

Busting water myths – chemicals, plastics and fish penises



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Australian Rivers Institute

Outline

- Anthropogenic pollution
- What are chemicals
- Toxicology 101: The dose makes the poison
- Where does drinking water come from?
- Water recycling
- Chemicals in water
- Endocrine disrupting compounds
- Plastic pollution
- What can we do?



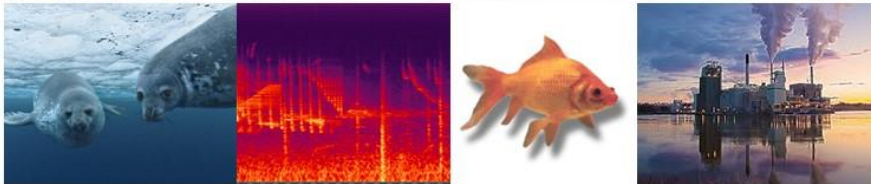
Fred in a nutshell

- Environmental Toxicologist
- BSc (1998), MSc (2001), PhD (2005)

McGill UNIVERSITY
BSc (Biology/Ecology)



UNB Saint John
MSc
(Environ. Science)



LINCOLN UNIVERSITY
PhD
(Environ. Toxicol.)

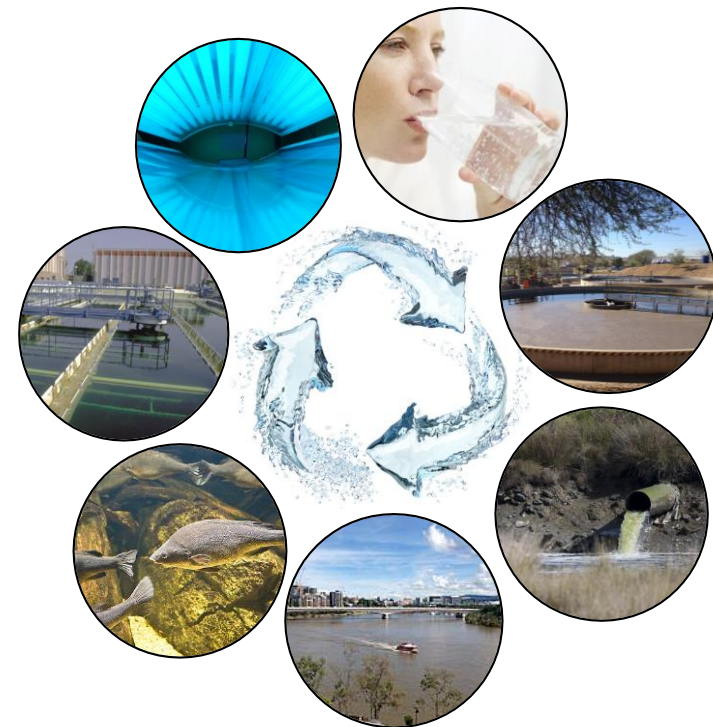
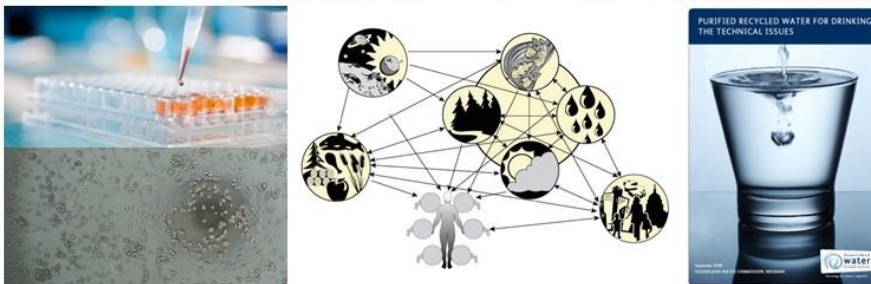


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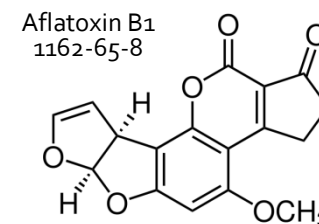
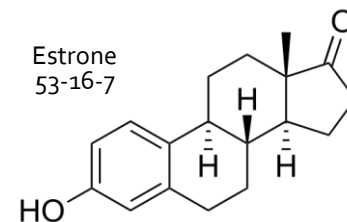
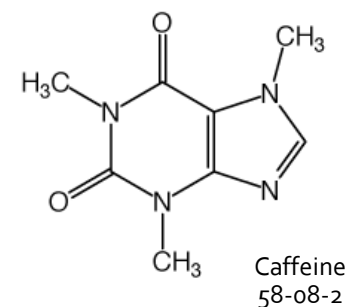
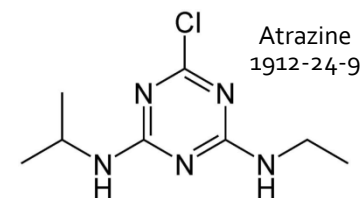
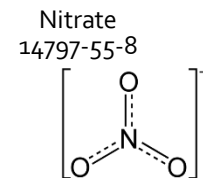
Anthropogenic pollution

- Humans release vast quantities of waste to the environment
 - Much ends up down the drain and into our waterways
- Two main types of pollutants:
 - “**Gross pollutants**”, such as plastics, e-Waste ...
 - “**Toxic chemicals**”, such as heavy metals, industrial chemicals, pesticides, radioactive waste, dioxins, nanoparticles ...



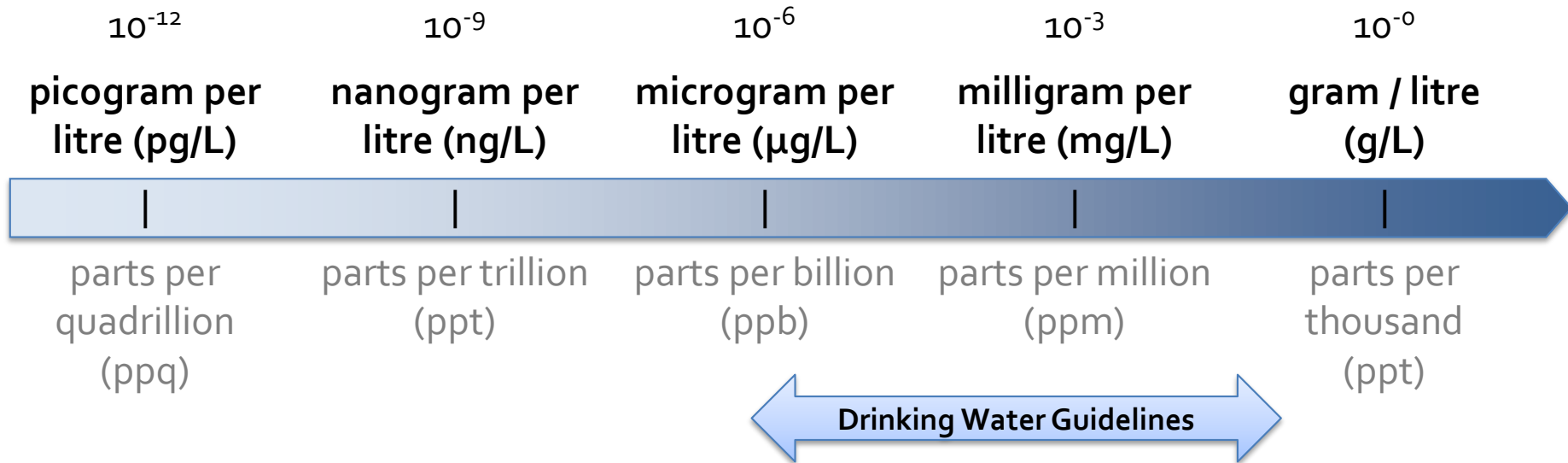
What are chemicals

- In this context, an organic or inorganic compound with a fixed chemical composition present in water
- Can be natural or synthetic
 - Natural \neq safe!!! (e.g., arsenic, aflatoxin)
- Chemical Abstract Service (CAS)
 - CAS Registry Number (CASRN)
 - >130 million substances registered (a)



Unit of measure

- Concentration expressed as mass per volume
 - Usually as mg/L, or parts per million (ppm)



The dose-response concept

"All substances are poisons.


*There is none which is not a
poison.*

*The right dose differentiates a
poison from a remedy."*



Paracelsus (1493-1541)

Toxicology

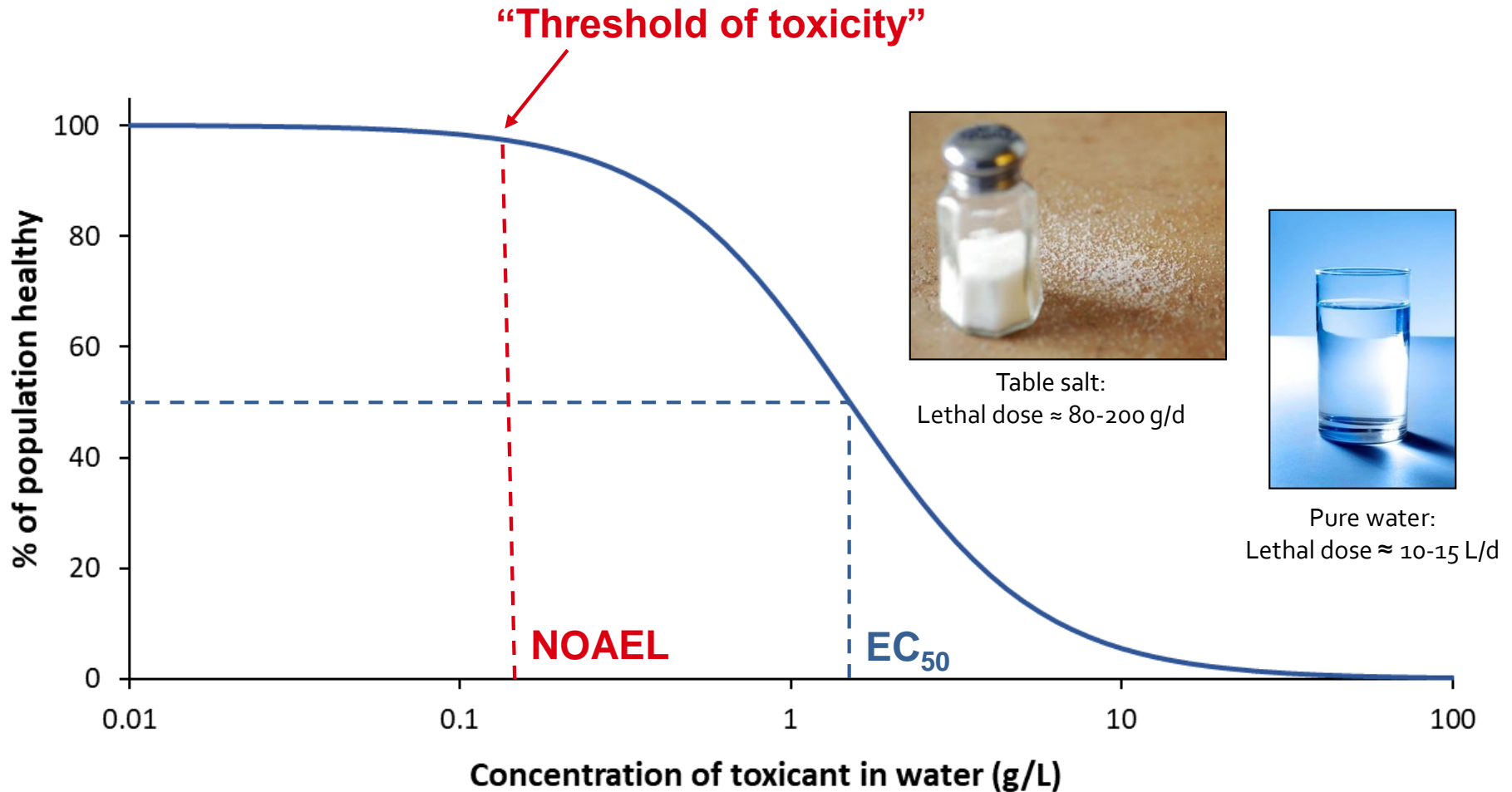
- Toxicology is the science of poisons 
- Long development as a science
 - Cave dwellers used poisonous plant extracts on tips of spears
 - **Paracelsus** (~1500CE) demonstrated that the “dose make the poison”
 - **Orfila** (~1800CE) developed a systematic approach to study toxicology
 - 20th Century: advances in genetic biology have helped us understand the molecular basis for toxicity

Water – good or bad?

- Recommended daily intake is about 3 L

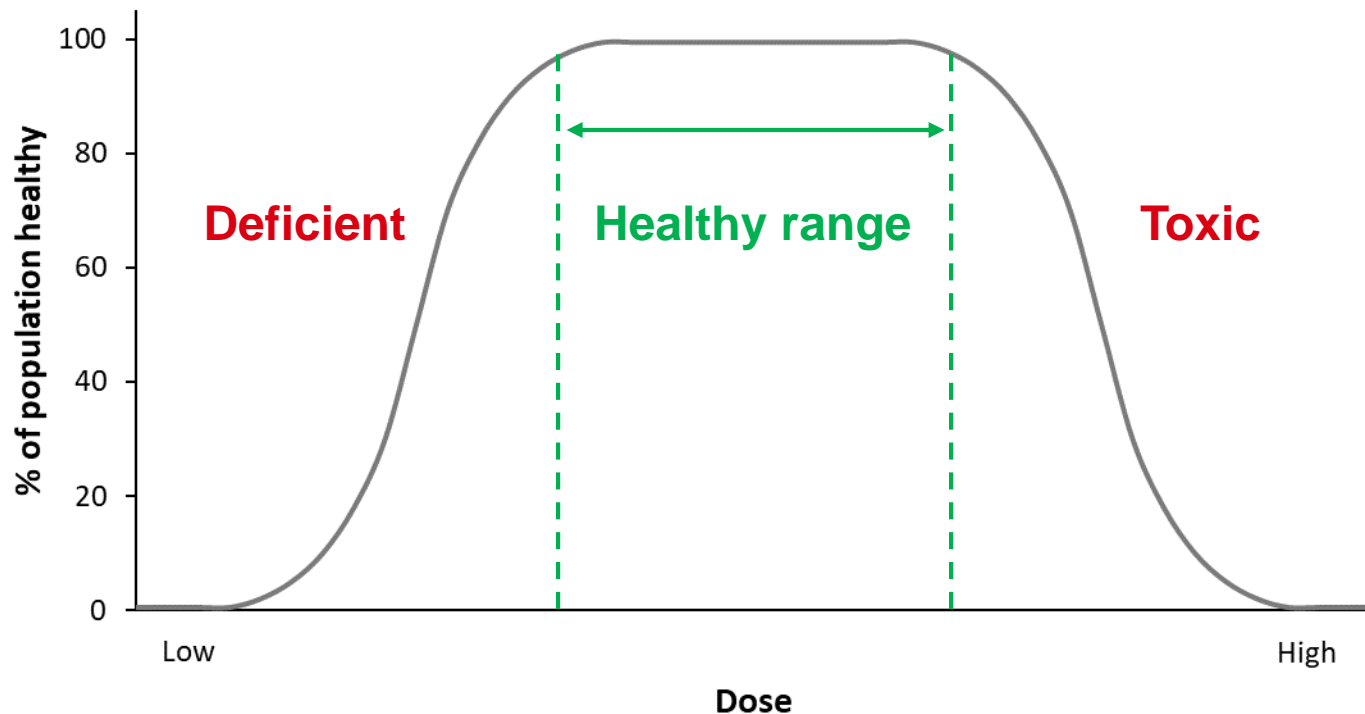


A typical dose-response curve



U-shaped dose-response curve

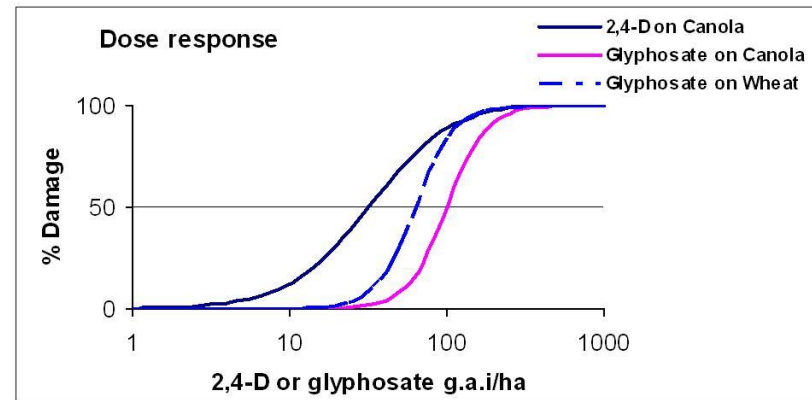
- Some things are “good in moderation”



- E.g., “essential minerals”
 - Na, K, Mg, Ca, but also As, Se, Cr, Co, Ni, Cu, Zn, etc

Beyond Paracelsus

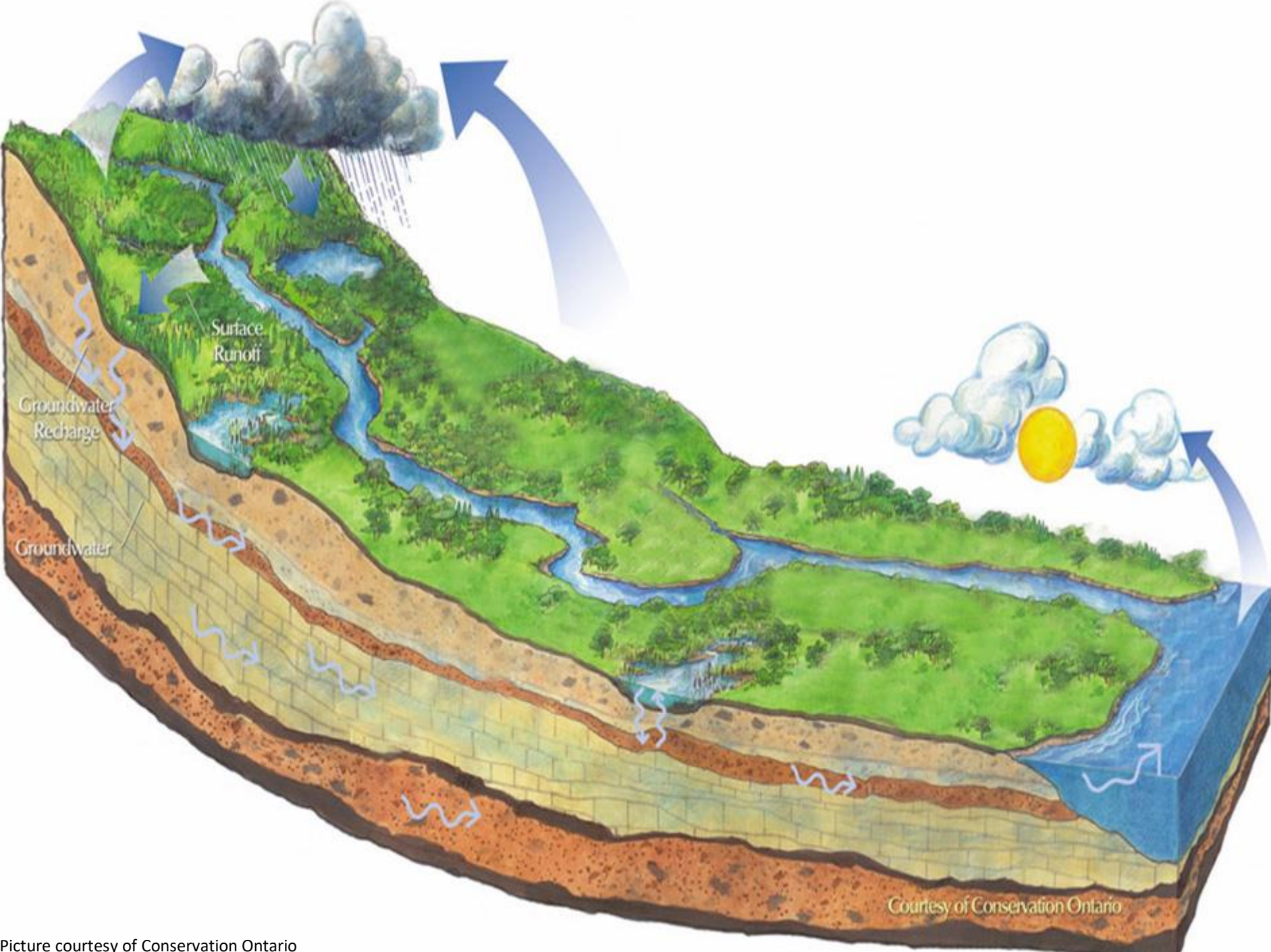
- “The dose makes the poison” but toxicity also depends on:
 - Species
 - Exposure duration (acute vs. chronic)
 - Sensitive sub-populations
 - Specific window of exposure



The effect of 2,4-D on canola and glyphosate of canola and wheat.



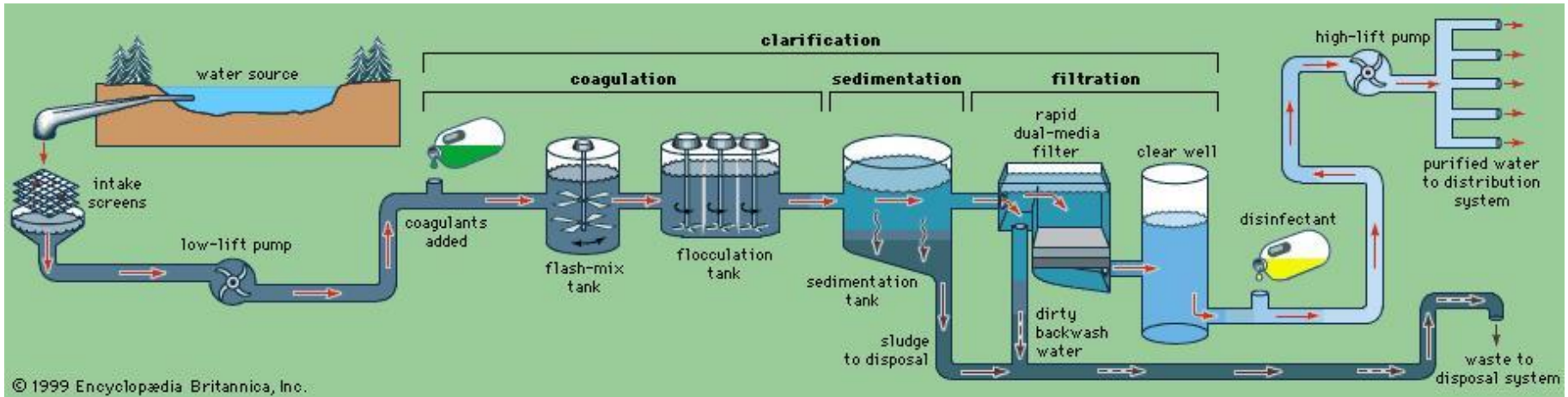
So how do we make water safe?



Courtesy of Conservation Ontario

Picture courtesy of Conservation Ontario

Conventional water treatment



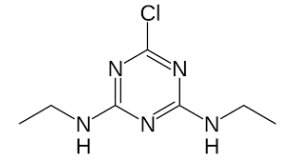
- Production of drinking water from conventional surface water usually quite straightforward
 - Coagulation / flocculation
 - Sedimentation (removes flocs, produced sludge waste)
 - Filtration (eg sand)
 - Disinfection (eg chlorine)
 - Fluoridation
 - pH correction (eg addition of lime)

Australian water guidelines

- National Water Quality Management Strategy
 - 22 documents, including ANZECC WQG, ADWG, AGWR, groundwater, stormwater, industrial effluent
- Based on the concept of dose-response
 - Guideline set to concentration below which no adverse effect
- Based on current knowledge (*i.e.*, can change)
- Several uncertainties from risk assessment
 - Extrapolate from high dose acute to low dose chronic
 - Extrapolate to different species
 - Inclusion of “safety” (uncertainty) factors
- Very conservative



An example from the ADWG



- The herbicide **simazine** (CASRN 122-34-9)

$$GV \text{ (mg/L)} = \frac{\text{NOAEL (mg/kg/d)} \times \text{bw (kg)} \times P}{\text{UFs} \times 2 \text{ L/d}}$$

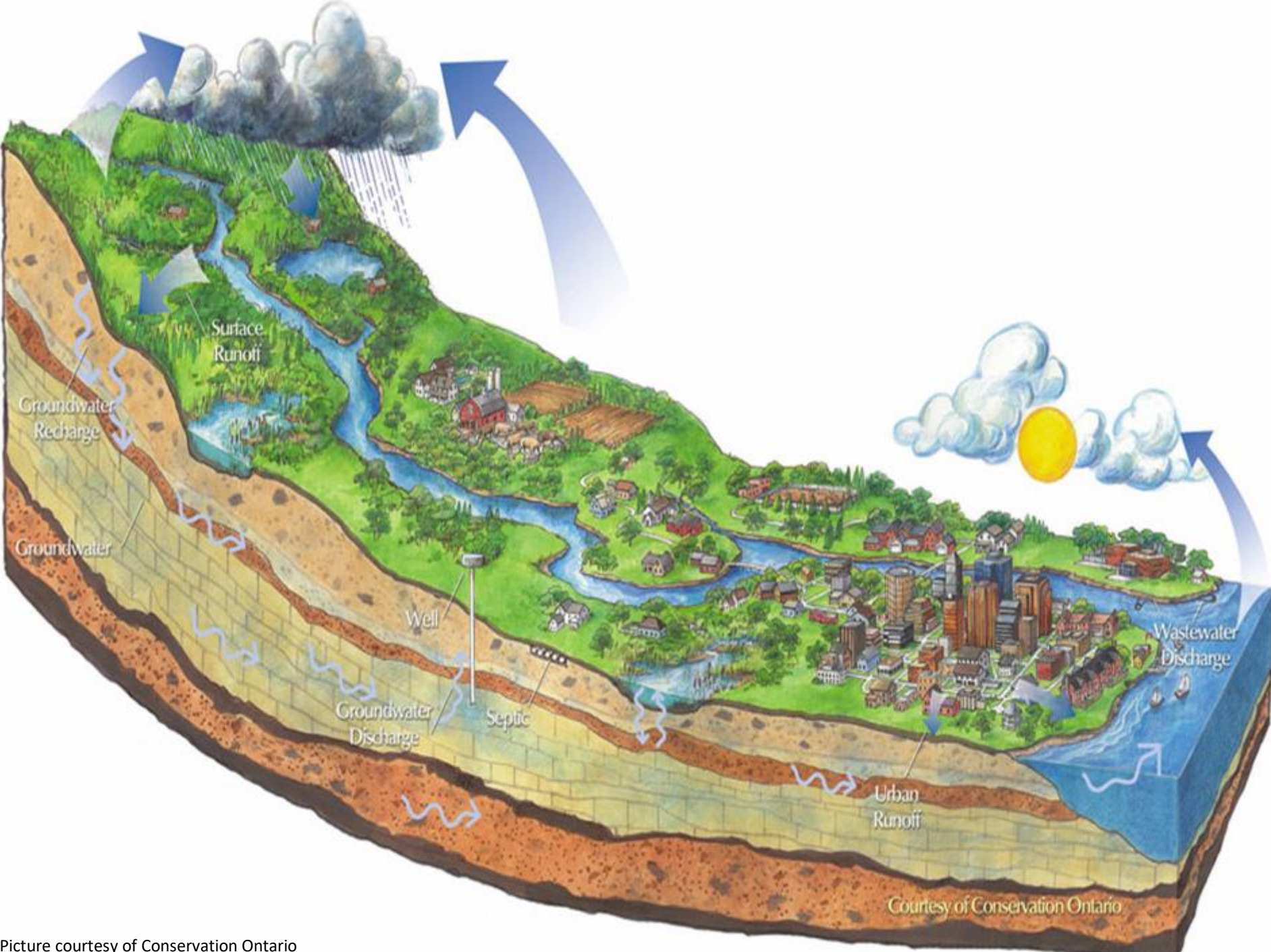
NOAEL based on rat 2-yr dietary study

$$GV \text{ (mg/L)} = \frac{0.5 \text{ mg/kg/d} \times 70 \text{ kg} \times 0.1}{10 \times 10 \times 2 \text{ L/d}}$$

Intersp. Intrasp.

$$GV = 0.0175 \text{ mg/L} \approx 0.02 \text{ mg/L}$$



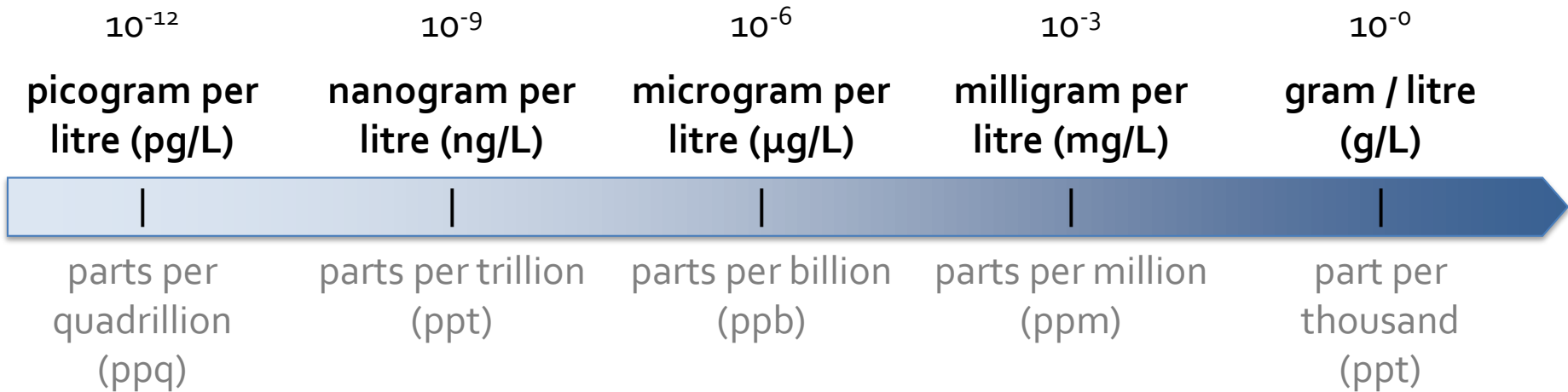


Courtesy of Conservation Ontario

Picture courtesy of Conservation Ontario

All water is recycled

- 2008: “probe finds drugs in US drinking water”
 - Pharmaceuticals (ibuprofen, gemfibrozil, etc), caffeine, sex hormones (at ng/L concentrations)



- For comparison: average cup of coffee has 500 mg/L caffeine, concentration in drinking water 10-100 ng/L

Comparison of caffeine intake



Comparison of ibuprofen intake



The image features a close-up of numerous water droplets of various sizes on a light blue, textured surface. The droplets are rendered in a slightly darker shade of blue, creating a sense of depth and texture. In the center of the image, there is a faint, semi-transparent watermark of a universal recycling symbol, which consists of three chasing arrows forming a triangle. The overall composition is clean and minimalist, emphasizing the natural cycle of water.

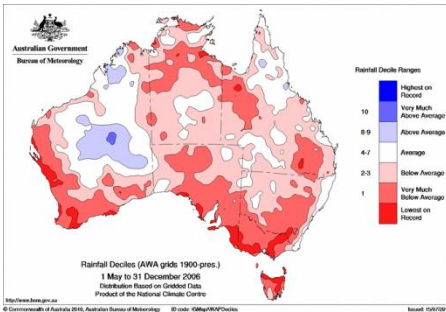
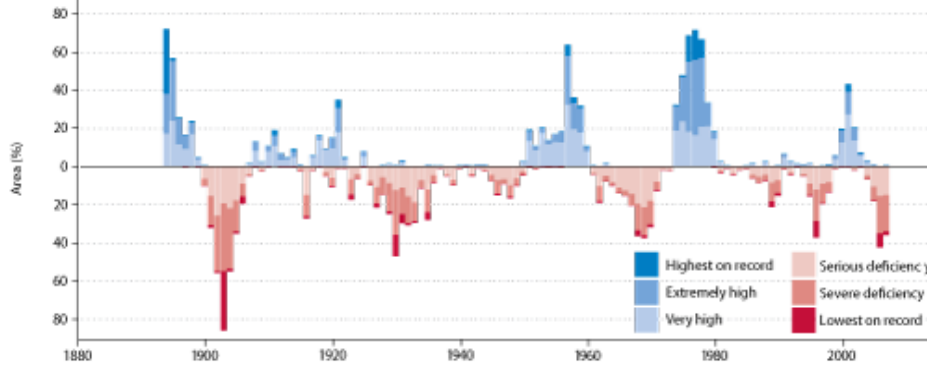
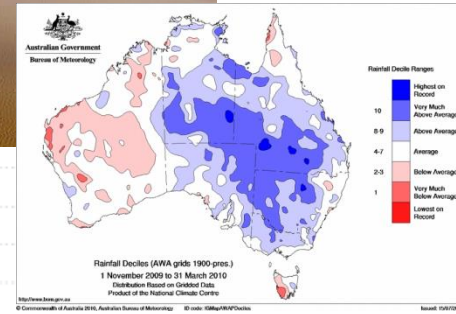
Water recycling

What is “water recycling”?

- Recovery of valuable raw material from waste stream
 - e.g. **aluminium** from **discarded aluminium cans**
 - e.g. **water** from **wastewater**
- Also known as “water reclamation” or “water reuse”
- Different uses: irrigation, industry, aquifer recharge, potable reuse



In Australia: long wet/dry cycles



It's just a simple math problem ...

- Increasing population, no new dams ...

	1990	2006	2021
Population in SEQ	2,200,000	2,800,000	3,900,000
Per capita water use (L/d)	300	220	200
Regional water use (ML/d)	660	616	780
Useable water storage capacity (in ML)*	1,900,000	2,000,000	2,000,000
Years of supply	7.9	8.9	7.0

* calculated as 80% of total dam capacity

Solutions to the water crisis

- Water shortages are due to
 - Unreliable and unpredictable rain patterns
 - Population growth



- No silver bullet ... but a silver buckshot?

Three-pronged solution to the water crisis:

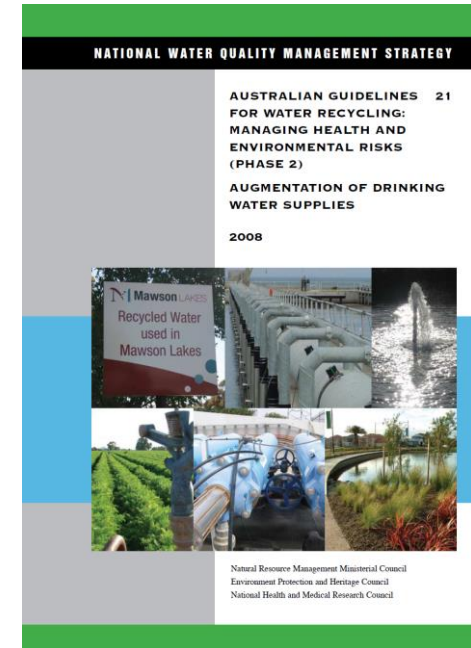
- Water reduction measures (“use less”)
- Desalination (“find more”)
- Water recycling (“make better use of what we have”)

Pros and cons of water recycling

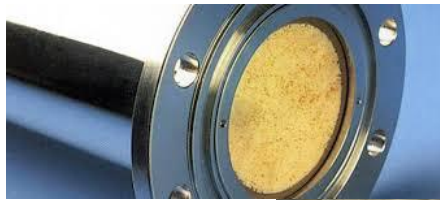
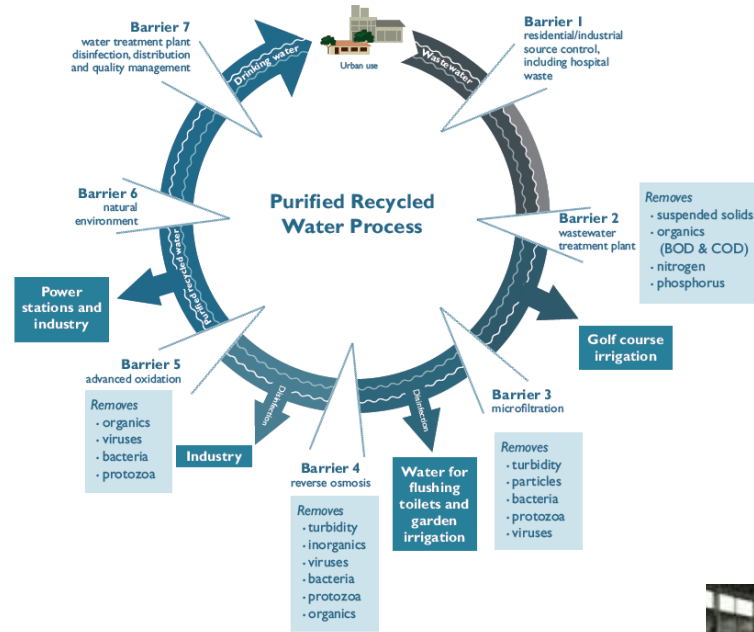
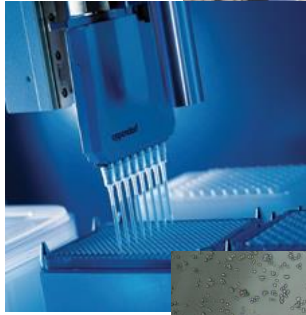
- **Pros:**
 - A large, reliable supply of water of known quality
 - Requires less energy than seawater desalination
- **Cons:**
 - Source water (treated wastewater) contains microbial pathogens and chemical pollutants → **risks**

How do we manage the risks?

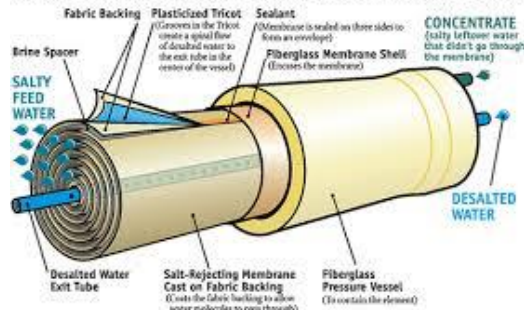
- Source control
 - Manage what chemicals can get in
- Advanced treatment technologies
- HACCP approach
 - Multiple and redundant barriers
 - Online monitoring at critical control points
- Application of Australian Guidelines for Water Recycling (2008)
- Regular and ongoing water quality monitoring



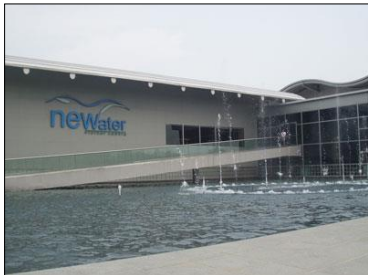
How do we manage the risks



Reverse Osmosis Membrane Element inside a Pressure Vessel



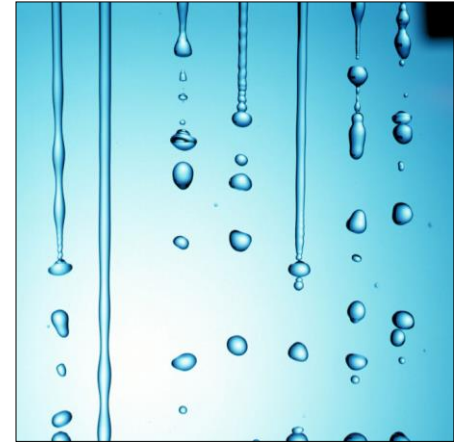
Is recycled water safe?



- Several examples of planned recycling
 - Windhoek (Namibia), Orange County (USA), Upper Occoquan (USA), Singapore, Perth, etc ^(a)
 - International Space Station
 - Western Corridor Scheme (SEQ)
- Unplanned water recycling happens in pretty much every river in the world ...
 - Thames River (12-70%), MO-MS river system
 - 2 million people live in the Murray Darling Basin
 - Canberra, Wagga Wagga, Albury, Dubbo, Wentworth
 - Hawkesbury Nepean (Richmond NSW, 33%)
 - Wivenhoe Dam

Is recycled water safe?

- Public is concerned about chemicals in recycled water
- Independent scientific studies confirm that recycled water is safe
 - Multiple barriers provide safe-guards to error
 - Thorough testing (chemical, *in vitro*, *in vivo*) has not uncovered any unexpected surprises
 - Health-based guidelines are available (and met)
- Perception of risk >>> actual risk



An aerial photograph of a river with a large, swirling eddy of greenish-brown water. The water is murky and has a distinct circular pattern. The surrounding water is a darker blue-green. The banks are visible at the top and right, with some vegetation and rocks.

**There are a few things that muddy
the waters ...
and it's not just the chemicals!**

A complex language

- Chemical names are:
 - Complicated
 - *e.g.*, 1,3,7-Trimethyl-2,6-dioxopurine (= caffeine)
 - Specific
 - *e.g.*, 17 α -estradiol is different from 17 β -estradiol
 - Confusing
 - One chemical can be known by many other names, *e.g.*, the pesticide malathion has about 100 synonyms, including “maldison”
- New guideline documents now provide CASRN (*i.e.*, chemicals now clearly identified)

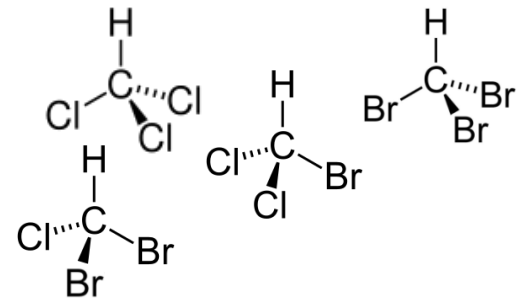
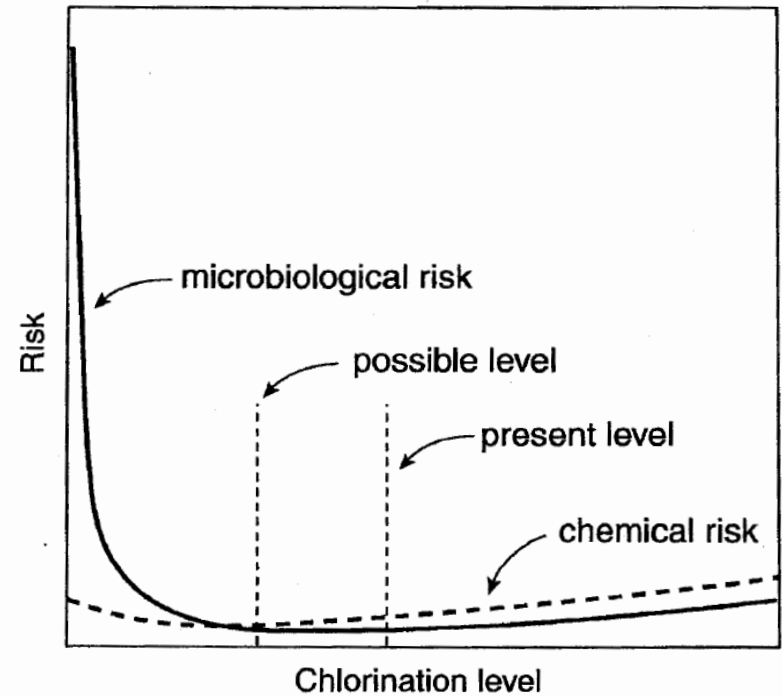
Advanced technologies

- Membrane technology
 - Micro- and ultra-filtration
 - Reverse osmosis
- Disinfection
 - Chlorine, chloramine, ozone, UV
- Advanced oxidation



Complicated issues

- Disinfection destroys pathogens
- Too much disinfection can create disinfection by-products, which are toxic (NDMA, bromate, etc)
- “There is no higher priority in any water supply system than effective and safe disinfection of the water”



Quirks of the scientific community

- Scientists are (often) not good communicators
- Some level of disagreement is normal (and healthy!) in science – but confusing to the public
- Weight of evidence approach
- Nothing is 100% risk-free
- Nothing is 100% certain
- Difficult to prove a negative (absence of evidence is not evidence of absence)



Some example issues ...

ION LIFE
Filtration
Australia 1800 265 409
New Zealand 0800 826 587

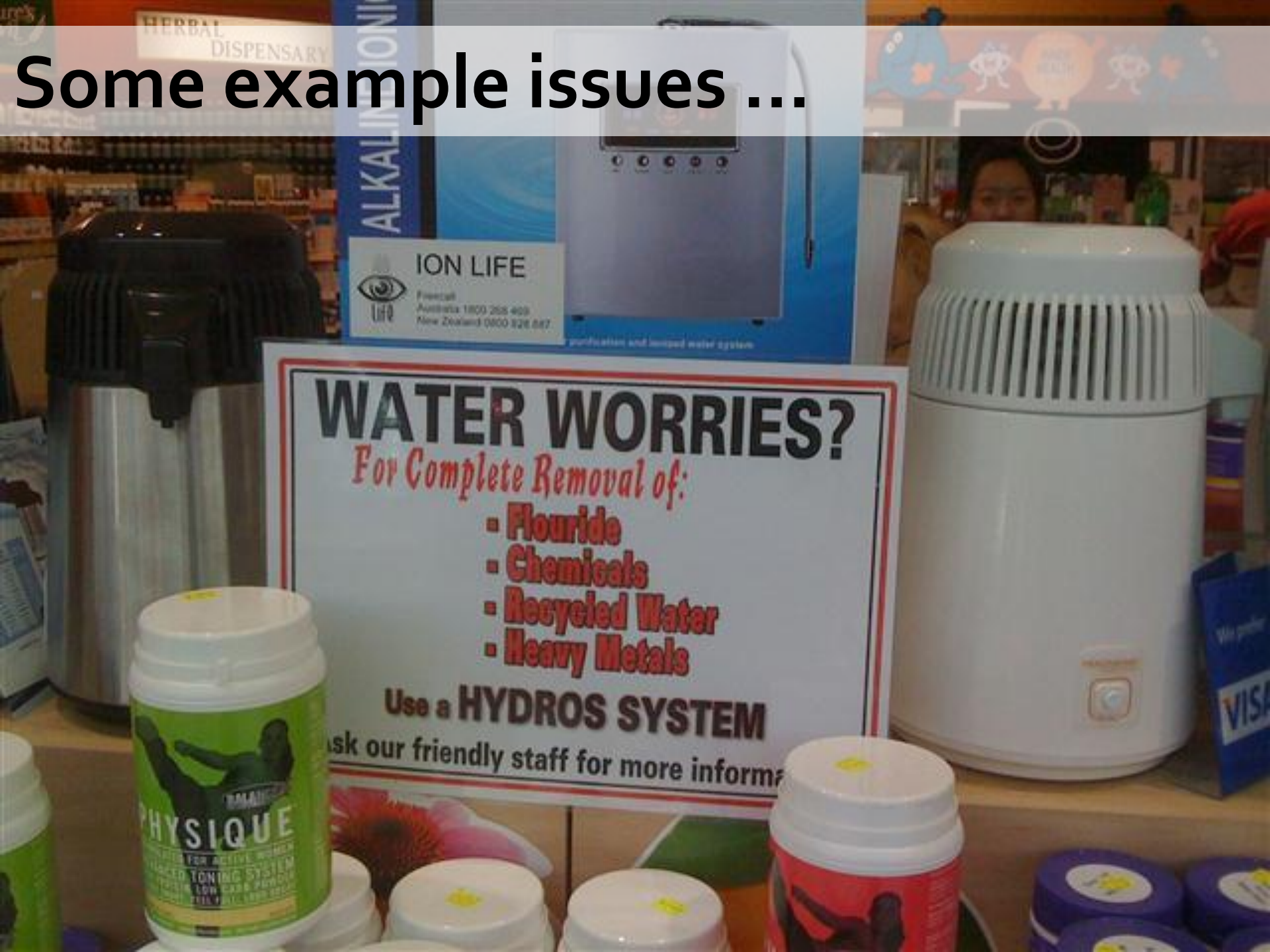
WATER WORRIES?

For Complete Removal of:

- **Flouride**
- **Chemicals**
- **Recycled Water**
- **Heavy Metals**

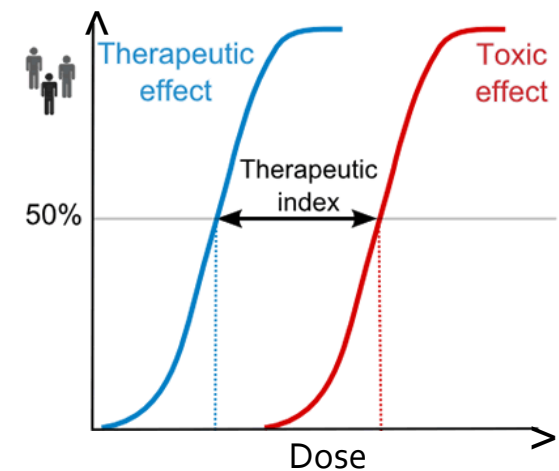
Use a **HYDROS SYSTEM**

ask our friendly staff for more information



Example 1: Fluoride

- Fluoride found in all natural waters at varying concentrations
- In Australia, fluoride is often added to drinking water because of its beneficial effect on teeth (reduction in tooth decay at 0.5-1 mg/L)
- Excessive exposure can cause adverse effects:
 - Chronic: teeth (> 1.5 mg/L) and skeletal damage (> 10 mg/L)
 - Acute: from 30 – 1,000 mg/L



Opposition to fluoridation

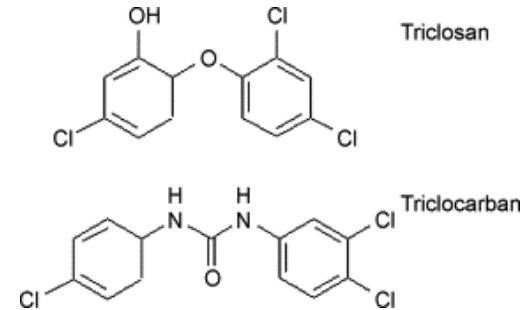
- Concern about health effects of fluoridation
 - Studies taken out of context (often too high doses) used as “evidence” that fluoride is toxic
- Lack of understanding of U-shaped dose-response relationship
 - Healthy teeth need a bit of fluoride every day
 - Naturally occurring fluoride in Australian surface waters is very low
 - So fluoridation (introduced TAS 1964) targets 0.6-1.1 mg/L to produce community-wide beneficial effect
 - Safety of community water fluoridation underpinned by significant amount of evidence reviewed by NHMRC

What can we do?

- Be critical when evaluating evidence:
 - Peer-reviewed?
 - Authoritative? Conflict of interest?
 - Confounding factors? (other pollutants also present)?
 - Meaningful sample size?
 - Relevant concentration / dose?
 - Plausible link or mechanism?
- Help educate the community about “the dose makes the poison”

Example 2: Triclosan

- **Triclosan** (and **triclocarban**) is an antibacterial compound added to some personal care products (toothpaste, soaps)
- Turns out it has no added benefit in soap – other than as a marketing gimmick ^(a)
 - Banned in the US in 2016
- High concentrations of triclosan and triclocarban found in rivers throughout the world



^a <http://www.abc.net.au/news/2016-11-20/antibacterial-soaps-in-spotlight-as-companies-remove-chemicals/8040054>

Triclosan in the environment

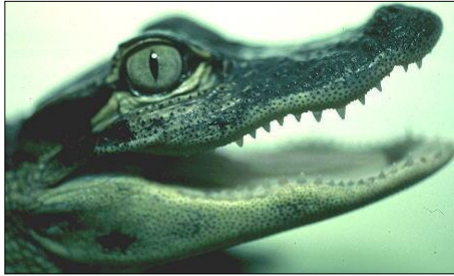
- Triclosan detected in 58% of streams monitored in US ^(a) and 25% of stream in Australia ^(b)
 - Up to 87 ng/L in Aus, and up to 2300 ng/L in US
- Triclosan is acutely toxic to:
 - Bacteria ($EC_{50} = 50 - 600 \mu\text{g/L}$) ^(c)
 - Algae ($EC_{50} = 0.7 - 19 \mu\text{g/L}$) ^(d)
 - Invertebrates ($EC_{50} = 100-500 \mu\text{g/L}$) ^(d)
 - Fish ($EC_{50} = 160-2000 \mu\text{g/L}$) ^(d)
- Effects on reproduction at lower concentrations

What can we do?

- Consider the life cycle of a product ... what happens to it after we use it?
- Avoid personal care products that contain triclosan or triclocarban
 - And consider: do we need antibacterial soap everywhere?



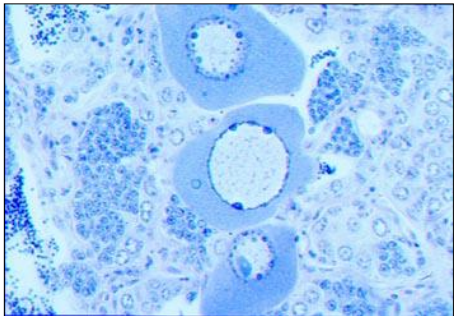
Example 3: Endocrine disruption



- Exposure to endocrine disrupting compounds (EDCs) shown to cause reproductive abnormalities in exposed wildlife



- Snails, fish, alligators, polar bears
- Wide range of compounds identified as EDCs



- Hormones, metals, industrial compound etc
- Exposure to natural and synthetic hormones present in poorly treated wastewater causes feminisation of fish

Endocrine disruption in humans?

- Effects in high exposure situations ^(a)
 - Diethylstilbestrol (DES) 1940-1970s
 - Industrial chemicals in Seveso (Italy), Aamjiwnaang (Canada)
 - Pesticides in agricultural workers (Mexico)
- Hundreds of chemicals found in human blood, at very low concentration ^(b)
- But ... what is the threshold dose?
 - Low concentration of EDCs in drinking (and recycled) water ^(c), main intake likely to be from food ^(d)



"Really?"

Yes...
desPLEX[®]
 to prevent ABORTION, MISCARRIAGE and
 PREMATURE LABOR

*recommended for routine prophylaxis
 in ALL pregnancies . . .*

96 per cent live delivery with **desPLEX**
 in one series of 1200 patients—
 — bigger and stronger babies, too.^{d,1}
 No gastric or other side effects with **desPLEX**
 — in either high or low dosage^{3,4,5}

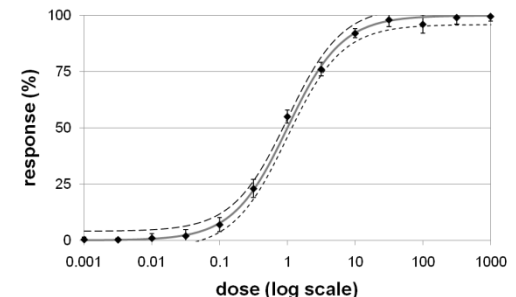
(Each **desPLEX** tablet starts with 25 mg. of diethylstilbestrol, U.S.P., which is then ultramicronized to smooth and accelerate absorption and activity. A portion of this ultramicronized diethylstilbestrol is even included in the tablet coating to assure prompt help in emergencies. **desPLEX** tablets also contain vitamin C and certain members of the vitamin B complex to aid detoxification in pregnancy and the effectuation of estrogen.)

For further data and a generous trial supply of **desPLEX**, write to:
 Medical Director

REFERENCES

1. Canario, E. M., et al. *Am. J. Obst. & Gynec.* 65:1709, 1953.
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3. Kameky, K. J. *South. M. J.* 45:1166, 1952.
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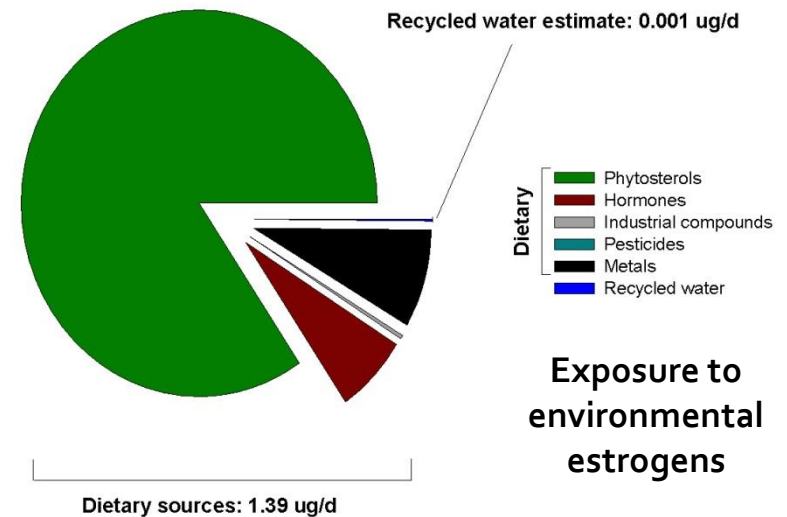
GRANT CHEMICAL COMPANY, INC., Brooklyn 26, N.Y.



^a WHO 2012 State of the Science on Endocrine Disrupting Chemicals; ^b Centers for Disease Control and Prevention 2017 National Report on Human Exposure to Environmental Chemicals; ^c Leusch et al 2017; ^d Leusch et al 2009

EDCs in recycled water

- 31 Jul 2006: “Reused water may alter sex” (Courier Mail)
 - “Recycled water changes the sex of fish and could have similar effects on humans, according to Queensland opposition leader Lawrence Springborg”



So what can we do?

- Be critical when evaluating evidence
 - Authoritative? Peer-reviewed? Conflict of interest? etc
- Help debunk bad science
- Be mindful of your exposure to EDCs
 - Rinse fruits/vegetables prior to consumption to reduce pesticides on the surface
 - Avoid extended contact of food with plastic containers (and tin cans, lined with plasticisers), esp. in microwave
 - Thoroughly ventilate rooms with new carpets/couches, which release flame retardants

Example 4: Plastics

PLASTIC PACKAGING IS PRESENT THROUGHOUT OUR EVERYDAY LIFE

 PET		Water and soft drink bottles, salad domes, biscuit trays, salad dressing and peanut butter containers
 HDPE		Milk bottles, freezer bags, dip tubs, crinkly shopping bags, ice cream containers, juice bottles, shampoo, chemical and detergent bottles
 PVC		Cosmetic containers, commercial cling wrap
 LDPE		Squeeze bottles, cling wrap, shrink wrap, rubbish bags
 PP		Microwave dishes, ice cream tubs, potato chip bags, and dip tubs
 PS		CD cases, water station cups, plastic cutlery, imitation "crystal glassware", video cases
 EPS		Foamed polystyrene hot drink cups, hamburger take-away clamshells, foamed meat trays, protective packaging for fragile items
 OTHERS		Water cooler bottles, flexible films, multi-material packaging

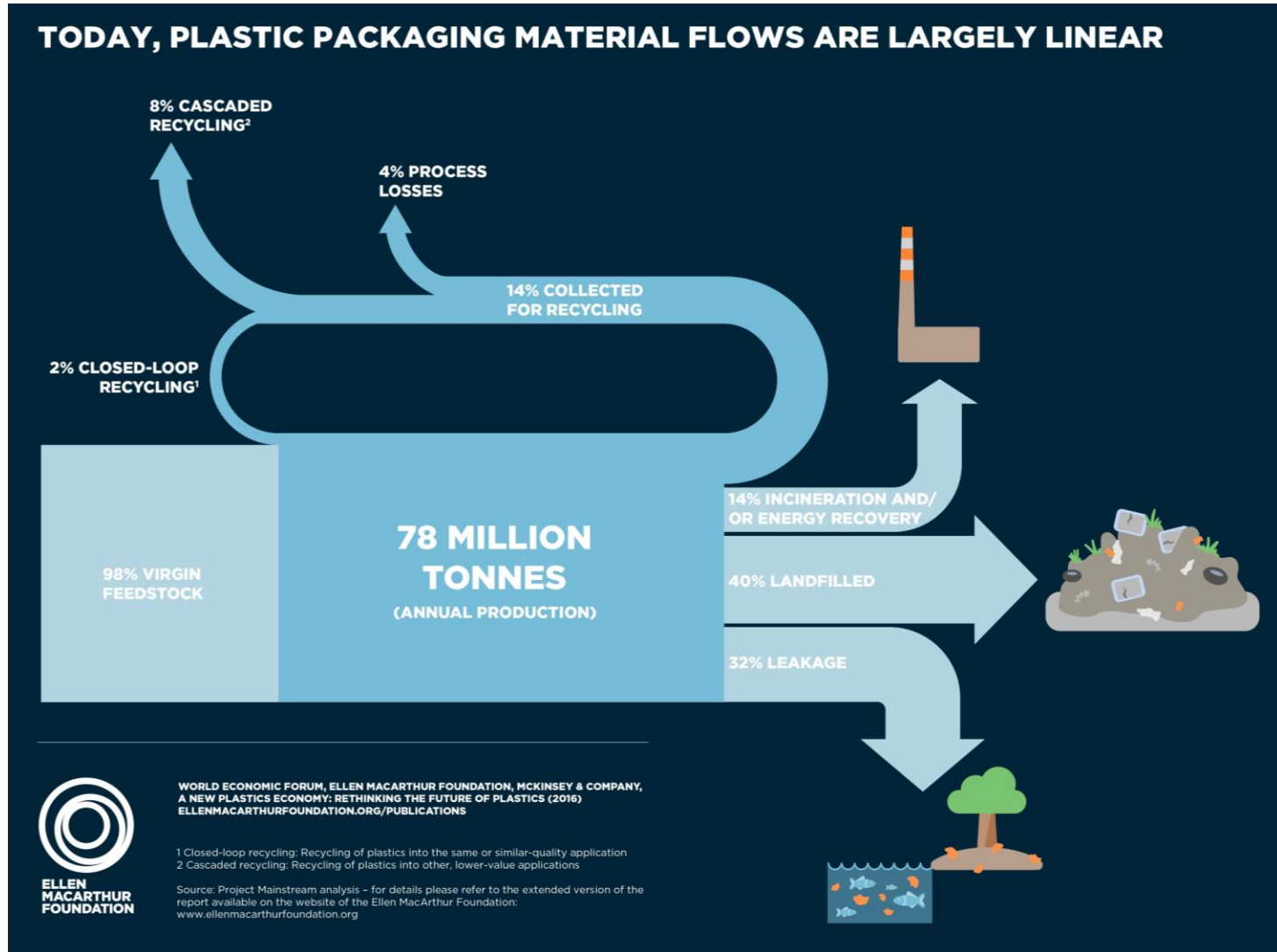
WORLD ECONOMIC FORUM, ELLEN MACARTHUR FOUNDATION, MCKINSEY & COMPANY.
A NEW PLASTICS ECONOMY: RETHINKING THE FUTURE OF PLASTICS (2016)
ELLENMACARTHURFOUNDATION.ORG/PUBLICATIONS

Source: Project MainStream analysis.



- Many consumer goods come wrapped in plastic packaging
 - Amount of plastic produced in a year is roughly the same as the entire weight of humanity
 - By 2050, oceans will contain more plastic by weight than fish

76% of all plastics is single use



Plastic bottles

- Staggering use
 - 1 million plastic bottles are sold every minute worldwide!
- In Australia
 - 466 million bottled water sold in 2015 (1.3 million every day)
 - Bottled water no safer than tap water ... much of it is filtered tap water (but 1000x more expensive)



Plastic bags

- Australians use more than 10 million plastic bags / days
- On average, bags are used for 12 min and take 1000 years to break down



- Several Australian states are moving towards banning plastic bags (#BanTheBag), including Qld (Jul 2017)

Microplastics

- Microplastics:
 - Large plastic items (bags, bottles, straws, takeaway coffee cups) break down into smaller bits
 - Microbeads in personal care
 - Plastic fibres from clothes
- Microplastics are ingested by sealife (mussels, fish, birds)
 - And eventually by humans ...

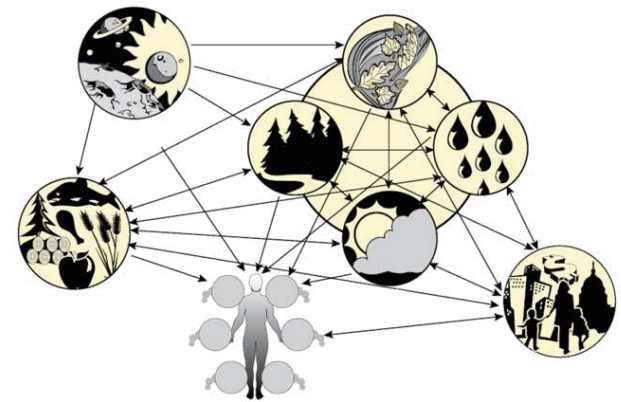


What can we do?

- Avoid plastic bags (use reusable bags)
- Don't buy bottled water – refill a reusable aluminium or glass bottle with tap water
- Avoid personal care products (toothpaste, beauty products) that contain microplastics
 - Polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), polymethyl methacrylate (PMMA)
- Support policy efforts to encourage recycling
- Support clean up Australia days

Environmental management

- We now recognise that we need to take better care of the planet
- Through sound environmental management, and considering the life cycle of our consumer products, we can minimise our impact on the environment while maintaining our standard of living



What we learned ...

- **“The dose makes the poison”**
- Humans pollute the environment with both toxic chemicals and gross pollutants (eg plastics)
- **All water is recycled**
 - Planned water recycling can produce safe drinking water
- We can (and should!) take action to reduce pollutants that we expose ourselves and our environment to
 - Be informed and help inform others
 - Evaluate evidence critically
 - Peer-reviewed, authoritative, no conflict of interest, exposure at right dose, no confounders, sufficient data, plausible mechanism
 - Vote with your wallet!



Any questions?
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PS: that is not me! ...

WHERE
REMARKABLE
BEGINS

— Professor Alan Mackay-Sim
Griffith Institute for Drug Discovery,
Professor Emeritus

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