QMRA of a wastewater system undergoing a novel treatment process for rural environments in a developing country

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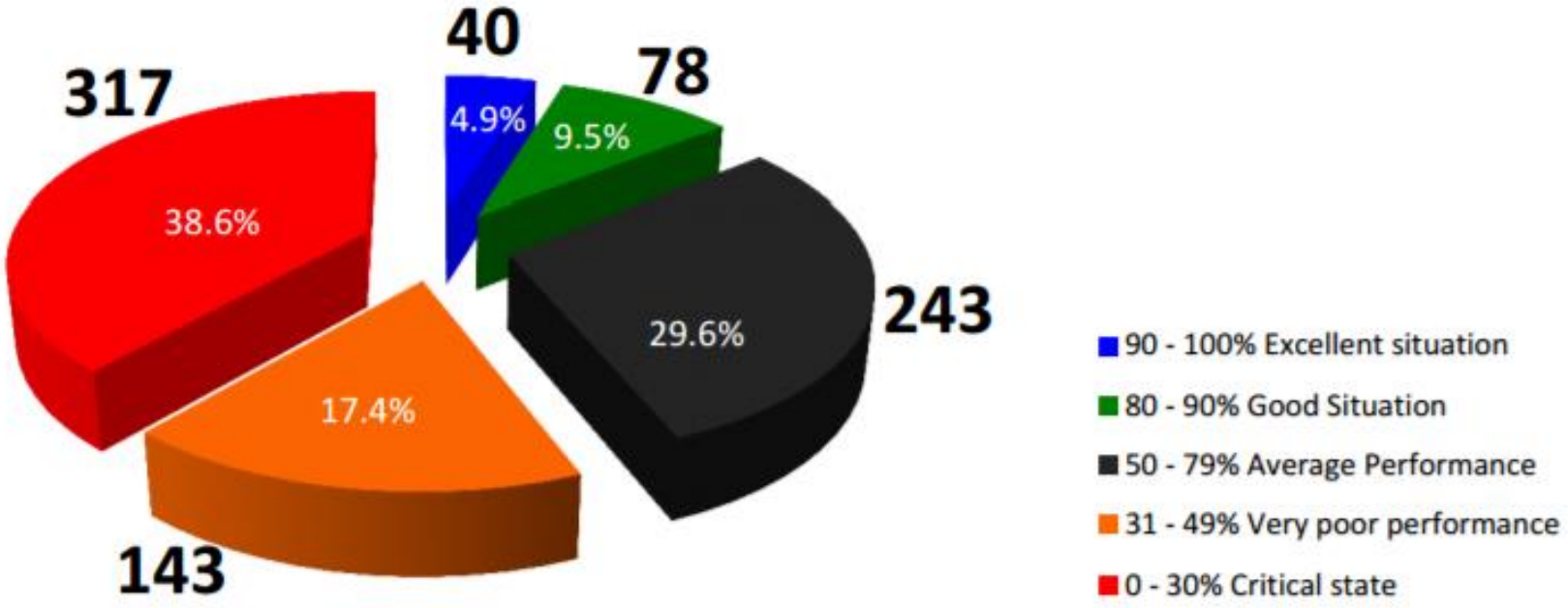
Background to project

- Conventional treatment processes such as activated sludge and biofilms are seldom used in rural South Africa due to lack of electricity and financial resources.
- Important to search for possible alternative options to improve the effluent of WWTPs in Southern Africa since classic ponds (waste stabilisation ponds) have been used as wastewater treatment option in most of the rural areas of Southern Africa.
- Phyco-remediation is an environmentally friendly and cost effective alternative treatment option for rural areas.

Wastewater treatment facilities in South Africa

- 156 municipalities provide services via an infrastructure network comprising 821 wastewater systems.



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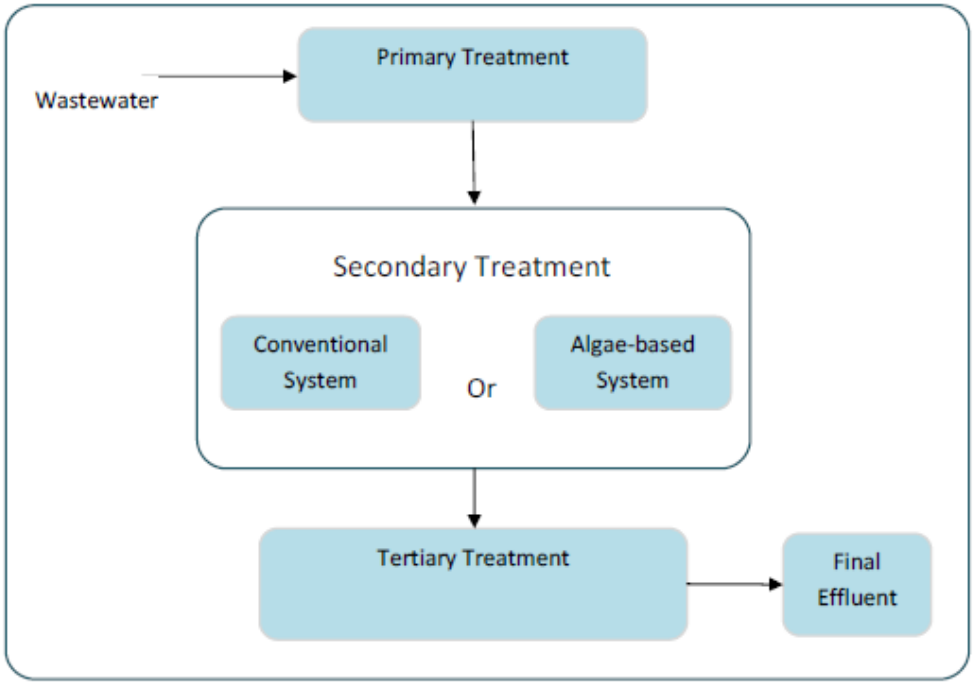
Wastewater treatment: phyco-remediation



- **Advantages of Algae wastewater treatment**
  - Cost effective
  - Low energy requirements
  - Reduction in sludge formation - minimal chemical use
  - Reduction in greenhouse gas emissions
  - Production of useful Algal biomass

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Phyco-remediation of WWTW

- Isolated algae that can absorb up to **80% of the phosphates in water**, specifically for this algae treatment system.
- The algae were cultivated at the CSIR before being transported to the wastewater treatment facility
- Before the algae are released into the ponds - stored in JoJo tanks that act as algae bio- reactors.

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Wastewater ponds

- Anaerobic Ponds:

biological oxygen demand (BOD) is achieved by sedimentation of solids and subsequent anaerobic digestion in the resulting sludge A short retention time of one to one and a half days is commonly used.

- Facultative Ponds:

designed for BOD removal through a healthy algal population, - oxygen needed for BOD removal by the pond bacteria and is generated primarily via algal photosynthesis.

- Aerobic (Maturation) Ponds or polishing ponds:

designed for pathogen removal - size and number of ponds depends on the bacterial quality of the final effluent

Potential health risks

- The public are at risk through the direct ingestion of untreated or inadequately treated water, engaging in recreational and domestic activities in contaminated waters, consuming contaminated fish and through unintentional exposure through splashes.

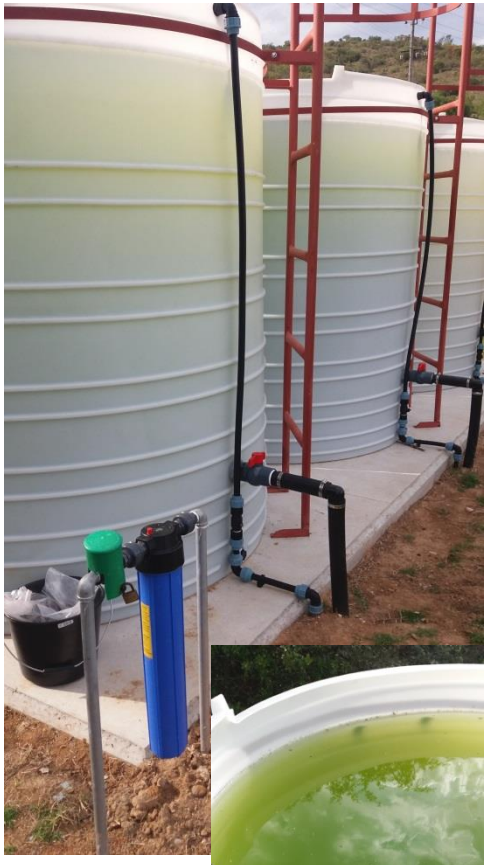
- The effects of contamination experienced 30 - 40 km downstream of a source (Oberholster et al, 2013) illustrating the importance of adequate treatment of wastewaters to protect public health.

Pre treatment

Mass culturing of algae - CSIR algae raceway

2 *Chlorella s*pecies cultured to be added to WWTW

Mass culturing of algae – continued on site



- Mass culturing of algae in a step-wise procedure using onsite algal reactors. Five algae bioreactor tanks (Semi-transparent tanks with a capacity of 5 000 L each) were installed at the WWTW.
- Mass algal culturing process was initiated - adding 20 g of fertiliser to each algal reactor.

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Phyco-remediation – from Raceway to WWTWs

Pumping at CSIR, PTA

QMRA – hazard identification / problem

- Typical concentrations of faecal coliforms in untreated sewage are 10^6 –10^8 /100ml (Feachem et al, 1983; George et al, 2002; Miescer and Cabelli, 1982; Hu and Gibbs, 1995).
- Salmonella sp. in wastewater typically range from 10^2 –10^4 /100ml . (Hu and Gibbs, 1995)
- 53% E. coli found in wastewater treatment works and environmental waters were of the pathogenic IPEC variety (Anastasi et al 2012).
- 7% of E. coli found in WW used to irrigate lettuce were pathogenic (Castro-Rosasa et al, 2012)

Potential for exposure to WW effluent

- Unintentional direct ingestion of the wastewater
- Ingested volumes can range from 1 to 50 ml from accidental exposure through splashing, playing, wading, fishing, boating and swimming
- Children swim in the WW ponds
- According to studies pathogenic *E. coli* varies from 53% to 7% (for the QMRA assumed 7% of *E. coli* bacteria were pathogenic)

Microbial tests

Pathogens

- Cryptosporidium and Giardia
- Enteric viruses, Norovirus
- Pathogenic bacteria

Indicator organisms – surrogates

- *E. coli*
- Clostridium
- Coliphage (somatic)

QMRA models used

Daily risk of infection (WHO, 2001)	Daily risk of infection Exponential model (Haas, 1996)
$P_i = 1 - \left[1 + \frac{d}{N_{50}}\left(2^{\frac{1}{\alpha}} - 1\right)\right]^{-\alpha}$	$Pi = 1 - \exp(-rN)$

P_i = probability (risk) of infection
d = dose or exposure (number of organisms ingested based on consumption of water per day)
α = parameter characterised by dose-response relationship
N_{50} = median infectious dose
r = parameter characterised by dose-response relationship

- Unlikely that a person living in the community will be exposed to the water on only a single occasion,
- repeated exposures were also calculated

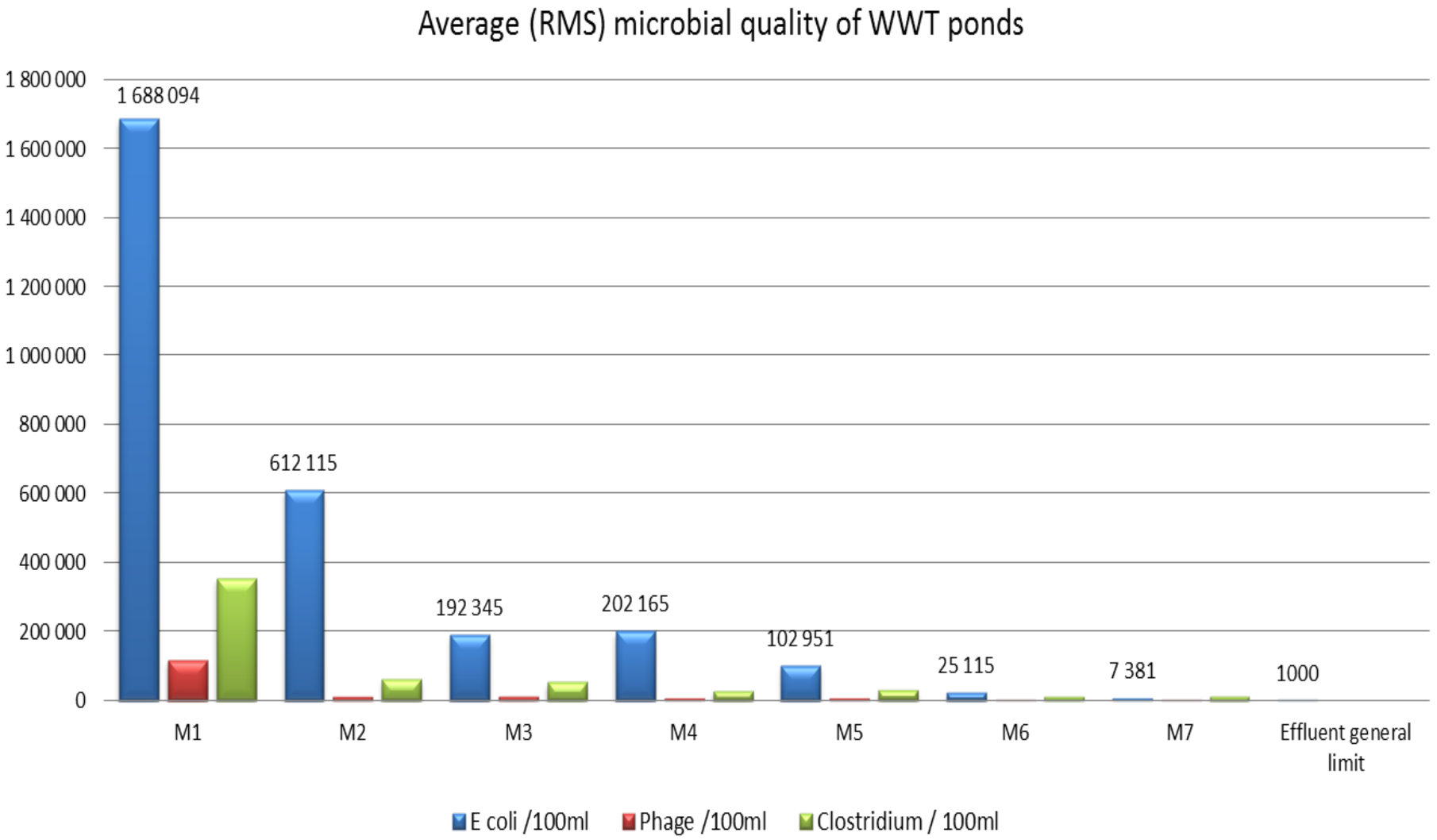
$$P(n) = 1 - ((1 - Pi))^{n}$$

Where n is the number of times exposure occurs.

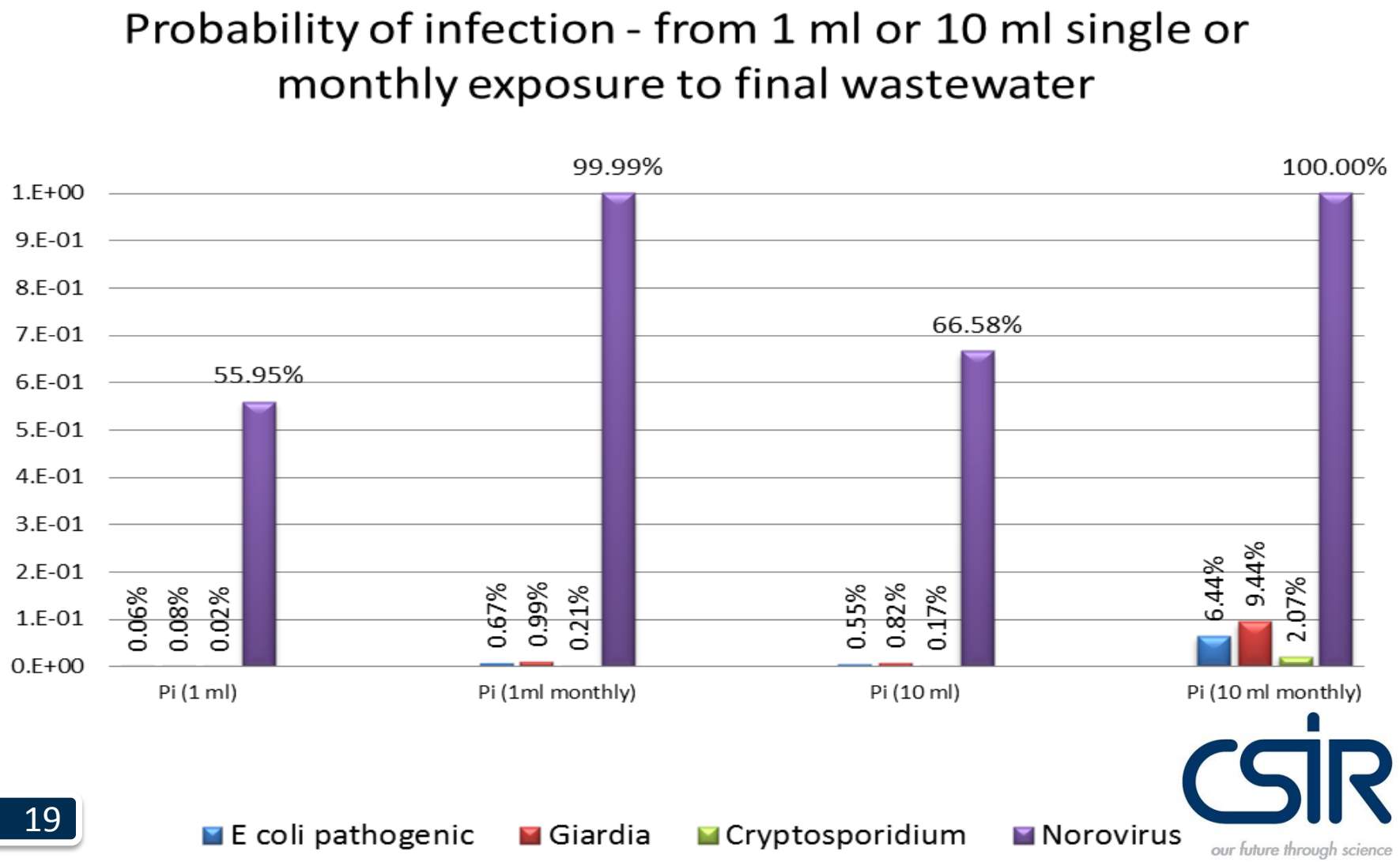
Parameters used in QMRA

Organism	α	N_{50}	r	Reference
E. coli pathogenic	0.395	2.473		Strachan *et al*. 2005
Giardia sp.			0.0198	Teunis *et al*. 1996
Cryptosporidium sp.			0.00419	Teunis *et al*. 1996
Norovirus	0.040	0.055		Teunis *et al*. 2008
Pathogens tested in untreated wastewater together with indicators Monitoring continued for indicators and used for QMRA				

Microbial water quality results



QMRA results



Results

- The health risks associated with exposure to the wastewater were significantly reduced from the beginning of the wastewater treatment process to the final effluent, and the results illustrate that with proper operations and management of the system, it is expected that health risks to the community can be significantly reduced.
- Health risks are greatest from possible exposure to viruses such as norovirus,

Results

- The probability of infection is reduced from almost certain (95% or 0.95) in wastewater that enters the pond system to a probability of infection of ~6 in 10,000 from exposure to pathogenic E. coli in treated effluent assuming a single exposure event of 1 ml.
- For Giardia, the probability of infection was reduced from 2% at the start of the wastewater treatment process to 0.08% in the final effluent.
- Risks for exposure to viruses were not as effectively reduced where the probability of infection from untreated wastewater was almost definite - starting at 64% and reduced to 55% in final effluent.

Conclusions

- This study has shown how QMRA can be used to identify where additional processes will need to focus to reduce viral concentrations as well as illustrating the effectiveness of the phyco-remediation.
- Future considerations being investigated

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Aquaculture and algae recovery

- Introduction of Aquaculture to the wastewater treatment ponds
- Other options being tested

    Isolation of algae to use as fertiliser

Thank you

Questions?