Overview of Water Reuse

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IMESA Western Cape Half Day Seminar

Welgeleë Wine Farm, Klapmuts

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Presentation Overview

1. Background and introduction
2. Reuse: Internationally
3. Reuse: South Africa
4. WRC reuse research projects
5. Project 2212: Monitoring guidelines for DPR
6. Project 2369: Health aspects of CECs in water reuse
7. Treatment technologies and validation
8. Future imperatives

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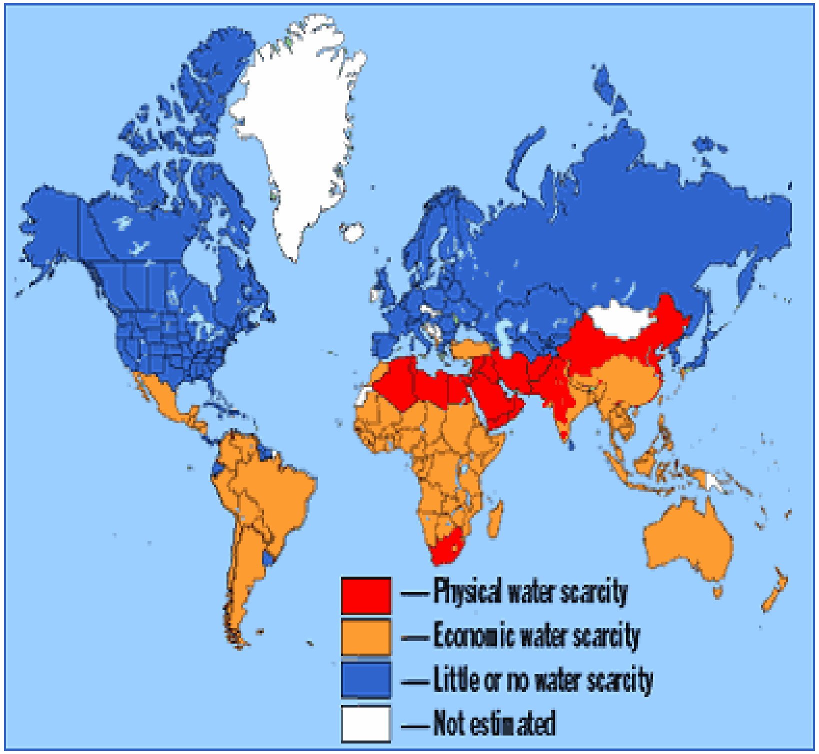
Background and introduction

Water demand



South Africa is already a water stressed nation

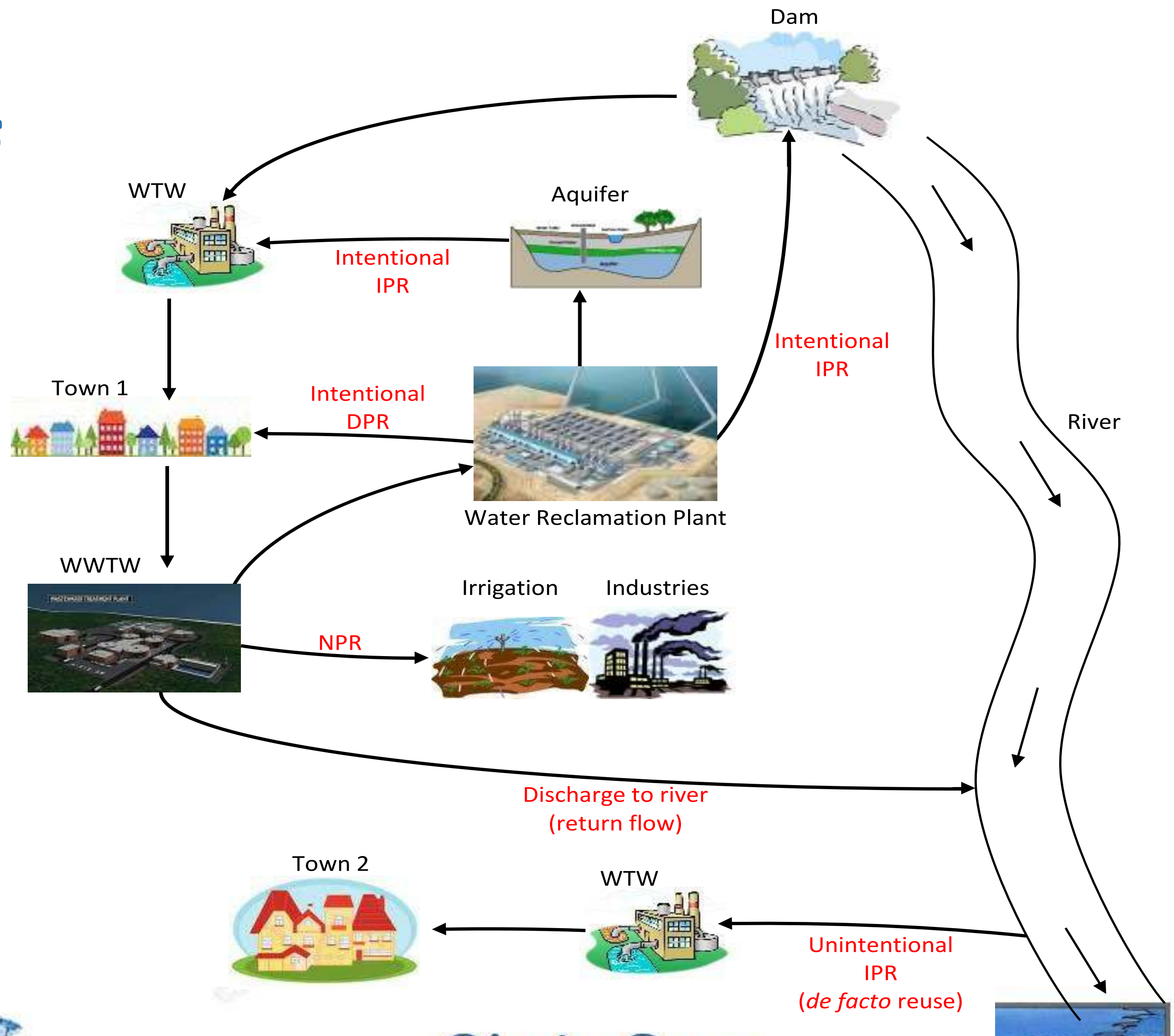
Global demand for water

- By 2050, the World population will be close to 9 billion people, and more regions of the world may be without freshwater, with a sharp decrease in the average water supply per person
- In South Africa, close to 5.7 million people do not have access to basic water while 17–18 million lack access to adequate sanitary facilities
- Most effluent discharge and urban run off are not reused
- Wastewater re-use is expected to offset more clean water resource and reduce discharged effluent

South African water crisis

- South Africa population is growing with nearly 52-million people
- On any given day, 70% of the population including farm animals are ingesting, knowingly or unknowingly, some form of a chemical or pharmaceutical compound
- Public perception of wastewater recycling for direct potable reuse is highly variable
- This is due to the perceived health risk associated with direct potable water reuse (DPR)
- Wastewater often contains endocrine-disrupting chemicals (EDCs) and pharmaceutically active compounds (PhACs) such as antibiotics, anti-inflammatories, antiseptics, antiepileptics, antibiotics/antimicrobials
- Conventional treatment technologies are not sufficient and unable to completely degrade the compounds
- Thus, hundreds of contaminants of emerging concerns (CECs) are currently detected in water sources at low concentration (ng/L to µg/L)

Types of water reuse



DPR = Direct Potable Reuse   **IPR** = Indirect Potable Reuse   **NPR** = Non-Potable Reuse

WTW = Water Treatment Works   **WWTW** = Wastewater Treatment Works

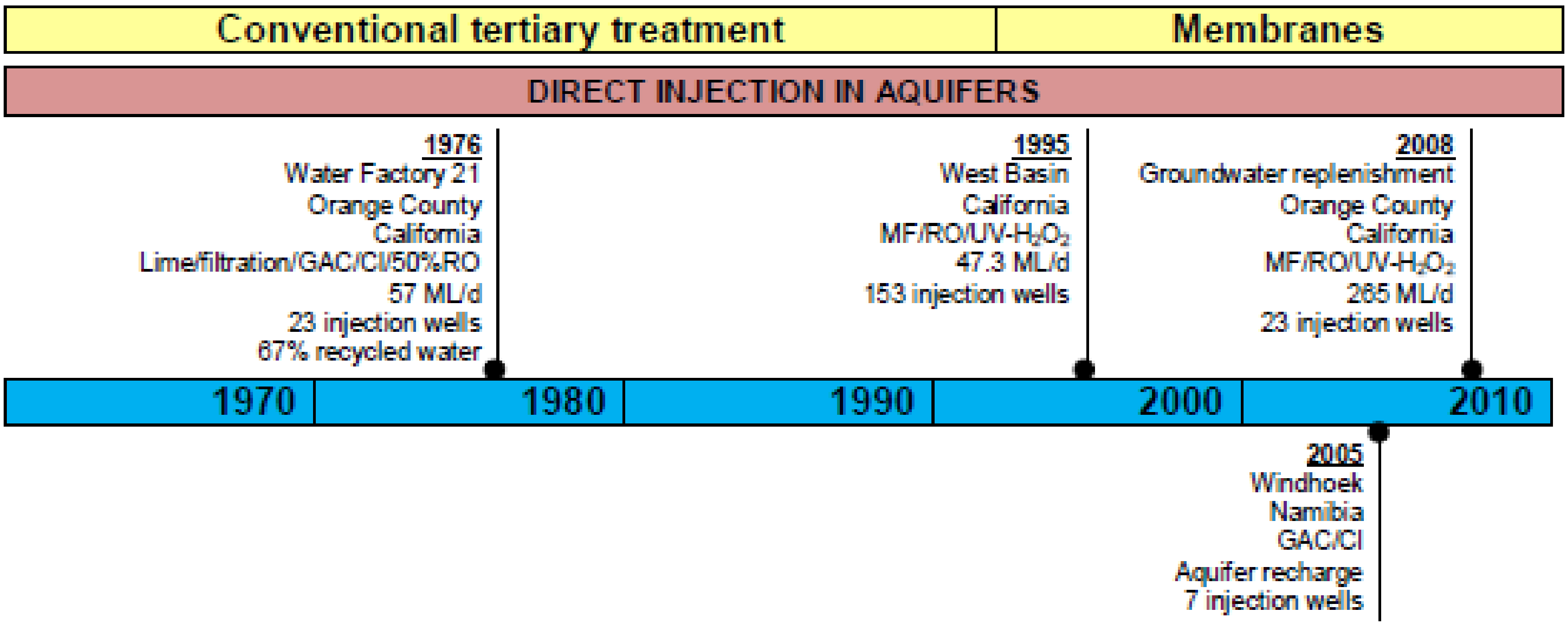
Reuse: Internationally

Reuse: Internationally

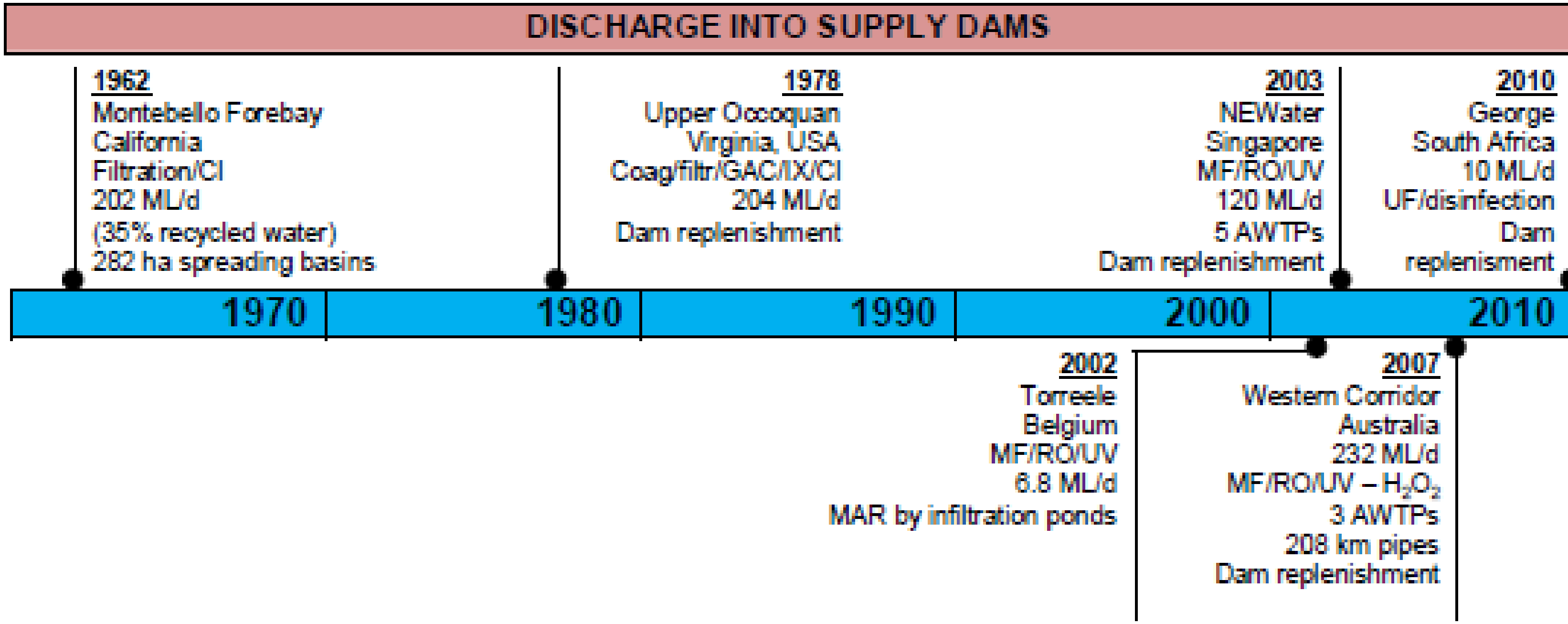
Most of the development in water reuse has taken place in the following regions:

- California, USA
- Australia
- Middle East
- Southern Europe
  (Mediterranean countries)
- South West and Southern Africa
- China
- Singapore (not strictly potable reuse).

Some reuse timelines:
Indirect potable reuse (aquifers)



Some reuse timelines:
Indirect potable reuse (dams)



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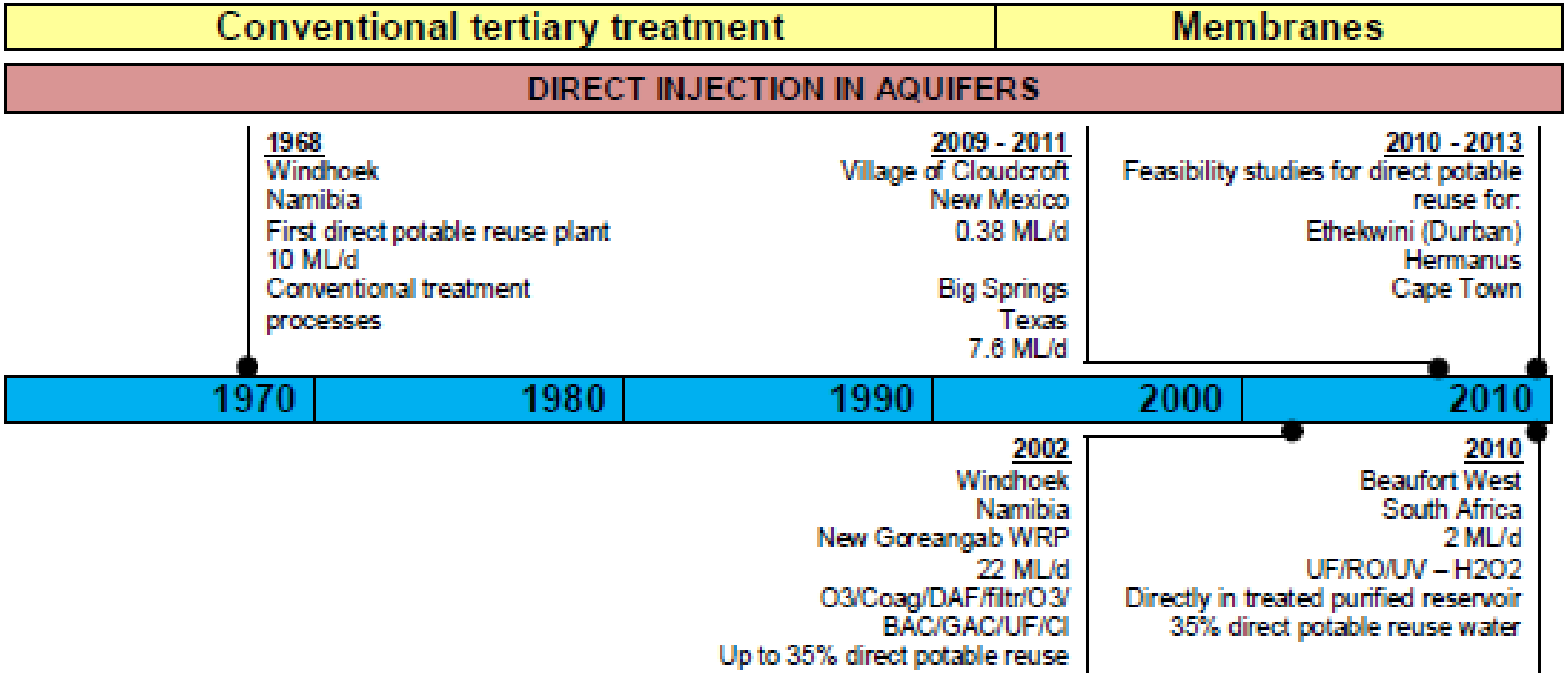
Some reuse timelines:
Direct potable reuse



Status of water reuse in SA

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Status of water reuse in SA

Reuse plants

- Windhoek (Goreangab)
- Beaufort West

Feasibility studies

- Cape Town (feasibility study)
- eThekwini (IPR)
- Hermanus (DPR feasibility and tender)
- Port Elizabeth (NPR/IPR, feasibility study complete)
- East London (planning stage)
- …….

Developments during the past 20 years

- IPR and DPR systems now found worldwide

- Increasing concern about emerging contaminants
  - EDCs (Endocrine Disrupting Compounds)
  - DBPs (Disinfection By-Products)
  - PPCPs (Pharmaceuticals and Personal Care Products)

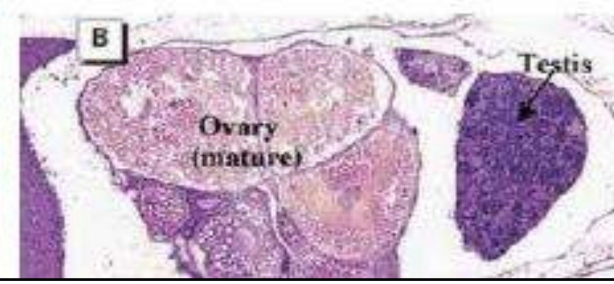
Effects of EDCs

Reproductive problems:

- Reduced fertility
- Male & female reproductive tract abnormalities
- Skewed male/female sex ratios
- Loss of fetus
- Menstrual problems

Changes in hormone levels:

- Early puberty
- Brain and behavior problems
- Impaired immune functions
- Wide variety of Cancers



WRC reuse research projects

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WRC reuse research projects

- **Costing and decision support model (K5/2119)**
  - Excel based model for costing and decision support regarding various treatment configurations for potable water reclamation.

- **Monitoring guidelines for reuse (K5/2212)**
  - The first proposed water quality guidelines for potable water reclamation in South Africa.

- **Health aspects of CECs in water reuse (K5/2369)**
  - A detailed view of the human health implications of various micro pollutants typically found in South African wastewater.

WRC reuse research projects

- **Costing of desalination and reuse plants (K5/2121)**
    - Costing and O&M of reuse and desalination plants in South Africa
- **WW reclamation for potable use (K5/1894)**
    - Performance of various treatment configurations for potable reclamation of secondary treated waste water
- **Implementation plan for DPR and IPR (K8/1029)**
    - Sector discussion document for the progressive implementation of the Water Reuse Strategy

WRC Project K5/2212

Monitoring Guidelines for Direct Potable Reuse

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Guidelines and monitoring practices for water reclamation

Three monitoring regimes:

1. **Raw inflow monitoring**
2. **Operational monitoring (process control)**
3. **Final water monitoring (compliance monitoring)**

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Raw inflow monitoring

Why is it important?

- Variable inflow quality (rapid changes)
- Early warning
- Rapid response

Raw inflow monitoring

Managing raw water quality

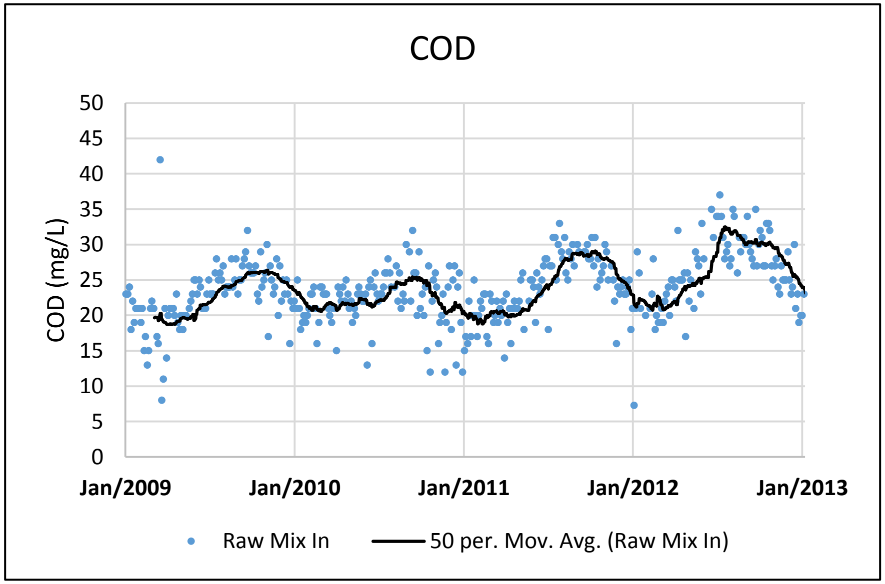
- Use historic data; track catchment practices implications
- Manage risks in catchment area

Activity	Expected problems in water supply	Surface Source	Ground Source	Reclamation
Life stock (overgrazing)	Taste & Odour, Toxins, Filter clogging, Eutrophication, parasites	H	M	
Mining		H		
Settlements (urban & rural)	Water difficult to treat, higher treatment cost	H	M	H
Boating		H		
Evaporation	High chlorine demand, Pathogens, Dissolved Metals	H		
Treatment chemicals		H		M
Industrial Pollution	Corrosion, DBPPs, Toxicity, Mutagenicity, AOX & other		M	H
Probability of occurrence: High (H), Medium (M), Low (L)				

Raw inflow monitoring

Changes in raw water quality

- Seasonal variability:
  - Maturation pond water quality (rain = turbidity; sunshine = algae)
  - Residential wastewater quality (more dilution during rainfall periods)



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Operational monitoring (process control)

- **What is operational monitoring?**
  - Vastly different from inflow and final water monitoring
  - Monitors less parameters, but at higher frequencies
  - Establishes plant conditions for optimal performance
- **Controlling system performance**
  - Each treatment unit is important
  - Understand how upstream and downstream units affect each other
  - Monitor each of the units individually

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Operational monitoring (process control)

Unit function and performance measures

- What, how and when to measure

Process unit	Treatment step	Performance indicator	Measured Parameter
DAF	Aesthetic treatment	Treated water aesthetics/quality (Clarity, taste and odour)	Turbidity, Colour
	Constituent removal	Concentration of constituent in treated water (FOG, algae, colloids, etc.)	mg/L constituent, Turbidity
Filtration (sand or multi-media)	Constituent removal	Concentration of constituent in treated water (flocks, fine materials, etc.)	Turbidity, Colour
BAC (biologically activated carbon)	Constituent removal	Concentration of constituent in treated water (Organics, inorganics, CECs, etc.)	µg/L constituent
	Aesthetic treatment	Treated water aesthetics/quality (Clarity, taste and odour)	Turbidity, Colour
GAC (granular activated carbon)	Constituent removal	Concentration of constituent in treated water (Organics, DBPs, EDCs, etc.)	µg/L constituent
	Aesthetic treatment	Treated water aesthetics/quality (Clarity, taste and odour)	Turbidity, Colour
PAC (powder activated carbon)	Constituent removal	Concentration of constituent in treated water (Organics, DBPs, EDCs, etc.)	µg/L constituent
	Aesthetic treatment	Treated water aesthetics/quality (Clarity, taste and odour)	Turbidity, Colour
Microfiltration	Constituent removal	Concentration of constituent in treated water (1 - 0.1 µm)	Turbidity, TSS
Ultrafiltration	Constituent removal	Concentration of constituent in treated water (0.1 - 0.01 µm)	Turbidity, HPC
Nanofiltration	Constituent removal	Concentration of constituent in treated water (0.01 - 0.001 µm)	Turbidity, UV254, EC
Reverse Osmosis	Constituent removal	Concentration of constituent in treated water (0.001 - 0.0001 µm)	Turbidity, UV254, EC
Ozonation	Constituent removal	Concentration of constituent in treated water (Organics, CECs, EDCs, etc.)	UV254, TOC/DOC
	Disinfection	Microbial activity in treated water (Parasites, bacteria, viruses)	HPC, total coliforms, etc.
UV/H2O2	Constituent removal	Concentration of constituent in treated water (Organics, CECs, EDCs, etc.)	UV254, TOC/DOC
	Disinfection	Microbial activity in treated water (Parasites, bacteria, viruses)	HPC, total coliforms, etc.
Chlorination	Disinfection	Microbial activity in treated water (Parasites, bacteria, viruses)	HPC, total coliforms, etc.

Operational monitoring (process control)

Measuring unit performance

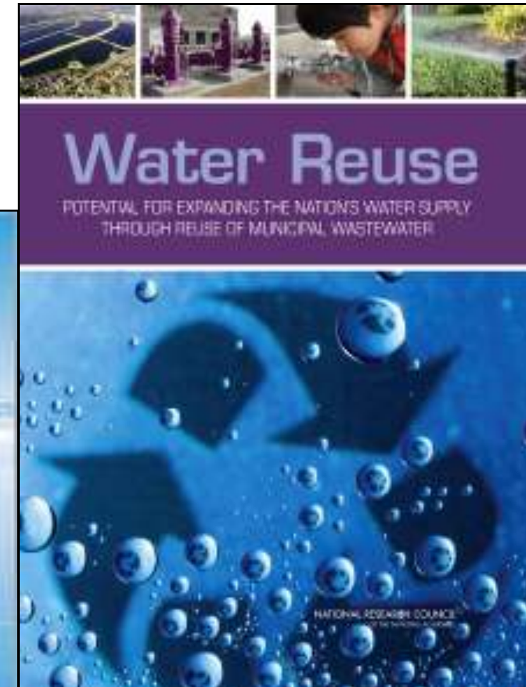
- What, how and when to measure (use surrogates where possible)

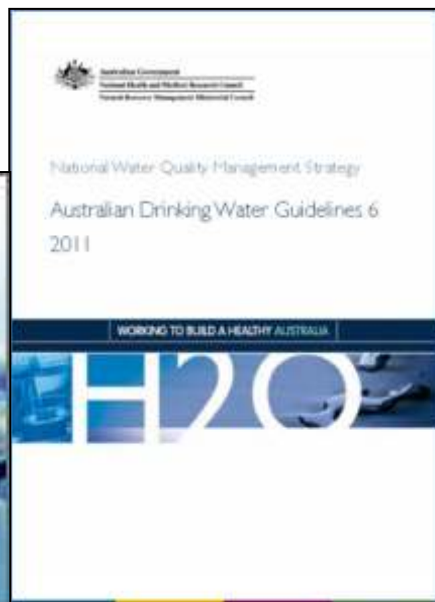
Parameter	Measurement Method	Minimum Frequency
pH	On-line, portable instrument	Hourly
TSS	Laboratory/On-line (inferred)	Four times per day
EC	On-line, portable instrument	Hourly
Colour	Laboratory/On-line (inferred)	Hourly
Turbidity	On-line, portable instrument	Hourly
DOC	Laboratory/On-line (inferred)	Hourly
Inorganics	Laboratory	Daily
Organics	Laboratory/On-line (inferred)	Four times per day
Microbiological	Laboratory	Daily
UV254	On-line	Hourly

Final water monitoring (compliance monitoring)

Existing guidelines for water reclamation

- Local and internationally available





Final water monitoring (compliance monitoring)

Risk management of final water quality

- Control of microbial contaminants (acute risk)
  - Disability Adjusted Life Year (DALY)
  - Quantitative Microbial Risk Assessment (QMRA)
- Control of chemical contaminants (chronic risk)
  - Threshold effects
  - Non-threshold effects
- Include redundancy, and recycle (retreat) when needed

The safety of water can never be compromised in an attempt to mitigate costs!

WRC Project K5/2369

Health aspects of CECs in water reuse

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Three sampling campaigns

- **Dates**
  - April 2015, October 2015 and January 2016
- **Plants**
  - 2 WRPs, 3 WWTPs and 1 WTP
- **Sampling points**
  - Raw Inlet, Final Effluent/Water and after each treatment process in-between
- **Analyses**
  - Macro-determinants
  - CECs on the priority list
  - PFCs based on work done by UWC
  - Bioassays (Ames mutagenicity and Oestrogen mimicry tests)

Selection of treatment systems for evaluation

- 2 DPR plants
- 3 WWTPs

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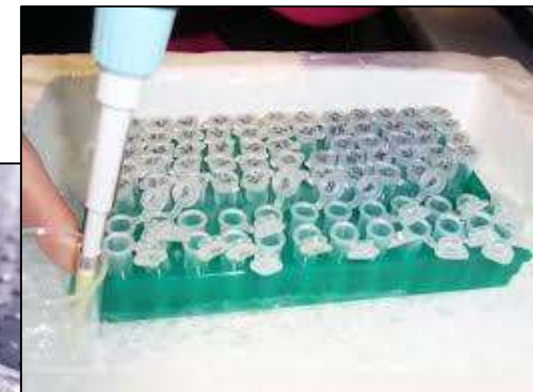
Analyses performed

- Routine analysis (Macro-determinants).
  - This includes pH, Turbidity, conductivity, DOC, Total organic carbon (TOC), biodegradable organic content (BDOC) etc.



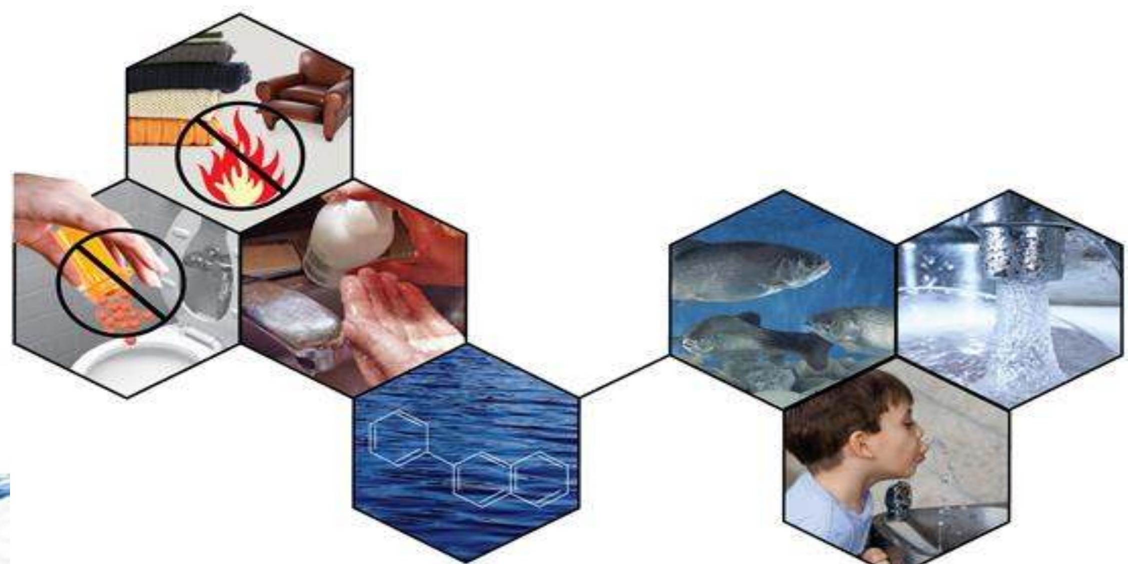
- Advanced analysis
  - These include GC, LCMS, SPE, HPLC analyses as well as biological analyses like the Ames test.

- Research analysis
  - Analysing for Perfluorinated Compounds (PFCs), developed by UWC students.

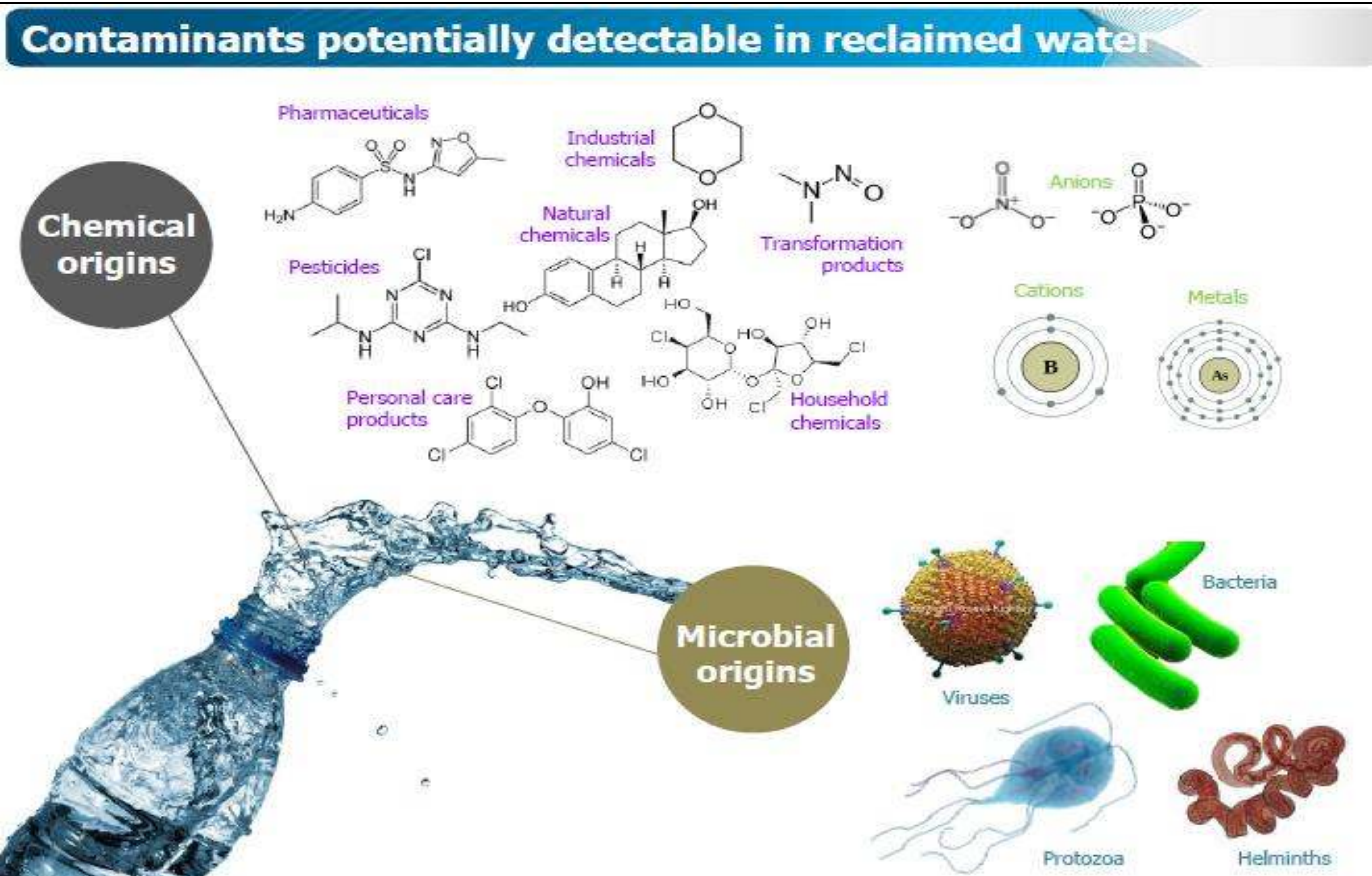
Chemicals of Emerging Concern

What are CECs?

- Chemicals of Emerging Concern
  - Not always new chemicals, but chemicals with new found implications
  - An ever growing list of micro and macro chemicals, nano-particles and radionuclides

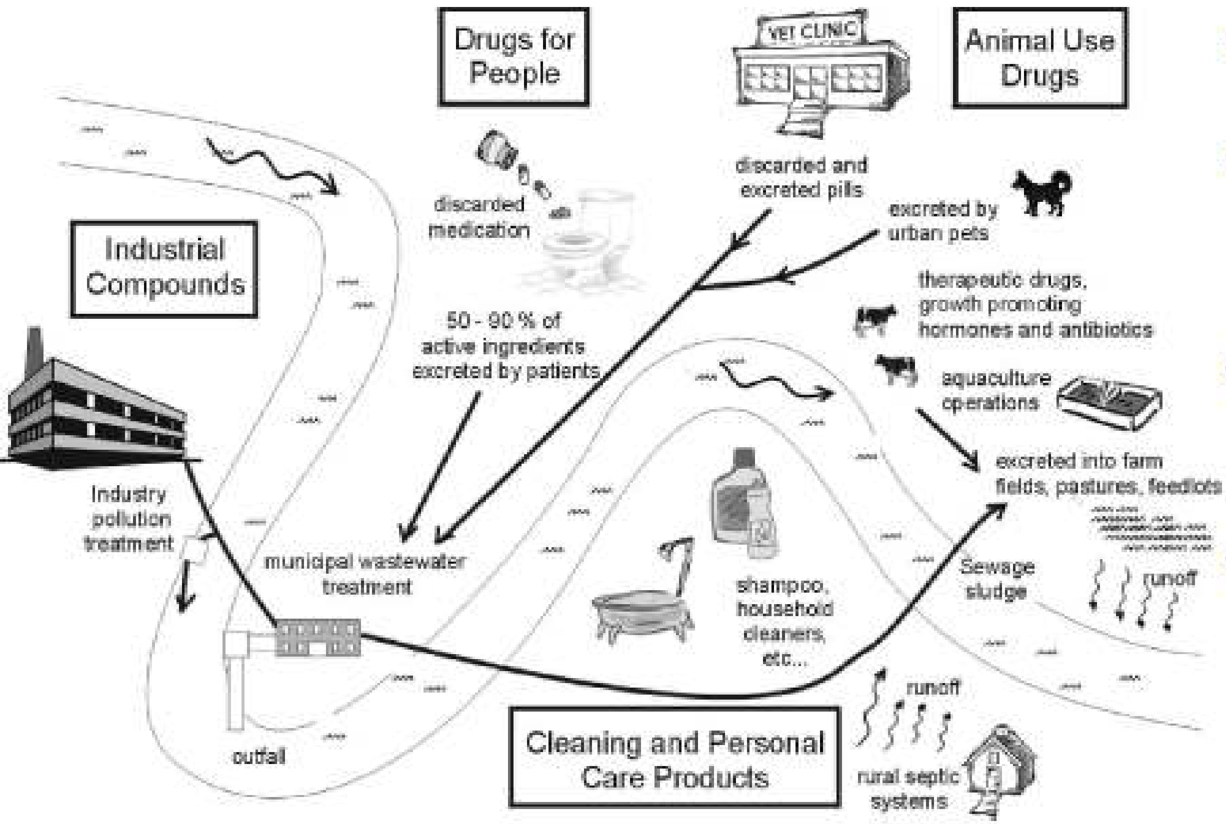


Chemicals of Emerging Concern



Pathways

Emissions and routes of PhACs



Source: (Holtz, 2006)

- Effluent of municipal WWTPs
- Solid and industrial waste from production sides and hospitals.
- Application of manure containing veterinary pharmaceuticals.
- Disposal of unused PhACs to garbage or toilets.

Chemicals of Emerging Concern

Types of CECs

- Pharmaceuticals and veterinary medicines
  - Prescribed and over-counter drugs
- Endocrine disrupting compounds
  - An exogenous compound that mimics or blocks hormonal functions in the body
- Personal care products
  - Active ingredients in cosmetics, fragrances, soap, insect repellents, toothpastes e.g. antiseptics (triclosan/triclocarban)
- Flame retardants
  - Active ingredient incorporated into consumer products such as electronics, plastic and children's toys
- Perflorinated and brominated compounds
  - Used as dirt-repellent coatings, spray for leather and textiles
- Pesticides and herbicides
- Nanomaterials, etc.

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Chemicals of Emerging Concern

- **What should we focus on (priority list for South Africa)**

Industrial chemicals	Flame retardants, TDCPP and TCEP X-ray contract fluid, Iopromide PAH, Benzo(a)pyrene
Pesticides, biocides and herbicides	Atrazine, Terbutylazine, Imidacloprid and Simazine
Natural chemicals	Caffeine, 17 beta estradiol
Pharmaceuticals and metabolites	Antiretroviral drugs Lamivudine and Stavudine Anti-epileptic, Carbamazepine Anti-malarial drugs Cinchonidine and Cinchonine Analgesic, Paracetamol Antibiotic, Sulfamethoxazole
Personal care products	Anti-microbial, Triclosan
Household chemicals and food additives	Plasticiser, Bisphenol-A
Transformation products	By-product , N-Nitrosodimethylamine (NMDA)

Treatment technologies and validation

Chemicals of Emerging Concern

- **Removal of CECs**
  - Reverse Osmosis
    - Cannot necessarily remove all the micro-pollutants as is often believed
    - High cost treatment option (high energy requirements)
    - Generates a problematic brine stream
  - Nanofiltration
    - Cannot necessarily remove all the micro-pollutants
    - High cost treatment option
      (less energy, but less availability of membranes)
    - Not as effective as RO for CEC removal
  - Ozonation + BAC + GAC
    - Cannot necessarily remove all the micro-pollutants
    - Can be difficult to operate and maintain
    - Produces by-products

Treatment validation

- **What is treatment validation**
  - Australian guidelines for water recycling (2006)
    - Technology or processes must be validated before commissioning
    - Provides confirmation that technology can achieve performance targets
    - Only conceptual, not standardised or regulated
  - Applications
    - Most of the reuse and desalination plants in Australia
    - New Goreangab Water Reclamation Plant, Namibia
  - Currently addressed by WRC for implementation in South Africa

Future imperatives

Future Imperatives

- **South African Water Reclamation Centre of Excellence**
  - A center where knowledge and experience is shared
  - Not attached to any public or private entity (ultimately)
- **National Centre for Water Reuse Analysis**
  - A nation-wide standardised virtual laboratory network
  - Many analytical laboratories all reporting to one central virtual laboratory where results are received, archived and distributed to clients

Future Imperatives

Flow of information from decentralized laboratories to the proposed National Centre for Water Reuse Analysis (NCWRA)

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Future Imperatives

IWA Reuse Conference (Harbin, 2015):

- Communicating risk to decision makers
- Statistics show 80% human failure and 20% technical failure. Efforts to improve the qualifications of operating personnel
- Dual pipe systems are seen as a higher risk due to high probability of cross connections being made by error vs DPR or IPR.
- Challenge to move to DPR without artificial buffer. It means on-line real-time monitoring.

Current focus area: De Facto reuse

- Unintentional reuse (De Facto reuse)
- Polluted dams and rivers (failing WWTWs)
- Increasing pressure on existing (conventional) water treatment plants
- Provide design protocols and costing models for upgrading of these plants

Thank you!

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