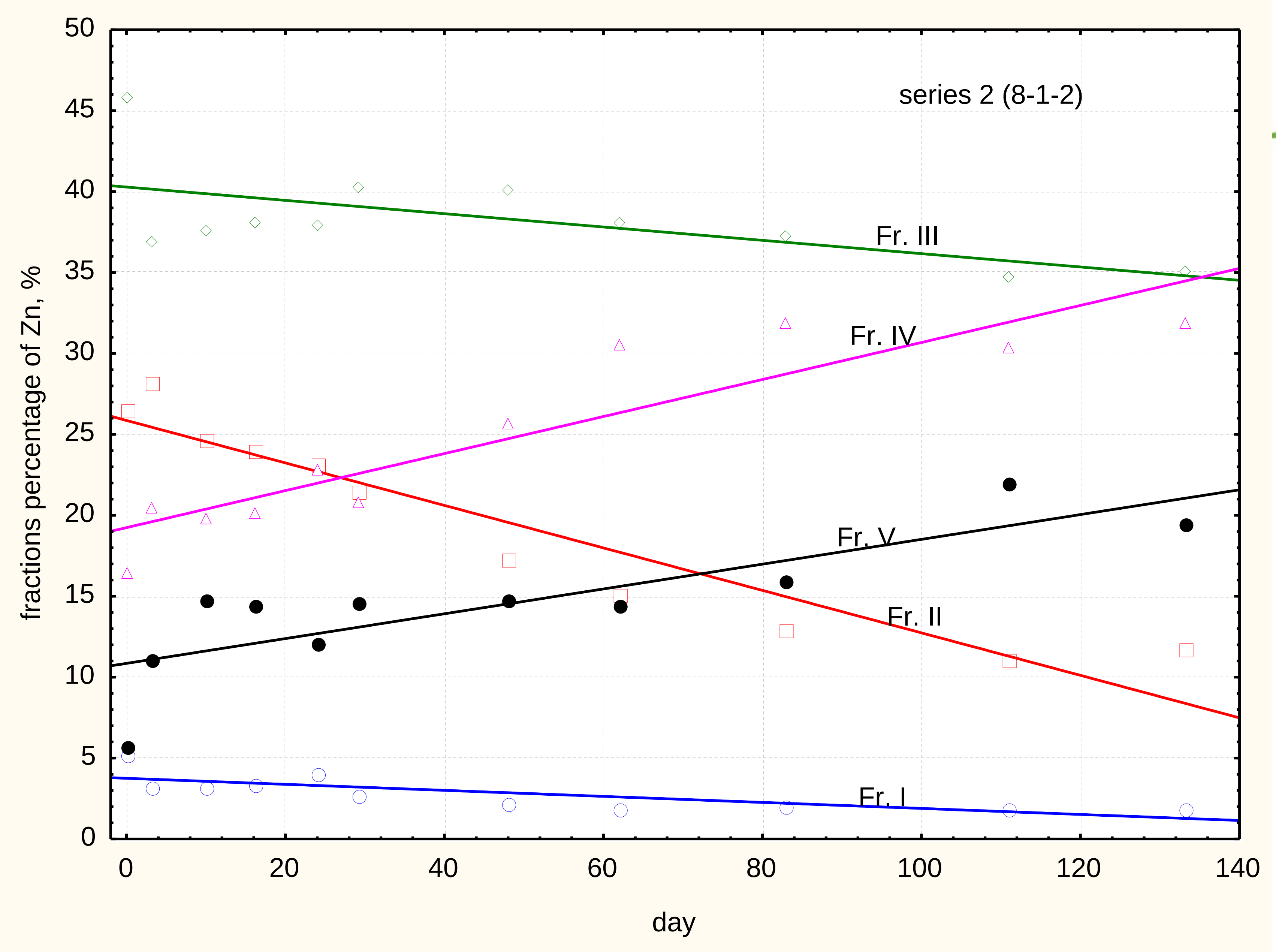
series 1	average Cu content in fractions, [mg/kg s.m.]					
	fr. I	fr. II	fr. III	fr. IV	fr. V	total
1/1	18,00	6,75	5,25	117,63	34,88	182,50
2/1	6,38	2,63	3,63	145,50	44,38	202,50
3/1	7,13	3,00	3,75	132,00	46,88	192,75
4/1	6,08	2,25	3,63	120,25	37,80	170,00
5/1	6,08	2,13	4,50	133,00	48,05	193,75
6/1	5,48	1,75	2,88	120,50	44,90	175,50
7/1	4,13	1,38	3,00	129,38	41,63	179,50
8/1	3,15	1,63	2,88	122,00	54,60	184,25
9/1	3,45	2,13	3,00	122,63	59,05	190,25
10/1	3,90	2,13	2,63	125,88	66,73	201,25
sludge	27,75	8,88	9,00	131,38	48,25	225,25

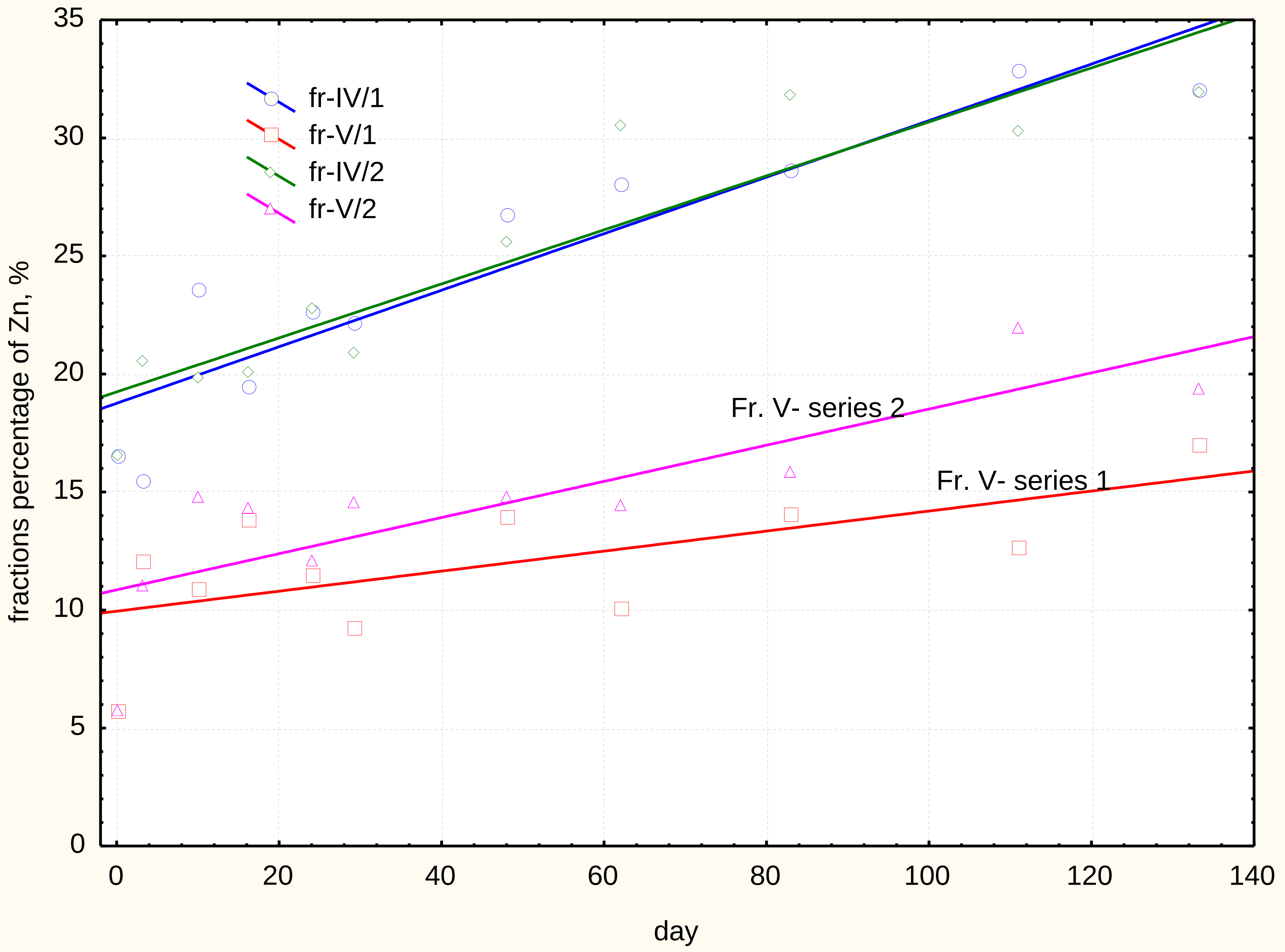
Fr (I + II + III)= 8,7

Fr (IV + V)= 192,6

Conclusion: the sum of bioavailable Cu form is 8,7 mg/kg s.m. And is less than the allowable value - 200 mg/kg s.m.


series 1 (4-1-1)
Fr. III
Fr. IV
Fr. II
Fr. V
Fr. I
fractions percentage of Zn, %
day
0
5
10
15
20
25
30
35
40
45
50
0
20
40
60
80
100
120
140

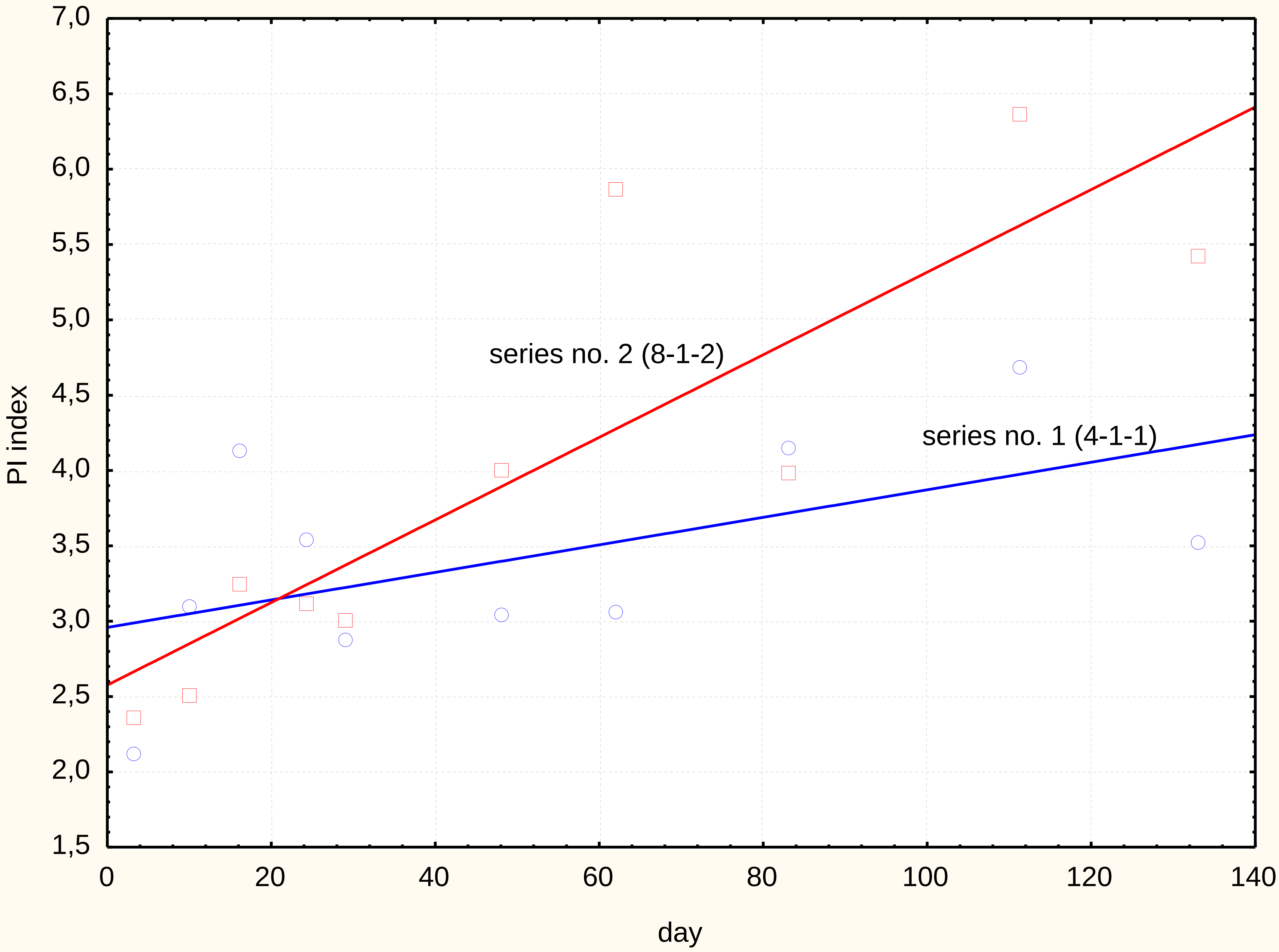

series 2 (8-1-2)
Fr. III
Fr. IV
Fr. V
Fr. II
Fr. I
fractions percentage of Zn, %
day
0
5
10
15
20
25
30
35
40
45
50
0
20
40
60
80
100
120
140



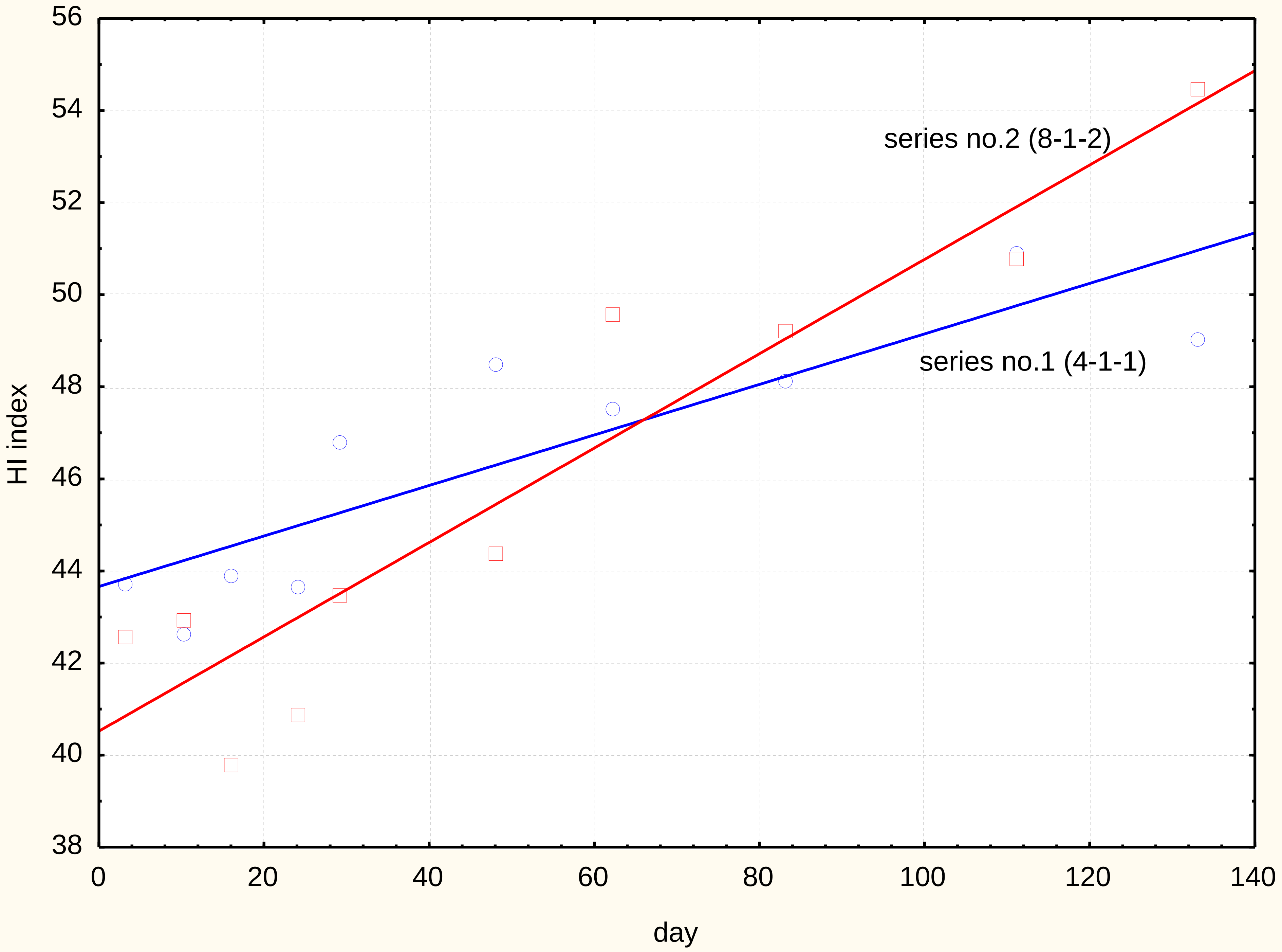
fr-IV/1
fr-V/1
fr-IV/2
fr-V/2
Fr. V- series 2
Fr. V- series 1
fractions percentage of Zn, %
day
35
30
25
20
15
10
5
0
0
20
40
60
80
100
120
140

Content of humic substance and values of humification indexes in samples of composts and sludge, stage I.

STAGE I	sample symbol	humic substance						C org., [g/kg s.m.]	humification index	
		specific, [g/kg d.m.]			non specific, [% d.m.]				PI, [-] (HA/FA)	HI, [%] (C_{HA}/C_{tot})100
		HA	FA	Total	lignin	cellulose	hemicell.			
series 1	I/1/1	174,22	81,96	256,18	18,28	9,37	15,21	398,35	2,13	43,74
	I/1/2	159,29	51,12	210,41	30,25	10,83	11,14	373,25	3,12	42,68
	I/1/3	164,58	39,69	204,27	29,48	14,40	7,55	374,45	4,15	43,95
	I/1/4	162,63	45,77	208,40	34,26	11,56	12,87	372,20	3,55	43,69
	I/1/5	174,33	60,56	234,89	22,94	10,56	8,57	372,35	2,88	46,82
	I/1/6	176,84	57,96	234,80	29,41	11,54	10,31	364,70	3,05	48,49
	I/1/7	173,29	56,36	229,65	24,90	8,12	9,63	364,25	3,07	47,58
	I/1/8	183,18	44,02	227,20	27,61	10,11	3,56	380,35	4,16	48,16
	I/1/9	188,23	40,12	228,36	30,83	11,94	2,49	369,50	4,69	50,94
	I/1/10	174,93	49,60	224,53	29,87	10,41	0,68	356,65	3,53	49,05
series 2	I/2/1	164,99	69,39	234,38	25,18	11,76	5,75	387,55	2,38	42,57
	I/2/2	160,43	63,60	224,03	27,29	11,23	9,49	373,20	2,52	42,99
	I/2/3	148,81	45,80	194,61	30,61	13,86	10,56	373,50	3,25	39,84
	I/2/4	150,20	48,09	198,29	27,68	11,53	9,43	367,45	3,12	40,88
	I/2/5	152,95	50,58	203,53	26,45	13,53	16,43	351,70	3,02	43,49
	I/2/6	159,74	39,80	199,54	31,83	10,81	4,38	359,60	4,01	44,42
	I/2/7	172,65	29,40	202,05	32,30	8,50	5,54	347,90	5,87	49,63
	I/2/8	174,44	43,77	218,21	26,96	6,10	4,14	354,15	3,99	49,25
	I/2/9	176,44	27,66	204,09	26,96	5,40	2,27	347,35	6,38	50,80
	I/2/10	185,69	34,17	219,86	26,31	5,76	2,58	340,60	5,43	54,52
sewage sludge		169,73	105,38	275,11	14,27	3,53	13,64	339,15	1,61	50,04



7,0
6,5
6,0
5,5
5,0
4,5
4,0
3,5
3,0
2,5
2,0
1,5
PI index
series no. 2 (8-1-2)
series no. 1 (4-1-1)
0
20
40
60
80
100
120
140
day



series no.2 (8-1-2)
series no.1 (4-1-1)
HI index
day
56
54
52
50
48
46
44
42
40
38
0
20
40
60
80
100
120
140

Conclusions (preliminary) after I stage analysis

1. In comparison to the mixture (input) of sewage sludge with straw in mass proportion 4/1 (4-1-1), doubling the amount of sewage sludge to the level of 8/1 (8-1-2) results in the thermophilic phase (above 45°C) lasting 30 days longer.
2. The values of the HI and PI humification indexes in the compost samples in both prisms over the entire study period indicate a high degree of organic matter humification and its progress in the composting proces.
3. The contents of heavy metals in the sewage sludge do not increase the limits for their agricultural use.
4. The total content of Zn and Cu in samples of composts, classified as soil improver, taken from both prisms, exceeds the limit values, i.e:
   - prism 4/1: Zn= 453 > 300 mg/kg s.m.; Cu= 201 >100 mg/kg s.m.
   - prism 8/1: Zn= 555 > 300 mg/kg s.m.; Cu= 253 >100 mg/kg s.m.
5. Total content Zn i Cu in samples of composts excluding the forms permanently associated with the soil matrix (IV and V) - bio unavailable, is lower than the limit values, i.e:
   - prism 4/1: Zn= 230 > 300 mg/kg s.m.; Cu= 8,7 >100 mg/kg s.m.
   - prism 8/1: Zn= 270 > 300 mg/kg s.m.; Cu= 8,3 >100 mg/kg s.m.

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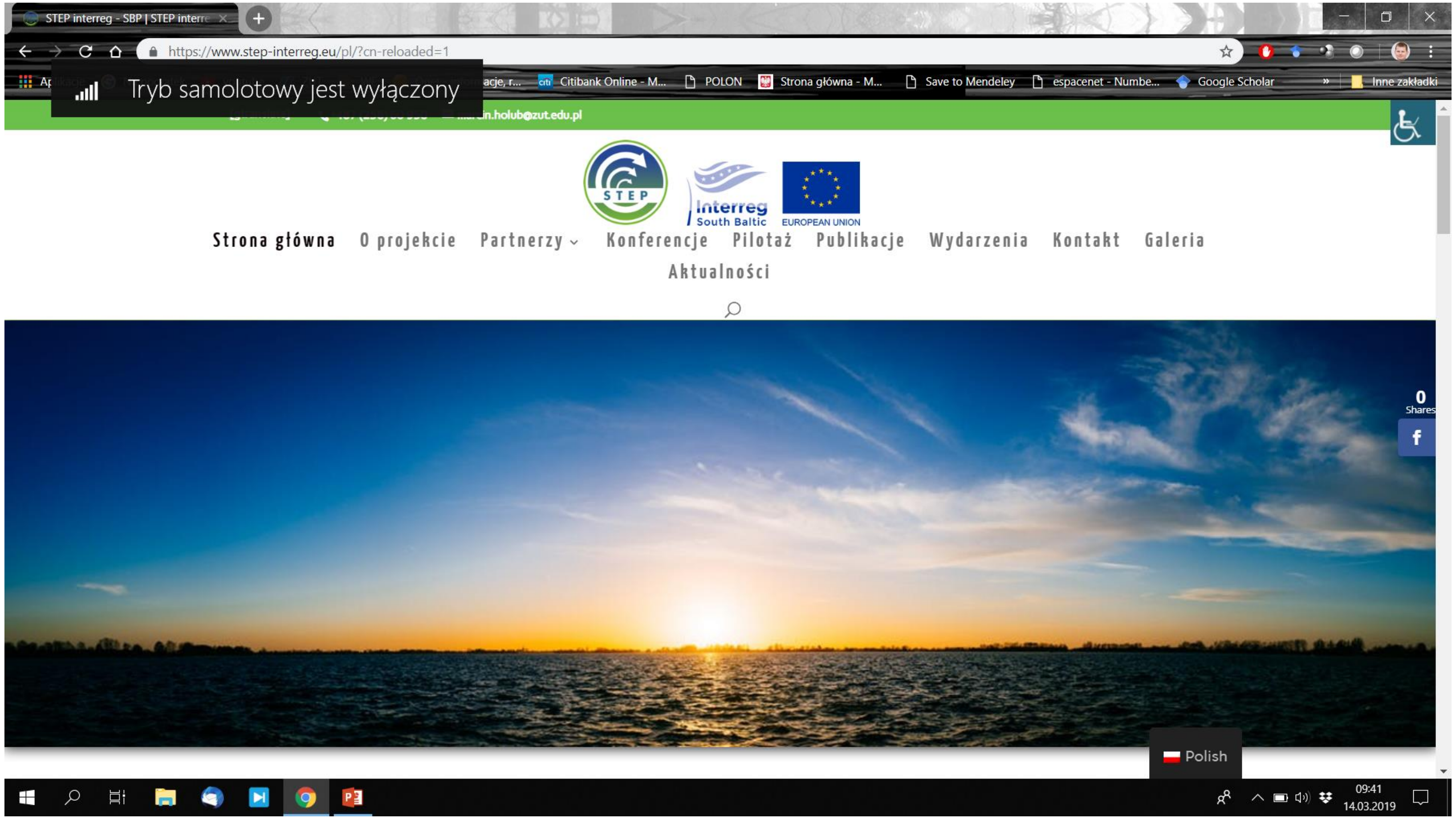

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Goleniowskie Wodociągi i Kanalizacja

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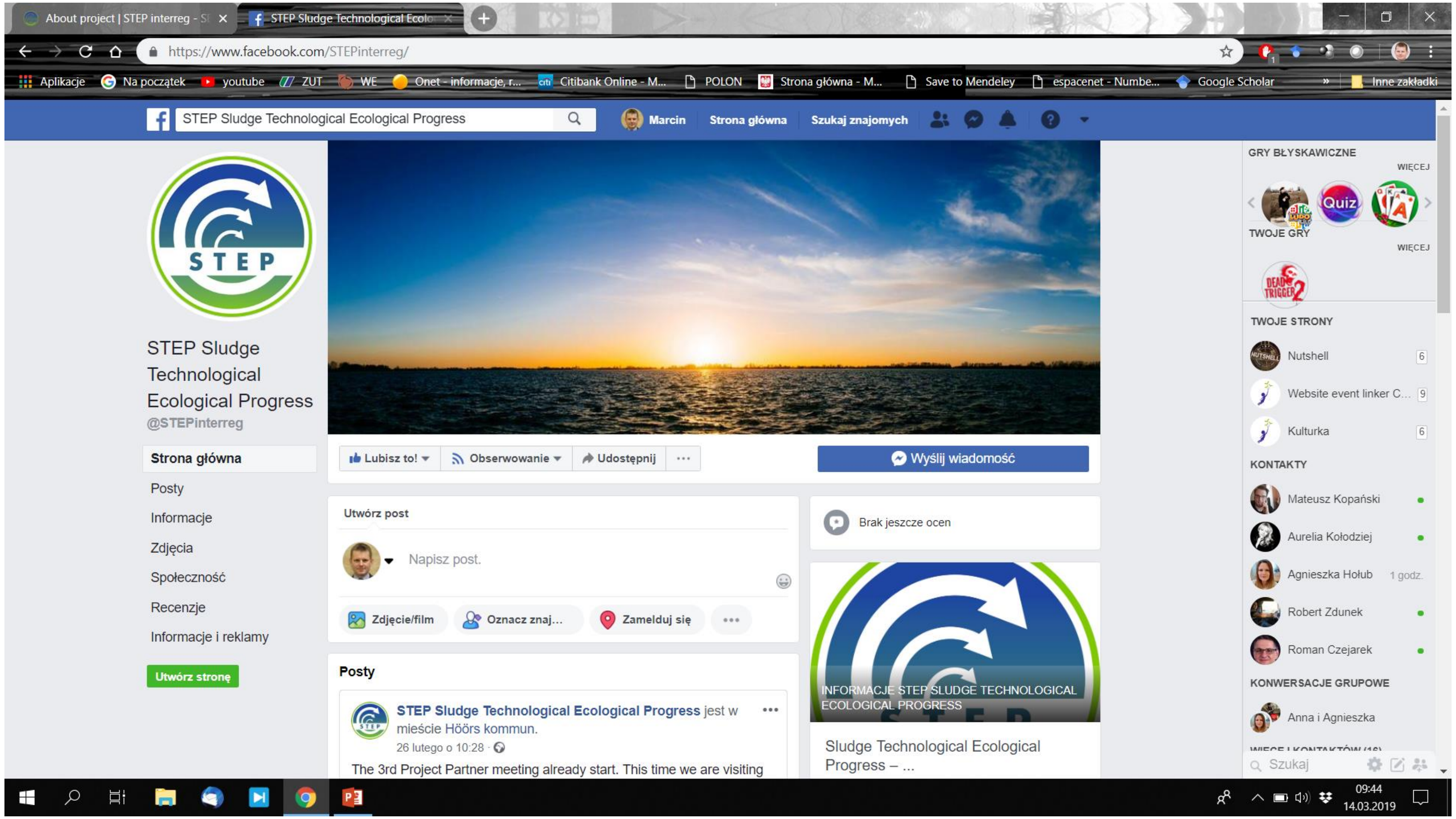

THANK YOU
FOR YOUR ATTENTION

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