LESSON 1

10/02/2020

Prof. Danilo Spasiano

NAPLES

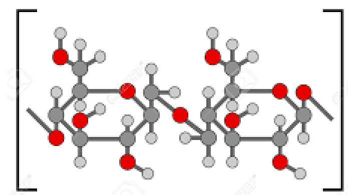
BARI

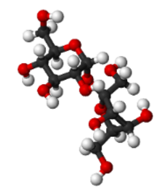
Organic and inorganic compounds

12% ethanol
water
CO_2
Glass

Polyethylene terephthalate

Hypothesis: the container is made of paper and contains sugar.
Cellulose
Sucrose

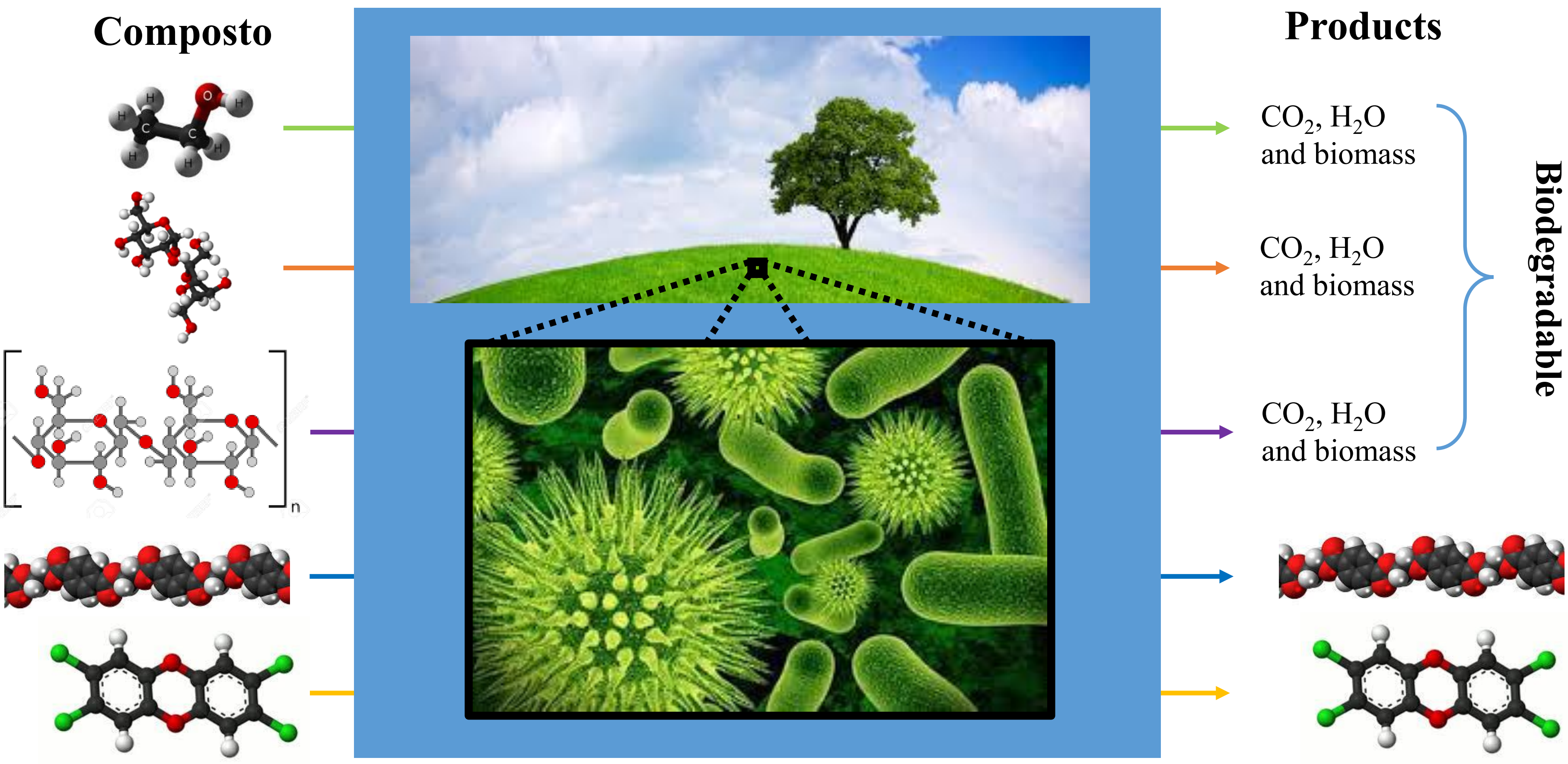




Dioxin

<u>All carbon-containing compounds (except CO_2, its salts and CO) are organic compounds</u>

Organic Compounds



OXIDATION OF BIODEGRADABLE COMPOUNDS

Biodegradable compounds are transformed by living organisms into carbon dioxide and water, but there is a problem: the oxidative process involves the consumption of oxygen. But how much oxygen is consumed?

Here's an example: Take a 1 L solution containing 1 mole of glucose (glucose concentration is 1 M i.e. 180 g/L). We assume that it is oxidized by microorganisms producing a negligible quantity of biomass compared to water and carbon dioxide:

$$C_6H_{12}O_6 + O_2 \xrightarrow{microorganisms} H_2O + CO_2$$

Let's balance the reaction

$$C_6H_{12}O_6 + 6\,O_2 \xrightarrow{microorganisms} 6\,H_2O + 6\,CO_2$$

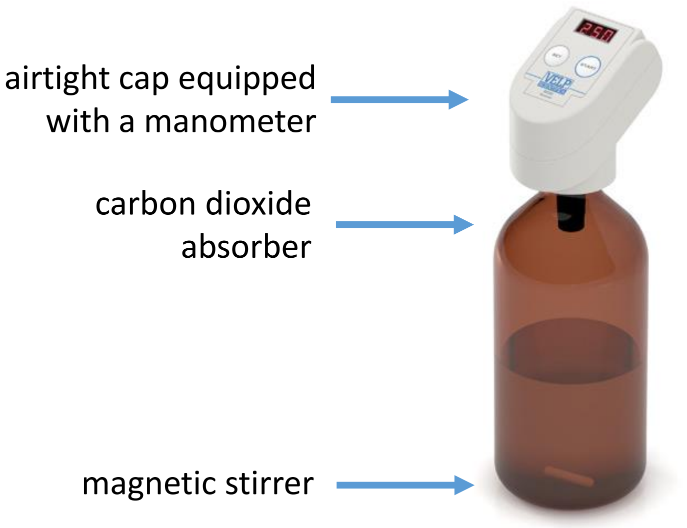
The biological oxidation of one mole of glucose requires the consumption of 6 moles of oxygen (192 g/L). In standard condition (25 °C, 1 atm), **the volume of consumed oxygen** is:

$$V_{O_2} = \frac{R \cdot n \cdot T}{P} = \frac{0{,}0821 \cdot 6 \cdot 298}{1} = 146\ \mathrm{L}$$

BIOCHEMICAL OXYGEN DEMAND: BOD

When a biodegradable compound is left in the environment, thanks to the intervention of living organisms, it is oxidized in carbon dioxide and water by the oxygen of the atmosphere. We can use this mechanism to estimate the amount of biodegradable compounds present in a water sample… Indeed, we can measure the amount of oxygen necessary for their biological oxidation.

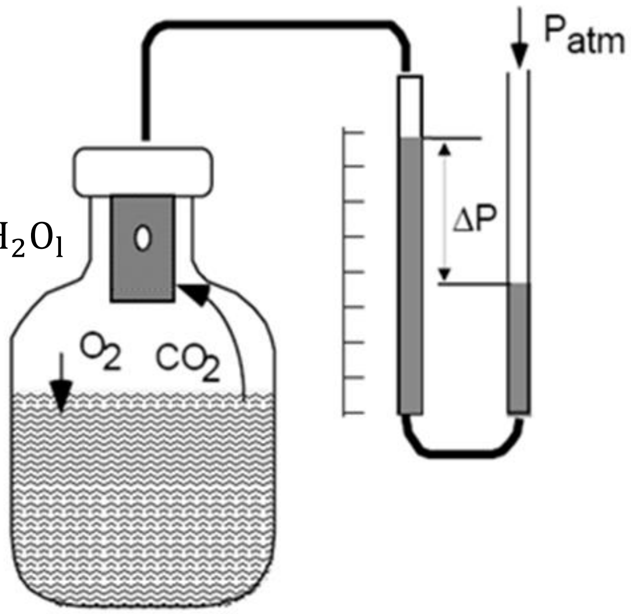
Ingredients :
- 1 amber glass bottle (V = 2 L);
- 1 L sample;
- If there is no bacterial flora in the sample, an inoculum is required;
- 1 airtight cap equipped with a manometer;
- 1 NaOH or KOH carbon dioxide absorber;
- 1 magnetic stirrer;
- 1 Thermostat to keep the solution temperature at 25 ° C;



BIOCHEMICAL OXYGEN DEMAND: BOD

Over time, the microorganisms present in solution oxidize the biodegradable compounds. As a consequence, microrganims produce carbon dioxide, which is absorbed by Na(OH), and consume oxygen.

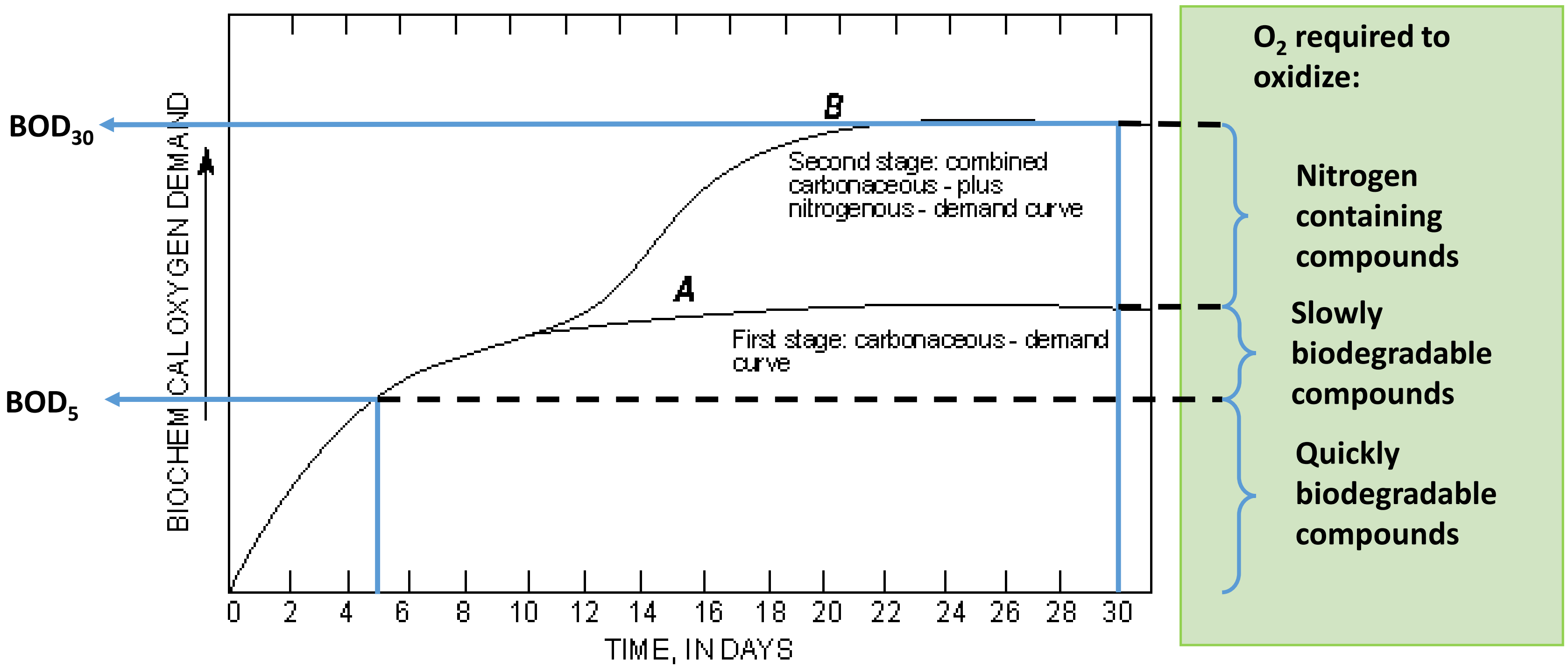
$$2NaOH_s + CO_{2,g} \longrightarrow Na_2CO_{3,s} + H_2O_l$$



The pressure in the headspace decreases!
By measuring the pressure difference, it is possible to trace the amount of oxygen consumed (in g_{O2}) and, considering the volume of the sample (1 L), biochemical oxygen demand is obtained.

$$\mathbf{BOD = \frac{g_{O_2}}{L}}$$

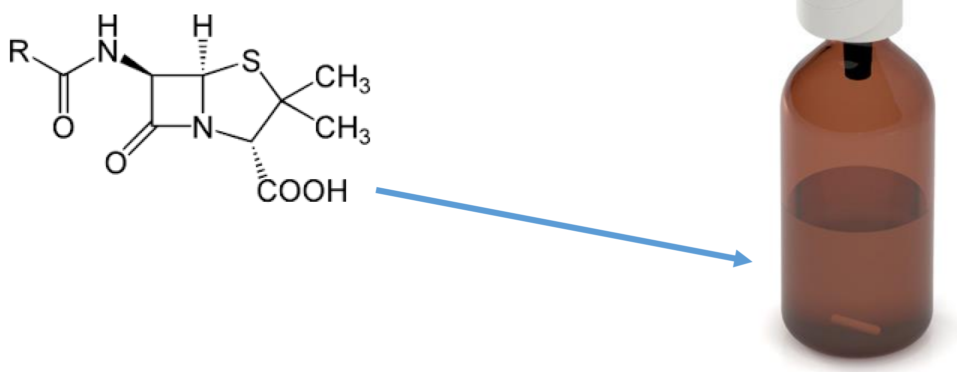
How long does a test for BOD measurement take?



BOD30
BOD5
BIOCHEMICAL OXYGEN DEMAND
B
A
Second stage: combined carbonaceous - plus nitrogenous - demand curve
First stage: carbonaceous - demand curve
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
TIME, IN DAYS
O2 required to oxidize:
Nitrogen containing compounds
Slowly biodegradable compounds
Quickly biodegradable compounds

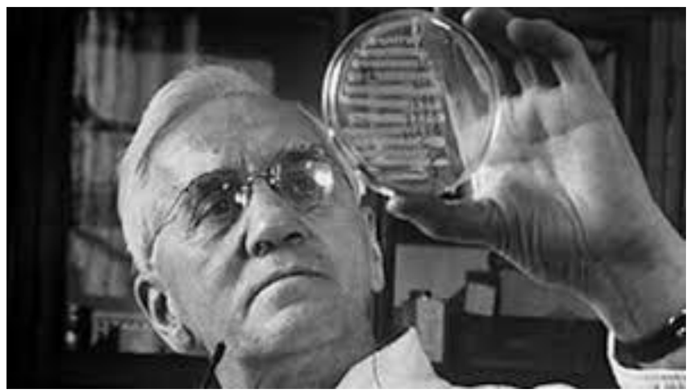
What would happen if we add penicillin to the solution?

Penicillin
(‘penicilina’, in spanish)



NOTHING HAPPENS!
PENICILLIN IS NOT BIODEGRADABLE.

As a result, oxygen is not consumed…
…and maybe it kills all the bacterial flora in the bottle!



We have a problem:
How do we take into account non-biodegradable compounds?

If you have a problem, ask a chemist…

…he has all the solutions

CHEMICAL OXYGEN DEMAND: COD

Instead of using microorganisms we use chemical reactions to oxidize all the compounds present in solution. Specifically, a solution of $K_2Cr_2O_7$ in sulfuric acid is added to the sample and the whole is brought to 120 ° C for 2h...

Cr^{6+}

(it is orange)

$$C_nH_aO_bN_c + dCr_2O_7^{2-} + (8d + c)H^+ \rightarrow$$

$$nCO_2 + \frac{a + 8d - 3c}{2} H_2O + cNH_4^+ + 2d\,Cr^{3+}$$

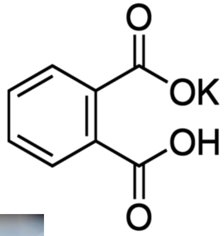
$$\text{dove } d = \frac{2n}{3} + \frac{a}{6} - \frac{b}{3} - \frac{c}{2}$$

(it is geen/light blue)

in the test tubes the content of oxidizable compounds increases, from left to right.

CHEMICAL OXYGEN DEMAND: COD

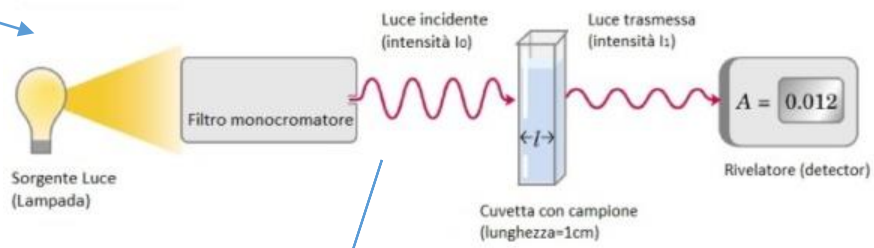
1) the standard solution containing a known quantity of COD are prepared with potassium acid phthalate (KHP)



$C_8H_5KO_4$ $\quad$ 1.176 mg O_2 / mg KHP

2) the reaction with H_2SO_4 and potassium dichromate occurs

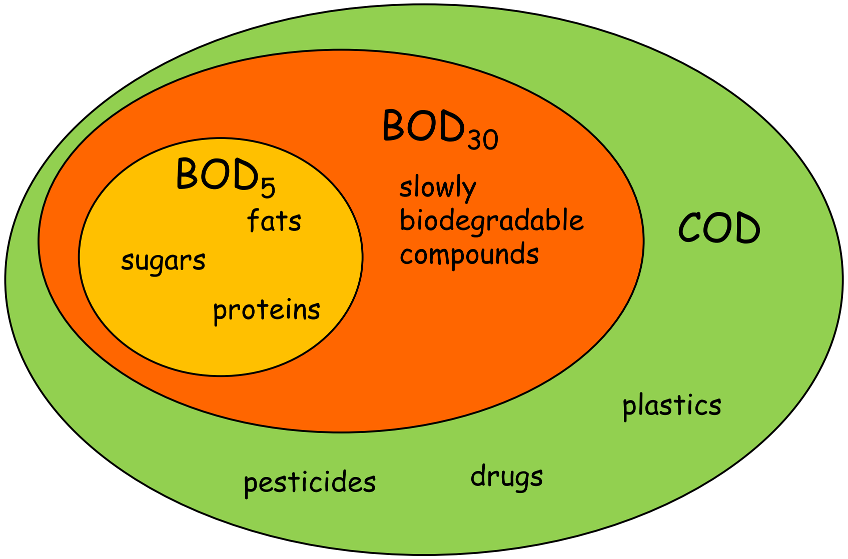
3) the standards and the samples are analyzed with a spectrophotometer and the absorbance (A) of the solution at 600 nm is measured



4) The calibration curve 'ABSORBANCE vs COD' is prepared with the standard solution (see point 1)

5) Now it is possible to convert the absorbance of the sample in a COD values

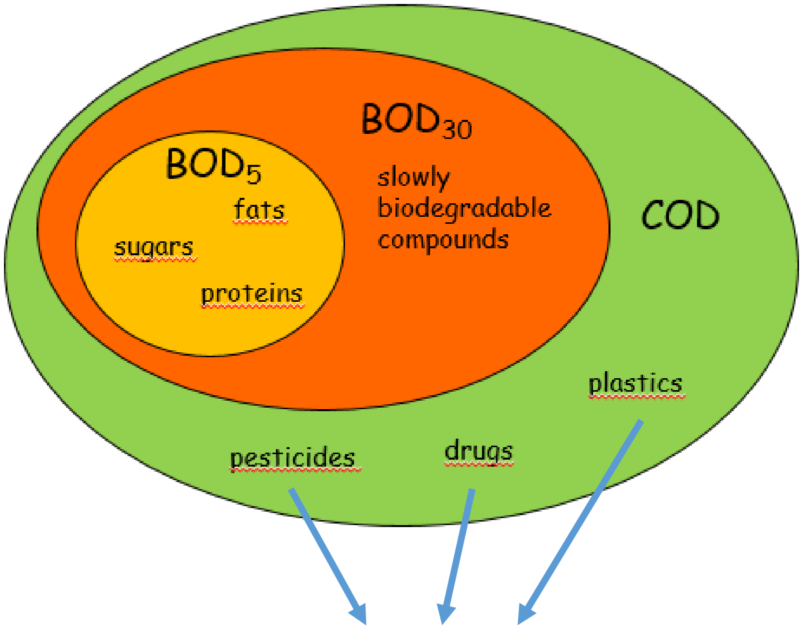
$$\mathbf{COD} = \frac{\mathbf{g_{O_2}}}{\mathbf{L}}$$



Por supuesto…

$COD \geq BOD_{30} \geq BOD_5$

EMERGING CONTAMINANTS



Emerging contaminants are naturally occurring or manmade chemicals, which have **recently been detected in environment** and whose toxicity or persistence **may threaten the survival of living beings** (Bell et al., 2019; Mo et al., 2019).

Bell, C.H., Gentile, M., Kalve, E., Ross, I., Horst, J., Suthersan, S. (2019). Emerging Contaminants Handbook. CRC Press.

Mo, L., Zheng, J., Wang, T., Shi, Y.G., Chen, B.J., Liu, B., Ma, Y.H., Li, M., Zhuo, L., Chen, S.J. (2019). Legacy and emerging contaminants in coastal surface sediments around Hainan Island in South China. Chemosphere, 215, 133-141. DOI: 10.1016/j.chemosphere.2018.10.022

Why emerging contaminants?

Many emerging contaminants, such as antibiotics, pharmaceuticals, illicit drugs, and personal care products, are discharged in municipal sewers and reach the WWTPs

Concentration range of selected ECs in raw influent (ng/L) and treated effluent (ng/L) from full-scale WWTPs in different geographical regions.

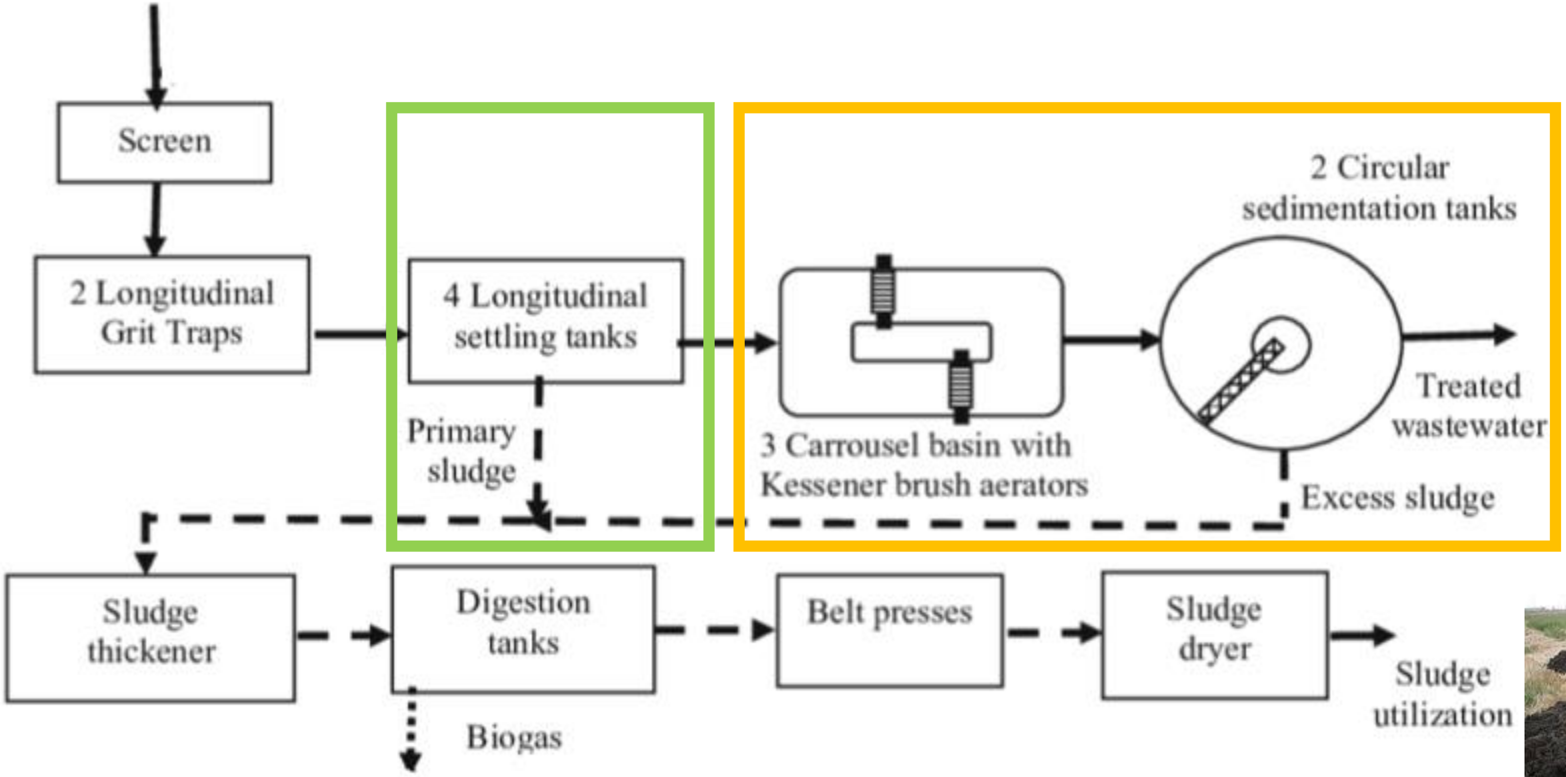
Selected ECs	Asia			North America			Europe		
	Influent	Effluent	Reference	Influent	Effluent	Reference	Influent	Effluent	Reference
Antibiotics									
Amoxicillin	<MQL–6516	<MQL–1670	[1–4]	n.r	<MQL	[5]	<MQL	<MQL–190	[6–8]
Azithromycin	1537–303,500	60.1–980	[1, 9]	61–2500	57–1300	[10]	77–1139	38–784	[11–13]
Ceftazidime	<MQL	<MQL	[1]	–	–	–	–	–	–
Chloramphenicol	<MQL–2430	<MQL–1050	[1, 4, 14, 15]	–	–	–	<MQL–319	<MQL	[16, 17]
Chlortetracycline	2333–15,911	<MQL–1986	[1, 4]	<MQL–310	<MQL–420	[10, 18]	n.r	<MQL	[8]
Ciprofloxacin	15.5–6453	<MQL–524.1	[1, 9, 19, 20]	<MQL–246,100	<MQL–620	[10, 18, 21, 22]	<MQL–13,625	<MQL–5692	[6, 11, 13, 23]
Clarithromycin	26–1854	4.79–637.1	[1, 20]	<MQL–8000	130–7000	[10, 22]	0.4–647	25–359	[11–13]
Clindamycin	23.8–26.6	2.94–4.24	[1]	–	–	–	<MQL–101	10–180	[16, 24]
Enrofloxacin	<MQL	<MQL	[25]	5.9–250	3.5–270	[10, 18]	<MQL–18	<MQL–636	[8, 26]
Erythromycin	111.4–403.3	70–186.6	[1]	–	–	–	<MQL–2130	<MQL–290	[6, 13, 23]
Erythromycin-H_2O	226–20,600	194.5–14,400	[1, 4, 20, 27]	<MQL–3900	<MQL–838	[10, 18, 22]	24–6755	15–2841	[11, 12, 17]
Lincomycin	<MQL–19,401	3.92–21,278	[1, 20, 28, 29]	<MQL–360	4.9–510	[10, 18, 21, 30]	<MQL–281	<MQL	[6]
Meropenem	264.8–433.6	27–67.9	[1]	–	–	–	–	–	–
Minocycline	730.9–3808	<MQL	[1]	<MQL	<MQL	[10]	–	–	–
Ofloxacin	54.8–1274	13.3–7870	[4, 20, 25, 31]	470–1000	<MQL–506	[21, 22]	n.r	71–8637	[8]
Oxytetracycline	<MQL–30,049	<MQL–2014	[1, 4, 20, 25]	<MQL–47,000	<MQL–4200	[10, 18, 21]	<MQL–7	<MQL–5	[32]
Sulfamethazine	<MQL–1814	<MQL–260.8	[1, 4, 20, 29]	<MQL–300	<MQL–363	[10, 18, 22]	<MQL–680	<MQL	[13, 16, 32]
Sulfamethoxazole	3.0–1389	<MQL–562	[1, 4, 20, 29, 33]	<MQL–4200	<MQL–1800	[5, 10, 18, 22]	<MQL–11,555	<MQL–544	[6, 11–13, 24, 34]
Tetracycline	<MQL–12,340	<MQL–1536	[1, 4, 20, 25, 27]	<MQL–48,000	<MQL–3600	[10, 18, 22]	<MQL–790	<MQL–850	[8, 13, 32]
Trimethoprim	19.5–570	3.7–772	[1, 14, 19, 20, 27]	<MQL–6796	<MQL–37,000	[5, 10, 18, 21]	<MQL–4342	<MQL–3052	[6, 11–13, 17, 24, 34]
Tylosin	<MQL	<MQL	[1, 4]	<MQL–1500	21–720	[10, 18]	<MQL	<MQL–173	[8, 16]
Vancomycin	962–43,740	<MQL	[1]	–	–	–	n.r	<MQL–8514	[8]
Antimicrobials									
Miconazole	<MQL–597	<MQL	[20, 25]	5.2–43	1.6–27	[10]	<MQL–337.9	<MQL–35.7	[35, 36]
Thiabendazole	<MQL–1.29	<MQL	[20, 25]	6.8–220	6.2–140	[10]	–	–	–
Triclocarban	341.1–8880	8.4–5860	[1, 28, 37]	340–4644	64–617	[10, 38]	97–140	n.r	[39]
Triclosan	1.3–2500	49.1–263.9	[1, 28, 37, 40]	14–6817	3.1–360	[10, 38, 41]	<MQL–5260	<MQL–430	[13, 34, 39]

Selected ECs	Asia			North America			Europe		
	Influent	Effluent	Reference	Influent	Effluent	Reference	Influent	Effluent	Reference
NSAIDs									
Acetaminophen	67–147,700	<MQL–2568	[19, 20, 25, 33, 42]	21,000–500,000	<MQL–62,000	[9, 10, 38]	<MQL–482,687	<MQL–24,525	[6, 13, 17, 34, 43]
Codeine	<MQL–242	<MQL–208	[25, 28]	77–5700	80–3300	[10]	150–32,295	9.7–15,593	[17, 23, 44]
Diclofenac	13–445	<MQL–69.2	[20, 25, 29, 40, 42]	140–2450	<MQL–359	[30, 41, 45]	<MQL–4869	<MQL–5164	[13, 17, 34, 43, 46]
Fenoprofen	<MQL–2260	<MQL–23.4	[25, 42]	<MQL	<MQL–405	[45, 47]	n.r	<MQL–280	[48]
Ibuprofen	34.8–55,975	<MQL–1890	[19, 20, 25, 28]	2500–45,000	16–14,600	[5, 10, 30, 41, 45]	<MQL–83,500	<MQL–24,600	[13, 17, 34, 43, 46]
Indomethacin	<MQL–449.4	<MQL–61.4	[25, 42]	<MQL–640	<MQL–507	[41, 45, 47]	<MQL–297	<MQL	[6]
Ketoprofen	<MQL–286	<MQL–183	[25, 28, 29]	60–150	40–90	[41]	<MQL–5700	<MQL–1620	[6, 13, 17, 48]
Naproxen	<MQL–7762	<MQL–159	[19, 25, 29, 42]	1700–25,000	<MQL–3500	[9, 10, 45, 47, 49]	<MQL–611,000	<MQL–33,900	[6, 13, 17, 34, 43]
Salicylic acid	167–16,900	<MQL–1426	[20, 42]	2820–27,800	<MQL–320	[41, 47]	<MQL–164,400	<MQL–10,100	[6, 17, 34, 43]
Beta-blockers									
Atenolol	<MQL–294,700	<MQL–518.6	[9, 19, 25, 29, 42]	500–2642	<MQL–14,200	[5, 9]	<MQL–33,106	<MQL–7602	[6, 13, 17, 24]
Metoprolol	<MQL–79,500	<MQL–268	[9, 14, 25, 29]	16–154	15–212	[9]	<MQL–4148	<MQL–5762	[6, 13, 17, 23, 24]
Propranolol	<MQL–9.56	<MQL–8.3	[14, 25]	–	–	–	<MQL–1962	<MQL–615	[6, 13, 17, 23, 24]
Anticonvulsants									
Carbamazepine	<MQL–18,500	<MQL–900	[20, 25, 28, 29, 42]	<MQL–440	28–551	[5, 9, 30, 45, 50]	<MQL–3110	<MQL–4596	[6, 13, 17, 24, 34, 46, 51]
Gabapentin	4825.5–15,359	213–8855	[42]	n.r	1000 ± 900	[52]	6442–25,079	7651–56,810	[17, 24]
Sulpiride	64.9–15,358.8	70.7–322.4	[14, 42]	n.r	33–137	[53]	113–1100	110–294	[54]
Artificial sweeteners									
Acesulfame	560–13400	5840–9147	[20, 40, 55]	90–2270	600–4330	[56]	12,000–43,000	15,000–46,000	[57]
Cyclamate	<MQL–66,400	<MQL–160	[20, 28, 55]	–	–	–	10,000–65,000	<MQL–450	[57]
Saccharin	9310–389,000	<MQL–2370	[20, 28, 55]	1860–25,100	220–700	[56]	7100–18,000	<MQL–1800	[57]
Sucralose	1100–6520	1300–5490	[20, 28, 40, 55]	17,500–46,100	18,700–48,900	[56]	2000–9100	2000–8800	[57]
Lipid regulators									
Bezafibrate	16.8–159	<MQL–51.4	[14, 58]	–	65–359	[45]	100–7600	<MQL–4800	[13, 23, 24, 34, 46, 59]
Clofibric acid	<MQL–65	<MQL–44.9	[14, 20, 25, 29, 42, 58]	<MQL	<MQL–44	[45, 47]	<MQL–265.9	<MQL–91	[6, 17, 23, 34]
Gemfibrozil	<MQL–453.4	<MQL–535.2	[14, 20, 25, 29, 58, 60]	<MQL–36,530	<MQL–1493	[45, 47]	<MQL–17,055	<MQL–5233	[6, 23, 34, 43]

Selected ECs	Asia			North America			Europe		
	Influent	Effluent	Reference	Influent	Effluent	Reference	Influent	Effluent	Reference
Hormones									
Estrone	<MQL–132.5	<MQL–51.2	[29, 42, 61, 62]	8–52	<MQL–56	[5, 38, 41, 47]	2.4–670	<MQL–95	[13, 46, 63]
Estriol	<MQL–802	<MQL–30.2	[29, 42, 61]	<MQL–217	<MQL	[38, 64]	<MQL–660	<MQL–275	[13, 46, 63]
17α-ethinylestradiol	<MQL–26.1	<MQL–13.1	[61]	<MQL–242	<MQL	[30, 64]	0.4–70	0.5–106	[13, 46]
X-ray contrast media									
Iohexol	63.8–124,966	2100–8700	[20, 37, 40, 42]	n.r	8623–9237	[65]	18,000 ± 2000	1200 ± 100	[66]
Iopromide	47.7–12,200	<MQL–7140	[20, 37]	–	–	–	<MQL–7500	<MQL–9300	[13, 59]
Iopamidol	82.8–45,611	<MQL–6520	[20, 37, 42]	–	–	–	4300 ± 900	4700 ± 1000	[67]
UV filters									
Octocrylene	<MQL	<MQL–153	[42, 68]	–	–	–	100–1200	<MQL–300	[69]
Oxybenzone	<MQL–2616.8	<MQL–772	[28, 42, 68, 70]	–	–	–	<MQL–7800	<MQL–700	[23, 69]
Stimulant									
Caffeine	759–60,500	13–51,700	[14, 19, 20, 28, 60]	5809–82,882	<MQL–37,200	[5, 9, 38]	102–113,200	30–13,900	[6, 43, 71]
Anti-itching									
Crotamiton	<MQL–1500	<MQL–1000	[25, 42, 72]	–	–	–	<MQL–140	<MQL–100	[51]
Insect repellent									
DEET	124–2341.9	21.6–324.8	[14, 20, 42, 58, 60, 72]	200–42,334	13–1663	[9, 30]	<MQL–6900	n.r	[73]
Plasticizer									
Bisphenol A	55.6–5850	<MQL–123	[25, 72]	595–2469	2–450	[9, 41]	<MQL–2376	16–1840	[46, 73]

In some cases, there is a decrease in the concentration of some emerging contaminants. What happened?

CONVENTIONAL WWTP SCHEME



Concentration of selected ECs in sewage sludge and biosolids from WWTPs.

Selected ECs	Sludge (ng/g dw)	Reference	Biosolids (ng/g dw)	Reference
Antibiotics				
Amoxicillin	<MQL	[1]	–	–
Azithromycin	<MQL–666	[2, 3]	81–1220	[4, 5]
Ceftazidime	–	–	–	–
Chloramphenicol	<MQL	[6]	<MQL	[6]
Chlortetracycline	<MQL–1908	[6–8]	<MQL–28260	[4–6, 8]
Ciprofloxacin	1400–4800	[9, 10]	1780–160000	[4, 5]
Clarithromycin	<MQL–537	[2, 6]	4.6–580	[4–6]
Clindamycin	<MQL–6.54			
Enrofloxacin	7.6–11560	[8, 11]	<MQL–4247	[4, 5, 8]
Erythromycin	6–79	[6, 8]	13–50	[6]
Erythromycin-H_2O	–	–	1.6–183	[4, 5]
Lincomycin	<MQL–4967	[8, 12, 13]	8.3–8.7	[4]
Meropenem	–	–	–	–
Minocycline	1000–2000		121–2630	[4, 5]
Ofloxacin	1480–5760	[6, 10, 11]	150–8140	[4–6]
Oxytetracycline	<MQL–3790	[7, 11]	8.3–114	[4, 5]
Sulfamethazine	<MQL–54.58	[7]	<10	[4]
Sulfamethoxazole	<MQL–84.4	[7, 11, 13]	1.5–51	[4, 5]
Tetracycline	<MQL–466	[6, 11]	<MQL–2790	[4–6]
Trimethoprim	<MQL–13	[1, 2, 12, 13]	1.4–140	[4, 5]
Tylosin	31–139	[8]	<12	[4]
Vancomycin	<MQL	[8]	<MQL	[8]
Antifungal/antimicrobials				
Miconazole	<MQL–2609	[2, 11, 12, 14]	1.4–1100	[4, 5]
Thiabendazole	<MQL–10.6	[11, 12]	7.9–370	[4, 5]
Triclocarban	362–8460	[2, 11–13]	1200–48100	[4, 5]
Triclosan	354–15600	[2, 10, 11, 13]	2000–19700	[4, 5]
NSAIDs				
Acetaminophen	<MQL–586	[2, 6, 11, 12]	<MQL–370	[4, 6, 15]
Codeine	<MQL–79	[11, 13] [2]	<MQL–110	[4, 5]
Diclofenac	<MQL–133	[2, 6, 11, 16]	<MQL–34	[6]
Fenoprofen	<MQL	[11]	–	–
Ibuprofen	<MQL–3988	[10, 11, 13, 16]	<MQL–490	[4, 5]
Indomethacin	<MQL–77	[6, 11] [1]	32–44	[6]
Ketoprofen	<MQL–58.4	[6, 11–13]	5–12	[6]
Naproxen	<MQL–1022	[10, 11, 16]	2.9–273	[4, 5]
Salicylic acid	<MQL–13743	[10, 16]	–	–

Selected ECs	Sludge (ng/g dw)	Reference	Biosolids (ng/g dw)	Reference
Beta-blockers				
Atenolol	<MQL–86	[1, 6, 11]	<MQL	[6]
Metoprolol	<MQL–226	[6, 11]	<MQL	[6]
Propranolol	<MQL–849	[2, 6, 11]	<MQL–5	[6]
Anticonvulsants				
Carbamazepine	<MQL–50	[1, 2, 11, 13]	163–238	[5]
Gabapentin	–	–	–	–
Sulpiride	–	–	–	–
Artificial sweeteners				
Acesulfame	<MQL–166	[12, 13, 17]	–	–
Cyclamate	66.6–544	[13]	–	–
Saccharin	<MQL–19200	[12, 13, 17]	–	–
Sucralose	<MQL–1980	[12, 13, 17]	–	–
Lipid regulators				
Bezafibrate	17–64	[6]	–	–
Clobric acid	< MQL	[6, 11]	<MQL	[6]
Gemfibrozil	< MQL–1192	[10, 11]	152–159	[5]
Hormones				
Estrone	<MQL–17.5	[16, 18]	70–280	[19]
Estriol	<MQL–49	[10, 16, 18]	–	–
17α-ethinylestradiol	<MQL–17	[10, 16]	–	–
X-ray contrast media				
Iohexol	–	–	–	–
Iopromide	80 ± 4	[20]	–	–
Iopamidol	–	–	–	–
UV filters			–	–
Octocrylene	1060–9170	[21]	–	–
Oxybenzone	<MQL –790	[11, 12, 21]	–	–
Anti-itching				
Crotamiton	<MQL–62	[11] [6]	21–64	[6]
Insect repellent				
DEET	2–6	[6]	3–15	[6]
Stimulant				
Caffeine	<MQL–805	[2, 6, 11]	18–643	[5, 6]
Plasticizer				
Bisphenol A	<MQL–4700	[11, 18, 22]	–	–

Effect of pollutant characteristics on their presence in the WWTP sludge

	µg/kg$_{DS}$	logK$_{ow}$	pK$_a$	Ionization states at pH = 6.0 (%)				Ionization states at pH = 8.0 (%)			
				Anion	Neutral	Cation	Zwitterion	Anion	Neutral	Cation	Zwitterion
Antibiotics											
Azithromycin	<MQL - 1220	4.02	8.74	0	0.1	99.9	0	0	0.3	99.7	0
Chlortetracycline	<MQL - 28260	-0.62	3.3 / 7.4 / 9.3	0	0	0	100	0	0	0	100
Ciprofloxacin	1400 - 160000	-2.82	3.32 / 5.59 / 8.85	0	0	36.3	63.7	17.3	0	0.5	82.2
Clarithromycin	<MQL - 580	3.16	8.82 / 13.1	0	0.4	99.6	0	0	29.4	70.6	0
Enrofloxacin	7.6 - 11560	0.83	5.69	-	-	-	-	-	-	-	-
Lincomycin	<MQL - 4967	0.2	7.6	0.3	0	0.3	99.4	28	0	0	72
Minocycline	121 - 2630	0.05	2.8 / 5.0 / 7.8 / 9.3	0	0	0	100	0	0	0	100
Ofloxacin	150 - 8140	-0.39	5.97 / 9,28	-	-	-	-	-	-	-	-
Oxytetracycline	<MQL - 3790	-0.90	3.27 / 7.3 / 9.6	3.8	0	0.1	96.1	52.9	0	0	47.1
Tetracycline	<MQL - 2790	-1.37	3.3 / 7.7 / 9.7	0	0	0	100	5.2	0	0	94.8
Antifungal/antimicrobials											
Miconazole	<MQL - 1100	6.1	6.77	-	-	-	-	-	-	-	-
Triclocarban	362 - 48100	4.34	12.7	0	0	0	100	0	0	0	100
Triclosan	354 - 19700	4.76	7.9	2	94	2	2	67.6	32.4	0	0
NSAIDs											
Acetaminophen	<MQL - 586	0.46	9.7	0	100	0	0	3.3	96.7	0	0
Ibuprofen	<MQL - 3988	3.97	4.91	93.4	6.6	0	0	99.9	1	0	0
Naproxen	<MQL - 1022	3.18	4.2	98.5	1.5	0	0	100	0	0	0
Salicylic acid	<MQL - 13743	2.26	2.97	99.9	0.1	0	0	100	0	0	0
Beta-blockers											
Propanolol	<MQL - 849	2.02	-	-	-	-	-	-	-	-	-
Lipid regulators											
Gemfibrozil	< MQL - 1192	4.77	4.5	97.5	2.5	0	0	100	0	0	0
UV filters											
Octocrylene	1060 - 9170	7.04	14	0	100	0	0	0	100	0	0
Oxybenzone	<MQL - 790	3.79	9.6	7.8	92.2	0	0	89.4	10.6	0	0
Stimulant											
Caffeine	<MQL - 805	-0.07	14	0	100	0	0	0	100	0	0
Plasticizer											
Bisphenol A	<MQL - 4700	3.32	9.6	0	100	0	0	1.6	98.4	0	0

Cape Town

2017…

Cape Town water crisis: With drought, comes the horror of disease

Providing water is merely half the battle. Fighting disease will be The Cape's next big challenge

by Tom Head — 2017-10-10 12:24 in News

TIME

What It's Like To Live Through Cape Town's Massive Water Crisis

By ARYN BAKER
Photographs by MIKHAEL SUBOTZKY and JOHNNY MILLER for TIME

I knew we were in trouble when I found myself Googling dry composting toilets. That was on Feb. 1, just after the mayor's office here in Cape Town announced new water restrictions. We are now limited to using 13 gallons of water per person per day. That's enough for a 90-second shower, a half-gallon of drinking water, a sinkful to hand-wash dishes or laundry, one cooked meal, two hand washings, two teeth brushings and one toilet flush. I figured I could save an extra couple of gallons by forgoing the daily flush in favor of a dry composting toilet. Hippie friends living off the grid in the country do it. How bad could it be?

According to current projections, Cape Town will run out of water in a matter of months. This coastal paradise of 4 million on the southern tip of South Africa is to become the first modern major city in the world to completely run dry. And even though residents aren't responsible, the burden of making sure it doesn't happen rests largely on our ability to cut down on water usage. Dramatically.

Almost 50 L/(EAxd)

How towing an iceberg to South Africa could solve Cape Town's water crisis

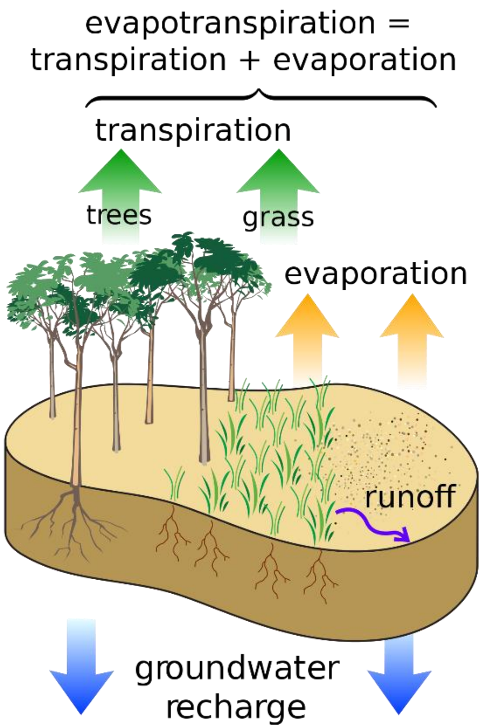
Nick Sloane has spent his life being lowered from helicopters onto flaming oil tankers and capsized liners in his role in marine salvage. He tells William Leith why his new project – involving 'harvesting' a 700 metre-long iceberg from the Antarctic – is not as mad as it seems

Annual water consumption in **Italy** is around $\mathbf{54 \cdot 10^9\ m^3/y}$**:**

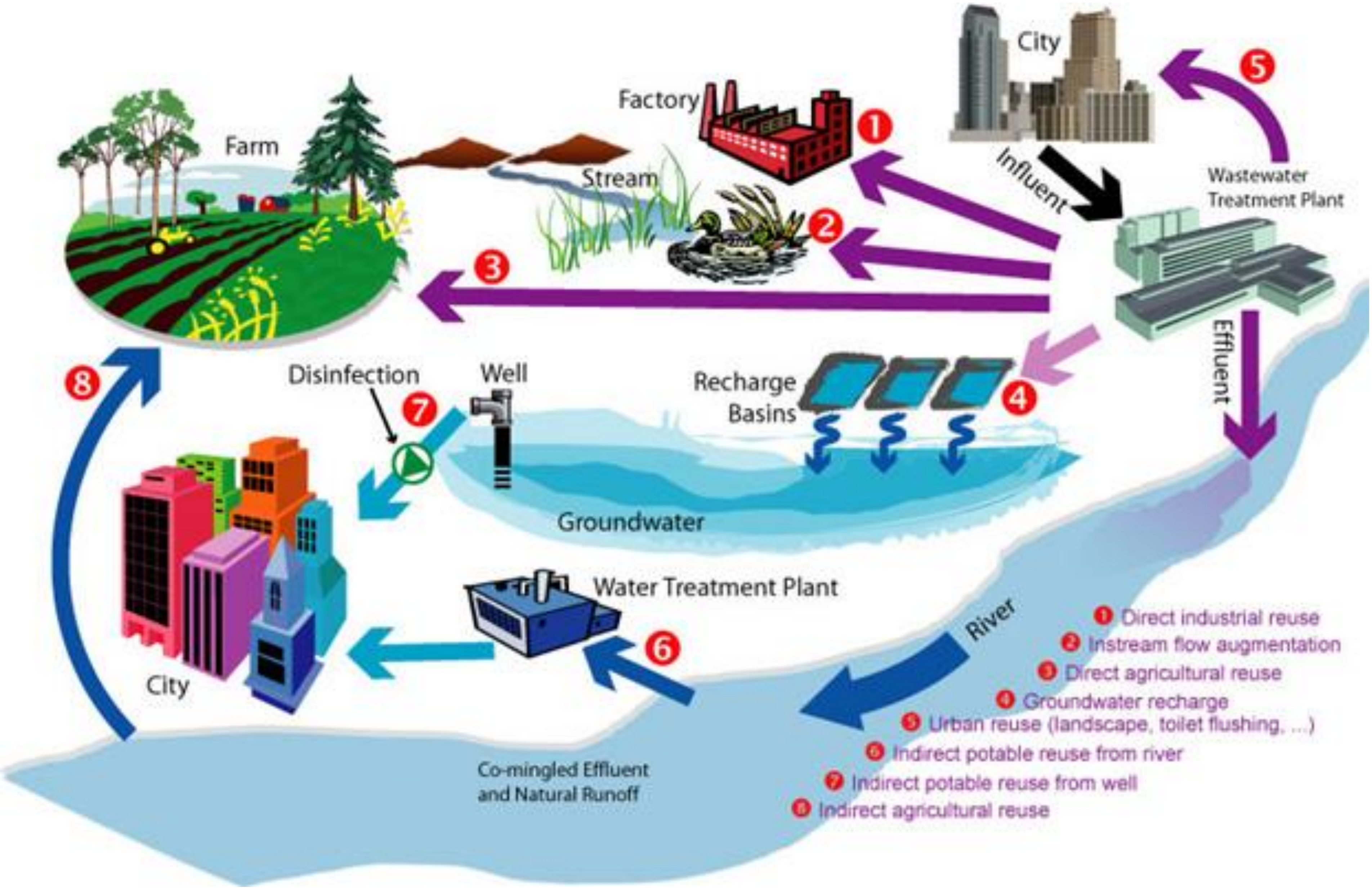
- 70% for agriculture;
- 20% for industries;
- 10% for urban activities.

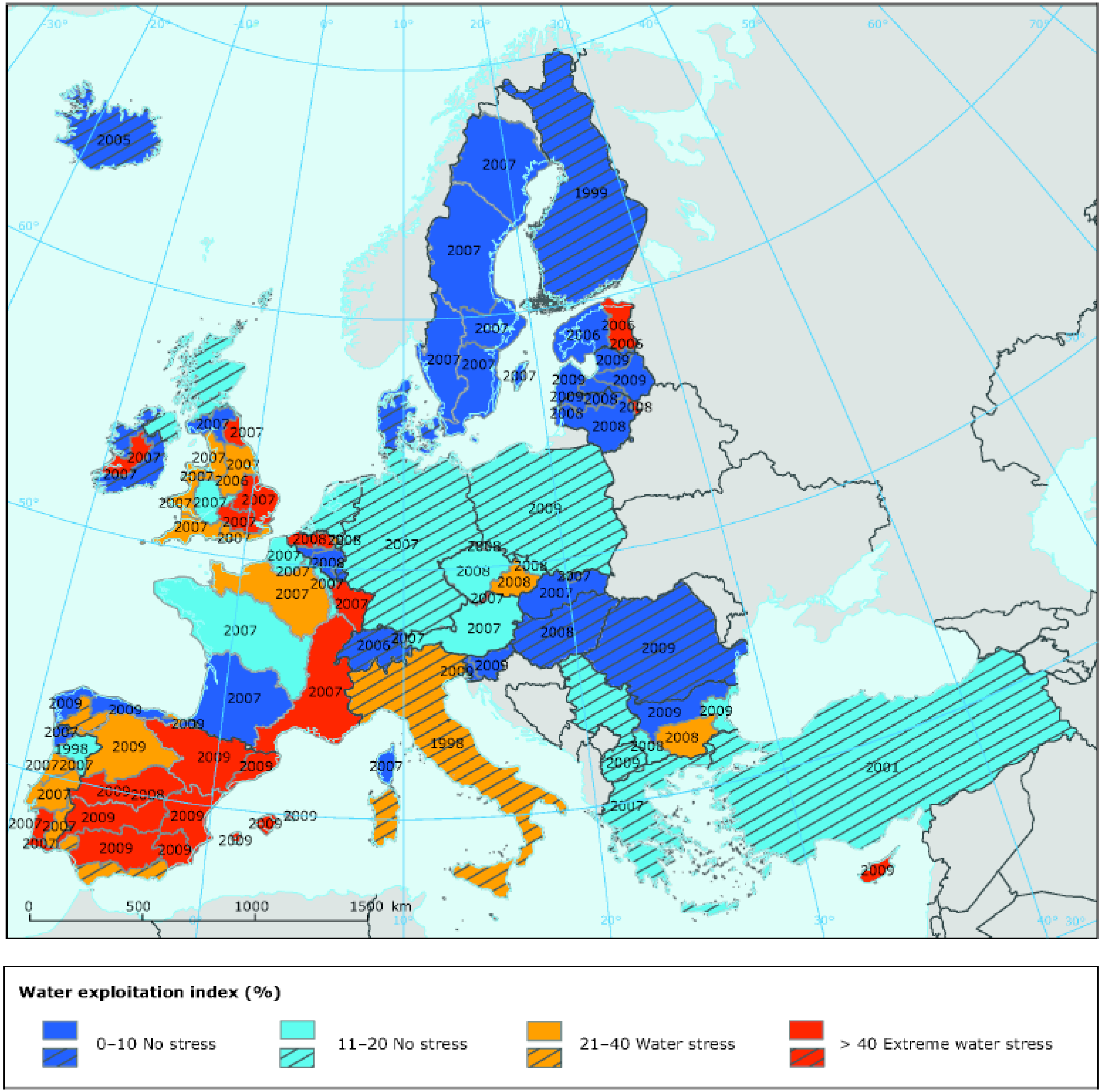
Faced with these needs, there is an estimated annual meteoric supply of around $\mathbf{300 \cdot 10^9\ m^3/y}$. (ISTAT 2000)

It seems that there are no problems. However…



- Evapotranspiration: 40-45%
- Runoff: 40-45%
- Groundwater recharge 10-15% ($\mathbf{30\text{-}45 \cdot 10^9\ m^3/a}$)


City
Factory
Farm
Stream
Influent
Wastewater Treatment Plant
Effluent
Disinfection
Well
Recharge Basins
Groundwater
Water Treatment Plant
River
City
Co-mingled Effluent and Natural Runoff
1 Direct industrial reuse
2 Instream flow augmentation
3 Direct agricultural reuse
4 Groundwater recharge
5 Urban reuse (landscape, toilet flushing, ...)
6 Indirect potable reuse from river
7 Indirect potable reuse from well
8 Indirect agricultural reuse


0 500 1000 1500 km
Water exploitation index (%)
0–10 No stress
11–20 No stress
21–40 Water stress
> 40 Extreme water stress

Possible wastewater reuse

Categories of use	Uses
Urban uses	Irrigation of public parks, sporting facilities, private gardens, roadsides; Street cleaning; Fire protection systems; Vehicle washing; Toilet flushing; Air conditioners; Dust control
Agricultural uses	Food crops not commercially processed; Food crops commercially processed; Pasture for milking animals; Fodder; Fibre; Seed crops; Ornamental flowers; Orchards; Hydroponic culture; Aquaculture; Greenhouses; Viticulture
Industrial uses	Processing water; Cooling water; Recirculating cooling towers; Washdown water; Washing aggregate; Making concrete; Soil compaction; Dust control
Recreational uses	Golf course irrigation; Recreational impoundments with/without public access (e.g. fishing, boating, bathing); Aesthetic impoundments without public access; Snowmaking
Environmental uses	Aquifer recharge; Wetlands; Marshes; Stream augmentation; Wildlife habitat; Silviculture
Potable uses	Aquifer recharge for drinking water use; Augmentation of surface drinking water supplies; Treatment until drinking water quality

(Report ‘Water reuse in Europe’, EU 2014)

Possible wastewater reuse in Europe

Intended use of reclaimed water	Cyprus	France	Greece	Italy	Portugal	Spain
Irrigation of private gardens						√
Supply to sanitary appliances				√		√
Landscape irrigation of urban areas (parks, sports grounds and similar)	√	√	√	√	√	√
Street cleaning			√	√		√
Soil compaction			√			
Fire hydrants			√	√*		√
Industrial washing of vehicles				√		√
Irrigation of crops eaten raw	√	√	√	√	√	√
Irrigation of crops not eaten raw	√	√	√	√	√	√
Irrigation of pastures for milk or meat producing animals		√	√	√	√	√
Aquaculture						√
Irrigation of trees without contact of reclaimed water with fruit for human consumption	√	√	√	√	√	√

(Report 'Water reuse in Europe', EU 2014)

Possible wastewater reuse in Europe

Intended use of reclaimed water	Cyprus	France	Greece	Italy	Portugal	Spain
Irrigation of ornamental flowers without contact of reclaimed water with the product		√	√	√		√
Irrigation of industrial non-food crops, fodder, cereals	√	√	√	√	√	√
Water process, and cleaning in industry other than the food industry			√	√**		√
Water process and cleaning in the food industry			√	√**		√
Cooling towers and evaporative condensers			√	√		
Golf course irrigation	√	√	√	√	√	√
Ornamental ponds without public access			√			
Aquifer recharge by localised percolation	√		√			√
Aquifer recharge by direct injection	√		√			√
Irrigation of woodland and green areas not accessible to the public		√	√	√	√	√
Silviculture						√
Environmental uses (maintenance of wetlands, minimum stream flows and similar)						√

(Report 'Water reuse in Europe', EU 2014)

What compounds should we worry about?

Chemical agents	Adverse effects
Biodegradable organics such as proteins, carbohydrates	Eutrophication of surface water.
Oils, greases, cellulose, lignin…	Anoxic conditions in aquatic ecosystems.
Macronutrients (N, P, K)	Eutrophication of soils and surface water, plant toxicity, nutrient imbalance in plants, pest and disease in plants, loss of biodiversity.
Micronutrients (B, Ca, Cu, Fe, Mg, Na, Co, …)	Plant toxicity, accumulation in soils.
Metals (Cd, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Zn, …)	Toxicity to plants and aquatic biota.
Inorganic salts (chlorides, sulphurs, nitrates, …)	Soil salinity due to a plant stressed from osmotic, soils contamination, increasing salinity of groundwater and surface water risk for human health (methemoglobinemia associated with nitrates).
Industrial chemicals (PFCs, MTBE, solvents, …)	Carcinogenic, teratogenic and/or mutagenic effects, risk for human health (cyanotoxins), bioaccumulation, toxicity to plants.
Pesticides, biocides and herbicides (e.g. atrazine, lindane, diuron, fipronil)	
Natural chemicals (hormones, phytoestrogens, geosmin, 2-methylisoborneol)	Various effects, often unexplored.

What compounds should we worry about?

Chemical agents	Adverse effects
Pharmaceuticals and metabolites (antibacterials (sulfamethoxazole), analgesics (acetominophen, ibuprofen), beta-blockers (atenolol), antiepileptics (phenytoin, carbamazepine), veterinary and human antibiotics (azithromycin), oral contraceptives (ethinyl estradiol))	
Personal care products (triclosan, sunscreen ingredients, fragrances, pigments)	Carcinogenic, teratogenic and/or mutagenic effects, risk for human health (cyanotoxins), bioaccumulation, toxicity to plants.
Household chemicals and food additives (sucralose, bisphenol A (BPA), dibutyl phthalate, alkylphenol polyethoxylates, flame retardants (perfluorooctanoic acid, perfluorooctane sulfonate)	Various effects, often unexplored.
Transformation products (NDMA, HAAs, and THMs)	