



FKITMCMXIX

Sveučilište u Zagrebu  
Fakultet kemijskog  
inženjerstva i tehnologije



# Kompostiranje - Održivo rješenje za zbrinjavanje mulja?

Izv. prof. dr. sc. Dajana Kučić Grgić

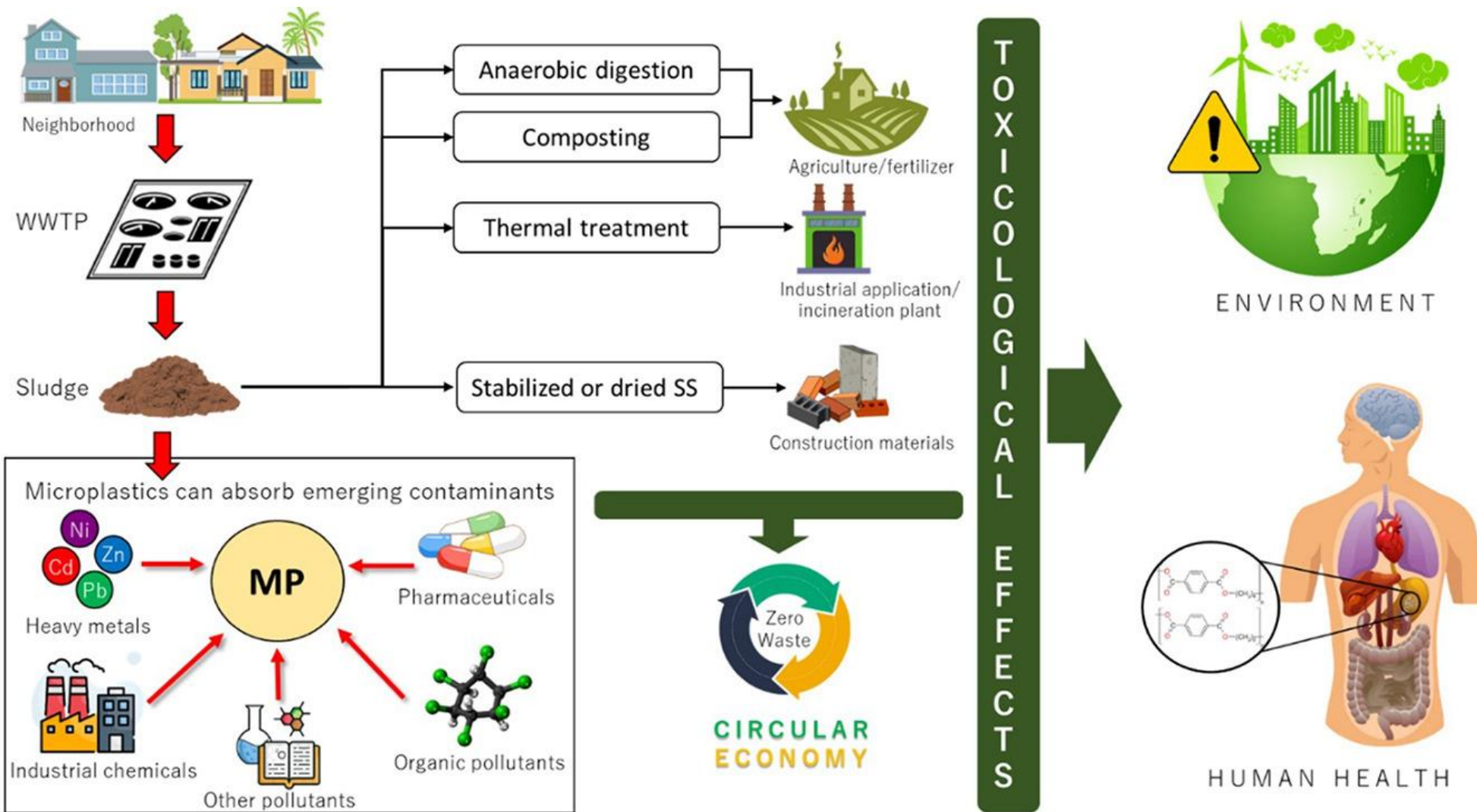
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Zavod za industrijsku ekologiju

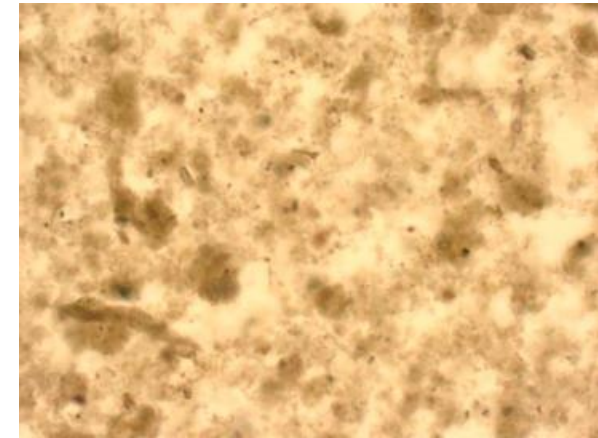
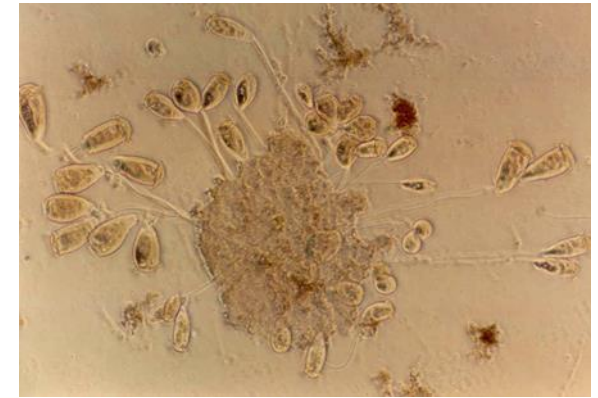
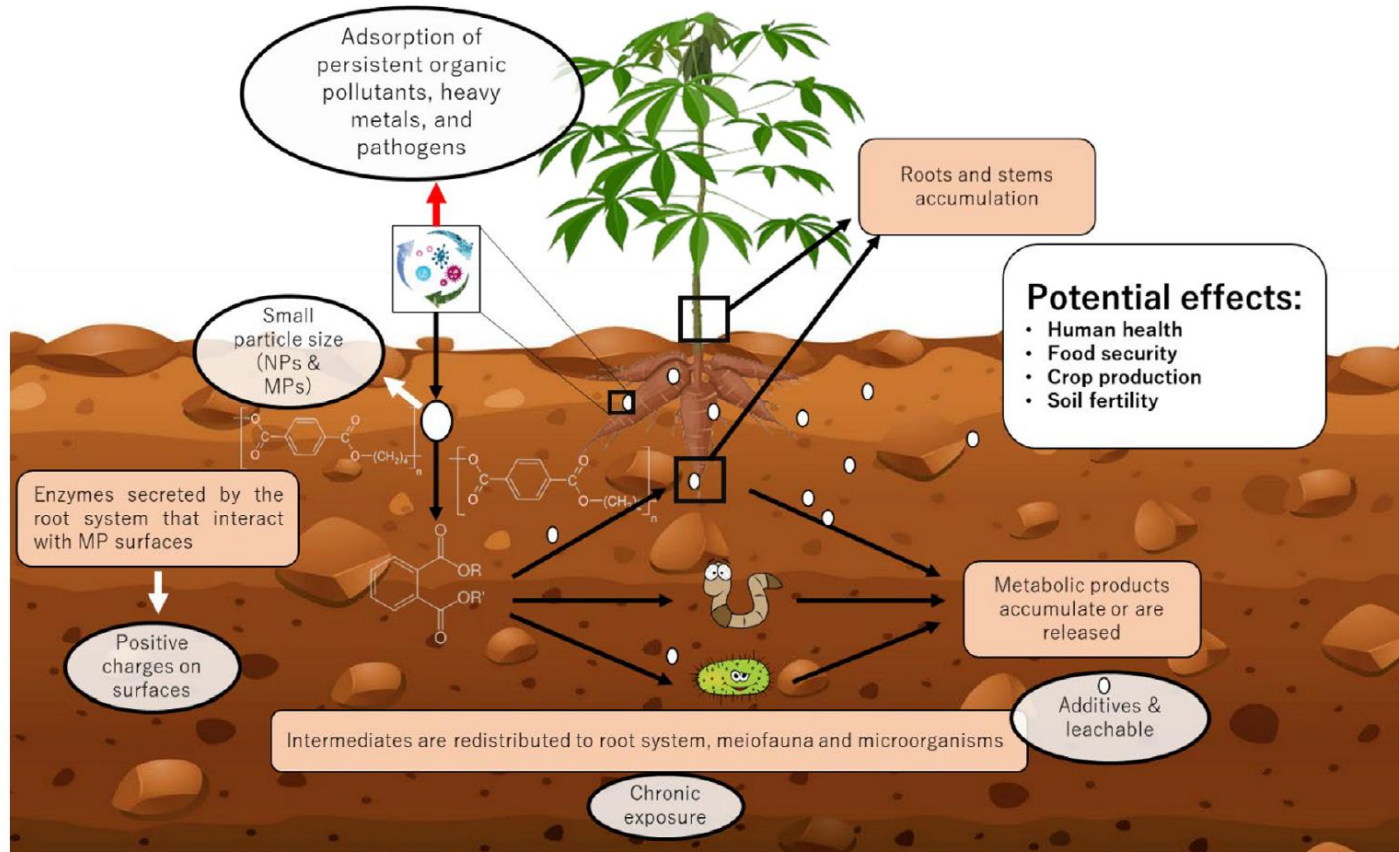
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# Mulj s pročištača odpadnih voda



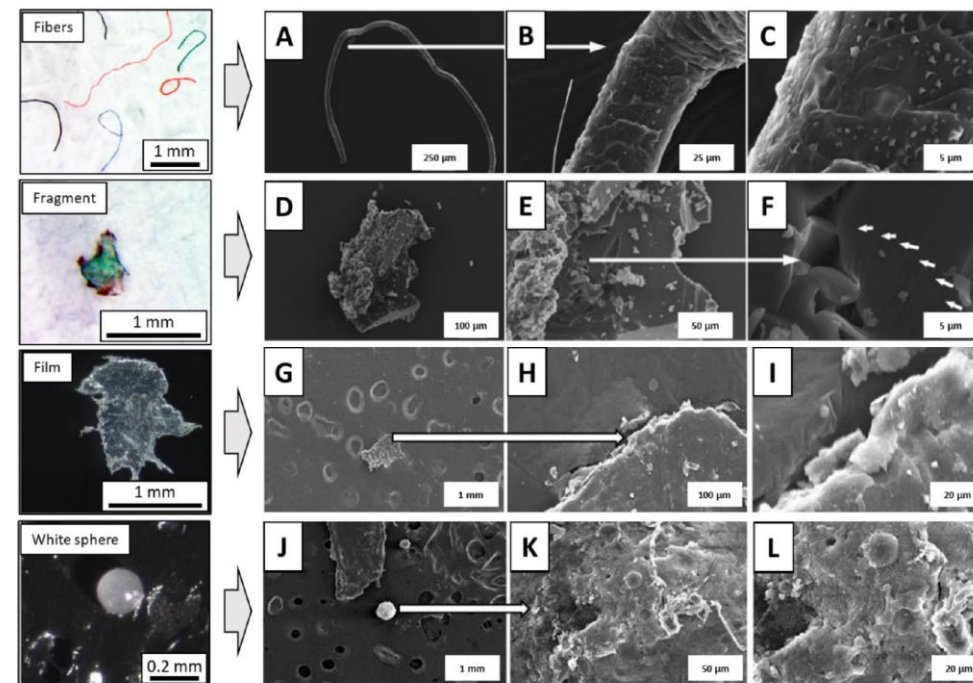
# Mulj s pročištača odpadnih voda



# Mulj s pročištača otpadnih voda

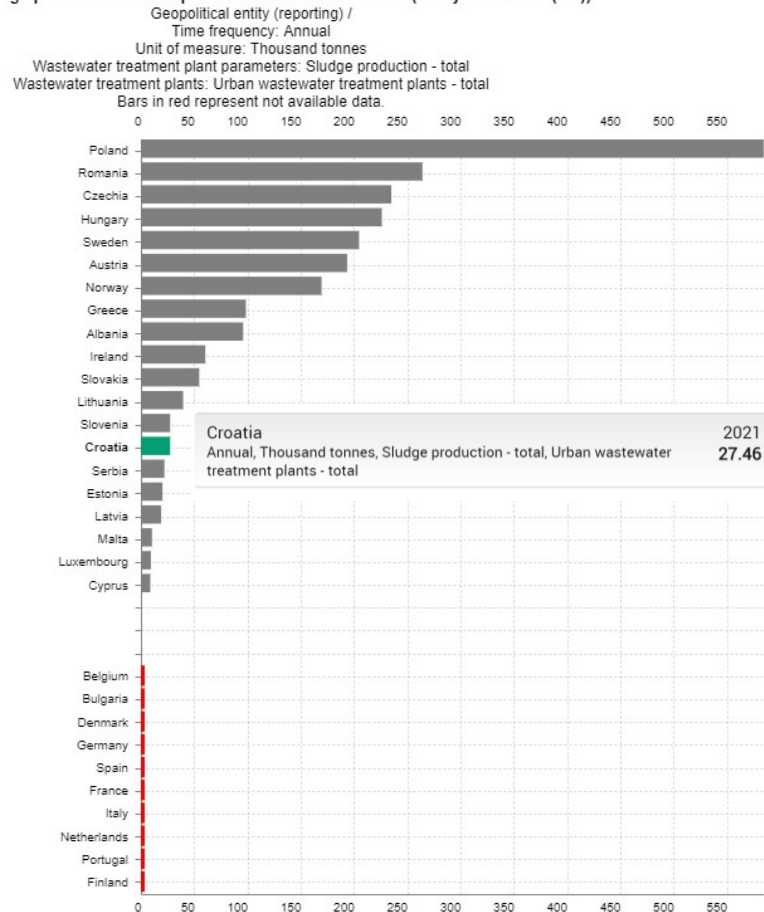
**Table 1**  
National characteristics of MPs contamination in sewage sludge.

Location	Treatment type	Trapping efficiency (%)	Sludge MP concentration	MP range analyzed ( $\mu\text{m}$ )	MP shape	Polymer	Reference
Italy	NR	84	113 particles $\text{g}^{-1}$ (DW)	10–5,000	Films, Fragments	Acrylonitrile, Polyethylene, Polyesters	Magni et al. (2019)
Netherlands	NR	72	370–950 particles $\text{kg}^{-1}$ (WW)	10–5,000	NR	NR	Leslie et al. (2017)
Finland	Anaerobic digestion	98	4.2–28.7 particles $\text{g}^{-1}$ (DW)	250–5,000	Fibers, Fragments, Spheres	Polyester, Polyethylene, Polyamide, Polypropylene	Lares et al. (2018)
Canada	NR	98	4.4 particles $\text{g}^{-1}$ (DW)	<5,000	Fibers, Fragments	NCR	Gies et al. (2018)
Germany	NR	NR	1,000–24,000 particles $\text{g}^{-1}$ (DW)	<500	NR	Polyethylene, Polypropylene, Polyesters	Mintenig et al. (2017)
Norway	NR	NR	1,701–19,837 particles $\text{g}^{-1}$ (DW)	50–5,000	Beads, fragments, fibers, glitter	Polyethylene, polyesters, polypropylene	Lusher et al. (2017)
Denmark	NR	NR	169,000 particles $\text{g}^{-1}$	20–500	NR	Polyethylene, nylon, polypropylene	Vollertsen and Hansen (2017)
Ireland	Various	NR	4,196–15,385 particles $\text{g}^{-1}$ (DW)	250–5,000	Fibers, fragments, films, spheres	HDPE, polyethylene	Mahon et al. (2017)
Sweden	Partial dewatering	>99,9	16,700 particles $\text{g}^{-1}$ (DW)	300–5,000	Only fibers were investigated	NCR	Magnusson and Norén (2014)
USA	Dewatering and anaerobic digestion	NR	4 fibers $\text{g}^{-1}$	NR	Only fibers were investigated	NCR	Zubris and Richards (2005)
Australia	Aerobic and anaerobic digestion	NR	996 microbeads $\text{kg}^{-1}$	<1,000	Only microbeads were investigated	NR	Wijesekara et al. (2018)
China	Various treatments	NR	1,565–56,386 particles $\text{kg}^{-1}$ (DW)	37–5,000	Fibers, shafts, films, flakes, spheres	Polyolefin, polyethylene, polyamide, polystyrene	Li et al. (2018)
Korea	Sludge thickening and dehydration	98	14.9 particles $\text{g}^{-1}$ (DW) and 9.6 particles $\text{g}^{-1}$ (DW)	106–5,000	Fragments, fibers	NR	Lee and Kim (2018)

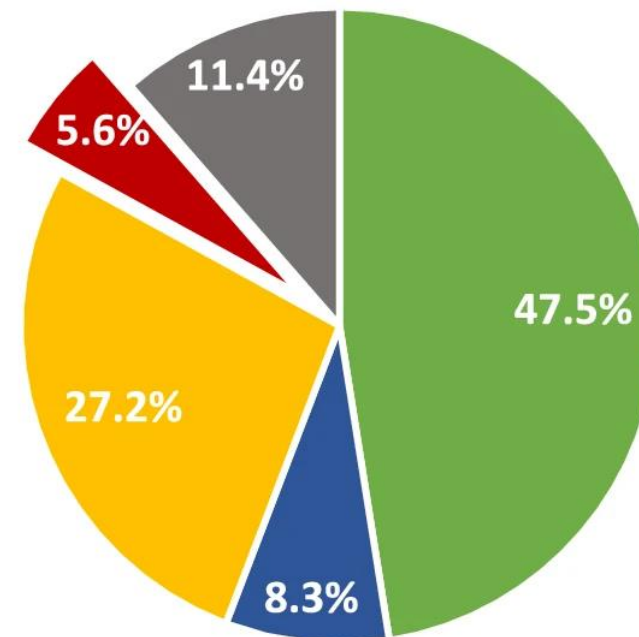


# Mulj s pročištača otpadnih voda (2021.)

Sewage sludge production and disposal from urban wastewater (in dry substance (d.s))



## Sludge fate in the EU (EurEau, 2021)



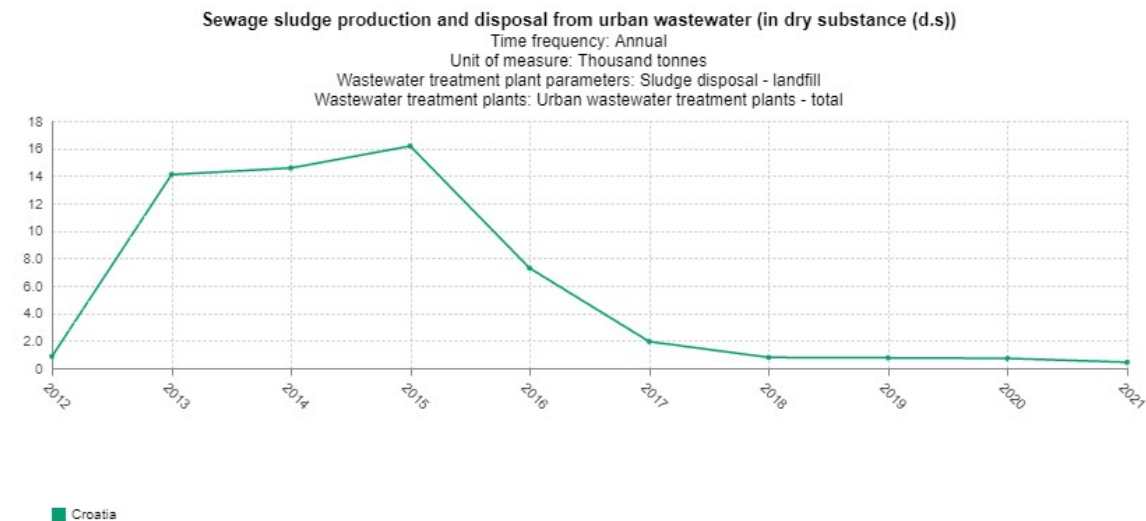
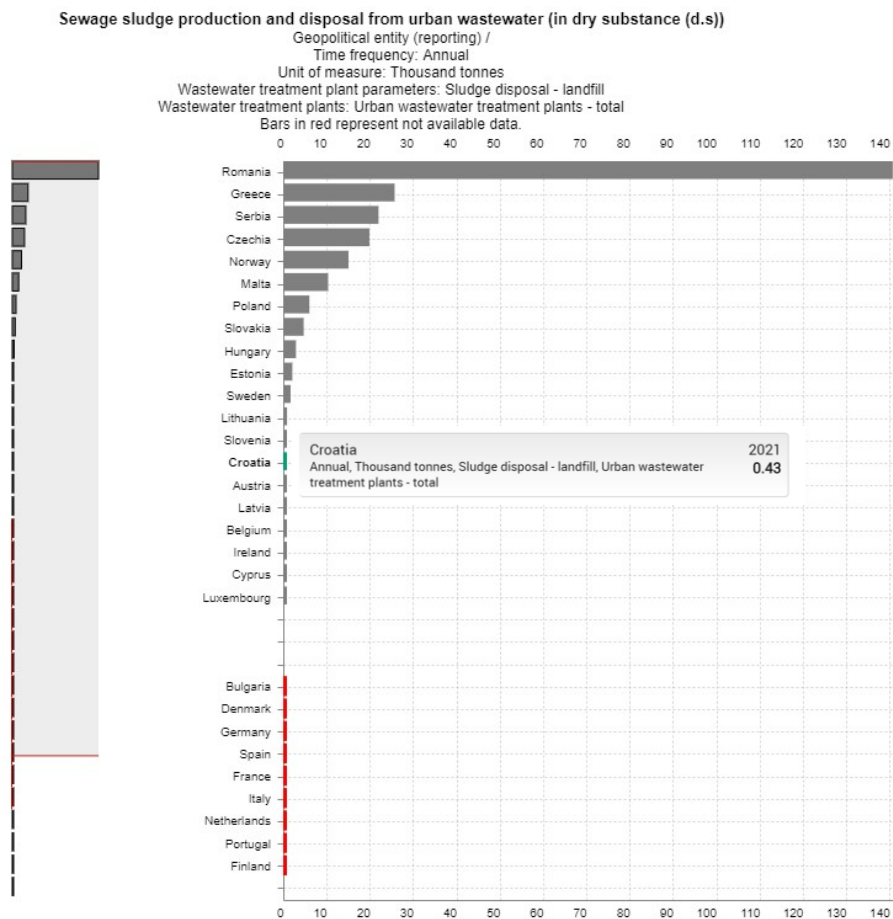
- Reused in agriculture
- Reused for recultivation
- Incineration
- Disposed on landfill
- Other

Source of data: Eurostat (online data code: ten00030)  
Last update: 03/01/2024 23:00

eurostat

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# Mulj s pročištača otpadnih voda (2021.) – odlaganje mulja na odlagalištu otpada



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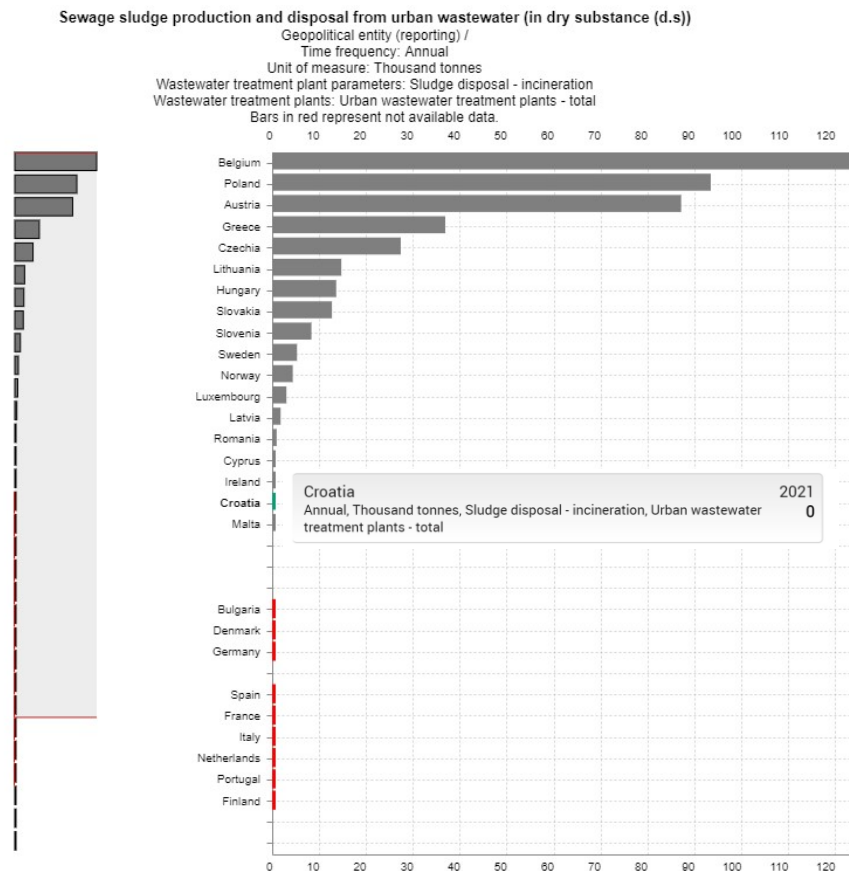
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# Mulj s pročištača otpadnih voda (2021.) – spaljivanje



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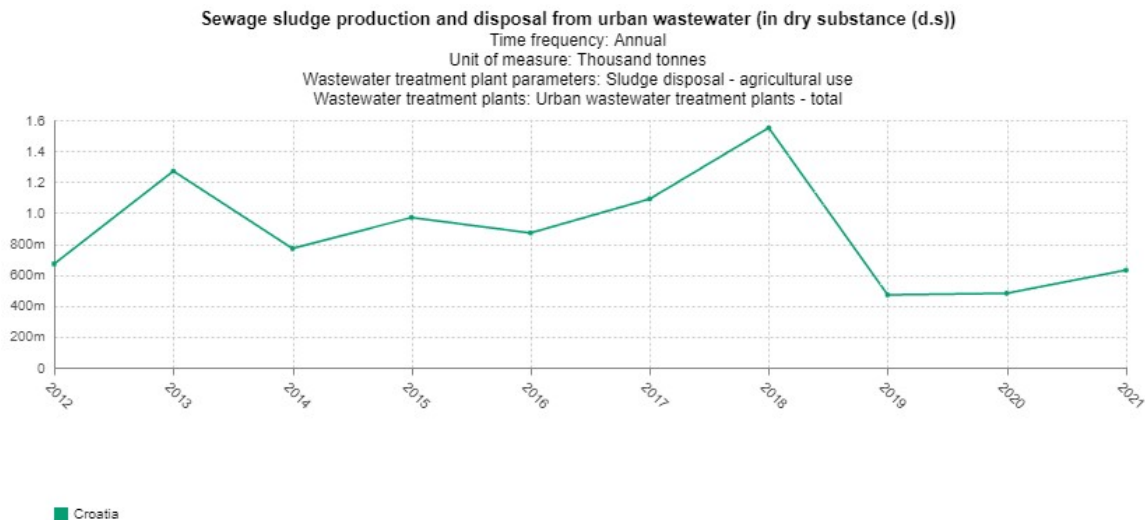
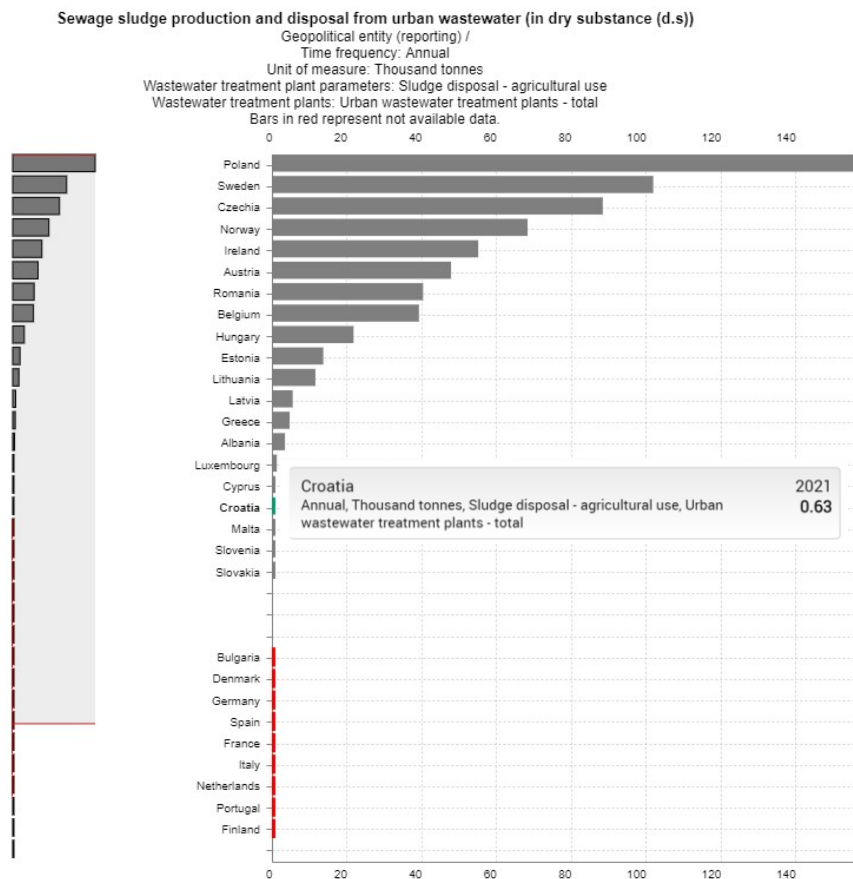
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# Mulj s pročištača otpadnih voda (2021.) – upotreba u poljoprivredi



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Source of data: Eurostat (online data code: ten00030)  
 Last update: 03/01/2024 23:00

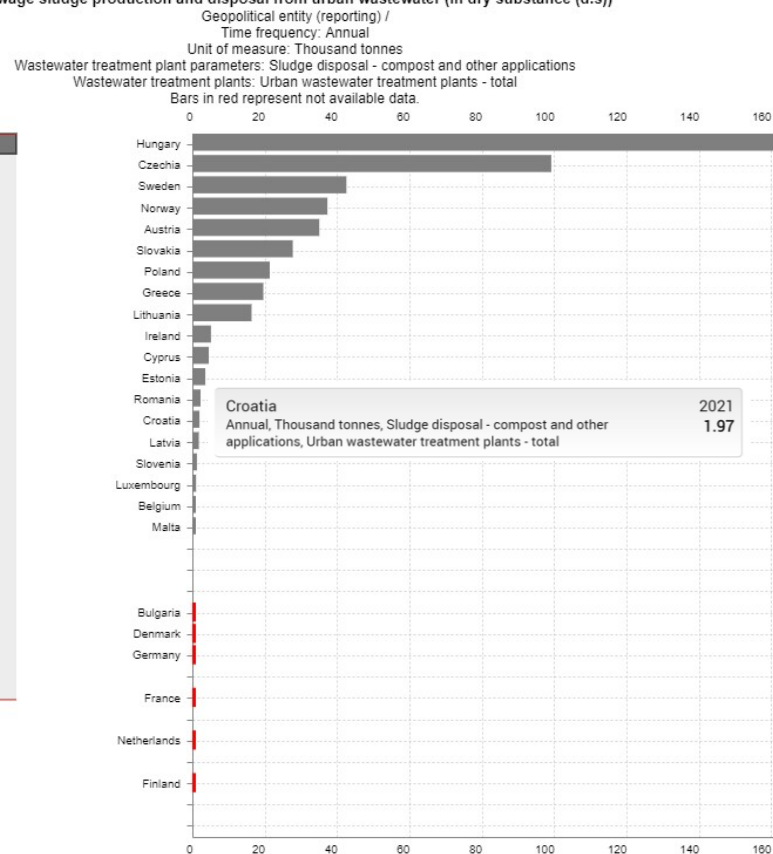
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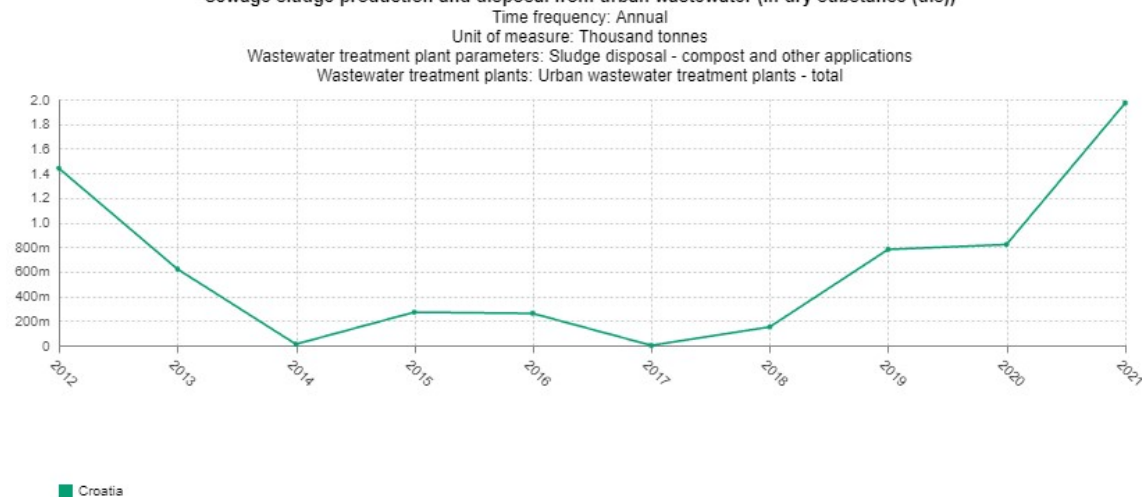


# Mulj s pročištača otpadnih voda (2021.) – kompost i druge primjene

Sewage sludge production and disposal from urban wastewater (in dry substance (d.s))



Sewage sludge production and disposal from urban wastewater (in dry substance (d.s))



Source of data: Eurostat (online data code: ten00030)  
Last update: 03/01/2024 23:00

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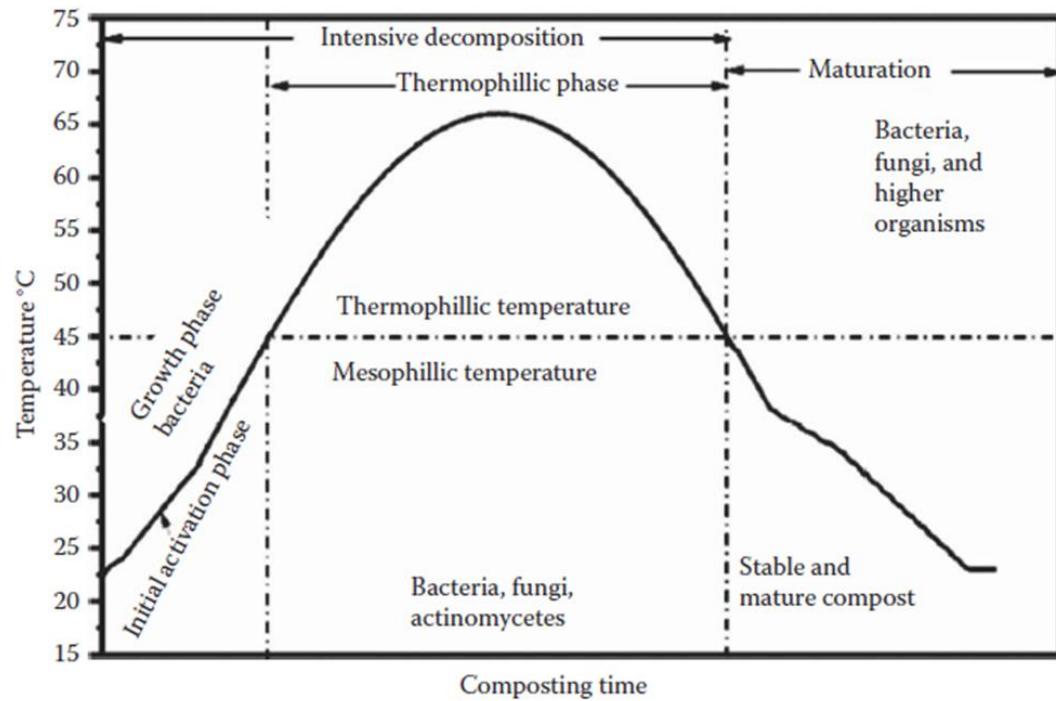
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Source of data: Eurostat (online data code: ten00030)  
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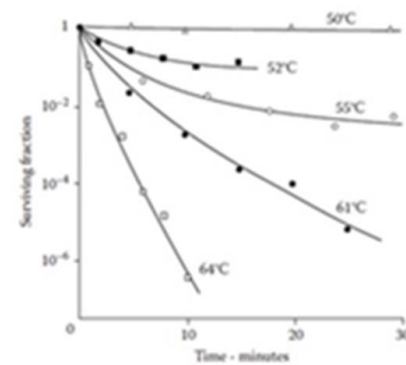
# Kompostiranje



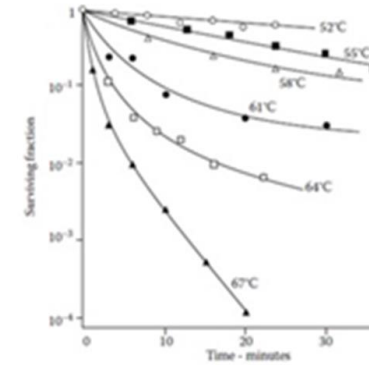
Rast mezofilnih gljiva (pljesni i kvasci) tijekom procesa kompostiranja



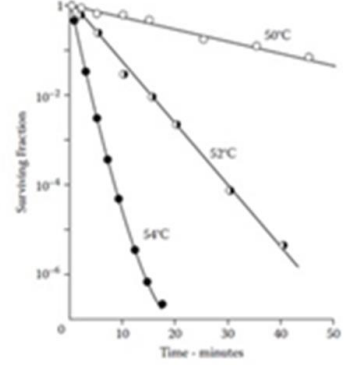
Rast mezofilnih bakterija tijekom procesa kompostiranja



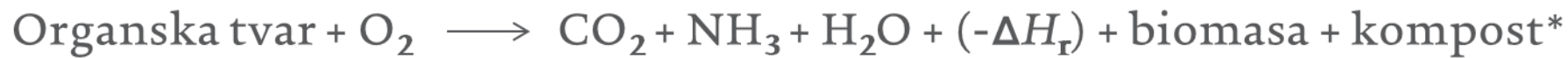
*E. coli*



*E. faecalis*

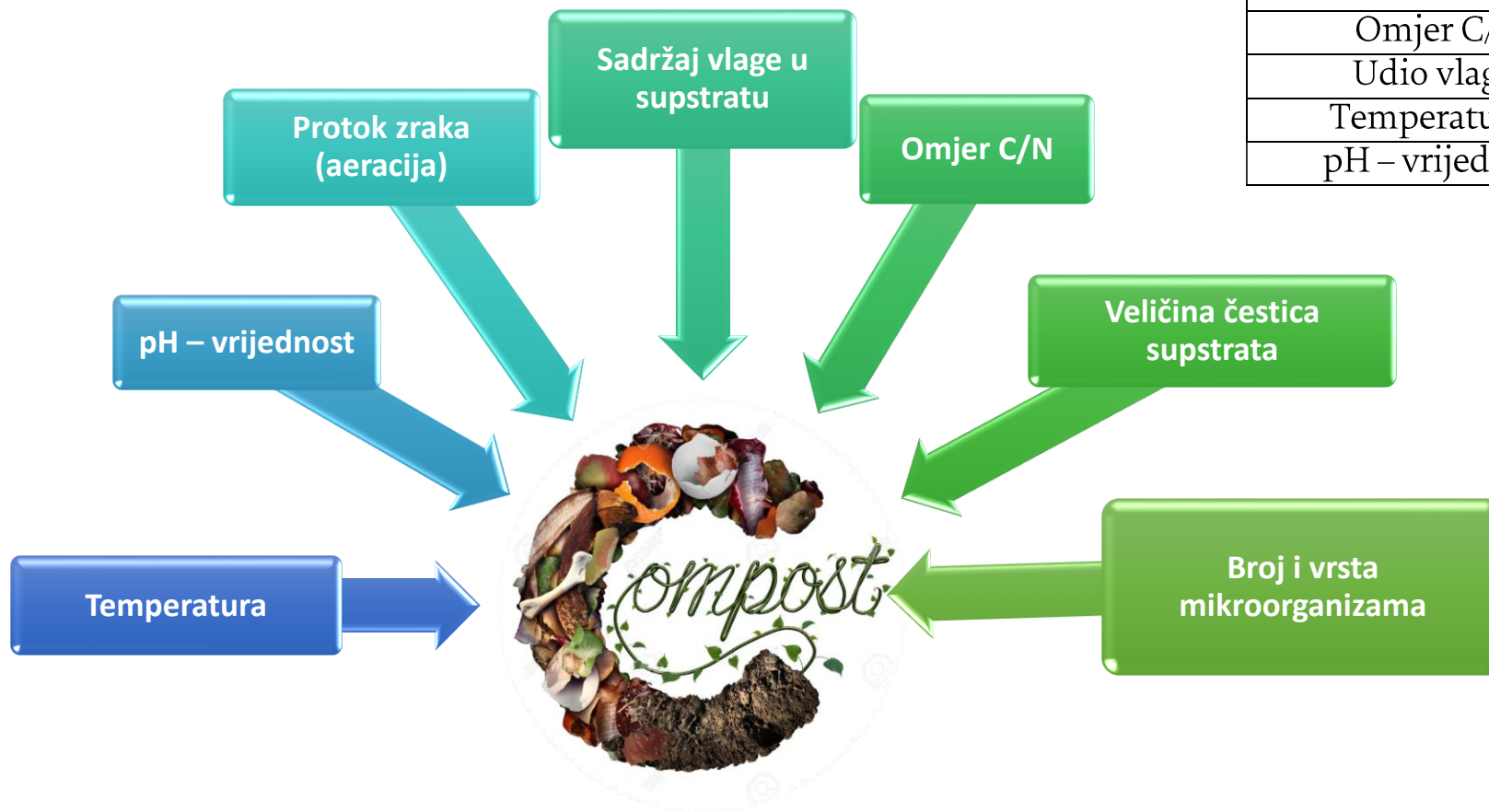


*Salmonella sp.*



# Čimbenici koji utječu na proces kompostiranja

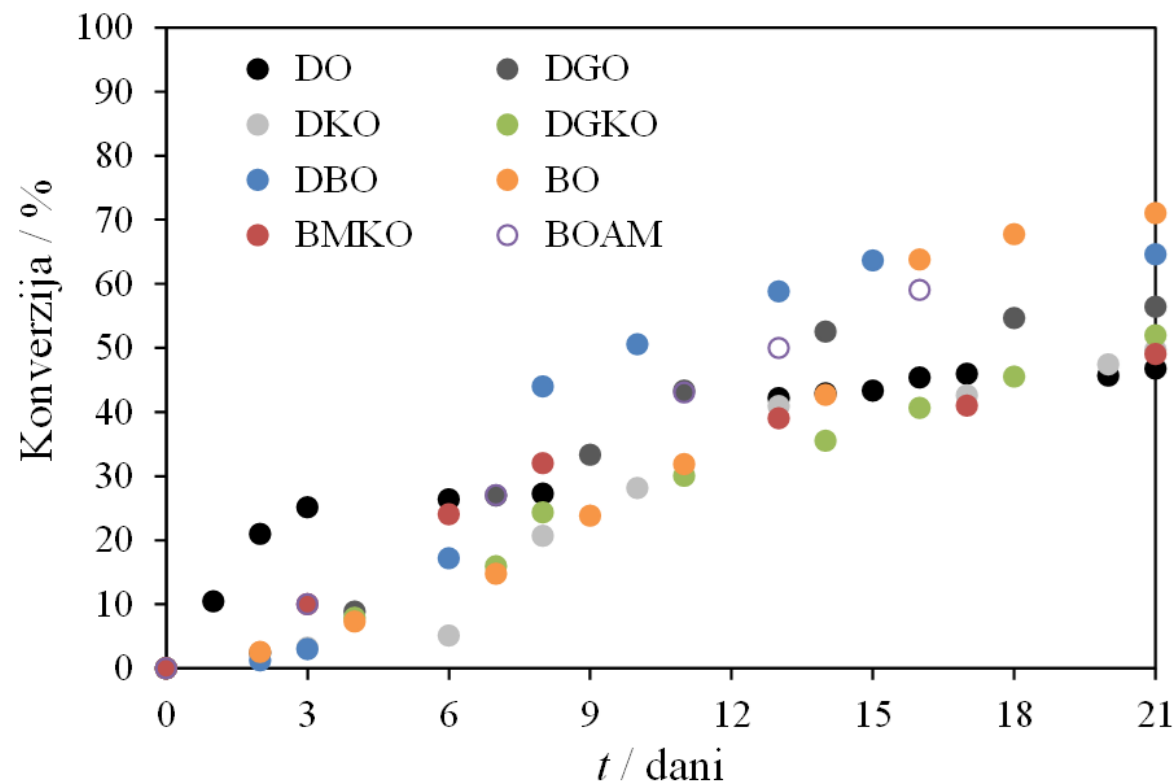
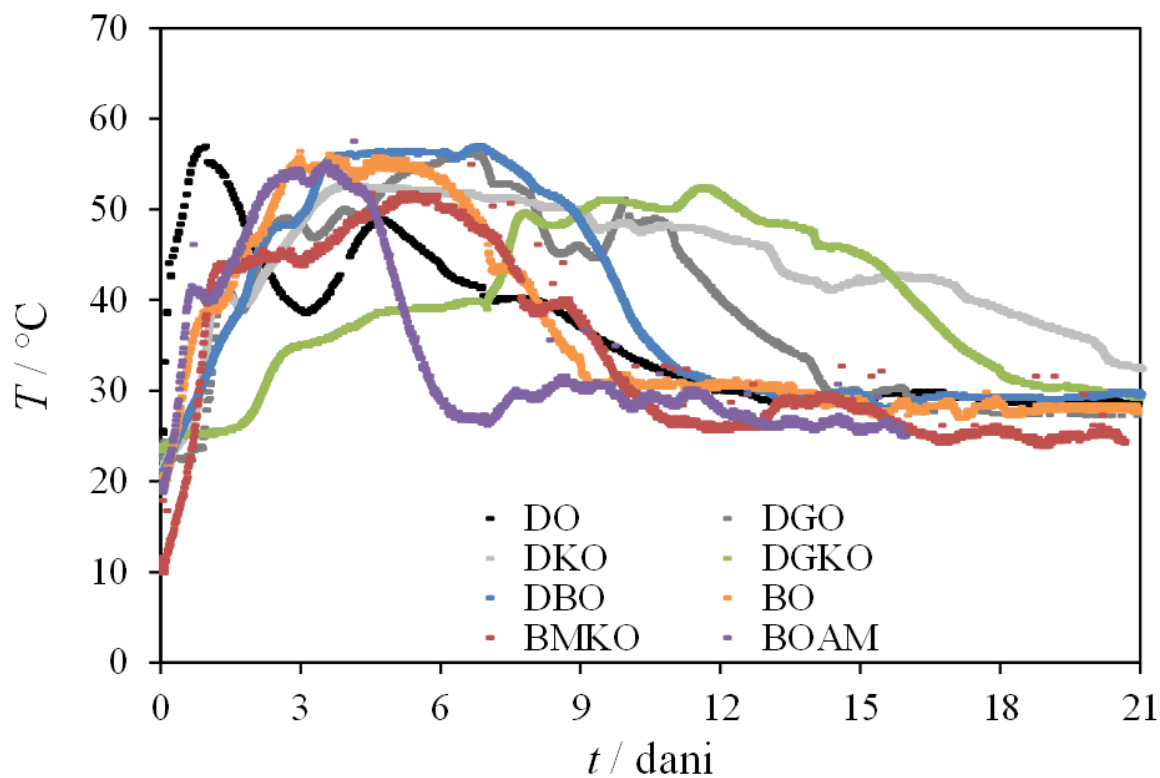
Čimbenici	Optimalne vrijednosti
Udio kisika / %	13 – 18
Veličina čestica / mm	10 – 50
Omjer C/N / -	25/1 – 35/1
Udio vlage / %	40 – 65
Temperatura / °C	55 – 65
pH – vrijednost / -	6.5 – 8.0



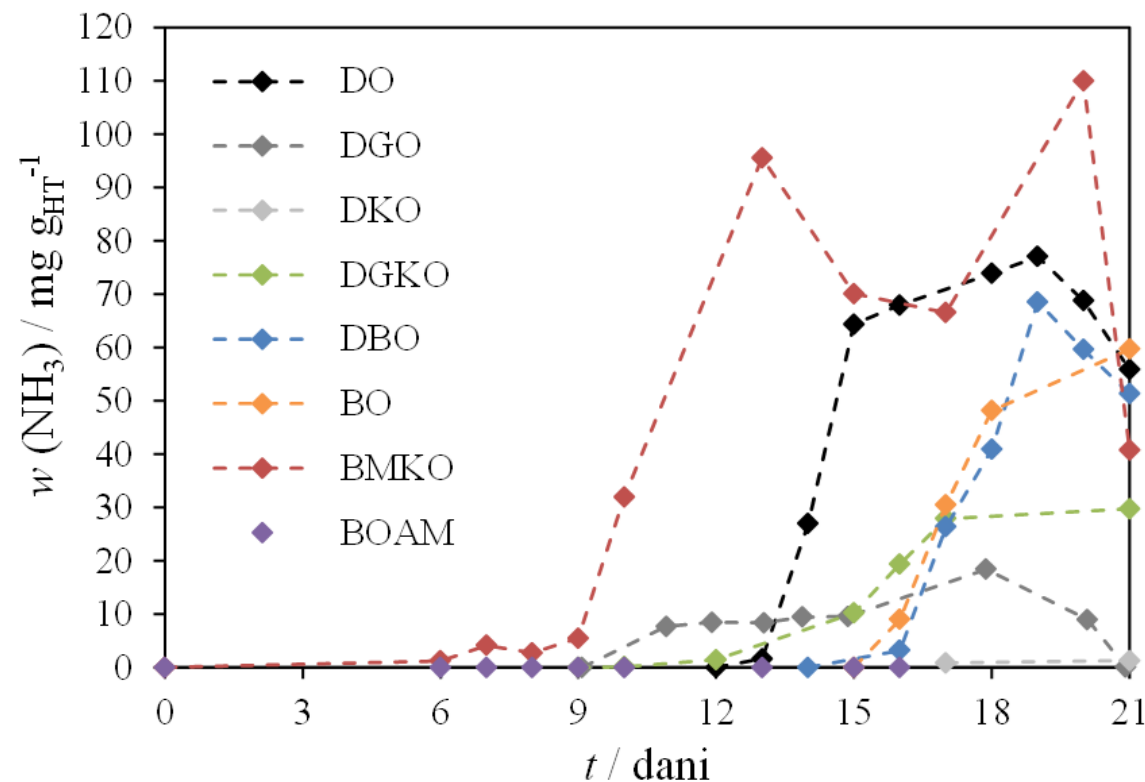
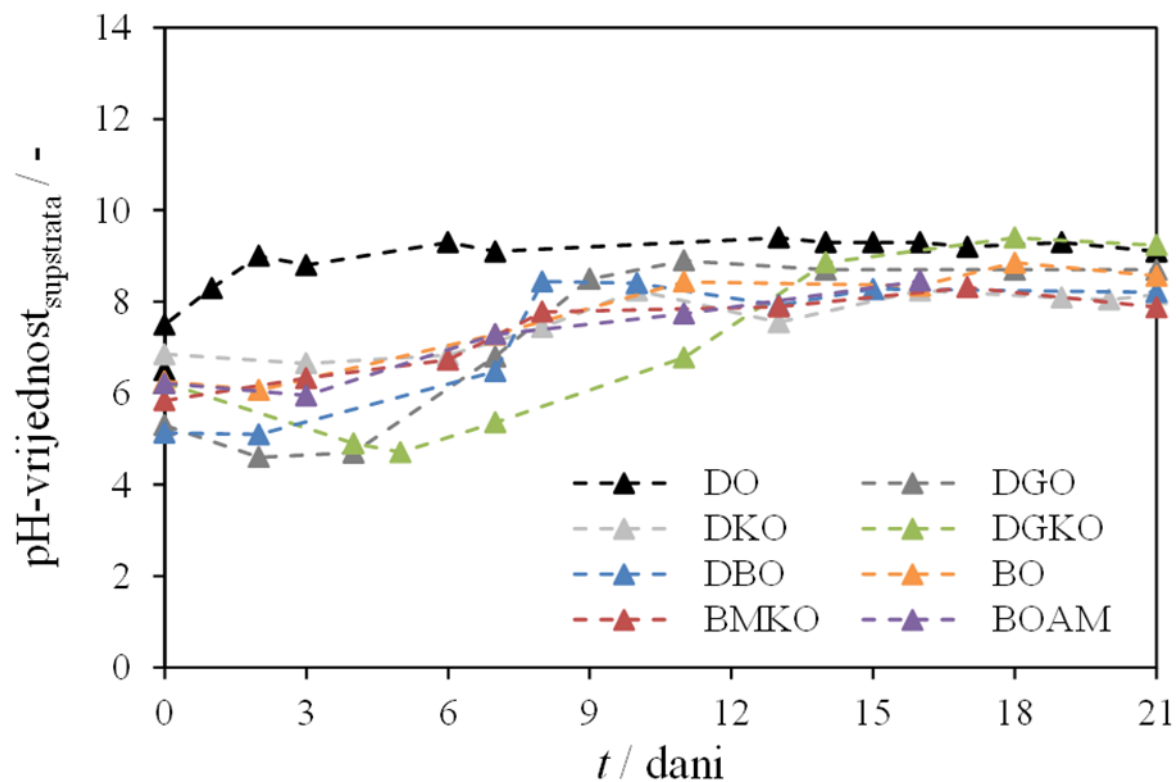
## Kompostiranje agroindustrijskog otpada, biootpada, mulja s pročištača otpadnih voda

	P1 (DO)	P2 (DGO)	P3 (DKO)	P4 (DGKO)	P5 (DBO)	P6 (BO)	P7 (BMKO)	P8 (BOAM)
$V(\text{reaktor}) / \text{dm}^3$	10							
$q_z / \text{dm}^3 \text{ min}^{-1}$	0,84							
$m_{(\text{vlažna tvar})} / \text{kg}$	4,5				4	2,5	4,5	2,5
$w(\text{suha tvar}) / \%$	40						37	32
$w(\text{hlapive tvari}) / \%$	78	87	85	82	85	87	85	83
C/N omjer /-	21/1	25/1	27/1	25/1	23/1	34/1	20	19
pH - vrijednost / -	6,50	5,31	6,45	6,23	5,13	6,26	5,84	6,21

# Kompostiranje agroindustrijskog otpada, biootpada, mulja s pročištača otpadnih voda



# Kompostiranje agroindustrijskog otpada, biootpada, mulja s pročištača otpadnih voda



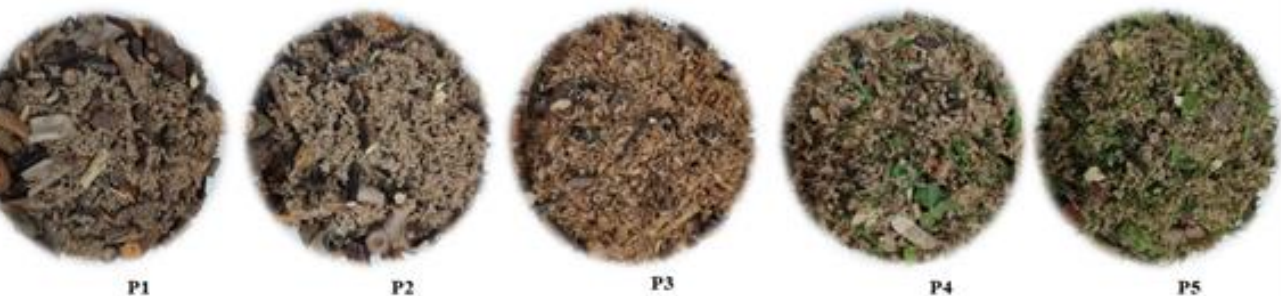
## Kompostiranje agroindustrijskog otpada, biootpada, mulja s pročištača otpadnih voda

	P1 (DO)	P2 (DGO)	P3 (DKO)	P4 (DGKO)	P5 (DBO)	P6 (BO)	P7 (BMKO)	P8 (BOAM)
w (H <sub>2</sub> O) / %	64	61	67	70	73	73	72	70
w (hlapiva tvar) / %	78	86	77	79	78	70	64	61
C/N omjer / -	9/1	12/1	14/1	17/1	13/1	10/1	12/1	7/1
pH - vrijednost / -	9,3	8,7	8,29	8,74	8,81	8,83	7,88	8,46
w (CO <sub>2</sub> ) / g kg <sub>HTO</sub>	101	141	115	122	138	186	298	344
w (NH <sub>3</sub> ) / mg kg <sub>HTO</sub>	436	71	2	88	249	147	429	0
X / %	47	56	50	52	65	71	49	59

# Kompostiranje mulja (primarni taložnik) s pročištača komunalnih otpadnih voda



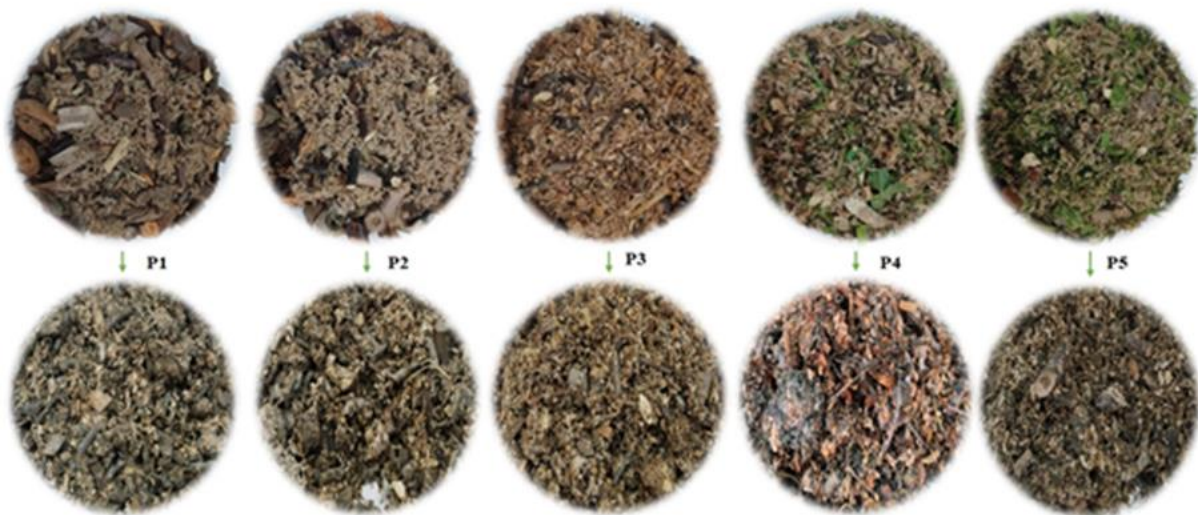
Mješavina supstrata na početku procesa kompostiranja



Eksp.	Mješavine	w / %	m (supstrata u reaktoru) <sub>vlažna tvar</sub> / g	q (zraka) / mL/min
P1	Mulj iz primarnog taložnika i strukturni materijal	<b>1:2</b> (200 g mulja i 400 g strukturnog materijala)	350	0,08 – 1,00
P2	Mulj iz primarnog taložnika i strukturni materijal	<b>1:1</b> (300 g mulja i 300 g strukturnog materijala)	370	
P3	Mulj iz primarnog taložnika, strukturni materijal i piljevina	<b>1:0.5:0.5</b> (300 g mulja, 150 g strukturnog materijala i 150 g piljevine)	350	
P4	Mulj iz primarnog taložnika, strukturni materijal, piljevina i svježa trava	<b>1:0.33:0.33:0.33</b> (300 g mulja, 100 g strukturnog materijala, 100 g piljevine i 100 g trave)	300	
P5	Mulj iz primarnog taložnika, strukturni materijal i svježa trava	<b>1:0.5:0.5</b> (300 g mulja, 150 g strukturnog materijala i 150 g trave)	350	

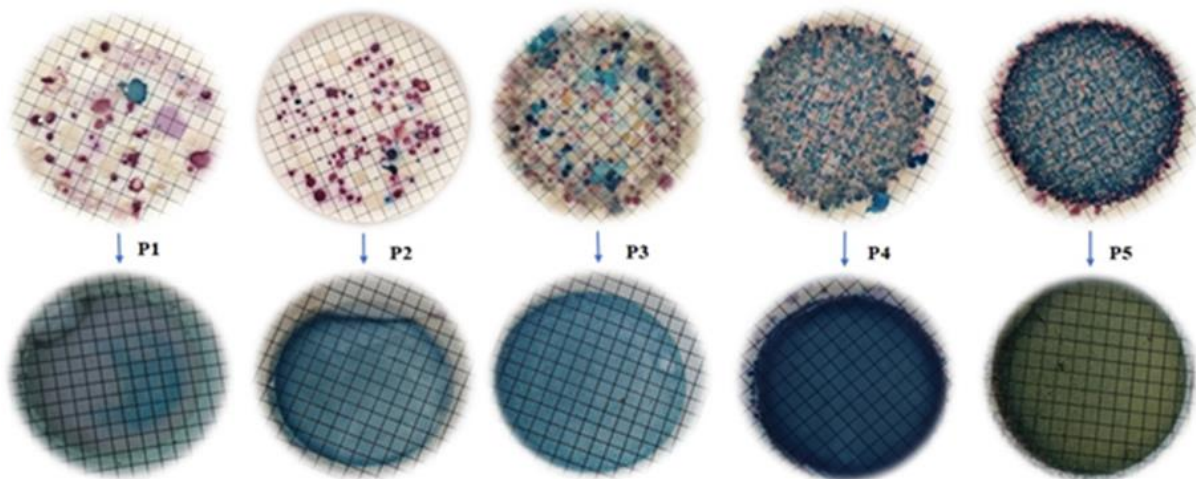


Mješavina supstrata na početku procesa kompostiranja

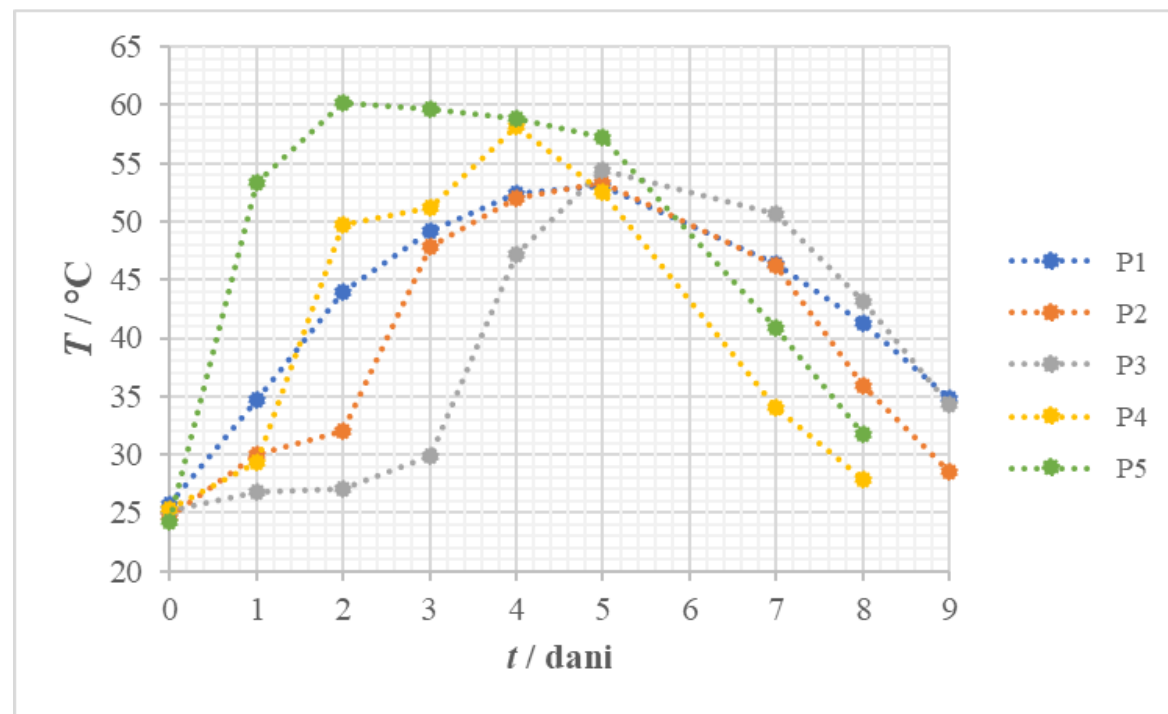


Mješavina supstrata na kraju procesa kompostiranja

Prisutnost *Escherichia coli* na početku procesa kompostiranja (plave kolonije)



Prisutnost *Escherichia coli* na kraju procesa kompostiranja (plave kolonije)



Eksperiment	P1		P2		P3		P4		P5	
t / dan	0	9	0	9	0	9	0	8	0	8
$m$ (supstrata) <sub>vlažna tvar</sub> / g	350,0	320,1	370,0	327,2	350,0	329,0	300,0	240,6	350,0	285,4
$m$ (supstrata) <sub>suha tvar</sub> / g	201,1	175,9	205,7	170,7	226,2	190,9	178,9	137,5	183,3	106,9
$m$ (supstrata) <sub>hlapiva tvar</sub> / g	182,2	156,1	185,6	144,9	188,2	122,9	150,9	101,0	164,8	75,9
w (vlage) / %	42,54	45,05	44,41	47,84	35,7	41,97	40,37	42,86	47,62	62,54
w (suhe tvari) / %	57,46	54,95	55,59	52,16	64,63	58,03	59,63	57,14	52,38	37,46
w (hlapive tvari) / %	90,61	88,78	90,21	84,89	83,2	64,35	84,35	73,50	89,91	71,05
Konverzija / %	14,30		21,92		34,72		33,03		53,92	
Maksimalna postignuta temperatura / °C	53,1		53,3		54,4		58,2		60,2	
pH-vrijednost <sub>supstrata</sub> / -	12,57	8,89	12,62	8,93	12,34	8,65	12,66	8,47	12,61	8,60
$\kappa$ / mS/cm	5,37	0,98	5,82	1,06	5,60	1,06	5,14	1,55	2,67	2,08
V (kondenzata) / mL	13,5		33,5		6,5		12,0		25,0	
pH-vrijednost <sub>kondenzata</sub> / -	7,65		8,36		7,76		8,7		8,73	
mg CO <sub>2</sub> /g <sub>HT</sub>	68,24		62,79		71,92		92,02		110,02	
mg NH <sub>3</sub> /g <sub>HT</sub>	0		0		0		0		0	
TU <sub>eluata (supstrat)</sub> / %	>100	>100	>100	>100	>100	2,46	>100	3,87	>100	2,32
Kategorizacija toksičnosti	vrlo visoko toksično	vrlo visoko toksično	vrlo visoko toksično	vrlo visoko toksično	vrlo visoko toksično	toksično	vrlo visoko toksično	toksično	vrlo visoko toksično	toksično



Hvala na pažnji!