“LA SOSTENIBILITA’ DEI FANGHI BIOLOGICI IN AGRICOLTURA

NELL’ERA DELL’ECONOMIA CIRCOLARE E DELLA RESILIENZA”

Fanghi biologici e Economia Circolare

F. Adani

GRUPPO RICICLA

Università degli Studi di Milano - DiSAA

Agriculture and Environment Lab. ; Biomass and Agroenergy Lab. ; Bioeconomy and Green Chemistry Lab.

Via Celoria, 2 20133 Milano, Tel. 02-50316546, Fax. 02-50316521

Web site: http://users.unimi.it/ricicla/

Adjunct Professor, National Center for International Research of BioEnergy, Science and Technology (iBEST), *China Agricultural University (China)*

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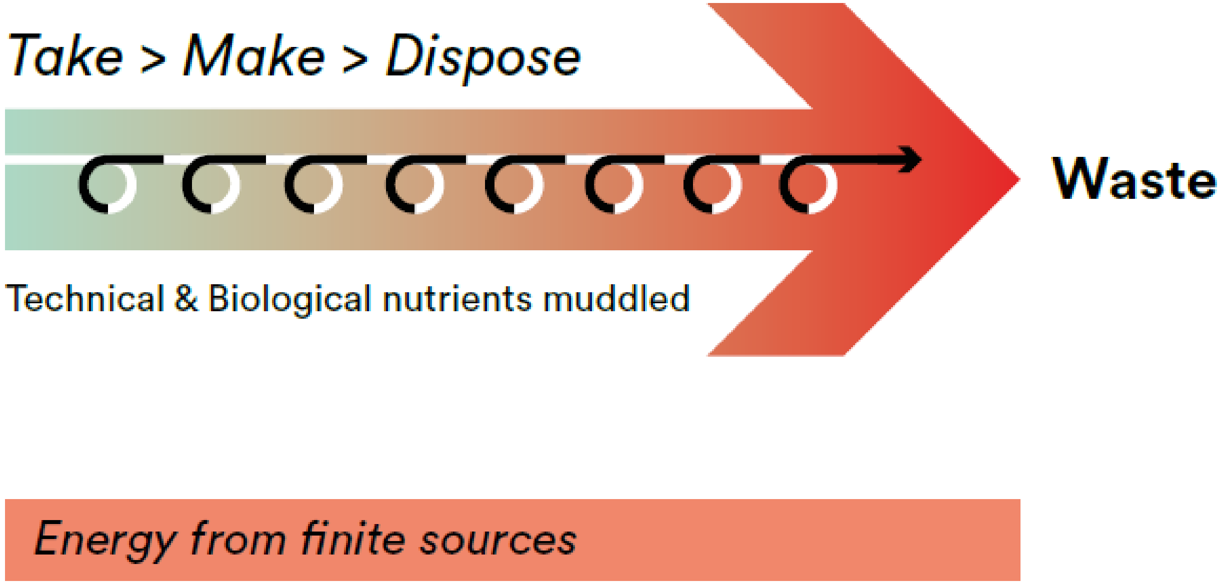
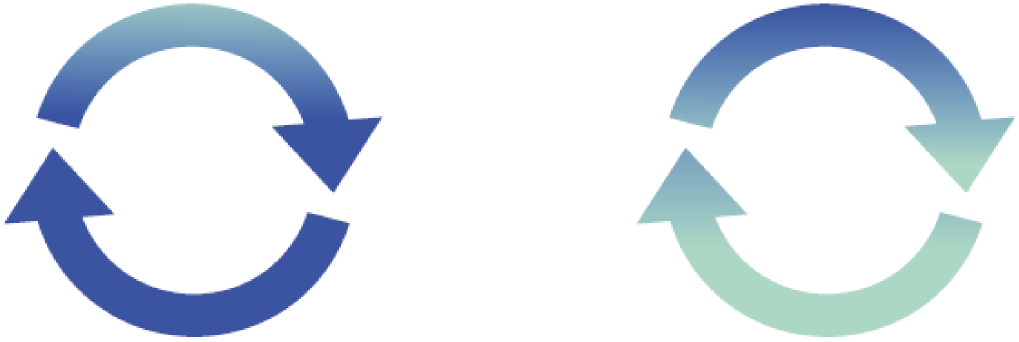
Linear Economy



After Ellen MacArthur Foundation, 2013

Circular Economy

Technical nutrients *Biological nutrients*



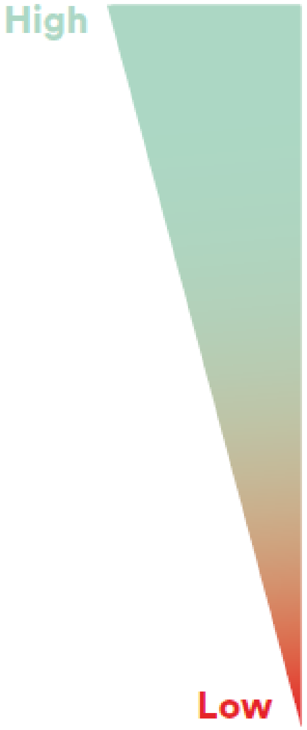
Making use of energy from renewable sources

Safeguarding the resilience of natural ecosystems

After Ellen MacArthur Foundation, 2013

Levels of circularity: 10 R's

Order of priority



Refuse: Prevent raw materials' use

Reduce: Decrease raw materials' use

Redesign: Reshape product with a view to circularity principles

Reuse: Use product again (as second hand)

Repair: Maintain and repair product

Refurbish: Revive product

Remanufacture: Make new from second hand product

Re-purpose: Reuse product but with other function

Recycle: Salvage material streams with highest possible value

Recover: Incinerate waste with energy recovery

11 *Cramer, J., The Raw Materials Transition in the Amsterdam Metropolitan Area: Added Value for the Economy, Well-Being and the Environment, Environment, 2017, 59, 3, 14-21, https://doi.org/10.1080/00139157.2017.1301167.*

L'Economia circolare implica un ripensamento completo della filiera produttiva.

Transforming linear into circular products implies not only technical innovation, but also a completely new organisation of product chains. As the raw materials and components should be apt for reuse and recycling, other types of suppliers must get involved. In the manufacturing stage, the production process must be carefully adjusted to the prescribed redesign requirements and, after use, a collection, take-back and/or reuse system should be available to give the product a second life. When the product cannot be reused, the resources should be recovered with the highest potential value and returned to the producer making new products from the reclaimed resources. To create a viable business case, a new financial arrangement that is economically attractive to all involved parties is often needed.

Cramer, 2022

…che coinvolga tutti gli attori……con un “pensiero circolare”

These different steps in redesigning, reusing and recycling cannot be organised by one individual company; all stakeholders must make a contribution. This requires alignment with suppliers, to access inputs or components with environmentally friendly features, and with customers further down the product chain. As this also requires new information and skills (e.g. ecodesign and life cycle thinking), cooperation with institutions, such as universities, consultancies and research centres is also important. Moreover, governments are often needed to set the necessary preconditions. Besides removing economic and legal obstacles and facilitating circular initiatives through innovation funds and other means, the government can also help promote circular products as a launching customer. Finally, civil society and business customers can play a role in the adoption of the circular product.

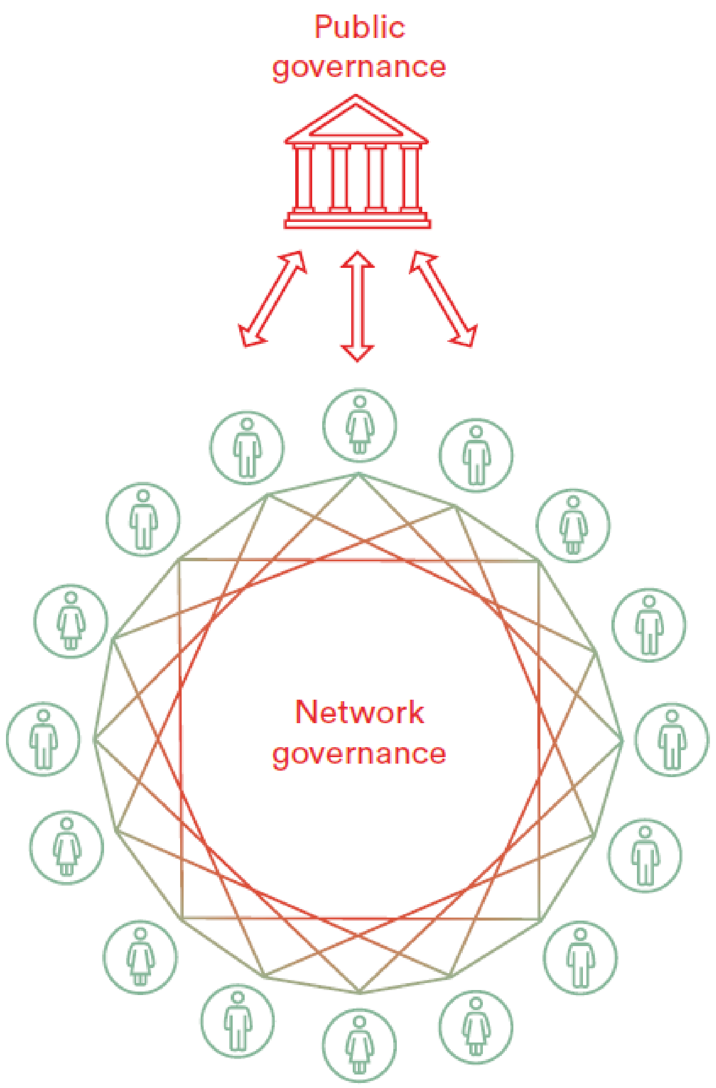
Cramer, 2022

L'Economia circolare non accade da sola, ma tutti gli stakeholder assieme devono volerla.

Thus, the circular economy concerns system changes in neighbourhoods, cities, regions and product chains, which means that governments, producers and consumers must adapt. It is a collective process: not one company, one citizen or one governmental body can make the change alone. Preparing the system's transformation to the circular economy requires alignment and cooperation between different stakeholders. It starts with frontrunners taking the lead; afterwards, practices should be scaled up and mainstreamed. This process does not happen by itself; it requires a new form of governance called network governance in which different stakeholders align and cooperate to make the change jointly from one system to another – in this scenario, from a linear to a circular economy. A transition broker is often needed to orchestrate this process.

Cramer, 2022

Relation between public governance and network governance



L'economia Circolare coinvolge tutti ……………..

…….e questo convegno ne è la prova

Perché una tale premessa?

Se è innegabile ed assodato il ruolo positivo del recupero dei fanghi in agricoltura sulla fertilità dei suoli.

L'effetto di fanghi sul contenuto di C e biomassa nei suoli

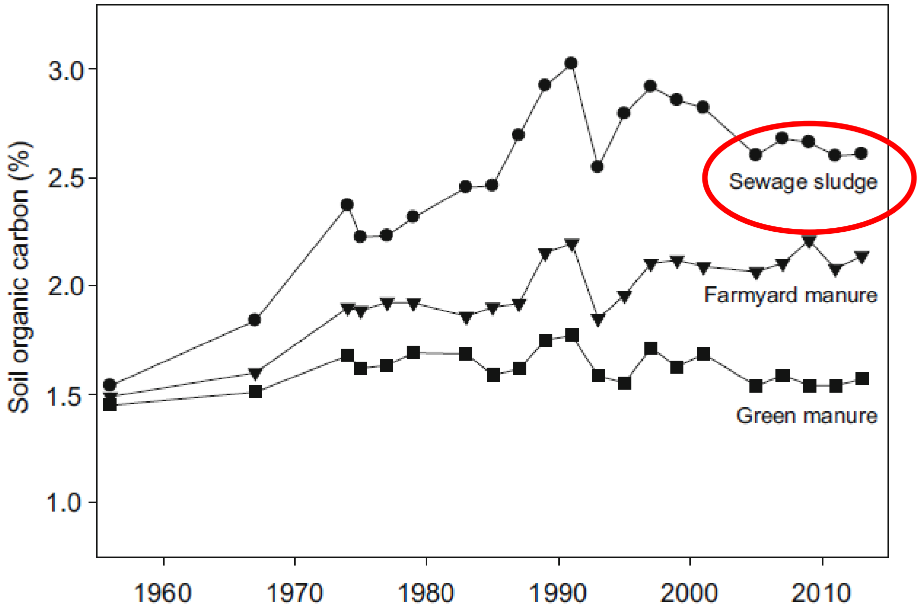
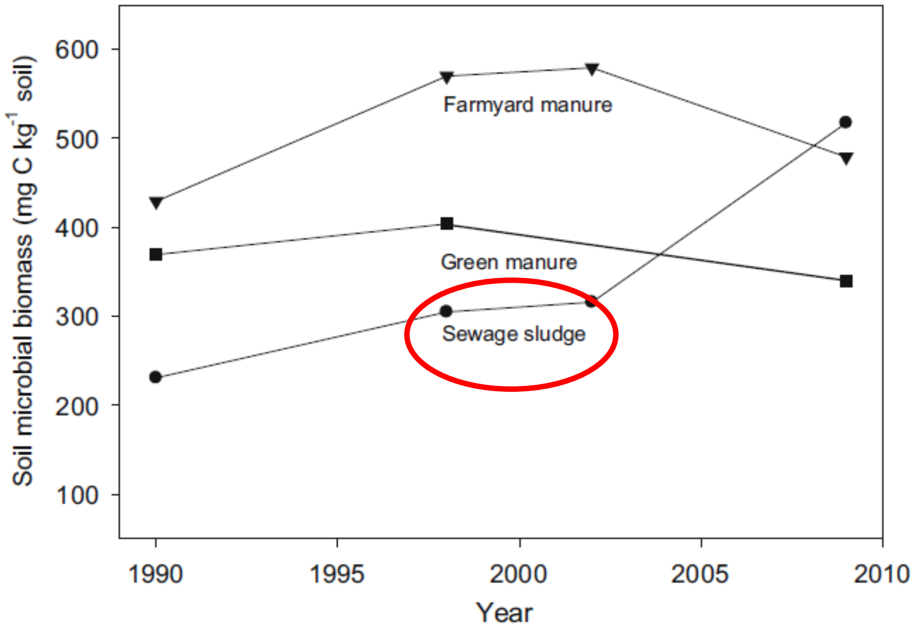


Fig. 2 Changes in (*upper diagram*) soil organic carbon and (*lower diagram*) soil microbial biomass in the topsoil (0–20 cm) of the Ultuna field experiment over time. Note the reverse in trend in the sewage sludge-treated soil since 1990 to a decline in organic carbon and an increase in microbial biomass. Estimates of soil microbial biomass carbon were derived from previous publications using different methods. The following conversion factors were applied to obtain the same units of soil microbial biomass: 1990: ATP (Witter et al. 1993), 1 µg $C = 170.94$ µg ATP (Tate and Jenkinson 1982); 1998: dsDNA (Marstorp et al. 2000), 1 µg $C = 6.0$ µg DNA (Joergensen and Emmerling 2006); 2002: SIR (Enwall et al. 2007), 1 µg $C = 40.04$ ml CO_2 h^{-1} + 0.37 (Anderson and Domsch 1978); we assumed that 1 mg CO_2–C is equivalent to 1.868 ml CO_2 under standard conditions (0 °C and 1 atm). 2009: PLFAs (Börjesson et al. 2012), 1 µg C = 5.8 nmol PLFA (Joergensen and Emmerling 2006)



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Kirchmann t al., 2017

Effetto agronomico dei fanghi

Table 1 Yield, *N* use efficiency, soil balances of *N* and *P* and bulk density in the four Swedish long-term field experiments with sewage sludge

Site, years and soil treatments	Mean yield	Nutrient application		Nutrient removal		*N* use efficiency[a]	Δ*N* in soil	Δ*P* in soil	Bulk density (2009)
		N	*P*	*N*	*P*				
	kg ha^{-1}	kg ha^{-1} year^{-1}		kg ha^{-1} year^{-1}		% of added *N*	kg ha^{-1} year^{-1}	kg ha^{-1} year^{-1}	kg dm^{-3}
Ultuna 2002–2009									
Control	3329	0	20	35	8	–	−35	+12	1.43
Mineral fertilised	7176	80	20	95	15	75	−15	+5	1.28
Sewage sludge treated, 4 Mg C ha^{-1} every 2nd year	9719	276	233	146	19	40	+131	+215	1.02
Lanna 1996–2009									
Control	1316	0	0	19	4	–	−19	−4	1.38
Mineral fertilised	3407	80	20	57	11	55	+23	+9	1.36
Sewage sludge treated, 8 Mg dry matter ha^{-1} every 2nd year	3450	236	194	63	12	19	+173	+183	1.30
Igelösa 2006–2009									
Control	4038	0	0	96	26	–	−96	−26	n.a.
Mineral fertilised	8010	128	19	154	38	45	−26	−19	n.a.
Sewage sludge treated, 12 Mg dry matter ha^{-1} every 4th year	4838	105	171	110	29	13	−5	+141	n.a.
Sewage sludge + *N* treated, 12 Mg dry matter ha^{-1} very 4th year	7698	232	190	161	38	28	+71	+152	n.a.
Petersborg 2006–2009									
Control	3308	0	0	79	21	–	−79	−21	1.68
Mineral fertilised	6850	139	23	167	41	63	−28	−18	1.59
Sewage sludge treated, 12 Mg dry matter ha^{-1} every 4th year	4235	132	105	98	25	14	+34	+80	1.61
Sewage sludge + *N* treated, 12 Mg dry matter ha^{-1} every 4th year	7330	271	128	196	43	43	+75	+84	1.56

n.a. not analysed

[a] Nitrogen use efficiency was based on the difference calculation: $(N\ \text{removal}_{\text{treatment}} - N\ \text{removal}_{\text{control}})/N\ \text{input} \times 100$

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Kirchmann t al., 2017

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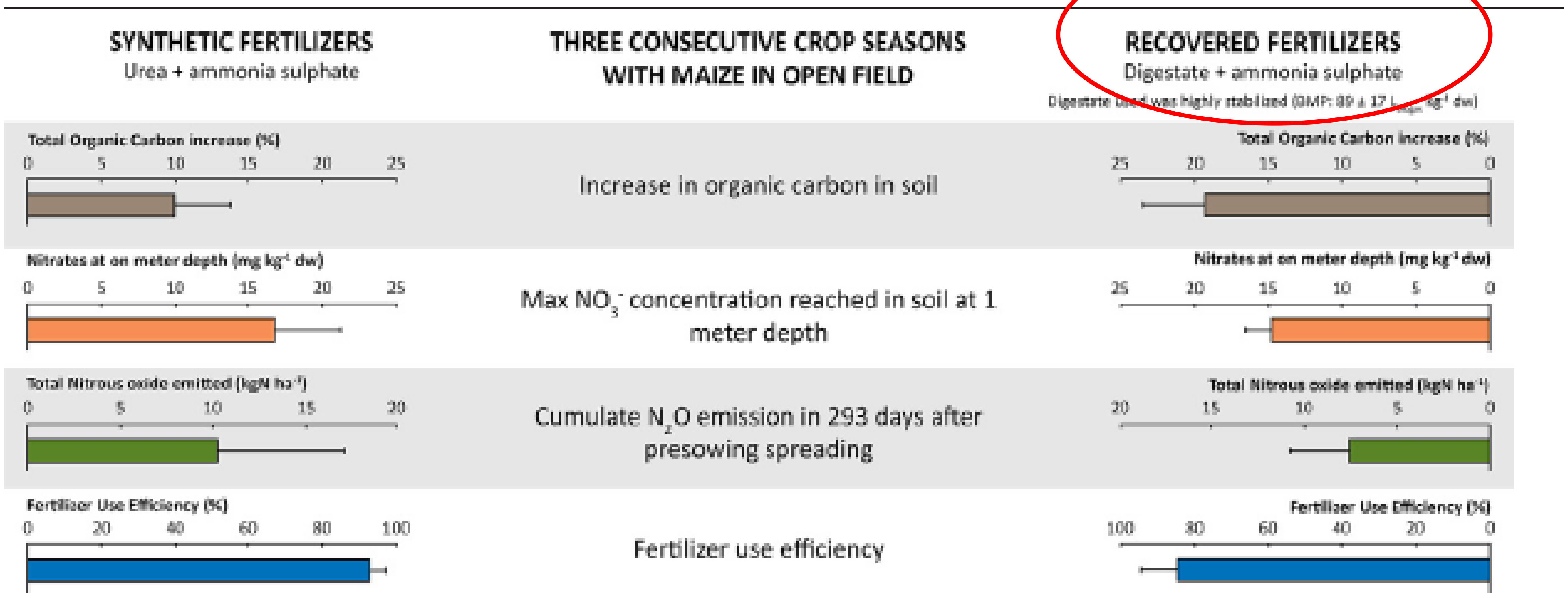
H2020

Digestato da fanghi

Using highly stabilized digestate and digestate-derived ammonium sulphate to replace synthetic fertilizers: The effects on soil, environment, and crop production



Zilio et al., 2022

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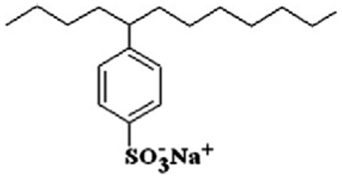
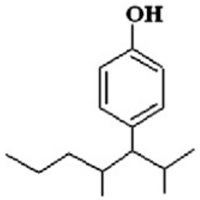
CRITICITA'

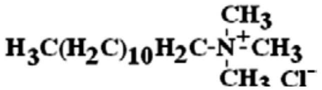
Surfactants
Sodium dodecylbenzenesulfonate, C12LAS



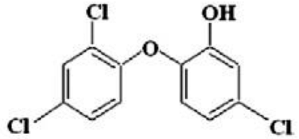
Nonylphenol, NP



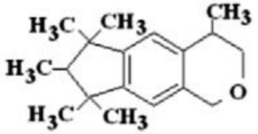
Dodecyl trimethyl ammonium chloride, C_{12}TMA



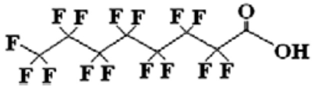
Personal care products
Triclosan, TCS



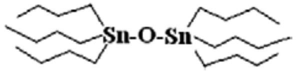
Galaxolide, HHCB



Perfluorinated compounds
Perfluorooctanoic acid, PFOA

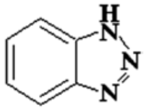


Organotins
Bis(tributyltin)oxide, TBTO



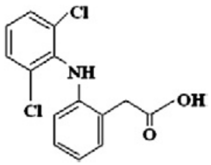
Brominated flame retardants
Tetrabromobisphenol A, TBBPA

Benzotriazoles
Benzotriazole, BTr

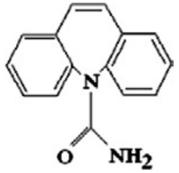


Inquinanti (es. emergenti nei fanghi

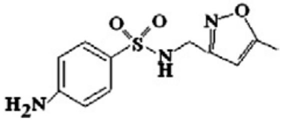
Pharmaceuticals
Diclofenac, DCF



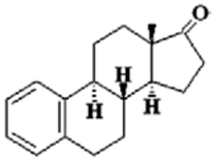
Carbamazepine, CBZ



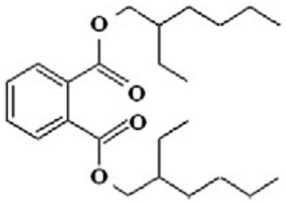
Sulfamethoxazole, SMX

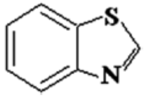


Estrogens
Estrone, E1



Phthalate acid esters
Bis(2-ethylhexyl) phthalate, DEHP



Compound	Chemical structure
Benzothiazoles Benzothiazole, BT	

Stakinakis, 2012

GLI INQUINANTI SI RIPARTISCONO TRA LA FRAZIONE ACQUA E FANGO.
APPARENTMENETE IL PROBLEMA E' IL FANGO (CONCENTRAZIONE RELATIVA)

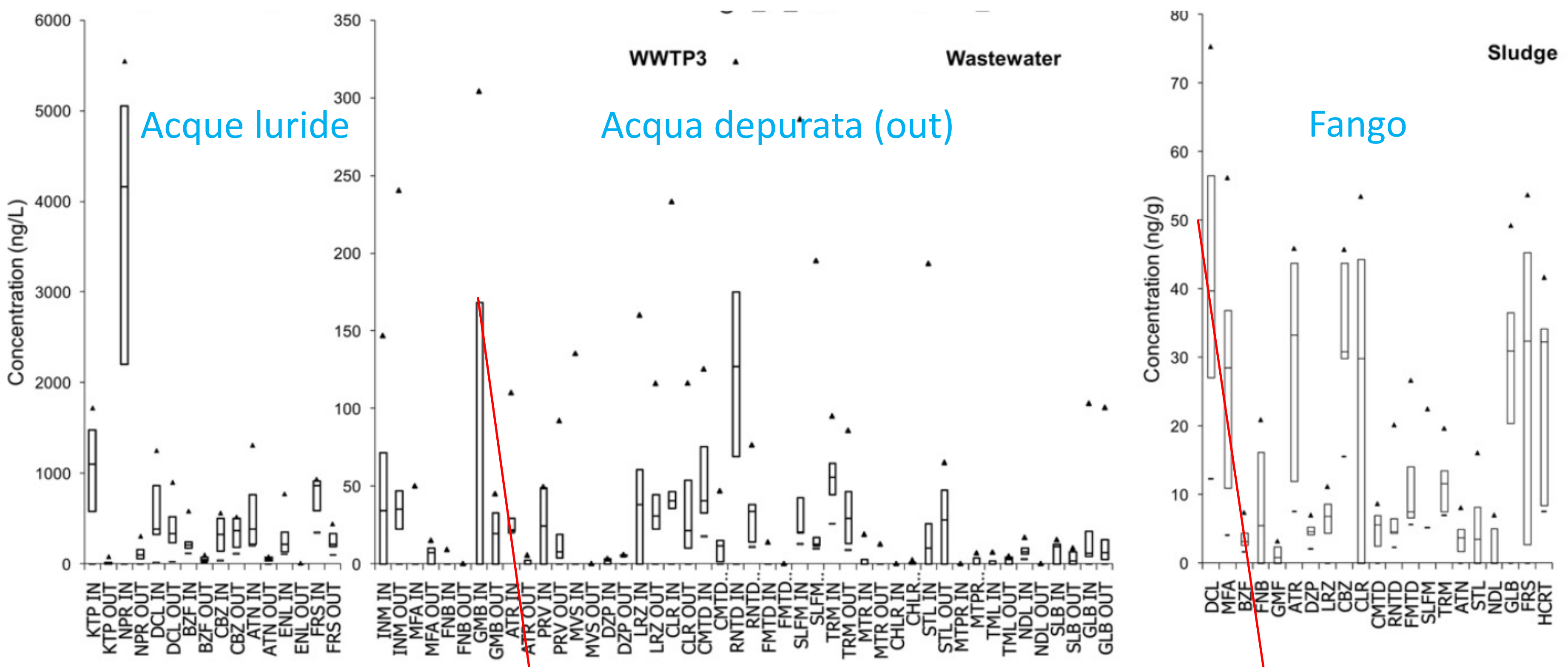


Fig. 2 – Box plots of concentration ranges (Min (–), P 0.25, Median, P 0.75 and Max (▲) of the pharmaceuticals detected in wastewater influent (IN), effluent (OUT) and sewage sludge from the studied wastewater treatment plants (WWTP1, WWTP2 and WWTP3) during 8 sampling campaigns (compound abbreviations are indicated in Table 2).

0.14 ng/kg suolo (10 tss/ha)

150 ng/kg acqua

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CIO’ TRASPARE MEGLIO DAI BILANCI DI MASSA ……………

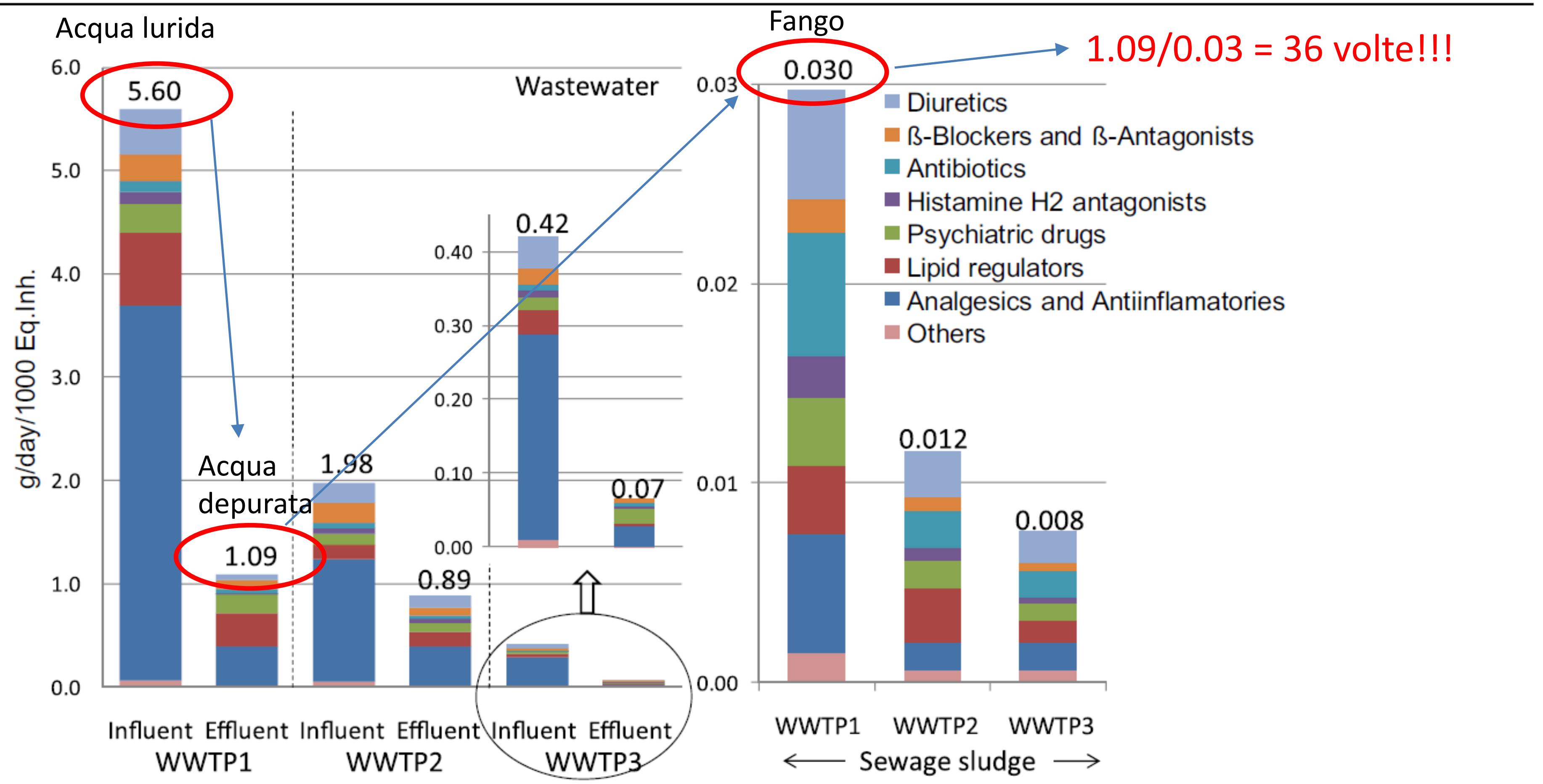


Fig. 3 – Daily mass loads (g/day per 1000 eq.inh.) of different therapeutic groups at the influent and effluent, and in the sludge from the studied WWTPs.

Jelic et al., 2011

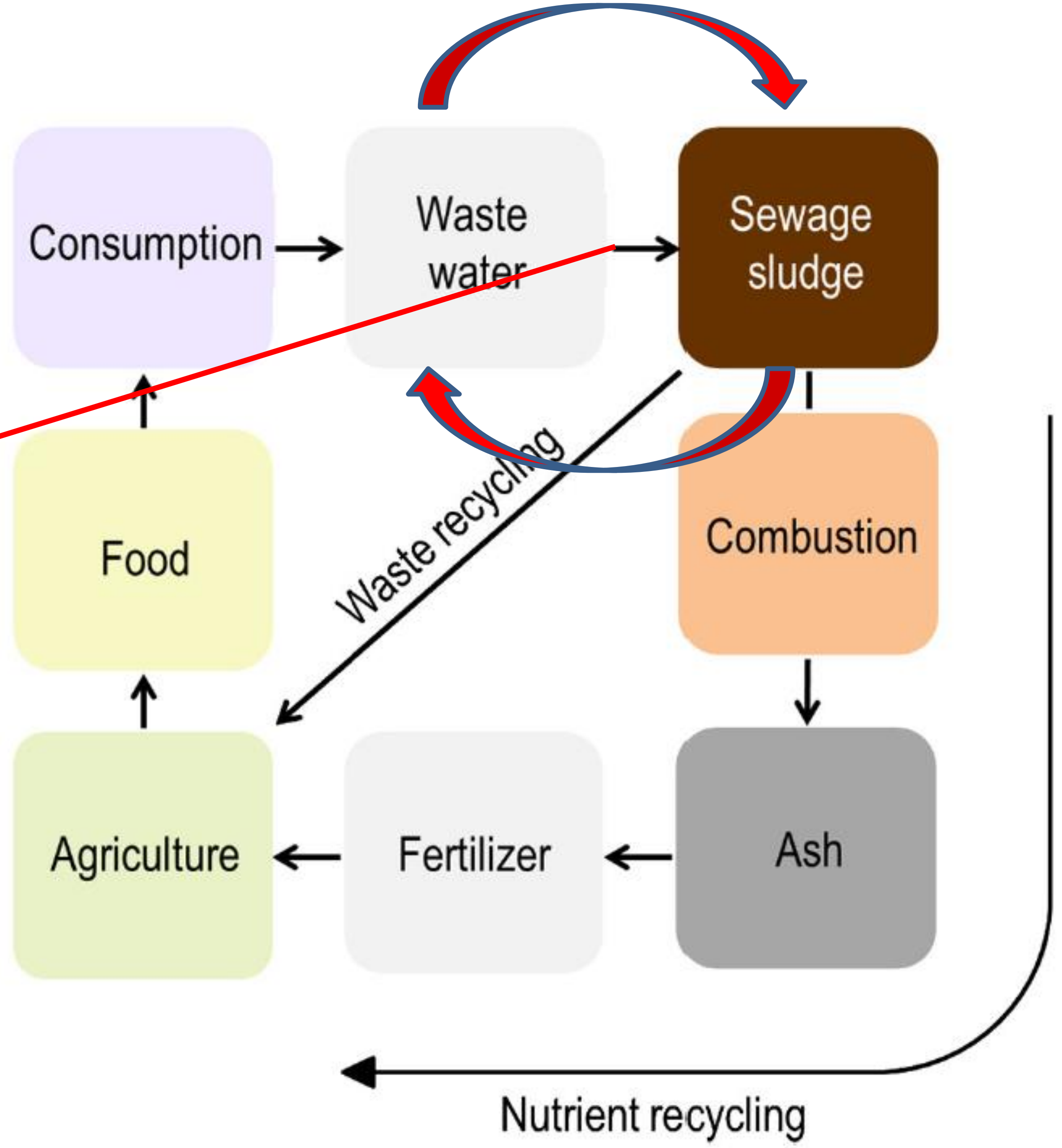
Effetto locomotive

Spinosa, 2018

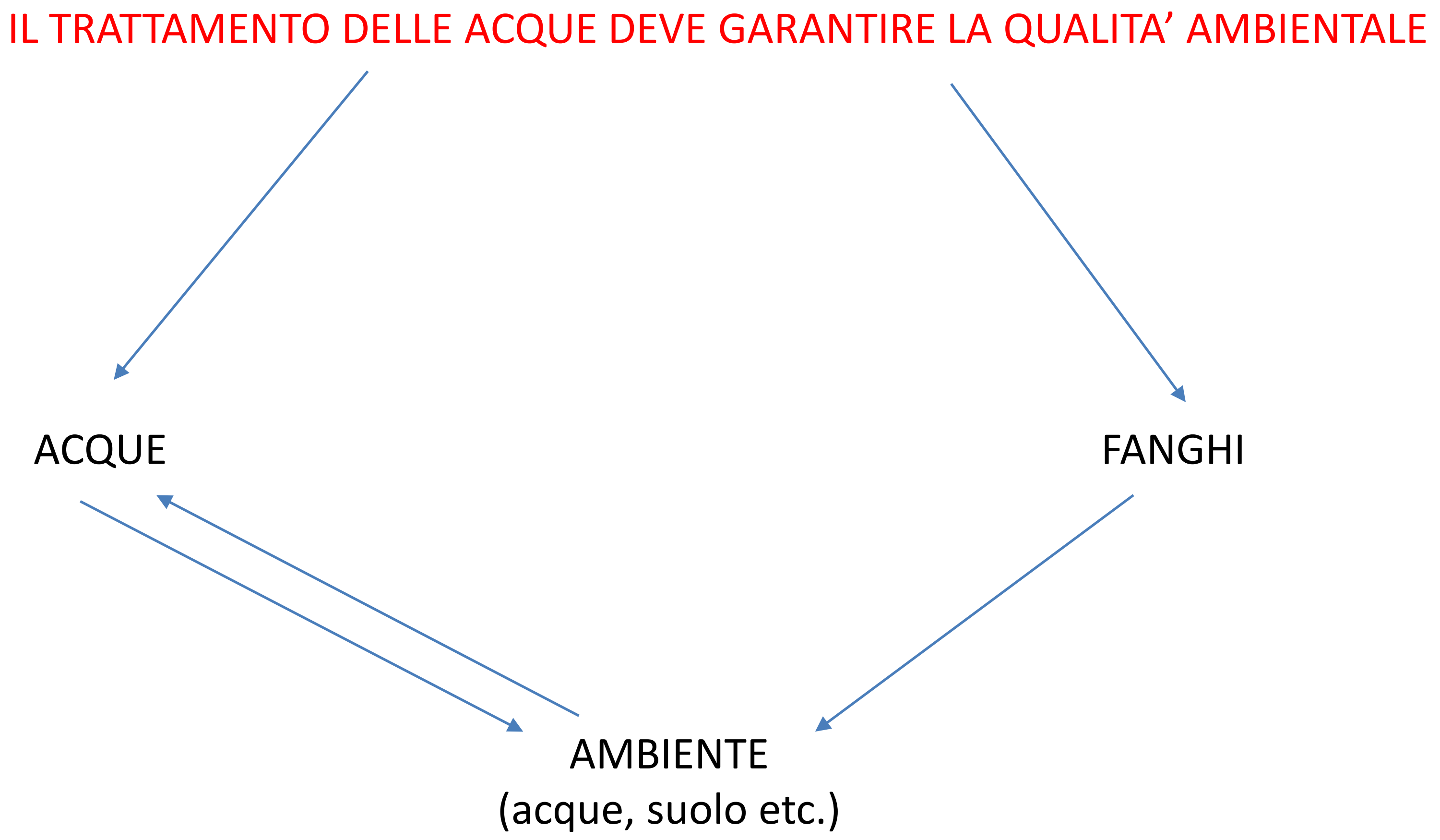
Secondo gli approcci più tradizionali, i fanghi sono generalmente considerati come “*l’ultimo vagone*” del treno del ciclo delle acque e non la “*locomotiva*”…..visione errata!!!

Intervenire sulla qualità dei fanghi, intervenendo sulla depurazione delle acque e qualità degli scarichi

Fango = Locomotiva e non ultimo vagone !!!!!



Spostare l'attenzione dal fango ai sistemi di rimozione degli inquinanti e alle cause di inquinamento



Tutto ciò mi rimanda agli anni ‘90 !!!

- Compost da rifiuti indifferenziati
- Proposta di implementazione della raccolta differenziata
- Scetticismo circa la possibilità di farlo i.e. va bruciato tutto!!
- …adesso…la raccolta differenziata è una realtà ed è di qualità !!!!!

Ieri Vs. Oggi

Deliberazione del **27/07/1984**
Disposizioni per la prima applicazione dell'articolo 4 del D.P.R. 10 settembre 1982, n. 915, concernente lo smaltimento dei rifiuti.

Gazz. Uff. Suppl. Ordin. n° **253** del **13/09/1984**

TABELLA 3.2.

LIMITI DI ACCETTABILITA' PER IL COMPOST AI FINI DELLA TUTELA AMBIENTALE

Parametri	Unita' di misura	Valori limite
Salmonelle	N°/50 g	assenti
Semi infestanti	N°/50 g	assenti
pH	unita' di pH	6 ÷ 8,5
Arsenico	mg/kg sostanza secca	10
Cadmio	mg/kg sostanza secca	10
Cromo III	mg/kg sostanza secca	500
Cromo VI	mg/kg sostanza secca	10
Mercurio	mg/kg sostanza secca	10
Nichel	mg/kg sostanza secca	200
Piombo	mg/kg sostanza secca	500
Rame	mg/kg sostanza secca	600
Zinco	mg/kg sostanza secca	2.500

DECRETO LEGISLATIVO 29 aprile 2010, n.75 - Riordino e revisione della disciplina in materia di fertilizzanti, a norma dell'articolo 13 della legge 7 luglio 2009, n. 88

Metalli	Ammendanti
Piombo totale	140
Cadmio totale	1,5
Nichel totale	100
Zinco totale	500
Rame totale	230
Mercurio totale	1,5
Cromo esavalente totale	0,5

Metalli pesanti

Riduzione progressive del contenuto di metalli nei fanghi (Svezia)

Kirchmann t al., 2017

Ambio 2017, 46:143–154 145

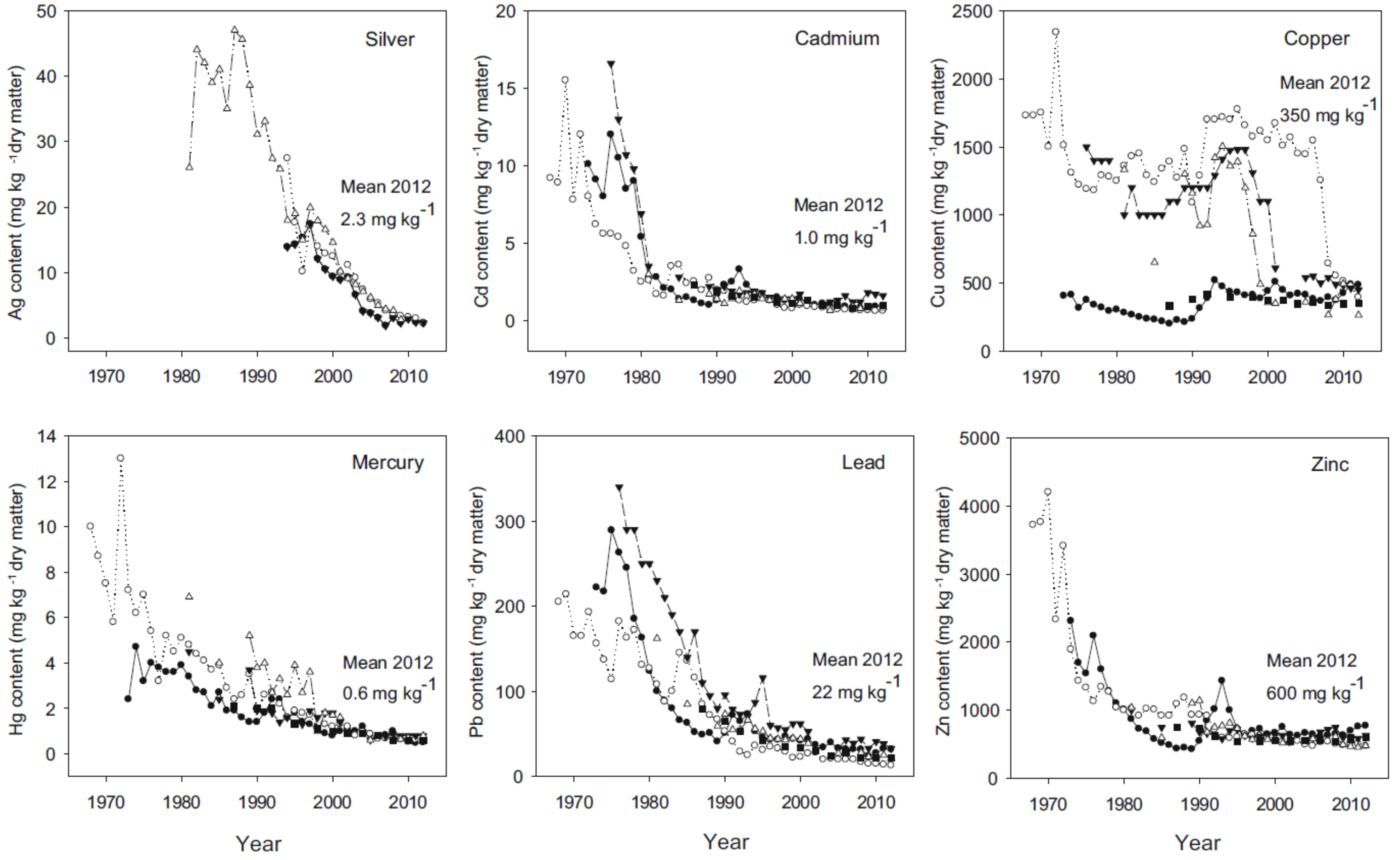


Fig. 1 Decline in the concentrations of silver, cadmium, copper, mercury, lead and zinc in Swedish sewage sludge over time (1970–2010). Mean data for silver are not available (*open circle* sludge from Uppsala; *filled circle* sludge from Gothenburg; *open triangle* sludge from Stockholm; *inverted filled triangle* sludge from Malmö/Lund; *filled square* mean data on Swedish sewage sludge). Data taken from Statistics Sweden (SCB 1987, 1990, 1992, 1995, 2012) with additional information from Sveder (2002), Ernst-Olof Swedling, Kungsängsverket, Uppsala (pers. comm. 1 Dec. 2011), Lars Nordén, Gryyab, Gothenburg (pers. comm. 14 April 2014) and Mats Thuresson, Stockholm County Administrative Board (pers. comm. 1 March 2013)

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Contenuto di metalli pesanti in suoli trattati con fanghi e fertilizzanti minerali

Started on 1954

Table 2 Mean concentrations of cadmium, copper, lead and zinc in soils (mg kg^{-1} soil dry weight) due to long-term sewage sludge application, compared with the use of mineral fertiliser, in four Swedish field experiments. (Data from Börjesson et al. 2012)

Site, start and sampling year	Cadmium		Copper		Lead		Zinc	
	Sewage sludge	Fertiliser	Sewage sludge	Fertiliser	Sewage sludge	Fertiliser	Sewage sludge	Fertiliser
Ultuna, 1956–2010	0.73	0.24	196.0	27.8	41.0	21.6	271.0	87.6
Lanna, 1996–2010	0.14	0.12	20.8	8.9	14.4	14.1	83.1	65.6
Igelösa, 1981–2010	0.34	0.30	25.8	15.3	17.3	16.3	58.0	47.5
Petersborg, 1981–2010	0.26	0.24	21	9.4	14.0	13.5	45.3	38.0

La scelta di utilizzare fanghi in agricoltura di qualità è già una realtà…….ma attraverso l'applicazione di una reale economia Circolare si può milgiorare ancora e recuperare materia secondo i principi della ECONOMIA CIRCOLARE.

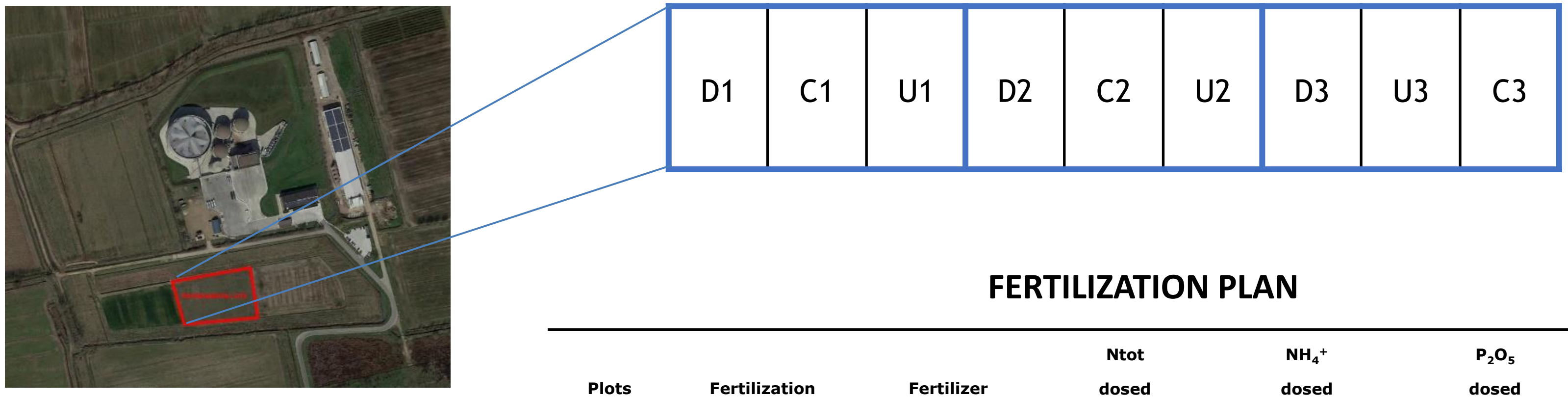
Sperimentazione di pieno campo sull’uso di fanghi (digestato): propietà concimanti, ammendanti, impatti emissivi, microinquinanti

Nutri2Cycle — Systemic

EU H2020

The same experimental plan for three years

FIELD **PLOTS**



FERTILIZATION PLAN

Plots	Fertilization	Fertilizer	Ntot dosed ($kgN\ Ha^{-1}$)	NH_4^+ dosed ($kgN\ Ha^{-1}$)	P_2O_5 dosed ($Kg\ Ha^{-1}$)	K_2O dosed ($kg\ Ha^{-1}$)
U	Pre-sowing	None				
	Top-dressing	None				
D	Pre-sowing	Digestate	370	229	307	84
	Top-dressing	Ammonia sulphate	100	100		
C	Pre-sowing	Urea	185	185	90	84
	Top-dressing	Ammonia sulphate	100	100		

All the experiments were carried out comparing Digestate and Urea treatments

Table 2

Main characteristics of infeed (mean ± SD) and full characterization of digestate in comparison with legal limits for its use as fertilizer in agriculture, and with data from literature for digestate and composts.

Parameter	Unit	Infeed[a] (this work)	Digestate[b] (this work)	Lombardy Law N. 6665/2019 – Legal limits[c]	Agricultural digestate[d]	Energy Crop digestate[e]	Green Compost 1[e]	Green Compost 2[e]
pH		7.3 ± 2.5	8.5 ± 0.3	5.5 < pH < 11		8.4 ± 0.1	8.8 ± 0.2	8.9 ± 0.3
Dry Matter 105 °C	g kg^{-1} ww[f]	191 ± 45	103 ± 3.7		61.1 ± 12.5			
Dry Matter 600 °C	g kg^{-1} ww	60 ± 48	40.4 ± 2.5					
Total Organic Carbon	g kg^{-1} DM[f]	351 ± 78	314 ± 30	> 200		432 ± 14	292 ± 30	210 ± 10
TKN	g kg^{-1} DM	54 ± 20	77 ± 3.7	> 15	80.6 ± 13.3	70.3 ± 0.8	15.2 ± 0.18	15.2 ± 0.6
$N\text{-}NH_4$	g kg^{-1} DM	n.d.[g]	35.9 ± 2.4		48.9 ± 26.7	44.1 ± 3.8	0.12 ± 0.01	0.5 ± 0.0
$N\text{-}NH_4$/TKN	%	n.d.	46.6		60.66	62.27	0.7	3.2
OD_{20}[g]	mg O_2 g^{-1} DM	n.d.	22.6 ± 6.1			66.8 ± 1	15.6 ± 0.3	10.3 ± 1.1
BMP[h]	L_{biogas} kg^{-1} DM	n.d.	57 ± 23			229 ± 31	144 ± 3.8	201 ± 20
P	g kg^{-1} DM	19 ± 11	28 ± 4.1	> 4	15 ± 5	13.8 ± 5	3 ± 0	20.75 ± 0.12
K	g kg^{-1} DM	n.d.	6.5 ± 1.3			14.8 ± 3	9.2 ± 0.1	12.01 ± 0.09
Ca	g kg^{-1} DM	n.d	43 ± 7			9.2 ± 0.1	31.47 ± 0.17	30.9 ± 0.2
Mg	g kg^{-1} DM	n.d	5.2 ± 0.6			2.8 ± 4	8.57 ± 165	7.5 ± 17.1
Fe	g kg^{-1} DM	n.d	26.2 ± 6.4			3.4 ± 0.0	10.6 ± 0.1	13.2 ± 0.1
Mo	mg kg^{-1} DM	n.d	10 ± 1					
Cu	mg kg^{-1} DM	277 ± 142	408 ± 60	≤ 1,000	71.1 ± 30.6	83.3 ± 1.1	53.5 ± 1.6	53.5 ± 0.86
Zn	mg kg^{-1} DM	673 ± 413	1,020 ± 120	≤ 2,500	353 ± 204	393 ± 4.4	151 ± 3	159 ± 0.1
Mn	mg kg^{-1} DM	n.d	444 ± 35					
Al	g kg^{-1} DM	n.d	25.8 ± 4.5					
Co	mg kg^{-1} DM	n.d	6.6 ± 2.3					
Se	mg kg^{-1} DM	4 [l]	3.7 ± 2.1	≤ 10				
Na	g kg^{-1} DM	n.d	1.9 ± 0.4			11.41 ± 0.034	0.807 ± 0.017	0.571 ± 0.001
Cr	mg kg^{-1} DM	54.2 ± 55.6	95 ± 22	< 200	8.56 ± 1.93	17.24 ± 0.4	88.8 ± 0.9	37.78 ± 0.8
Pb	mg kg^{-1} DM	45 ± 44	64 ± 11	≤ 750	1.97 ± 0.91	2.99 ± 0.04	24 ± 0.2	51.2 ± 0.08
Ni	mg kg^{-1} DM	36.8 ± 36.2	61 ± 13	≤ 300	10.3 ± 3.36	9.55 ± 0.47	41.8 ± 1	26.11 ± 2.2
As	mg kg^{-1} DM	6.3 ± 4.7	9.0 ± 2.2	< 20		1.05 ± 0.02	0.51 ± 0.06	0.57 ± 0.15
Cd	mg kg^{-1} DM	0.6 ± 1.1[i]	1 ± 0.5[i]	≤ 20	0.39 ± 0.17	0.37 ± 0.05	0.17 ± 0.03	0.34 ± 0.01
Hg	mg kg^{-1} DM	0.3 ± 0.7[i]	0.1 ± 0.3[i]	≤ 10		0.24 ± 0.1	0.75 ± 0.02	0.22 ± 0.01
PAH	mg kg^{-1} DM	0.2 ± 0.5[i]	0.5 ± 0.5[i]	∑< 6		1.08	0.04	< 0.83
PCB	mg kg^{-1} DM	0.04 ± 0.51[i]	< 0.1	∑< 0.8		0.12	0.008	0.03
PCDD/F + PCB-DL	ng TEQ kg^{-1} DM	2.3 ± 4.4[i]	10.6 ± 2.9[i]	∑≤ 25		0.87	1.02	1.01
DEHP	mg kg^{-1} DM	2.8 ± 7.0[i]	5.7 ± 5.3[i]	< 100		< 1.54	< 0.14	0.15
Hydrocarbon C10-C40	mg kg^{-1} wwmg kg^{-1} DM	807 ± 1,093[i]	284 ± 251[i](2,757)	≤ 1,000				
AOX	mg kg^{-1} DM	0.4 ± 3.3[i]	< 0.6	∑ < 500		< 0.46	2.75	0.04
Ciproflaxacin	mg kg^{-1} DM		< 0.01[m]					
Sulfamethoxazole	mg kg^{-1} DM		< 0.01[m]					
Fenofibrat	mg kg^{-1} DM		< 0.01[m]					
Gemfibrozil	mg kg^{-1} DM		< 0.01[m]					
Carbamazepine	mg kg^{-1} DM		< 0.01[m]					
Metoprolol	mg kg^{-1} DM		< 0.01[m]					

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Aspetti chimico-agrari e aspetti ambientali

Table 2
Main chemical parameters (mean ± SD; $n = 3$) of soil before the pre-sown fertilization on March 2018 and after the end of the third crop season on January 2021.

Parameter	Unit	March 2018	January 2021		
			Unfertilized	Synthetic fertilizer	Recovered fertilizer
Sand	%		47 ± 2.8	49 ± 3.7	46 ± 4.4
Silt	%		41 ± 0.2	39 ± 1.5	43 ± 1.4
Clay	%		12 ± 2	12 ± 1.1	12 ± 2.6
pH	pH unit	7 ± 0.7(a)[a]	7.14 ± 0.2 (a)	7.06 ± 0.1 (a)	7.05 ± 0.2 (a)
CEC	C (mol kg^{-1})	24.2 ± 2.1 (ab)	23.8 ± 0.4 (a)	26.8 ± 0.8 (b)	22.3 ± 0.9 (a)
Total organic carbon (TOC)	g kg^{-1} dw[b]	10.3 ± 0.6 (a)	11.9 ± 0.2 (ab)	11.3 ± 0.4 (a)	12.3 ± 0.4 (b)
Total nitrogen	g kg^{-1} dw	1.27 ± 0.1 (a)	1.3 ± 0 (a)	1.41 ± 0 (b)	1.42 ± 0.9 (b)
Ratio C/N		8.13 ± 0.9 (ab)	9.22 ± 0 (b)	8.01 ± 0.1 (a)	8.65 ± 0.4 (ab)
P_{tot}	mg kg^{-1} dw	575 ± 11 (a)	521 ± 26 (a)	581 ± 32 (a)	550 ± 15 (a)
$P_{available}$	mg kg^{-1} dw	43.6 ± 2.6 (a)	46.4 ± 0 (a)	60.1 ± 16 (a)	58.9 ± 16 (a)
As	mg kg^{-1} dw	19.9 ± 1.1 (a)	22.9 ± 2.8 (a)	19.6 ± 0.5 (a)	21.1 ± 2.3 (a)
Cd	mg kg^{-1} dw	<0.5	<0.5	<0.5	<0.5
Hg	mg kg^{-1} dw	<0.5	<0.5	<0.5	<0.5
Cr	mg kg^{-1} dw	39.2 ± 2.3 (a)	42.6 ± 2 (a)	40 ± 4.1 (a)	40.2 ± 1.6 (a)
Ni	mg kg^{-1} dw	23.3 ± 2.3 (a)	25.7 ± 1.7 (a)	25.9 ± 3.7 (a)	26 ± 1.6 (a)
Pb	mg kg^{-1} dw	32.8 ± 0.1 (a)	34.2 ± 4.2 (a)	33.4 ± 2.2 (a)	33.6 ± 4.5 (a)
Cu	mg kg^{-1} dw	19.1 ± 1.3 (a)	22.2 ± 3.3 (a)	21.4 ± 3.5 (a)	24.4 ± 3.1 (a)
Zn	mg kg^{-1} dw	69.8 ± 0.5 (a)	71.4 ± 3 (a)	71.4 ± 1.3 (a)	70.8 ± 1.8 (a)
PCDD/PCDF + PCB DL	ng WHO-TEQ kg^{-1} dw	–	4.09 ± 0.1 (b)	4.3 ± 0.2 (b)	4.16 ± 0.1 (b)
Hydrocarbon C10–C40	mg kg^{-1} dw	<30	<30	<30	<30
Toluene	mg kg^{-1} dw	<0.2	<0.1	<0.1	<0.1
Phenols NPE + NP2EO + NP1EO	mg kg^{-1} dw	<7.5	<7.5	<7.5	<7.5
ΣAOX	mg kg^{-1} dw	<0.6	<0.6	<0.6	<0.6
PCB	mg kg^{-1} dw	<0.005	<0.005	<0.005	<0.005
DEHP	mg kg^{-1} dw	0.24	<0.1	<0.1	<0.1
Ciproflaxacin	mg kg^{-1} dw		<0.01	<0.01	<0.01
Sulfamethoxazole	mg kg^{-1} dw		<0.01	<0.01	<0.01
Fenofibrat	mg kg^{-1} dw		<0.01	<0.01	<0.01
Gemfibrozil	mg kg^{-1} dw		<0.01	<0.01	<0.01
Carbamazepina	mg kg^{-1} dw		<0.01	<0.01	<0.01
Metoprolol	mg kg^{-1} dw		<0.01	<0.01	<0.01
Diclofenac	mg kg^{-1} dw		<0.01	<0.01	<0.01
Ethinylestradiol	mg kg^{-1} dw		<0.01	<0.01	<0.01
Estradiol	mg kg^{-1} dw		<0.01	<0.01	<0.01

[a] Letters in parenthesis are referred to One-way ANOVA comparing values in each row ($p < 0.05$; $n = 3$; Tukey post-test).
[b] dw: dry weight.

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Research Article

Environmental Performance in the Production and Use of Recovered Fertilizers from Organic Wastes Treated by Anaerobic Digestion vs Synthetic Mineral Fertilizers

Axel Herrera, Giuliana D'Imporzano,* Massimo Zilio, Ambrogio Pigoli, Bruno Rizzi, Erik Meers, Oscar Schouman, Micol Schepis, Federica Barone, Andrea Giordano, and Fabrizio Adani*

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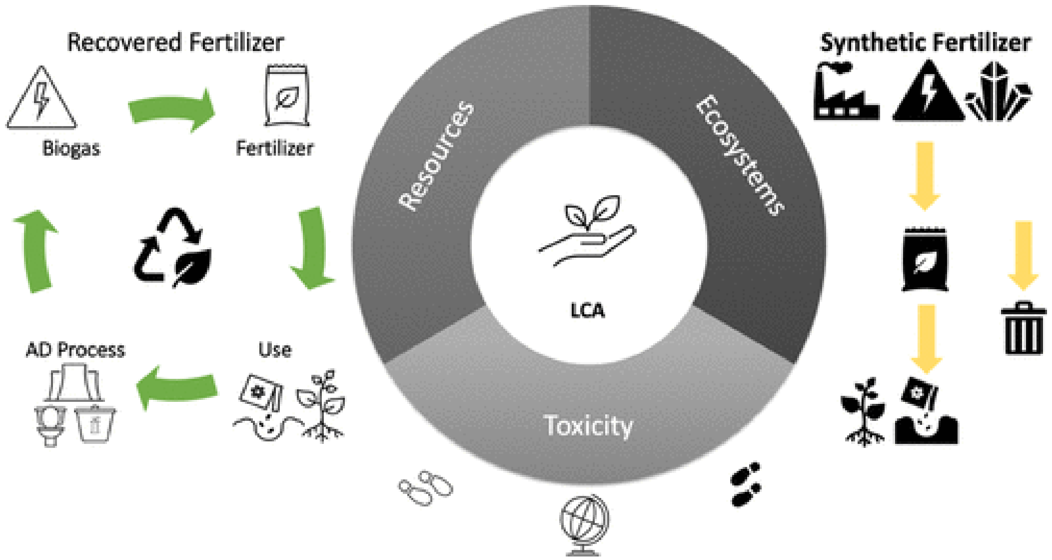

RF = recovered fertilizers (digestate)

RF = Synthetic mineral fertilizers

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RS Digestato da fanghi

RF
Fertilizzanti chimici

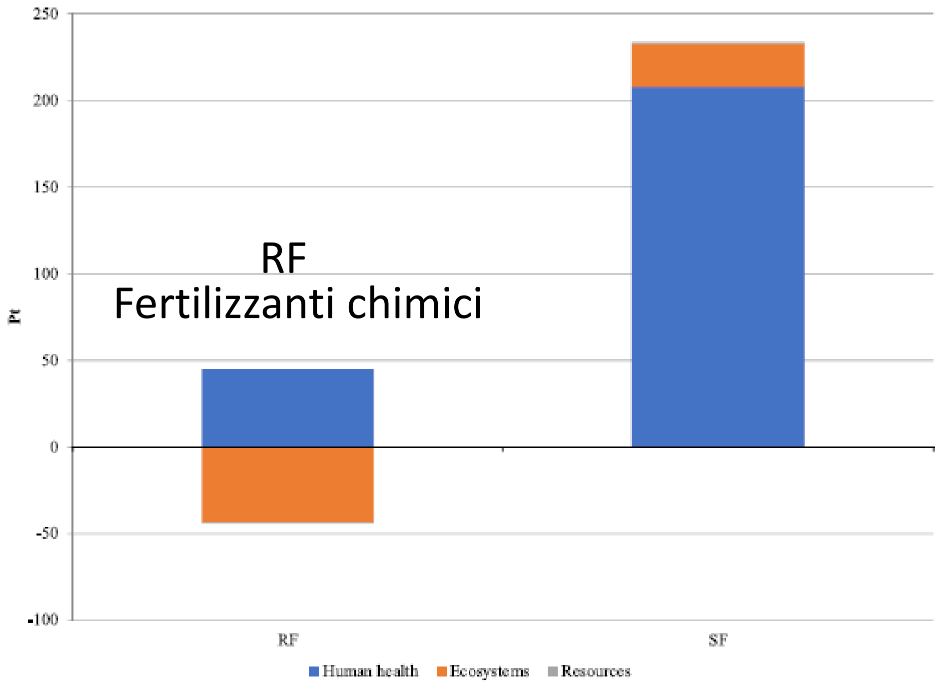

Figure 2. Comparative environmental results for Scenarios Recovered Fertilizers (RFs) and Synthetic Fertilizers (SFs). Impact assessment (Ecopoint—Pt) calculated according to the ReCiPe 2016 end point (H) V 1.03 impact assessment method.

Herrera et al., 2022, ACS Sustainable Chem. Eng. 2022, 10, 986−997

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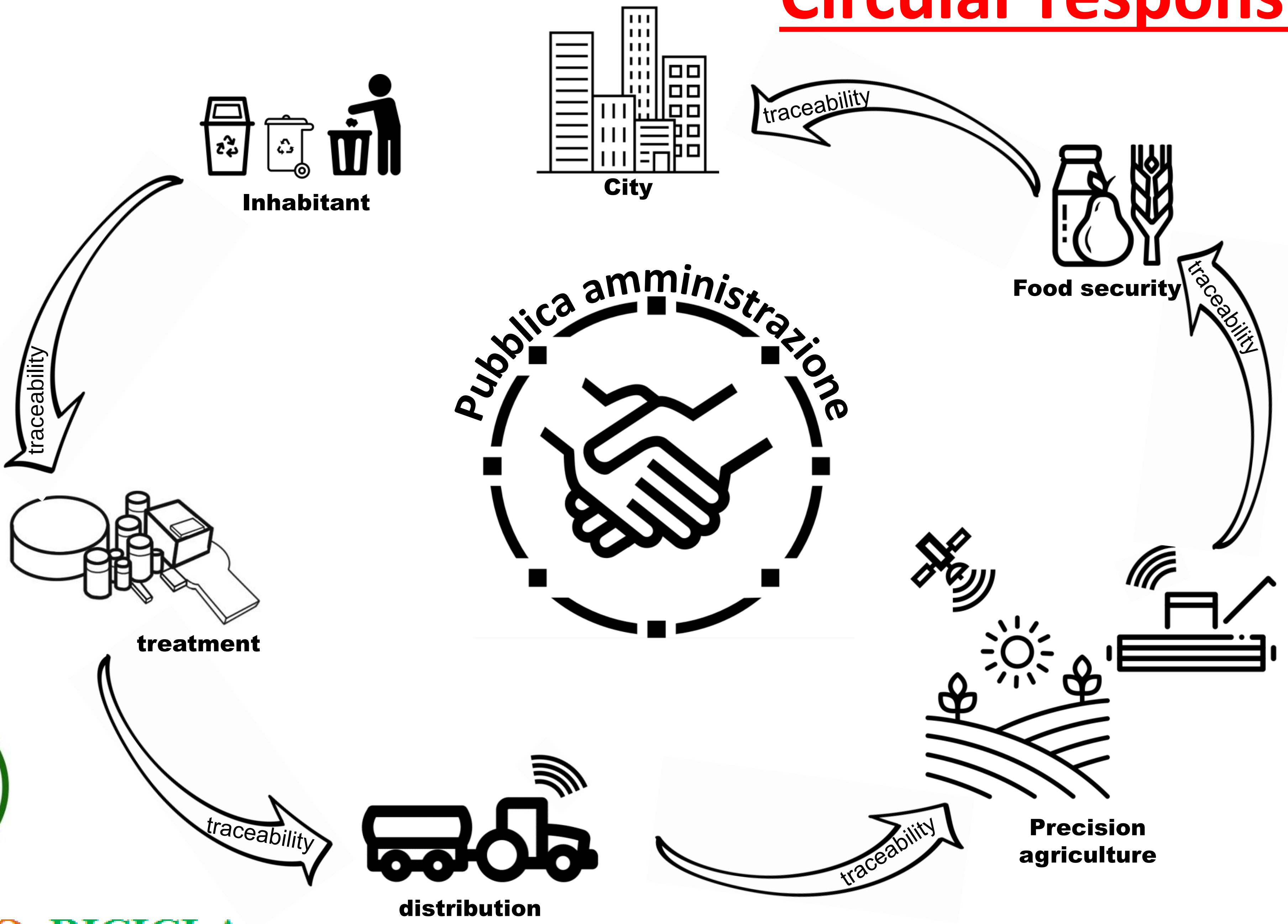
I risultati sull’Ecotossitià discussi dal collega non sono una sorpresa……

Circular responsibility



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Arianna Carrara
Biotechnologist

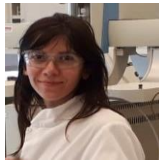
Fabrizio Adani
Full Professor

Fulvia Tambone
Associate professor

Parisa Abbasi Parizad
Biologist

Axel Herrera
Agricultural Engineer

Gabriella Papa
Biobased and Biofuels expert



Marta Dell'Orto
Agronomist

GRUPPO RICICLA

Barbara Scaglia
Associate professor

web site: http://users.unimi.it/ricicla/

Andrea Goglio
Bioelctrochemistry

Mirko Cucina
Biotechnologist

Min Su
Agricultural Engineer

Elisa Clagnan
Molecular biologist

Tommy Pepè Sciarria
Biologist

Massimo Zilio
Biologist

Patrizia De Nisi
Agronomist

Giuliana D'Imporzano
Agronomist

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