SOME OPPORTUNITIES AND CHALLENGES FOR URBAN WASTEWATER TREATMENT

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01Sep2011

WRC40th Conference

WATER RESEARCH COMMISSION

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7. Saline Sewage Treatment – the SANI Process
8. Urine Separation and Saline Water Distribution .
9. Some Evaluation and Conclusions.

INTRODUCTION (1)

- ***Wastewater*** treatment originated at end of 19^{th} century to ***reduce waterborne diseases*** (cholera, dysentery etc.).
- ***Changed*** over last century to ***protect the natural environment.***
- These days, new technical developments are assessed in terms ***sustainability.***

INTRODUCTION (1)

- In urban wastewater treatment….
  - improving the ***effluent quality***
  - ***recovery*** and ***reuse*** of ***nutrients*** (N,P,K,Mg)
  - using ***less energy and water***

are ***indicators of improved sustainability***.

WATER, CARBON and ENERGY (1)

- Svardal & Kroiss state the issue clearly.
- Energy available in wastewater (~0.02 kW/person) is 100 times lower than power consumption at 5 to10 kW/person, so recovering energy from wastewater (WW) will not solve the energy and C problem.

WATER, CARBON and ENERGY (1)

- For sustainability, the treated “fresh” water has far greater value than the energy required to produce it.
- Like Mark Twain said “We don’t know the value of water until the well runs dry.”

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WATER, CARBON and ENERGY (2)

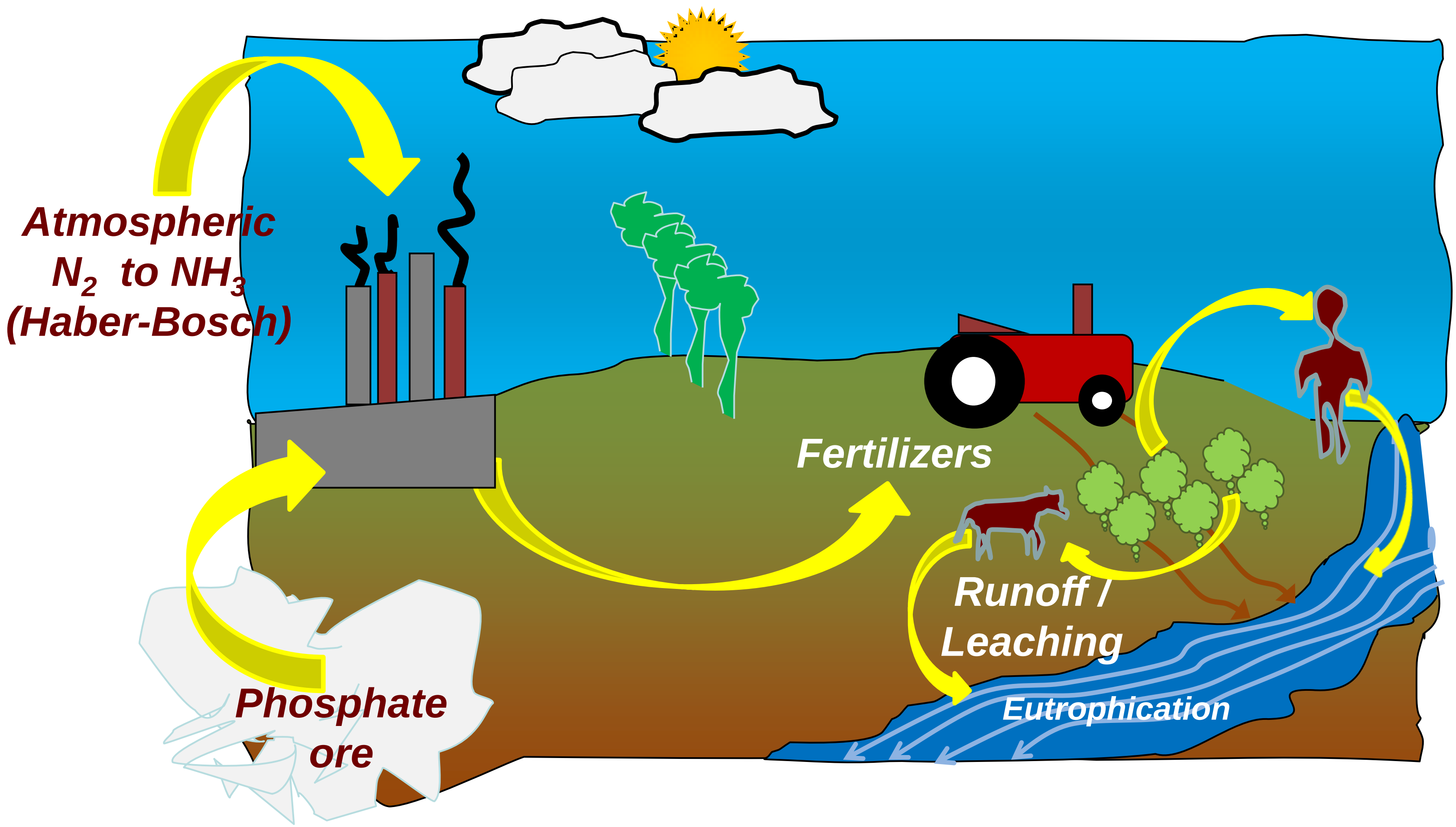
- CO_2 produced from WW organics is ~20 gC/person. Per person, this is only….
  - 50% of CO_2 produced by coal power plant for electricity to treat the WW,
  - 12% of CO_2 exhaled from a 6300kJ/d diet;
  - 1% of CO_2 emitted by 30km/d in small car;
  - 0.2% (1/500th) and 0.05 (1/2000th) of CO_2 produced by coal power plant for domestic and total per person energy consumption.

WATER, CARBON and ENERGY (3)

- Minimizing energy requirement for WWT is good, but its priority is far lower than human and environmental health, which are both closely related to surface fresh water quality.

- Human and environmental health requires fresh water quality and quantity conservation.
- Reduce eutrophication (N&P) and salination (AMD).

N & P SOURCES and SINKS

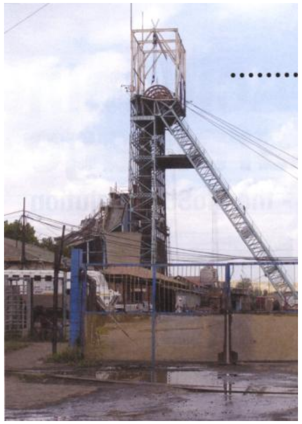


WATER QUALITY THREAT - EUTROPHICATION

- Technologies have been developed to remove biologically N & P from municipal wastewater reducing eutrophication.
- But here is an example that technology solves nothing if there are too few people who can use it effectively.

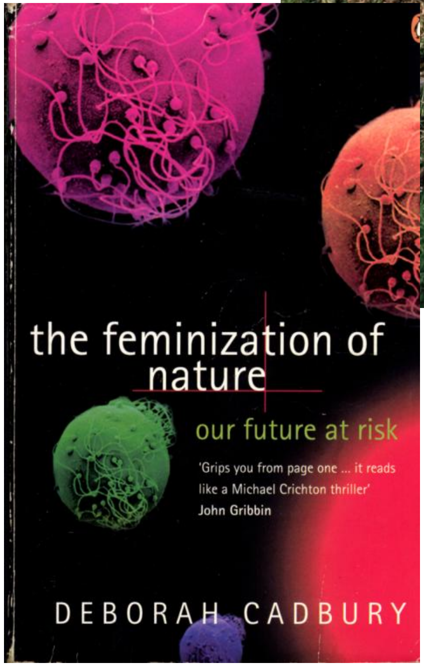
WATER QUALITY THREAT - SALINATION

- Some technologies also have been developed for metal & SO_4^{2-} removal from acid mine drainage so we can reduce salination,
- But we have a long way to go here to deal with the imminent decanting of AMD in the Witwatersrand basins



NEW WATER QUALITY THREAT - MICROPOLLUTANTS

- But a new water quality threat is emerging – micropollutants, such as pharmaceutical residues, hormones or environmental oestrogens and endocrine disruptors.



SOURCE SEPARATION OF URINE

- Most N, P and medical residues are in urine so source separation of urine (yellow water) will keep these out of the kitchen and bathroom (grey) and faeces and paper (brown) wastewaters.

Benefits of Urine Separation

- Recovery of nutrients such as Mg, P and N as struvite - urine contains 50% of WW P.
- Reduction in N & P loads on WWTPs – urine contains 80% of WW N and 50% of WW P.
- Reduction micropollutants (pharmaceutical residues) – urine contains about 2/3rds of these compounds.
- Reduced water consumption – less toilet flush water saving some 30-40 ℓ/person/d.
- Separate urine treatment targeted to specific composition of urine.

Urine Collection?

- Urine collection is a difficult problem – it quickly becomes odorous and causes mineral precipitation problems in pipes.
- Perhaps in the future, canisters of yellow water will be collected in the same rounds as solid waste.

Impact of Urine Separation on WWTPs

- Reduction in N & P loads on WWTPs – urine contains 80% of WW N and 50% of WW P.
- This will make biological N & P removal easier but not necessarily produce lower effluent N and P concentrations.
- Possibly ammonia is low enough to eliminate nitrification process at BNR WWTPs.
- This means sludge age can be halved, which increases WWTP capacity.

Impact of Urine Separation on WWTPs

- Biological P removal can be achieved at short sludge ages (5-8d).
- Very low effluent N & P concentrations may NOT be set by N & P loads but other (unknown?) factors set the limits of BNR technology.

DESALINATION OR SEA WATER DISTRIBUTION?

- Several water stressed coastal cities (PE, Cape Town) are considering desalination of sea water to augment dwindling fresh water supplies.
- But desalination is energy intensive and financially expensive.

DESALINATION OR SEA WATER?

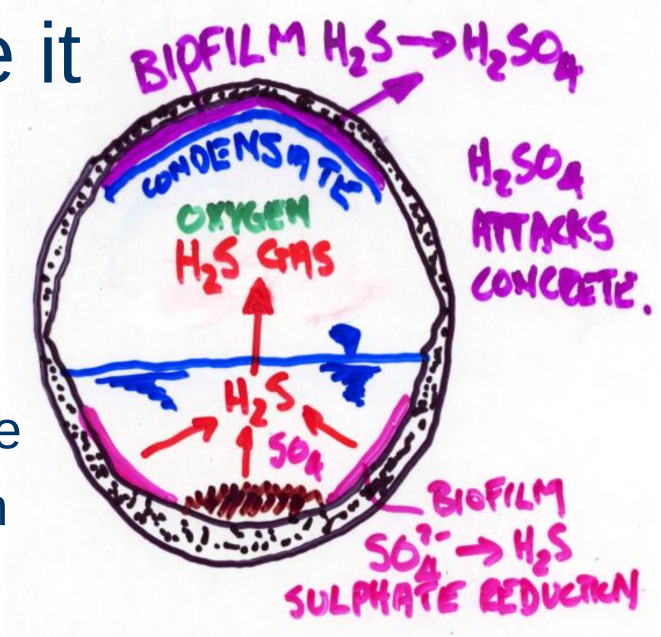
- To distribute desalinated seawater so that upper income people can water their gardens with it is environmentally indefensible.
- Rather distribute sea water for toilet flushing to save fresh water consumption.
- Need to explore the potential benefits and feasibility of this compared with desalination.

SALINE SEWAGE TREATMENT

- Hong Kong has a dual water distribution system
  - Potable water and
  - Seawater for toilet flushing.
- This saves 1/3rd fresh water (5HK$/kl), which all has to be imported from the mainland (seawater 1HK$/kl).
- This leads to high sulphate (200 mgSO_4-S/l) in the sewers.

SEWER CROWN CORROSION

- Usually, sulphate discharge to sewers is regulated because it causes sewer crown corrosion.
  - SO_4 is reduced to H_2S gas in the sewage
  - H_2S gas enters the upper air space of pipe
  - H_2S is oxidized to H_2SO_4, on sewer crown
  - Sewer crown is corroded by the acid.

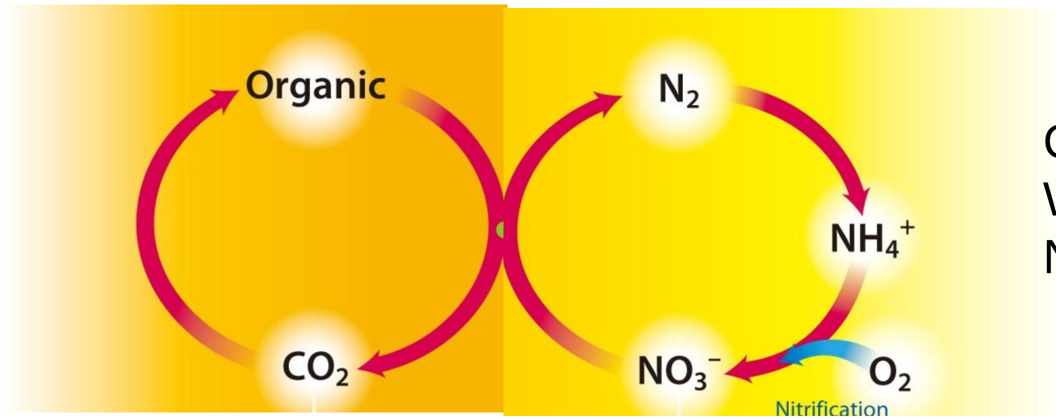


SEWER CORROSION

- But in Hong Kong, it's cheaper to repair sewers than to buy the extra fresh water.
- And the sulphate from the seawater (~200 mgSO_4-S/l) can be used to great advantage (and economy) as electron carrier in the wastewater treatment.
- So more often than not, necessity is the mother of invention so the problem becomes the means for the solution.

RE-CONFIGURE WWTPs?

C/N cycles:

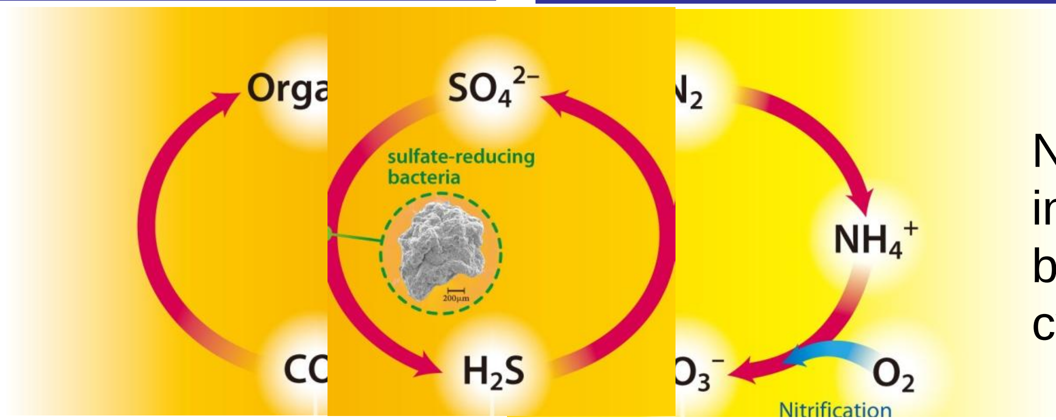


Conventional BNR WWT - link C and N cycles.

Sulfate-Reducing Bacteria (SRB):
SO_4^{2-} + COD+ H_2O → H_2S + HS^- + CO_2

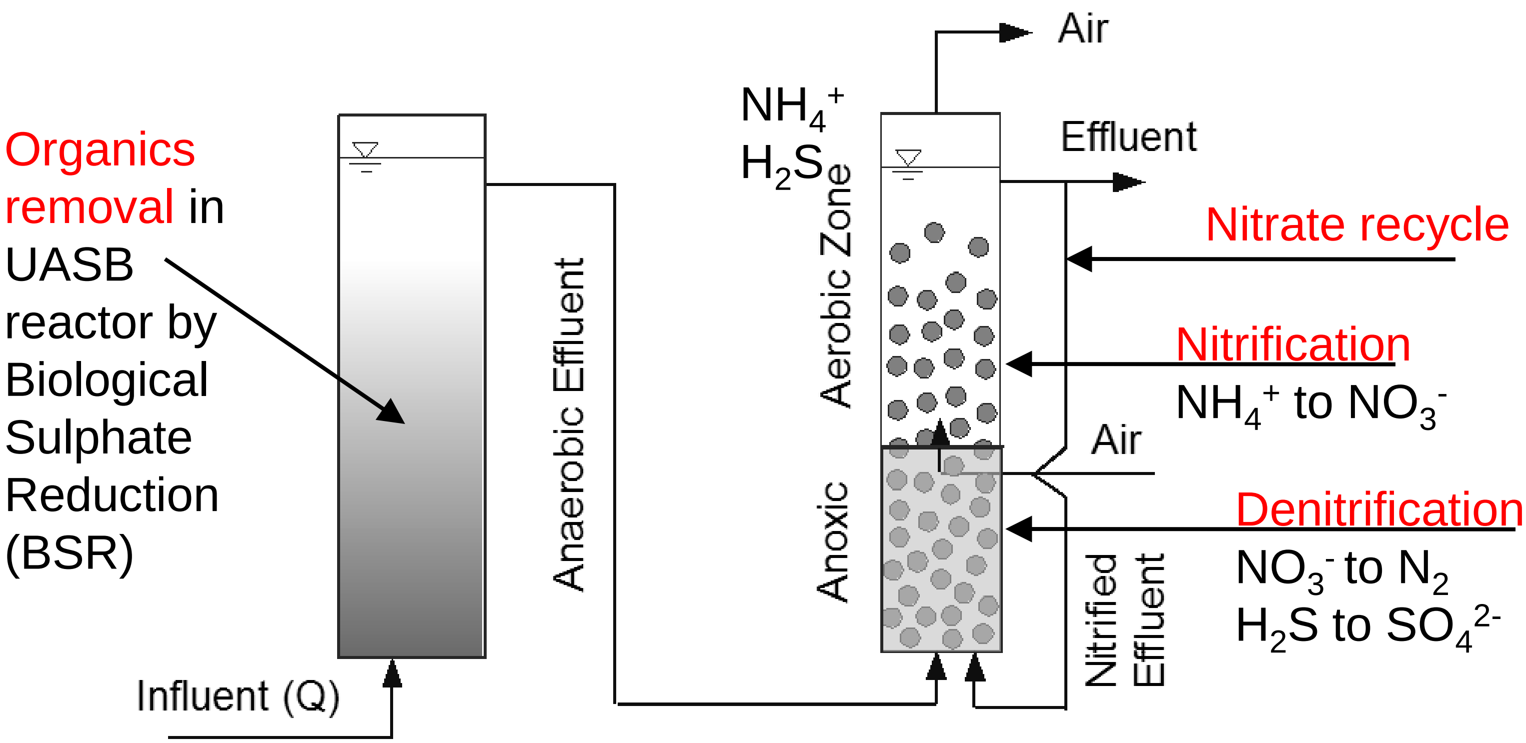
Autotrophic denitrifiers (ADN):
H_2S + HS^- +NO_3^- → SO_4^{2-}+ N_2 + H_2O

C/S/N cycles:



New WWT – interpose S cycles between C and N cycles.

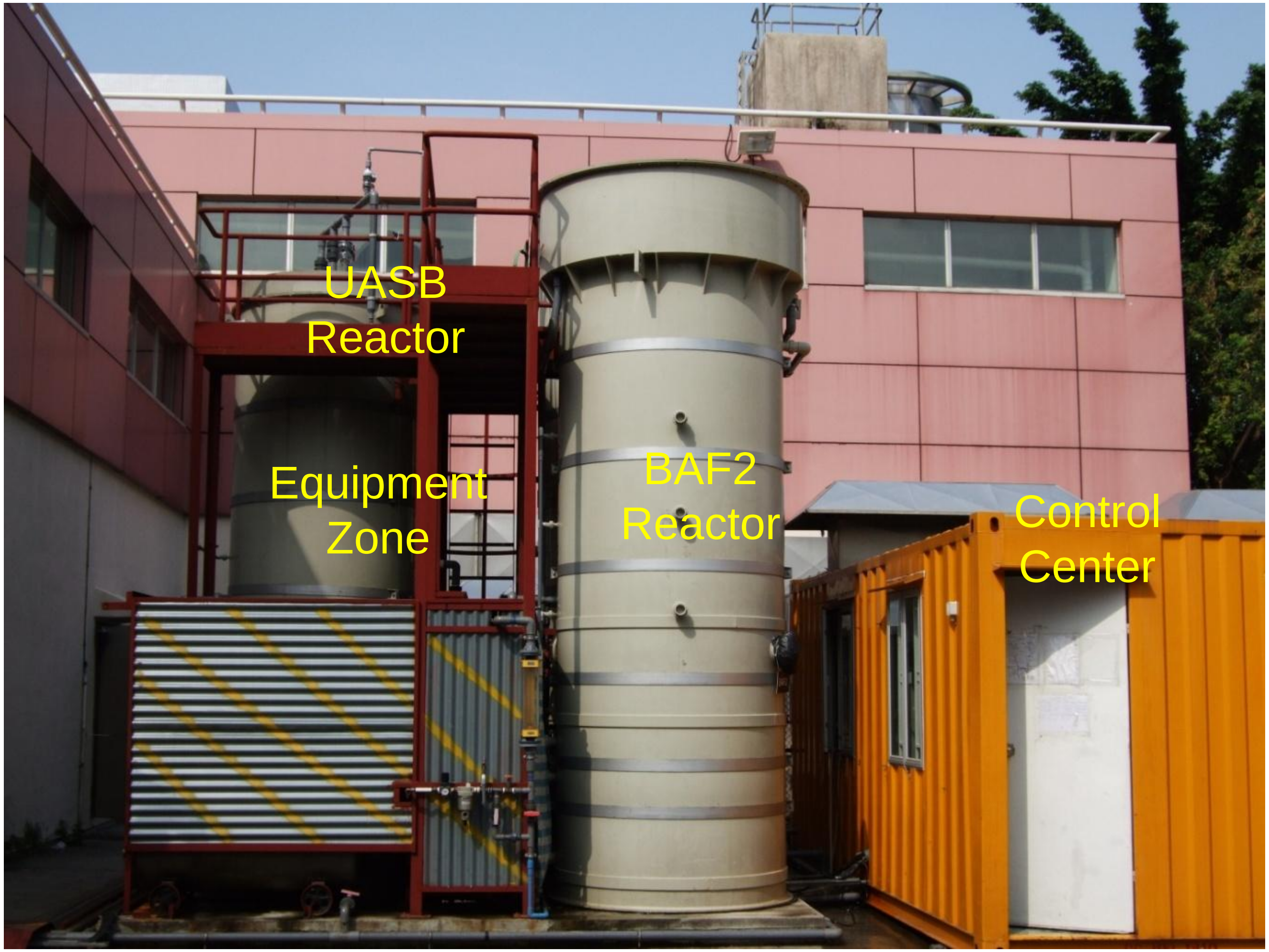
The SANI Process



Anaerobic Upflow Sludge Bed Reactor

Aerobic + Anoxic Filter

SANI Process pilot plant in Hong Kong.



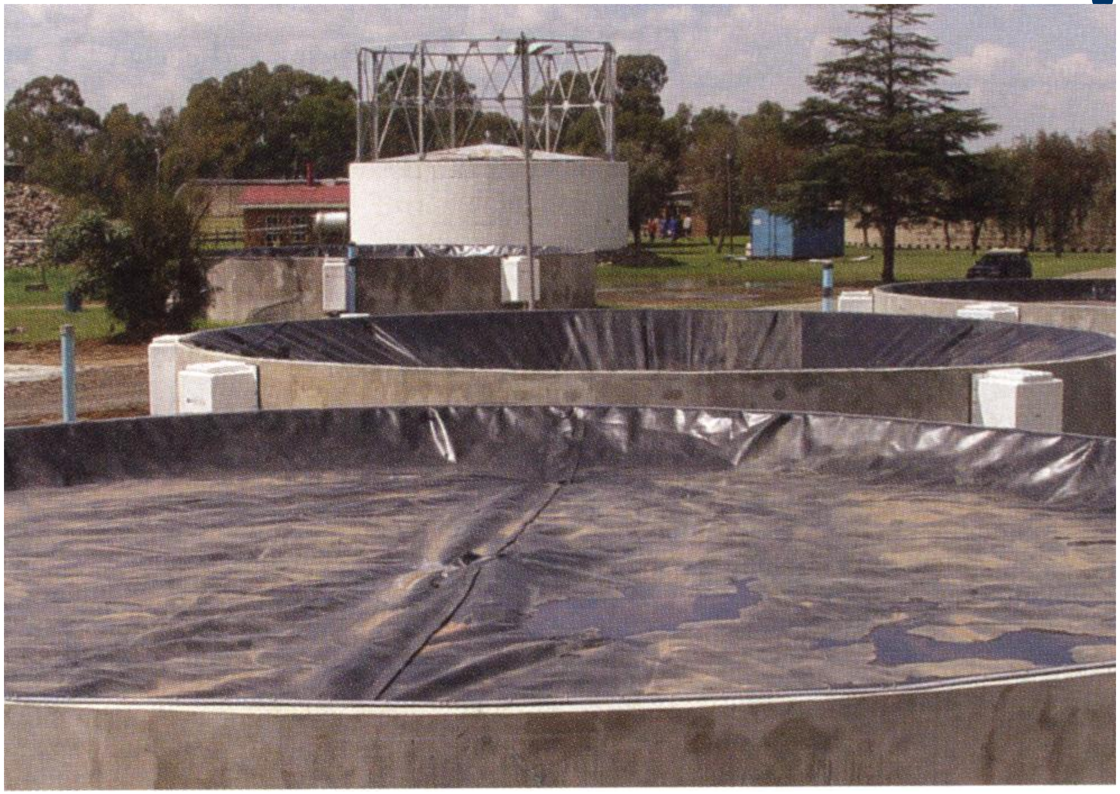
SA CONTRIBUTION

- Research on biological sulphate reduction (BSR) in acid mine drainage (AMD) with primary sewage sludge (PSS) (Biosure process) is directly applicable to the SANI process.
- Primary sewage sludge (PSS) is a product from raw sewage and so the characteristics of PSS (unbiodegradable fraction, hydrolysis rates) are directly transferable to raw sewage.

BIOSURE® DEVELOPMENT

- First ran lab UASB reactor fed primary sewage sludge and SO_4^{2-}

BIOSURE® DEVELOPMENT



- Then applied in 10 ML/d BIOSURE prototype fed PSS and AMD at ERWAT's Ancor works in South Africa.

BIOSURE® RESEARCH

- Developed stoichiometry, steady state and dynamic mathematical models for both methanogenic and sulphidogenic digesters (Biosure and SANI).

For Carbon deficiency producing $fH_2PO_4^-$ and $(1-f)HPO_4^{2-}$ from the organic P

$$C_xH_yO_zN_aP_b + \frac{Y_S}{8}(1-E)SO_4^{2-} + \left(3x-z+4b-E\frac{Y_S}{Y_B}(3k-m+4p)-\frac{4Y_S}{8}(1-E)\right)H_2O \rightarrow$$

$$+\left(E\frac{Y_S}{Y_B}\right)C_kH_lO_mN_nP_p + \left(a-nE\frac{Y_S}{Y_B}\right)NH_4^+ + f\left(b-pE\frac{Y_S}{Y_B}\right)H_2PO_4^- + (1-f)\left(b-pE\frac{Y_S}{Y_B}\right)HPO_4^{2-} + \left(x-kE\frac{Y_S}{Y_B}\right)HCO_3^-$$

$$+\left(x-a+b(2-f)-E\frac{Y_S}{Y_B}(k-n+p(2-f))-\frac{Y_S}{8}(1-E)\right)H_2S + \left(a-x-b(2-f)+E\frac{Y_S}{Y_B}(k-n+p(2-f))+\frac{2Y_S}{8}(1-E)\right)HS^-$$

SEA WATER DISTRIBUTION

- Coastal cities install dual water distribution – potable and seawater for toilet flushing.
- Saves fresh water and allows old system renewal (leak repair, additional saving).
- Avoids low grade water distribution (public health risk).
- Minimizes cross connections (taste, conductivity, no health risk - disinfected).

URINE SEPARATION AND SALINE SEWAGE

- Install urine separation toilets.
- Brown and grey water into sewer.
- Collect yellow water and nitrify decentrally (clusters of buildings)
- Discharge nitrified/treated urine to sewer.

SEWER DENITRIFICATION

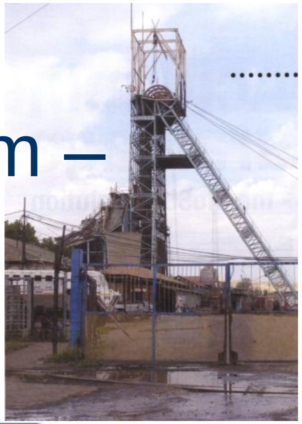
- Nitrate decreases sulphate reduction in sewer and is denitrified to N_2
- Sewer acts as denitrification reactor, removes dissolved organics and sewer corrosion is minimized.
- Treat brown and grey water in SANI process.
- SANI process ND packed bed reactor removes N from organic N and oxidizes residual H_2S to back to sulphate.

ADVANTAGES (1)

- Major reduction in oxygen demand at WWTP – only for nitrification. Electricity for oxygen demand is conventional WWTP's biggest carbon footprint.
- Major reduction in sludge production – essentially only unbiodegradable particulate organics of raw sewage (0.02 gVSS/gCOD – AS is 10x higher).

ADVANTAGES (2)

- Major water saving (sea water flushing).
- However, applies to coastal cities only – need seawater and no P removal (but P accumulating SRB are being studied).
- Could apply to acid mine drainage (AMD) water also but this adds more complexity - chemical P removal but additional sulphate can be removed.
- WWTP becomes resource recovery system – water (WW +AMD), S and P.



ADVANTAGES (3)

- There is one instance in SA where AMD is treated to potable water standard.
- If treated effluent is to be reclaimed, then its better (less energy, higher yield, more economical) to desalinate the effluent (lower salinity) than seawater (gulf states experience).

CONCLUSIONS (1)

- From a sustainability perspective, conservation of surface water quality and quantity has far greater priority than energy and carbon reduction in wastewater treatment.
- While energy reduction at WWTP is good, it should never be at the expense of water quality.

CONCLUSIONS (2)

- Seawater distribution in a dual system realizes fresh water saving with less energy consumption and carbon production than desalination.
- Saline sewage treatment combined with source separation of urine can mitigate sewer corrosion and obviate N removal at the WWTP.

CONCLUSIONS (3)

- Modelling biological sulphate reduction sewage treatment is progressing well and can be applied to saline sewage treatment systems.
- Applying saline sewage treatment and urine separation (dual distribution and collection) requires major rethink of the urban water cycle design and management – more complexity but greater sustainability.

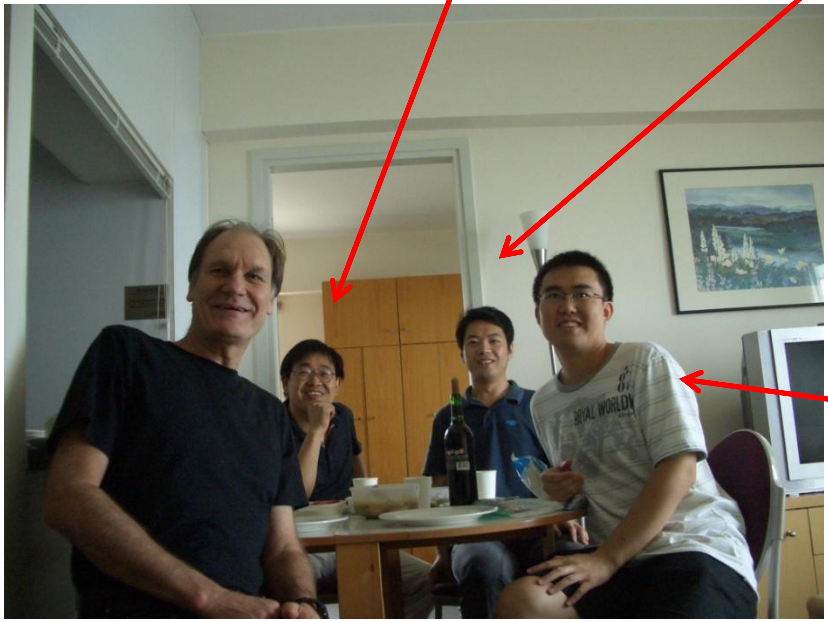
ACKNOWLEDGEMENTS

- My co-authors…..
  - Dr Jac Wilsenach, (PhD TU Delft) formerly at the CSIR but now at Virtual Consulting, led WRC Urine Separation project and
  - Professor GH Chen of Hong Kong Univ of Science and Technology, who is running saline sewage treatment projects in Hong Kong.
- Thank you for your attention.
- WRC Projects listed in abstract book.

THE PEOPLE

Mark van Loosdrecht from Technical University of Delft.

Professor GH Chen from Hong Kong University of Science & Technology



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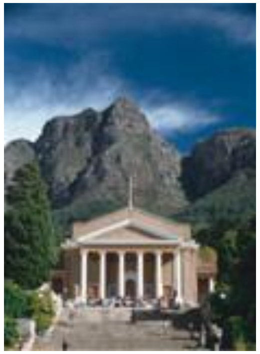
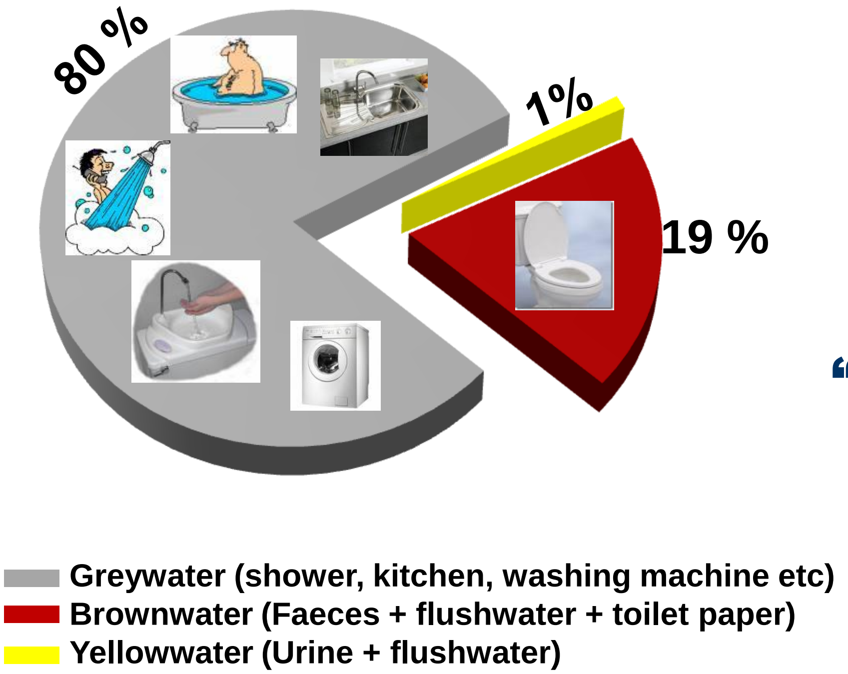


- Questions?

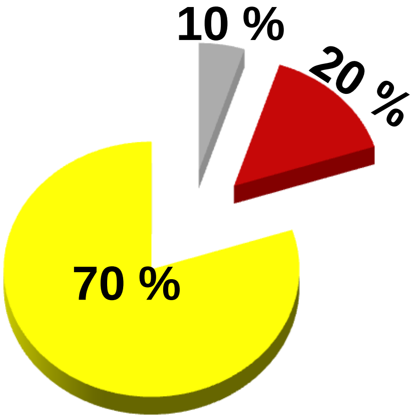
THE END

Urine Composition

Volume of Wastewater



"N" Content



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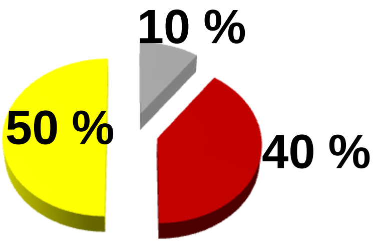
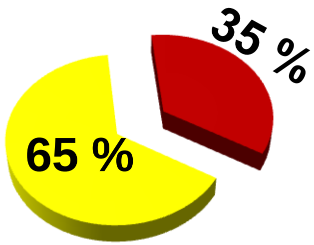
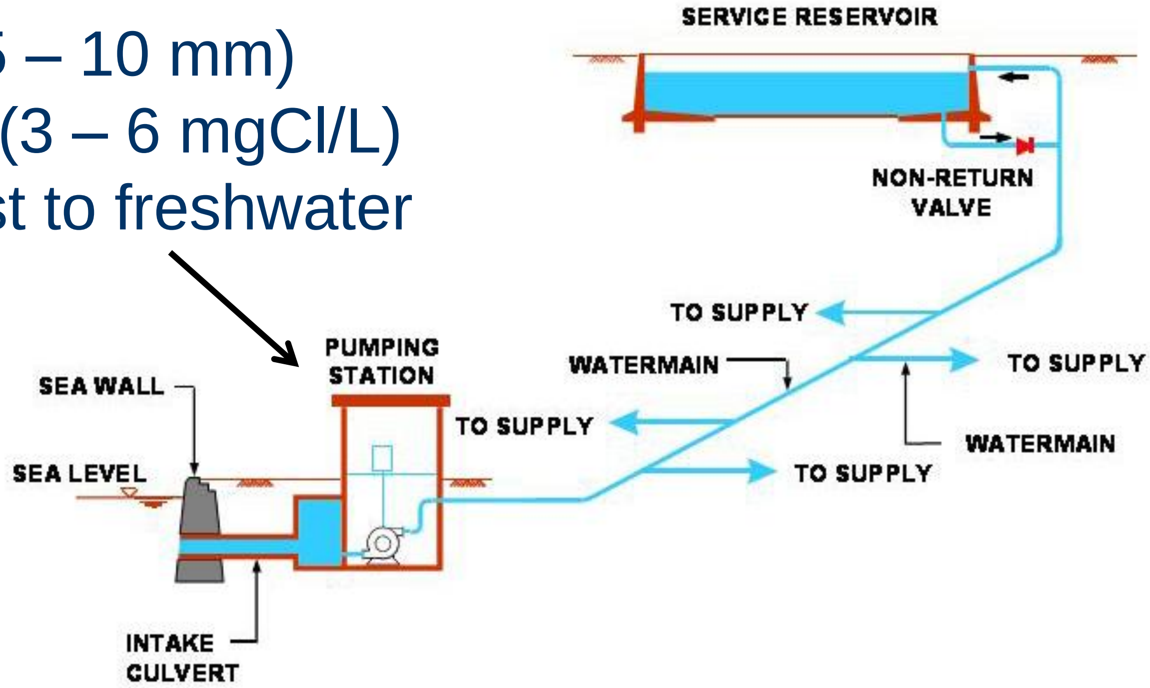


Micropollutants



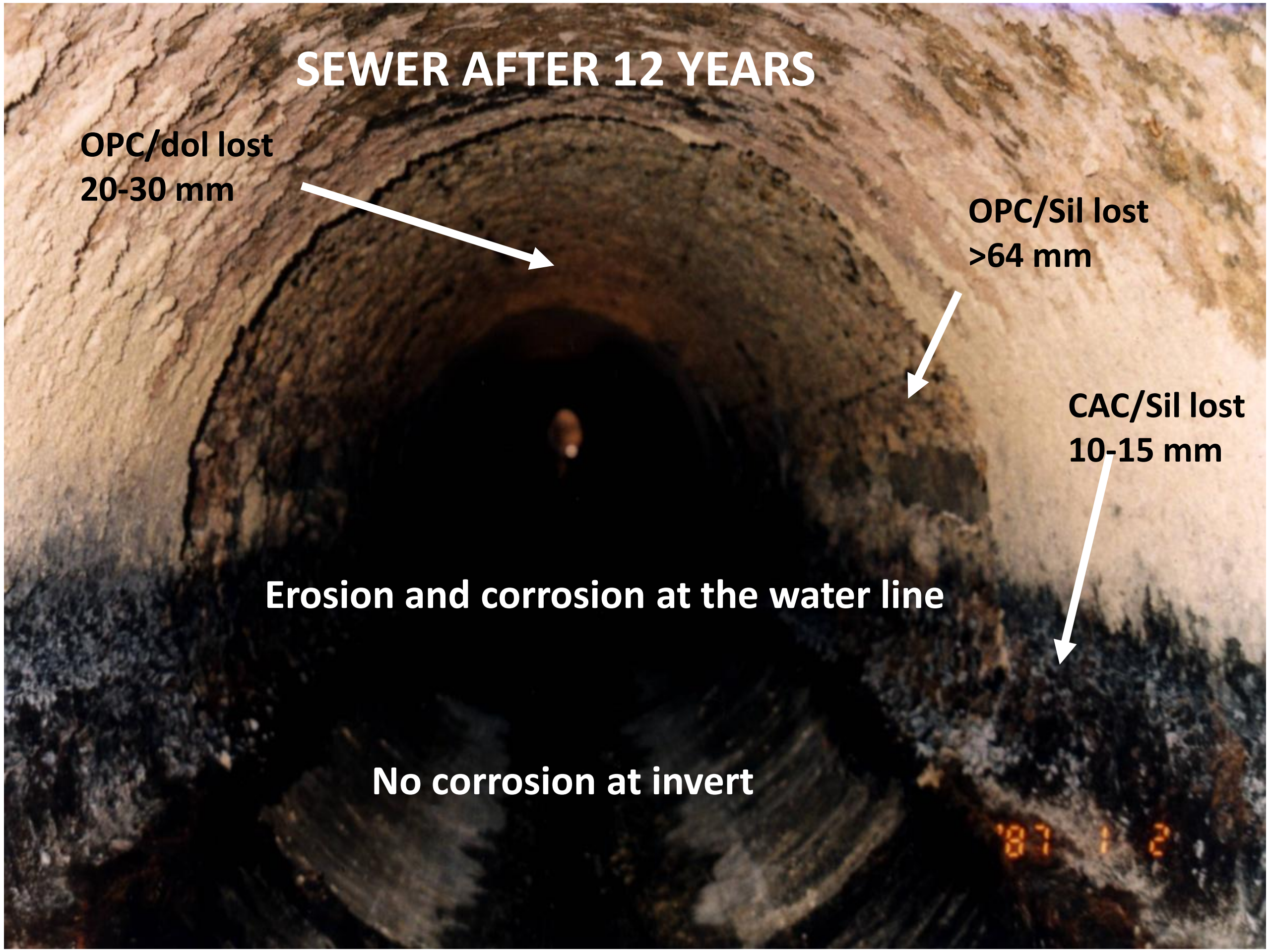
SEAWATER SUPPLY SYSTEM IN HK

- Coarse screening (5 – 10 mm)
- Electro-chlorination (3 – 6 mgCl/L)
- Similar pumping cost to freshwater



Production of	Seawater Toilet Flushing	Freshwater Supply	Reclaimed Water	Seawater Desalination
Energy Consumption (kWh/m^3)	0.013 – 0.025	0.05	0.2 – 1	2.5 – 4.0

SEWER CROWN CORROSION

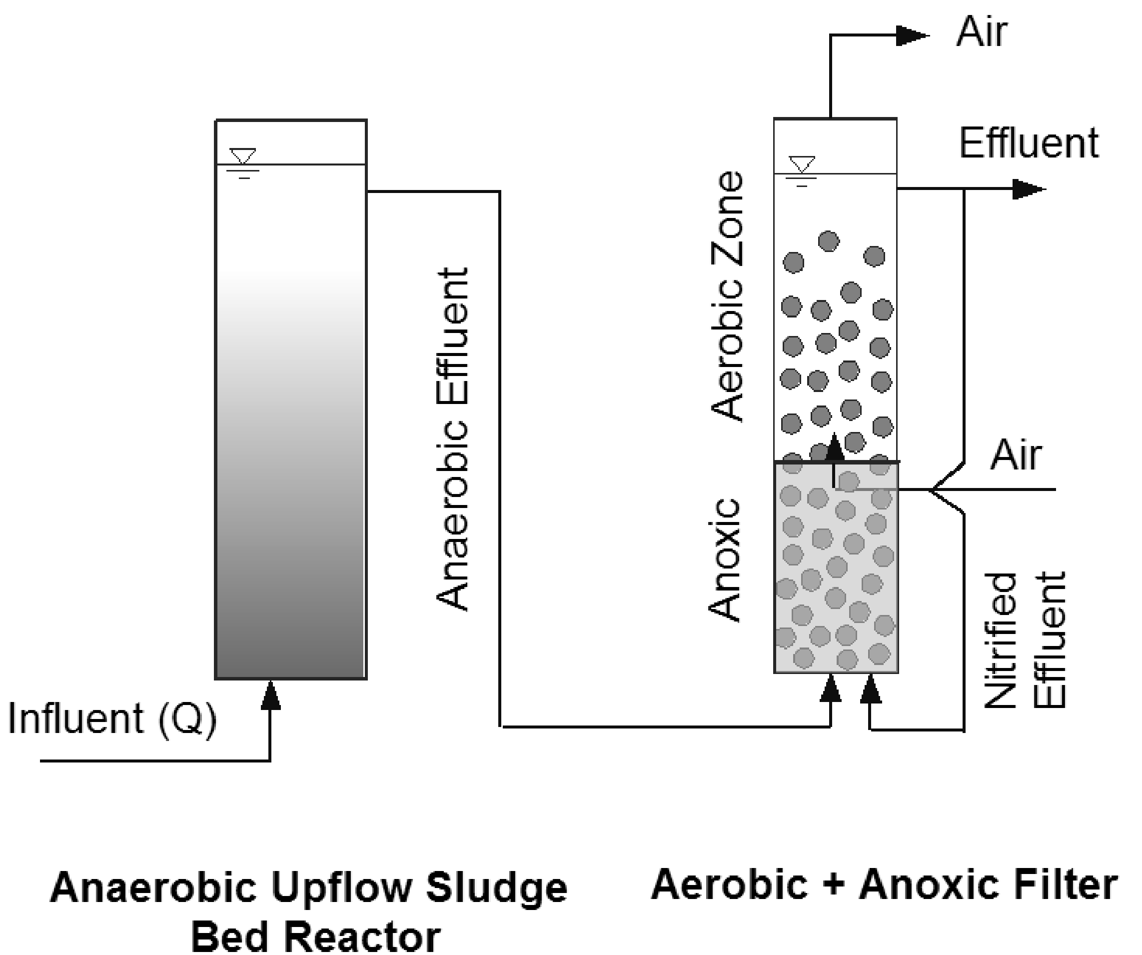


- This makes for costly sewer repair work.

BIOSURE ® RESEARCH

- Found hydrolysis rate of biodegradable particulate organics (BPO) under methanogenic and sulphidogenic conditions were the same.
- Found same unbiodegradable fraction of particulate organics (PO) for aerobic (activated sludge) and anaerobic systems (methanogenic & sulphidogenic).

The SANI Process



Sulphate reduction Autotrophic denitrification Nitrification Integrated process for saline sewage treatment.

BIOSURE® DEVELOPMENT

- Plant comprises 3 old Dortmund PSTs repaired and retrofitted to operate as UASB BSR reactors.

EVALUATION

Criterion	1. Conven'l/ Membrane	2. Seawater flushing	3. Urine separation	Combination (2) and (3)
Distribution	Single	Dual	Single	Dual
Collection	Single	Single	Dual	Dual
Sewer Corrosion	Normal	High	Normal	Normal
Energy demand	High/V.High	Very low	High	Low
Sludge production	High	Very Low	High	Very low
Sludge age	Long	Not Applic	Low	Not Applic
Reactor volume	Large	Large	Small	Large
Sludge treatment	High	No	High	No
Energy recovery	Yes	No	Yes	No
Nutrient recovery	Yes	No	Yes	Yes
Effluent Quality	V. Good	Fair	Good	Good
N&P Removal	Yes	No P rem.	Not Req'd	No P rem
Water Reuse value: N&P	Low	High P	Low	Some P
….Salinity	Low	High	Low	High
….Suspended solids	Low/V.Low	High	Low	High
….Pathogens	High/Low	Low	High	Low
……ED & EE's	High	High	Low	Low
Water saving	No	Yes	No	Yes
Water reclamation	Yes	No	Yes	No