Use of mesoescaled soil aquifers as wastewater treatment to efficiently reduce antibiotic resistance gene loads.

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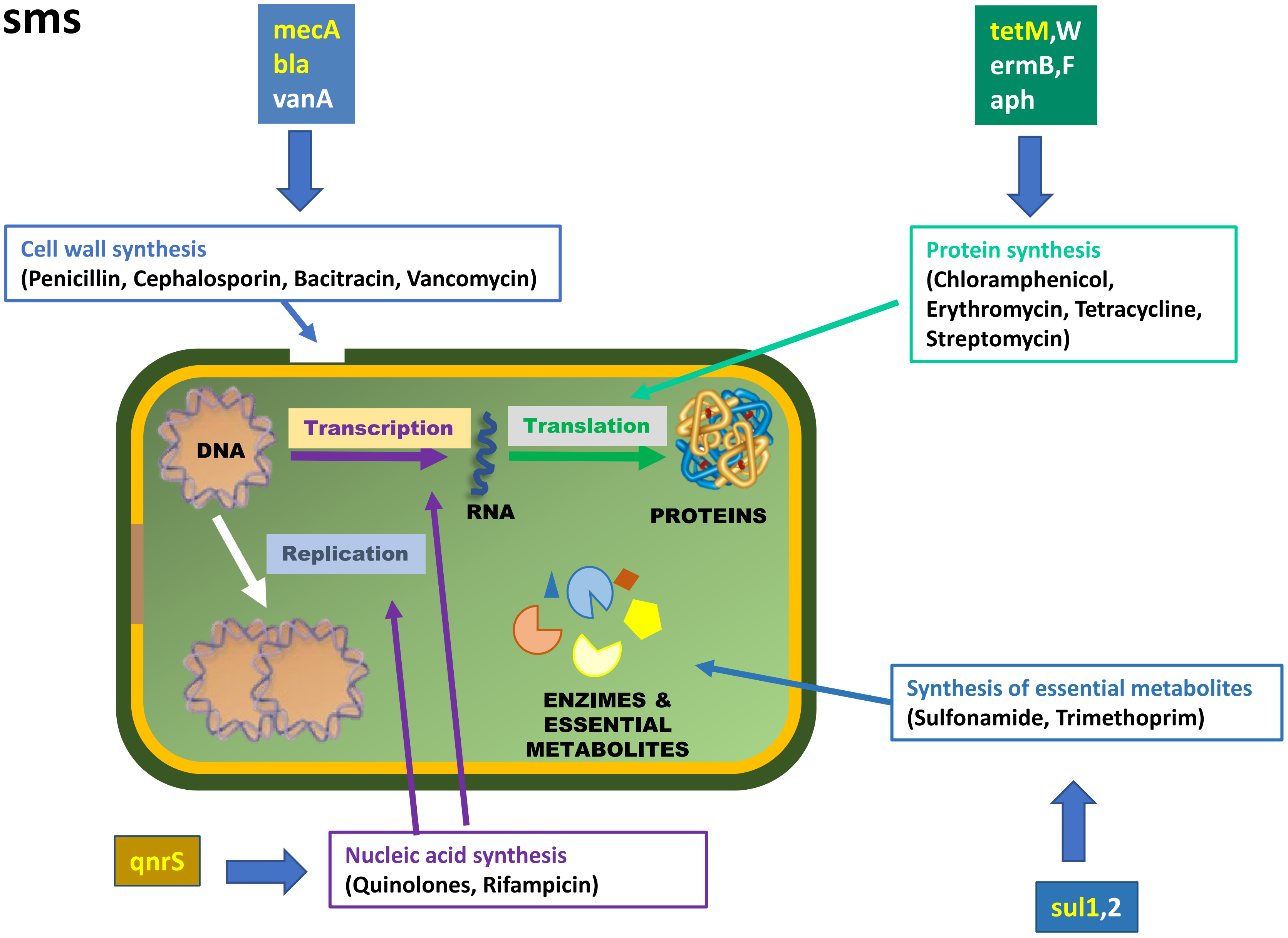
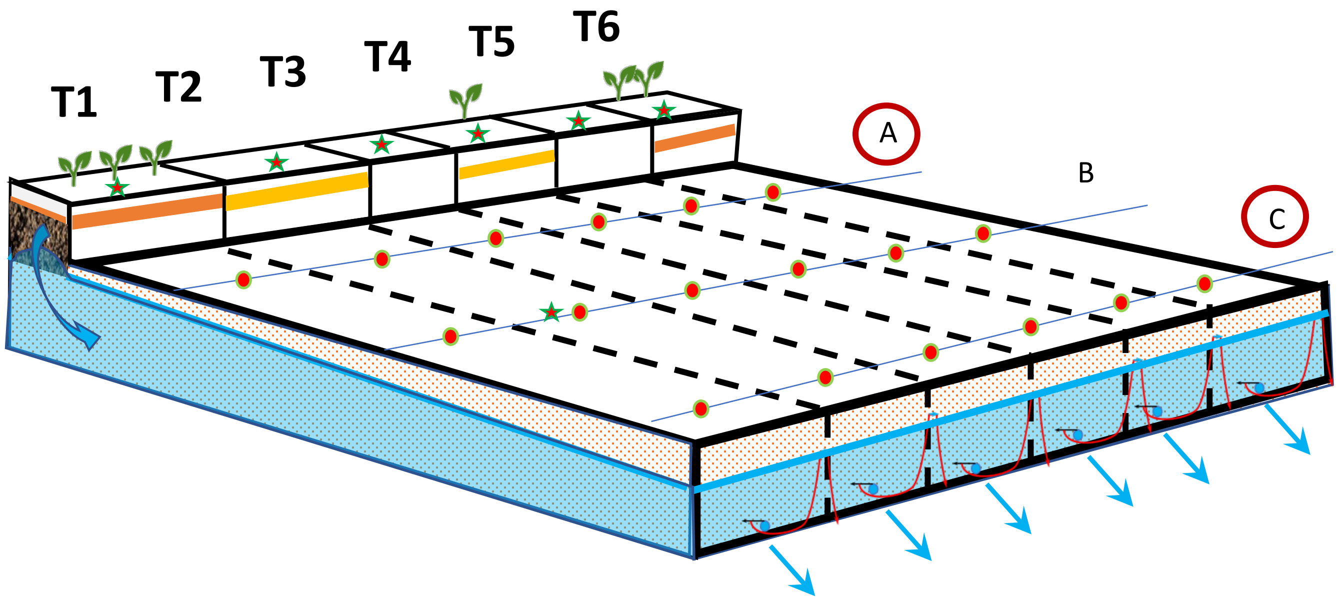
Antibiotic resistance mechanisms

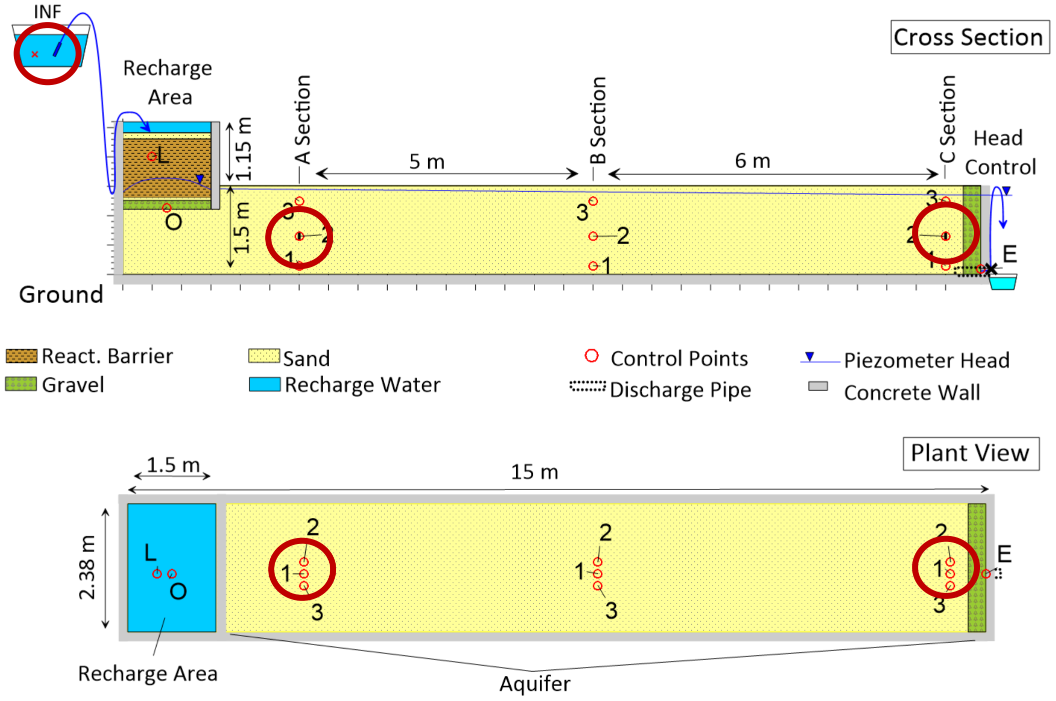
Antibiotic Resistance Genes, or ARGs, are genes that encode proteins that protect microbes from the action of antibiotic, either by facilitating their degradation or by counteracting their mode of action.

Measuring the levels of ARGs in a given sample allows estimating the degree of antibiotic resistance present in the corresponding bacterial population. The dissemination of this resistance is predicted to become a major threat to the global human health in the next years by the WHO

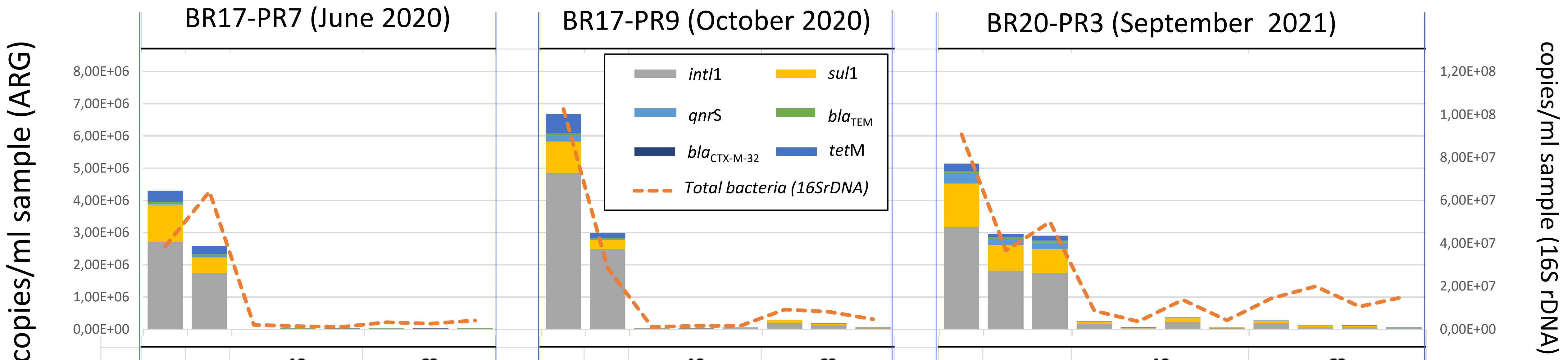


Artificial Aquifer set-up in WWTP Palamós (Girona, NE Spain)





T1:T6 barriers filled with sand plus different proportions of other components (clay, compost, woodchips, zeolites, biochar, inorganic iron, MO)



% change wrt SEC ouflow (inflow to SAT)

Resistance to different antibiotics

BR17-PR7 (June 2020)

	WWTP		After RB (A2)			11m aqf (C2)		
	PRIM	SEC	T2	T4	T5	T2	T4	T5
16s (total bact.)	60%	100%	3.33%	2.26%	1.89%	5.18%	4.14%	6.40%
intI1	155%	100%	0.35%	0.82%	0.30%	0.64%	0.48%	0.60%
sul1	243%	100%	0.84%	1.02%	0.58%	2.23%	1.14%	2.26%
qnrS	27%	100%	0.04%	1.49%	1.51%	1.32%	0.58%	1.32%
blatem	106%	100%	1.41%	32.82%	31.15%	25.81%	10.71%	25.18%
blactx	245%	100%	0.07%	15.66%	16.25%	14.57%	6.23%	14.77%
tetM	134%	100%	0.13%	0.26%	0.14%	1.00%	2.45%	1.04%

BR17-PR9 (October 2020)

	WWTP		After RB (A2)			11m aqf (C2)		
	PRIM	SEC	T2	T4	T5	T2	T4	T5
16s (total bact.)	358%	100%	3.88%	5.71%	5.81%	32.25%	28.61%	16.28%
intI1	195%	100%	0.97%	0.98%	2.04%	8.03%	5.34%	1.73%
sul1	342%	100%	2.19%	1.79%	3.53%	28.92%	16.10%	6.76%
qnrS	577%	100%	1.08%	2.73%	2.35%	0.36%	0.33%	0.03%
blatem	426%	100%	0.70%	1.22%	2.50%	0.11%	0.03%	0.12%
blactx	1174%	100%	0.85%	1.35%	0.67%	0.09%	0.04%	0.36%
tetM	379%	100%	0.86%	0.75%	0.63%	0.15%	0.16%	0.82%

BR20-PR3 (September 2021)

	WWTP			After RB (A2)				After 11m aqf (C2)			
	PRIM	SEC		T1	T2	T3	T6	T1	T2	T3	T6
16s (total bact.)	210%	85%	115%	20.05%	8.37%	31.69%	9.77%	33.12%	46.22%	24.47%	34.86%
intI1	177%	102%	98%	9.36%	1.74%	12.96%	1.81%	10.46%	3.71%	4.47%	1.93%
sul1	177%	104%	96%	10.11%	1.96%	16.28%	4.49%	11.47%	6.98%	5.06%	1.87%
qnrS	165%	93%	107%	0.92%	2.54%	2.47%	0.86%	3.36%	2.16%	0.05%	0.03%
blatem	109%	102%	98%	2.20%	1.29%	1.47%	1.47%	1.83%	2.03%	0.66%	0.77%
blactx	235%	117%	83%	0.16%	0.18%	0.27%	0.11%	0.68%	0.44%	0.08%	0.12%
tetM	190%	78%	122%	1.14%	0.85%	3.52%	0.64%	4.41%	3.91%	0.51%	0.06%

Remaining ARG loads after treatment (% from SPT influent)

Treatment Class	Treatment	Median	Max	Min
Conventional Treatment	Activated Sludge	3551.44%	18620.69%	0.80%
	Anaerobic-Anoxic-Oxic Tecnhology	456.44%	3033.33%	5.83%
Wetland-based Treatments	Horizontal Subsurface Flow Constructed Wetlands	45.32%	71.21%	23.85%
	Hybrid	28.70%	163.33%	4.76%
	Surface Flow Constructed Wetlands	27.31%	53.13%	16.67%
	Subsurface Flow Constructed Wetlands	20.59%	48.98%	0.87%
Advanced Oxidation	H202-UV / Peroxymonosulfate-UV / Peroxymonosulfate-Fe2+-UV	37.84%	63.10%	12.59%
	UV-Persulfate	35.52%	63.10%	7.94%
	UV/O3/Fenton/Fenton-UV	7.92%	15.85%	0.00%
	Fenton/ UV/H202	1.60%	3.16%	0.03%
	UV-A Assisted Iron-Based/UV-C Driven H2O2, Persulfate; Peroxymonosulfate	0.08%	0.10%	0.05%
Membrane-based procedures	Ultrafiltration/Nanofiltration/Reverse Osmosis	39.72%	79.43%	0.01%
	Microfiltration	0.64%	1.26%	0.01%
	Forward Osmosis Membrane	0.55%	1.00%	0.10%
	Microfiltration-Reverse Osmosis	0.55%	1.00%	0.10%
	Microfiltration-Ultrafiltration-Nanofiltration-Reverse Osmosis	0.00%	0.00%	0.00%
Barriers/aquifer	Aquifer JUN20	1.97%	24.38%	0.31%
	Aquifer OCT20	0.05%	8.45%	0.00%
	Aquifer SEP21	1.94%	6.48%	0.03%

Leiva, A.M., Piña, B., Vidal, G. (2021). Antibiotic resistance dissemination in wastewater treatment plants: a challenge for the reuse of treated wastewater in agriculture. Rev Environ Sci Bio/Technol. https://doi.org/10.1007/s11157-021-09588-8

% Reduction relative to the WWTP effluent

Supplementary data from Valhondo, C.; Carrera, J.; Martínez-Landa, L.; Wang, J.; Amalfitano, S.; Levantesi, C.; Diaz-Cruz, M.S. Reactive Barriers for Renaturalization of Reclaimed Water during Soil Aquifer Treatment. Water 2020, 12, 1012. https://doi.org/10.3390/w12041012 and some unpublished data

Conclusions

- Managed Aquifer Recharge (Soil Aquifer Treatment) may constitute a cost-effective alternative to power-consuming tertiary wastewater treatments.
- Their efficiency on removing biological hazards, and particularly ARG loads, appears to match the state-of-the art current membrane and advanced-oxidation technologies.
- While their efficiency to remove recalcitrant pollutants and toxic effects (e.g., estrogenicity) seemed to be lower, they performed similarly to, or better than, other tertiary technologies. In any case, they represent a significant improvement over the WWTP secondary effluent
- In addition, the system allows the direct replenishment of natural groundwater, rather to the simple increase in the surface water flow, therefore improving the status of the whole aquifer, and the recovery of river ecosystem services (which would further improve water quality).

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