Ozone Disinfection of Re-Claimed Wastewater

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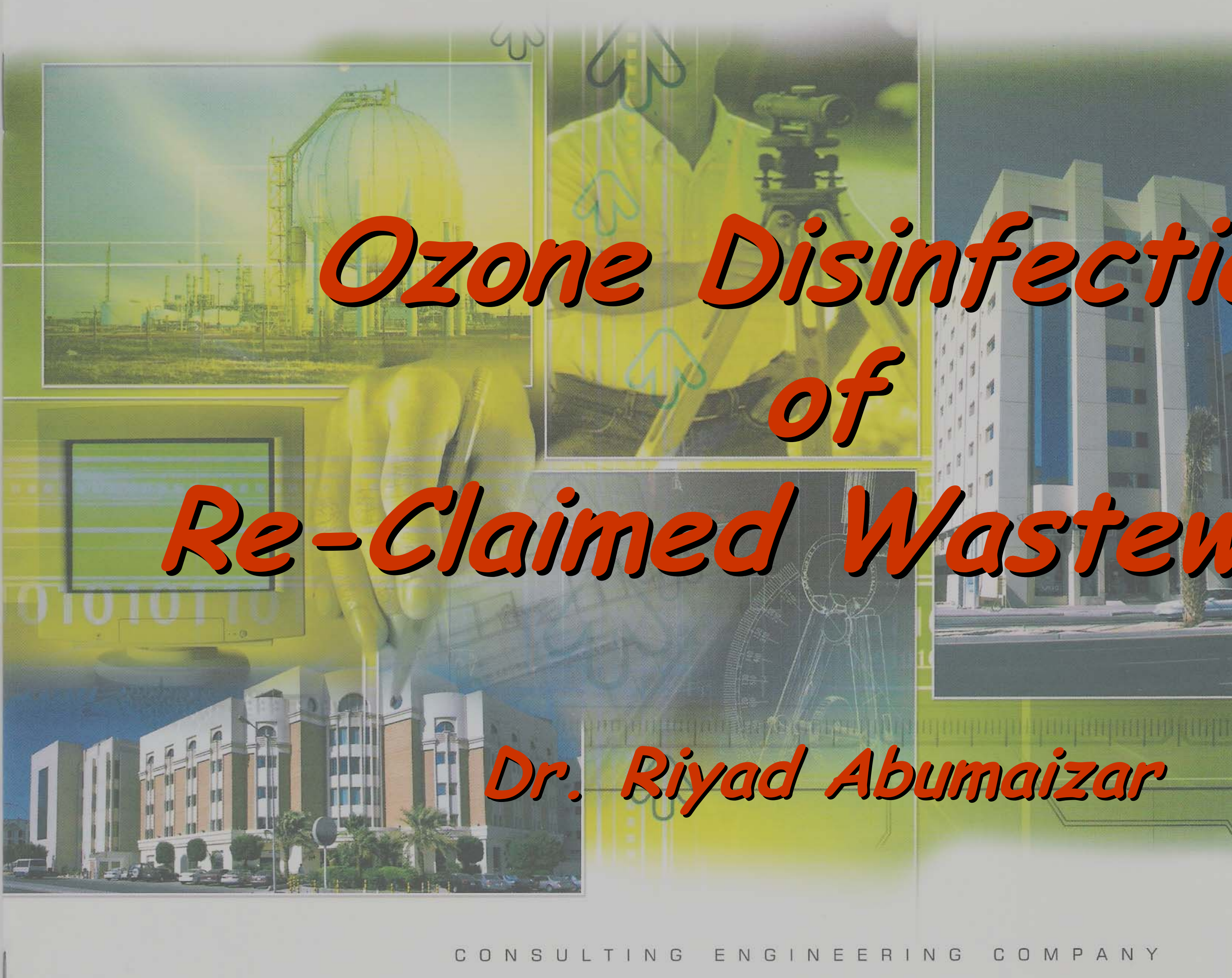

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Contents:

- Definitions and background.
- Quality criteria and guidelines.
- Disinfection alternatives.
- Chlorination pilot tests.
- Ozonation pilot tests.
- Adopted tertiary treatment scheme.
- Actual lab results of reclaimed water quality.

Disinfection:

Is the process of reduction of pathogens to acceptable levels of risks of transmission of disease.

When Wastewater Disinfection is Recommended or Required ?

- Discharge to surface waters
- Discharge to ground waters
- Irrigation of crops and landscape
- Other direct and indirect reuse and reclamation purposes

What is Reclaimed Water?

Reclaimed water is wastewater that has been treated well enough to be put to use for either irrigation, industrial or other water features.

While not clean enough to meet drinking water standards, the treated water is proven safe for plants, and even human contact with irrigated areas, such as parks and golf courses.

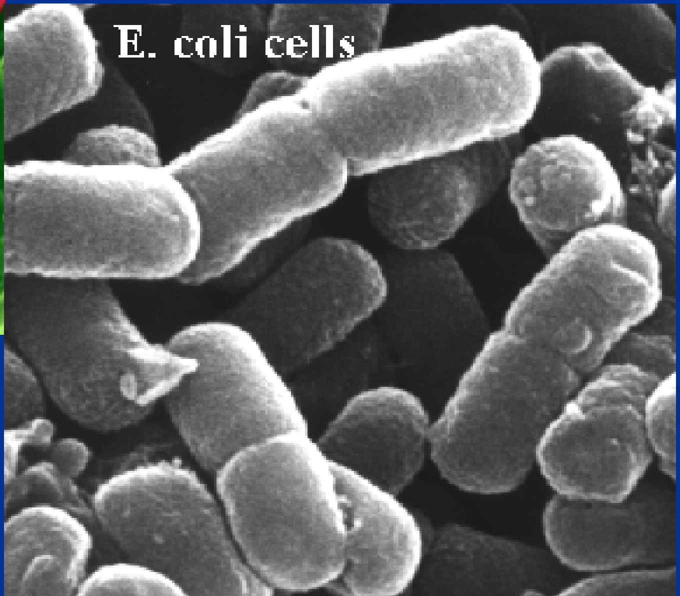
Benefits of wastewater re-use:

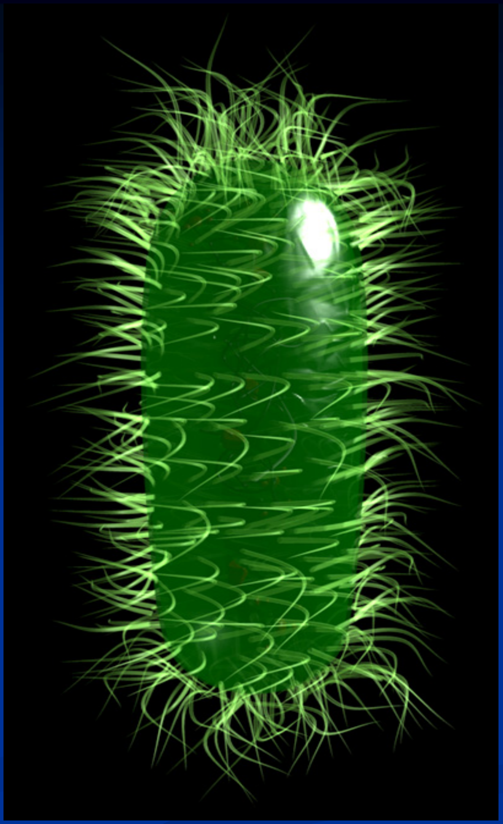
- ✓ A New Source of Water
- ✓ 

Pollution of the Environment
- ✓ Conservation of the Ground Water
- ✓ A Greener Environment
- ✓ Significant support to Agricultural Activities
- ✓ Economically attractive

Pathogens include four classes of microorganisms:

<u>1 - Bacteria</u>, such as: E. Coli, Shigella spp and Salmonella sp.

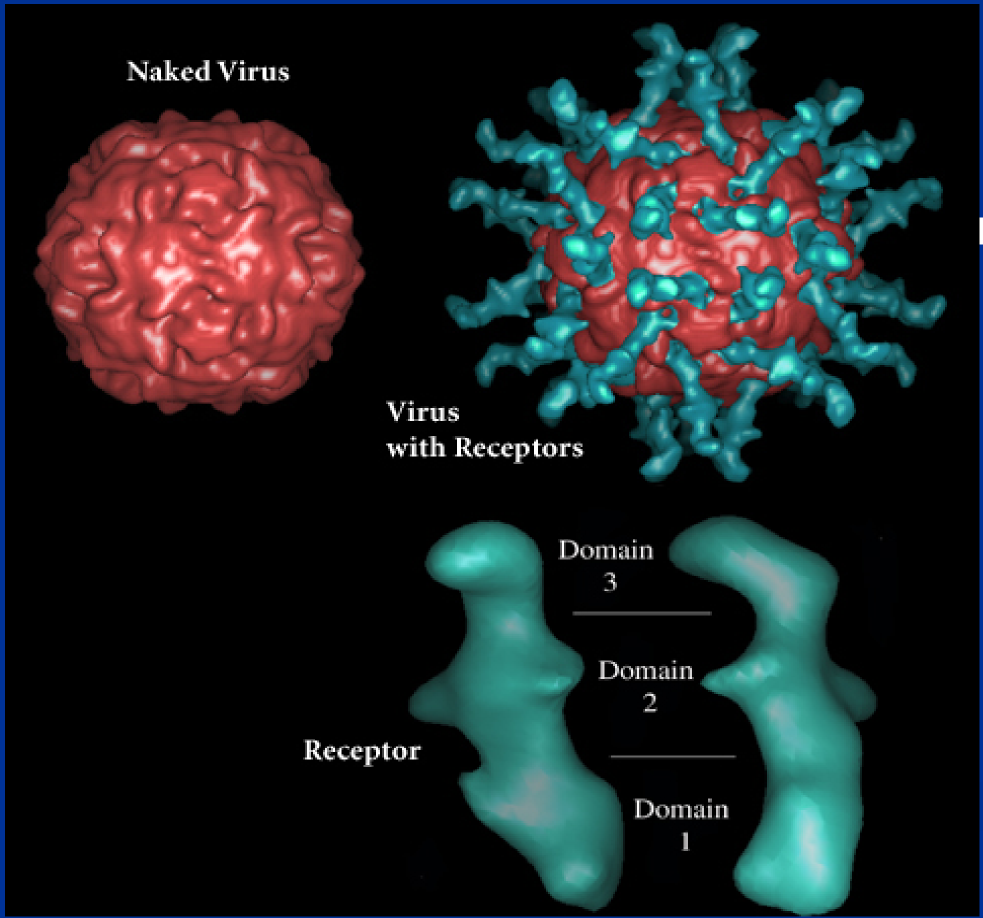


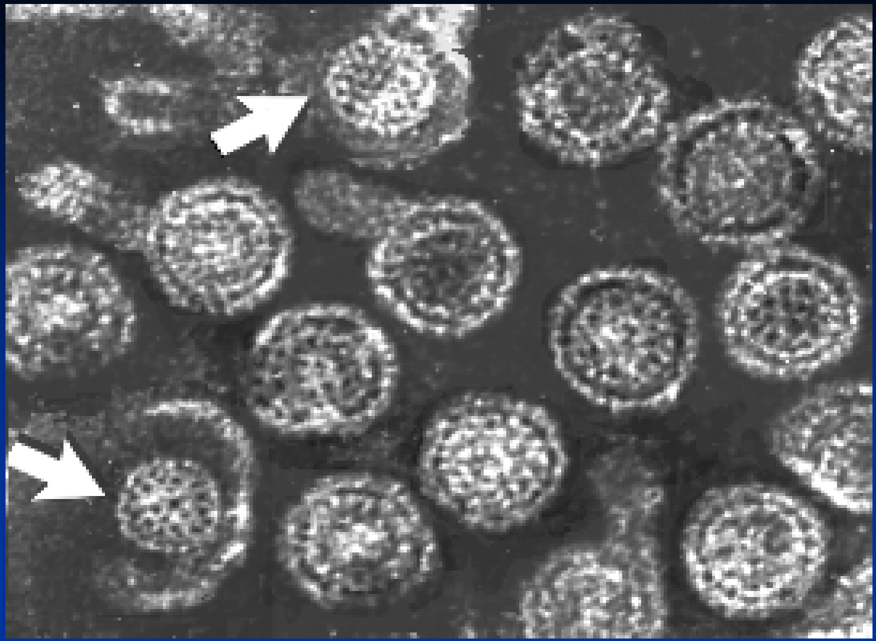


E. Coli

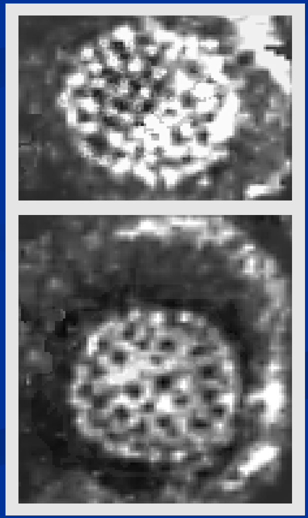
Shigella spp

2- Viruses, such as: Hepatitis, Poliovirus, …



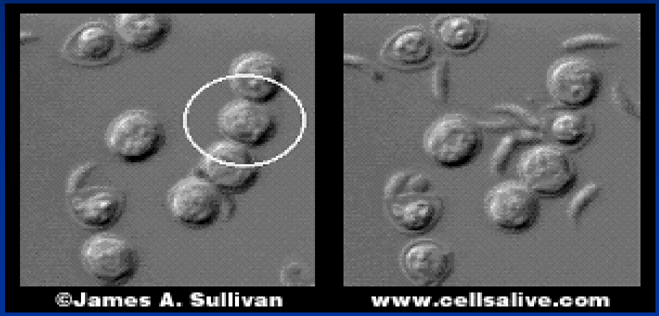


- *A group of hepatitis B virions*



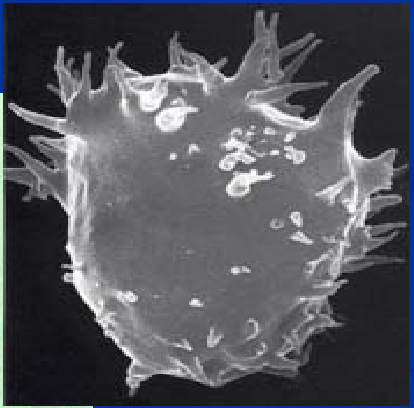
enlargements of the two exposed cores

3- Protozoa, such as:
Giardia spp. and Cryptosporidium spp.

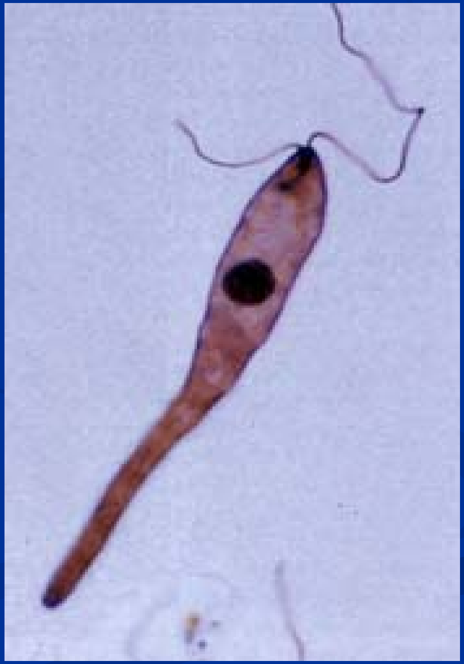


Cryptosporidium parvum

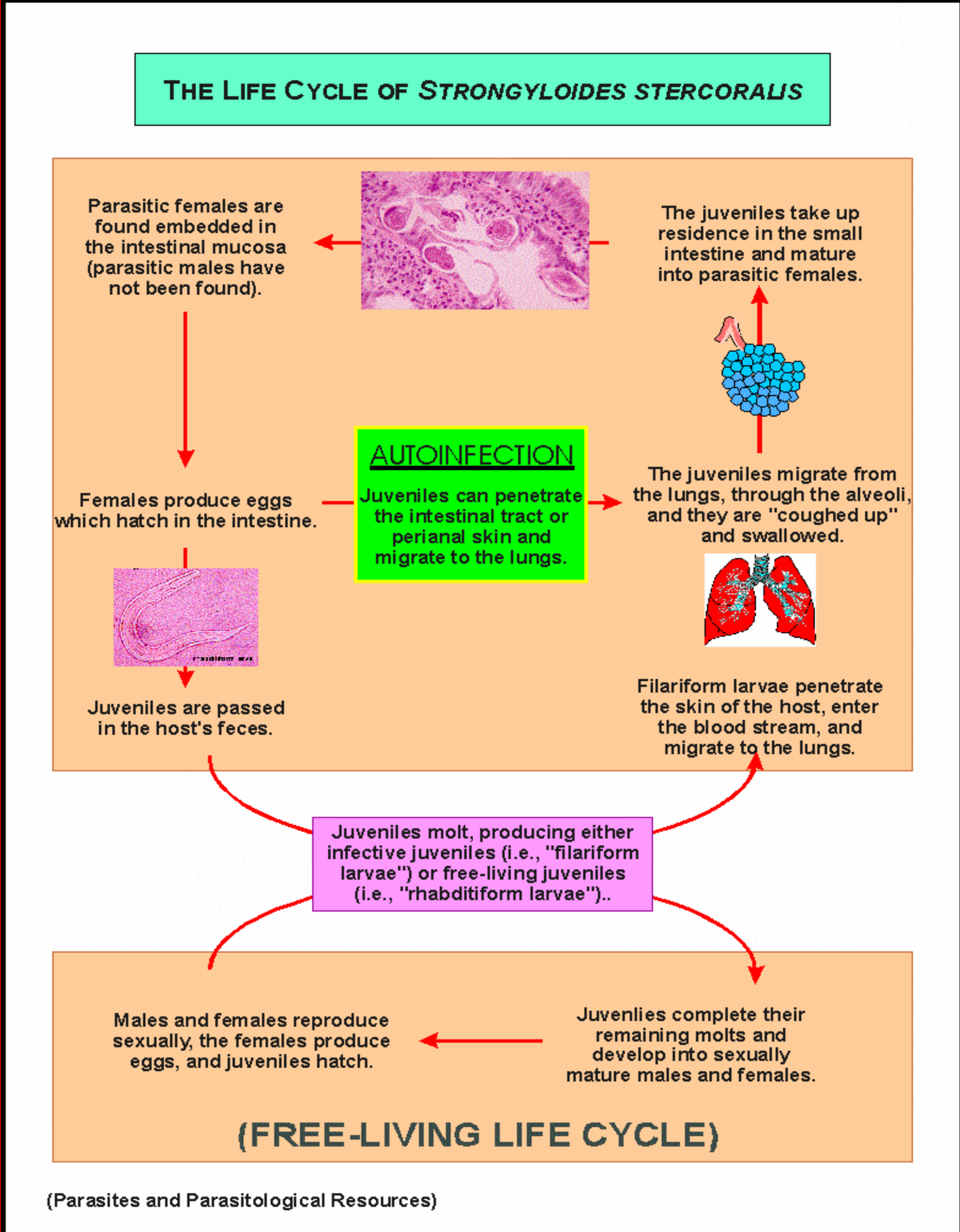
Ciliate Protozoa



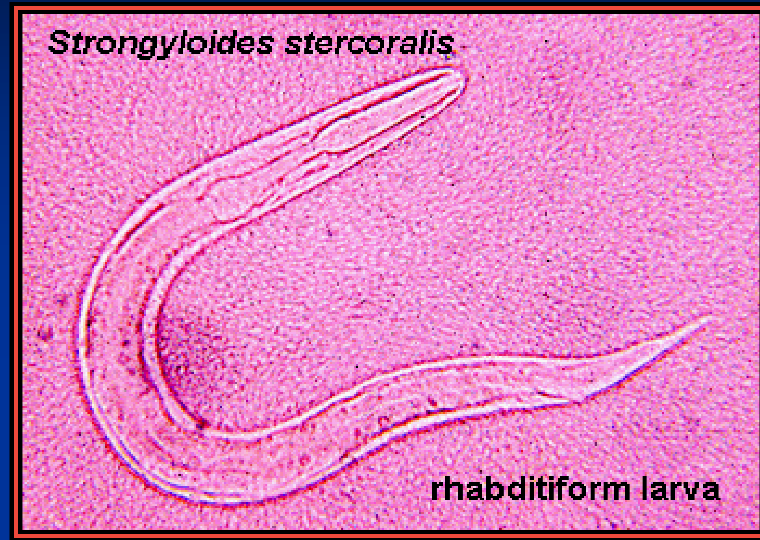
amoeba protozoa



Flagellate protozoa



4 - Helminths, such as: Strongyloides spp.



Common Name: Threadworm

Strongyloides first-stage larvae are 180-380 μm and 14-20 μ m wide.

The male is up to 0.9 mm long and 40 to 50 μ m wide. females reach a length of 2.0 to 2.5 mm

Pathogens commonly found in secondary treated wastewater
(US EPA 1992)

Pathogen		Disease or Type of infection	Indicative level of pathogens	Infectious dose
Class	**Example**			
Bacteria	Shigella spp. Salmonella sp. Eschrichia coli (enteropathogenic) Vibrio spp.	Dysentery Typhoid Gastroenteritis Cholera	10^4-10^6 Organsms/100ml	180 10^4-10^6 10^6-10^{10} 10^3-10^7
Viruses	Enteroviruses: • Poliovirus • Echovirus • Coxsackievirus Hepatitis A Adenovirus Calicivirus: • Norwalk virus Rotavirus	 Paralysis Gastroenteritis Meningitis Hepatitis Respiratory disease Gastroenteritis Gastroenteritis	10^1-10^4 viruses/L	1-10
Protozoa	Giardia spp. Cryptosporidium spp. Entamoeba spp.	Giardiasis Crypto- sporidiosis Amoebic dysentery	10^1-10^4 oocysts/L	< 10
Helminths	Ascaris spp. Ancylostoma spp. Trichuris spp. Strongyloides spp. Taenia spp.	Roundworm Hookworm Whipworm Threadworm Tapeworm in humans	10^1-10^3 eggs/L	1-10

Selected Guidelines and Criteria for WW re-use for irrigation:

	Crop Type	*Treatment required*	*Microbiological criteria (max.)*
USA	Any food crops not commercially processed (including crops eaten raw)	Secondary + Filtration + Disinfection (minimum **1 mg/L** chlorine residual)	**0.0** f. coliforms / 100 ml
NWRI	Unrestricted irrigation purposes	Tertiary treatment + disinfection.	**2.2** coliforms / 100 ml **4 - log** inactivation of poliovirus
South Africa	Food crops eaten raw, lawns, nurseries (unrestricted access)	Advanced (general drinking water standards	Drinking water standards
Saudi Arabia	All irrigation purposes (unrestricted)	Advanced wastewater treatment	**2.2** coliforms / 100 ml
Australia	Class A (high risk of human contact)	Tertiary treatment + disinfection	**10** org. / 100 ml and verified pathogen removal
WHO	Category A, irrigation of crops likely to be eaten uncooked, sports fields, public parks	Advanced wastewater treatment	**200** f. coliforms /100 ml **1** nematode egg / L
Bahrain	Unrestricted agricultural irrigation, landscape irrigation	Tertiary treatment + disinfection	**2.2** coliforms / 100 ml **1** helminth/L **1** PFU / 40 L (Enteric Virus)

NWRI : National Water Research Institute - USA

Disinfection Alternatives

The three most common disinfection methods for treated wastewater are:

1. Chlorination
2. Ozonation
3. UV radiation

1. ***Chlorine:***

- Most widely used disinfectant for municipal wastewater.
- Destroys target organisms by oxidation of cellular material.
- May be applied as chlorine gas, as a liquid (sodium hypochlorite) or as a solid (calcium hypochlorite).

……

Chlorine: advantages & disadvantages:

Advantages:

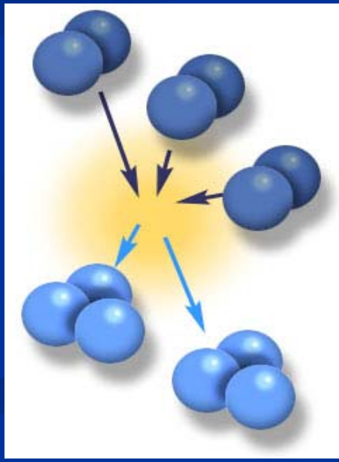
- Good bacterial reductions: typically, 99.99+%
- More cost effective (except when de-chlorination is required)
- Chlorine residual can prolong disinfection

Disadvantages:

- Chlorine is corrosive and toxic, storage shipping and handling pose risks and difficulties.
- Less effective for viruses and parasites: typically, 90% reduction
- Toxicity of chlorine and its by-products to aquatic life now limits wastewater chlorination; may need to:
  - De-chlorinate.
  - Use an alternative disinfectant.

2. *Ozone:*

- Generated by an electrical discharge through dry air or pure oxygen.
- Strong oxidizing agent. Ozone's oxidation potential is (-2.07 V), the chlorine's "op" is (-1.36 V).
- Ozone is 10 to 100 times more powerful than hypochlorite acid.



Ozone: advantages & disadvantages:

Advantages:

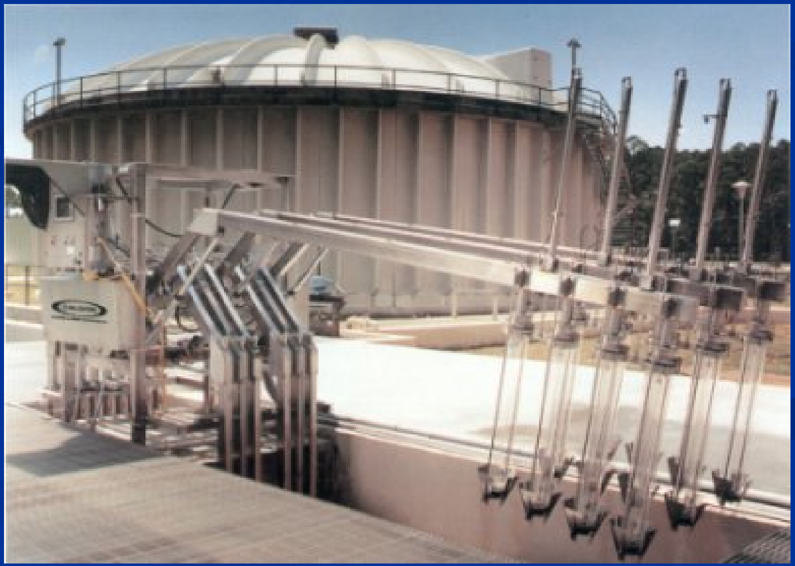
- Decomposes rapidly to oxygen after application, increasing the DO levels.
- It has a capacity to remove odors and colors.
- Effective against all pathogens unlike other disinfection alternatives.

Disadvantages:

- High production cost.
- Complicated operation and maintenance of the production equipment.
- Ozone does not leave residual in the treated effluent.

3. *UV radiation*:

- Generated by an electrical discharge through mercury vapor.
- Penetrates the genetic material of microorganisms and retards their ability to reproduce.
- Disinfection involves passing a film of WW within close proximity of the UV source.
- Efficiency depends on the characteristics of the treated effluent.
- Limited efficiency against protozoa and helminths.



Characteristics to consider when choosing the most suitable disinfectant:

- Ability to destroy infectious agents under normal operating conditions;
- Must have characteristics that are not harmful to people and the environment;
- Safe and easy handling;
- Absence of toxic residuals, such as cancer-causing compounds, after disinfection; and
- Affordable capital and operation and maintenance (O&M) costs.

Our experience in selecting a suitable disinfection alternative in the Gulf region:

1- Condition were evaluated, the following was found:

i. Pathogens and other parameters, in secondary effluents, are within normal values.

ii. Secondary effluents contain *Strongyloides stercoralis* (Ss). Counts of more than 100/L.

iii. Reported (Ss) counts in sand filter effluents exceeded those of the secondary effluent.

iv. Removal of more than 99% must be achieved to meet the guidelines.

2- Pilot testing program was carried out to evaluate a number of alternatives.

The results of the following disinfection options will be discussed:

i. Chlorination

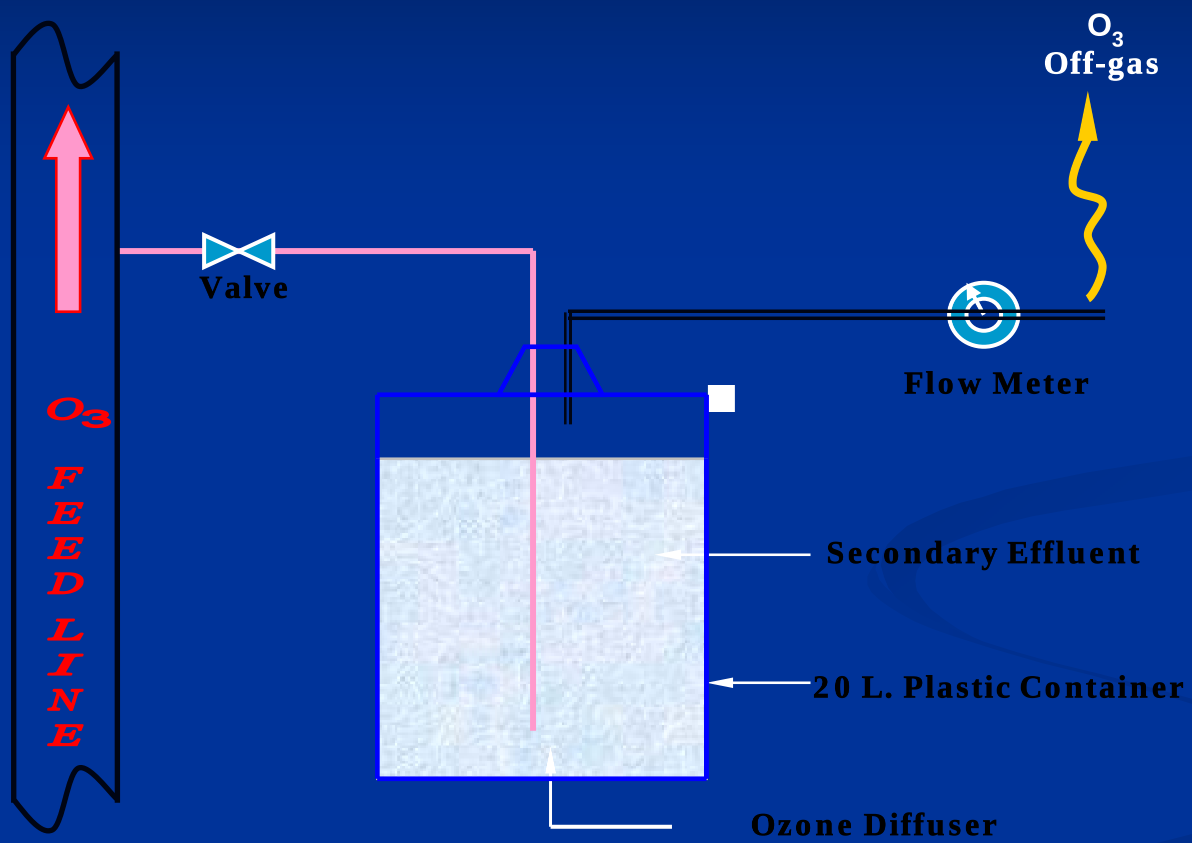
ii. Ozonation

i. **<u>Chlorination:</u>**

- **Efficient for bacteria inactivation.**
- **To achieve 99 % removal of *Strongyloides stercoralis*:**
  - **A CT of > 1500 mg.min/L is required for effective removal of *Ss*.**
  - **Chlorine dose must be ~ 30 mg/L**
  - **Contact time must be ~ 2 hours**
  - **For such a high chlorine residual, de-chlorination must be done.**

ii. Ozonation:

- **Batch and continuous setups were tested**

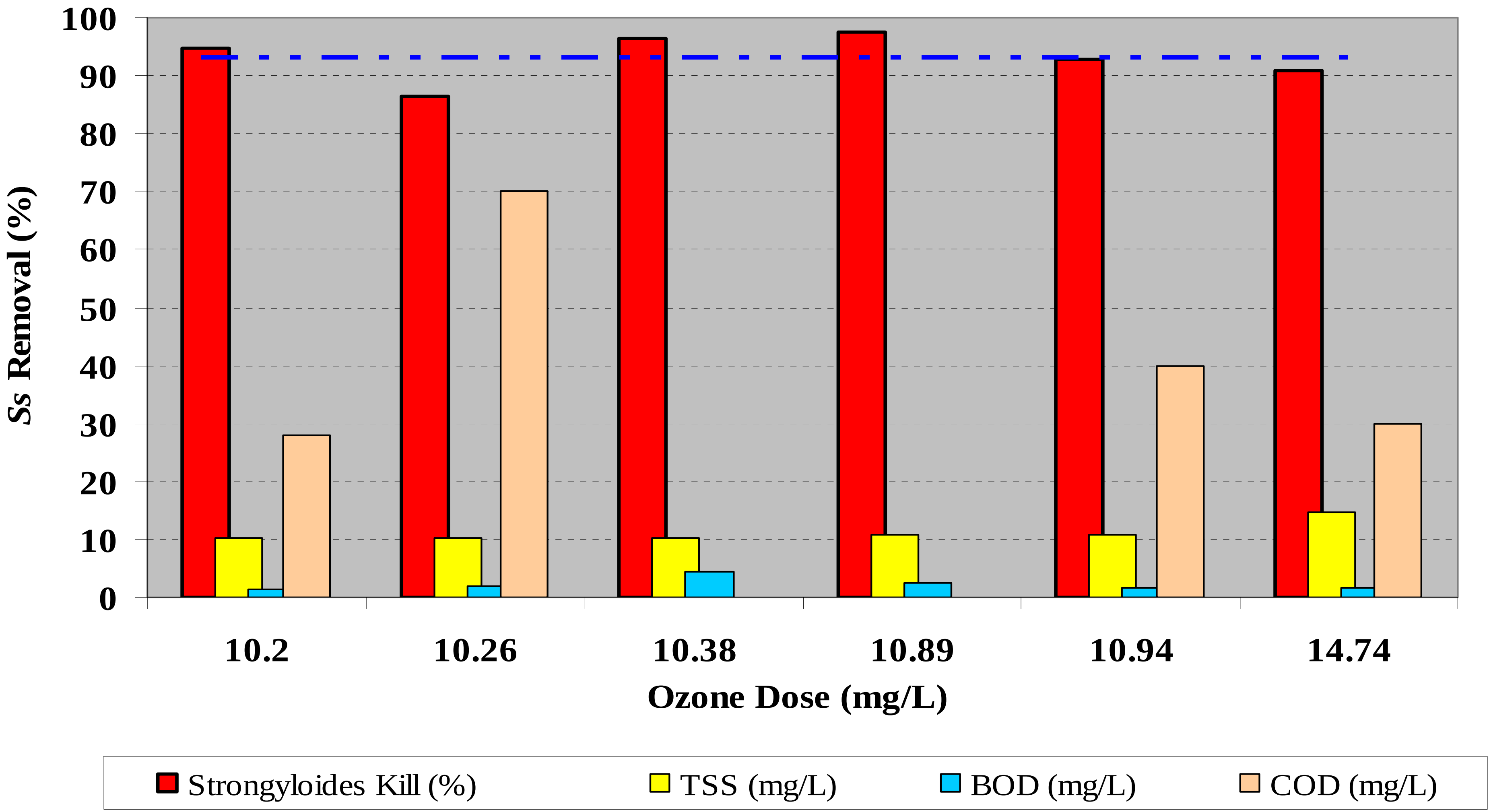


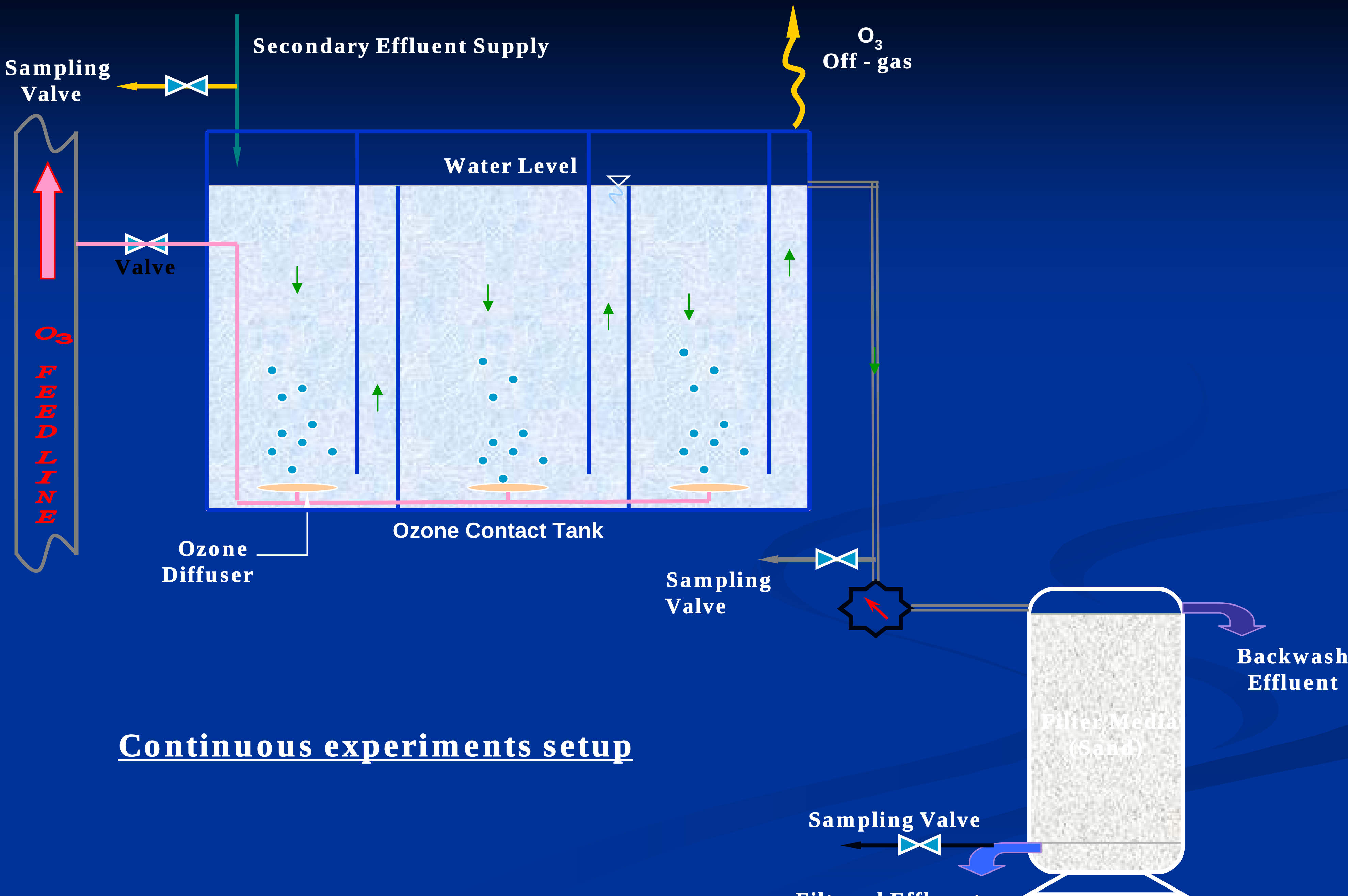
Batch experiments setup

Summary of Sample Characteristics and Ozone Efficiency – Batch Tests

Sample	TSS (mg/L)	BOD (mg/L)	COD (mg/L)	Ozone Dosage (mg/L)	Strongyloides Count	Strongyloides Kill (%)
1	11.6	1.4	28	10.2	75	94.7
2	16	2	70	10.26	95	86.3
3	9	4.5	~	10.38	111	96.4
4	6	2.6	~	10.89	85	97.6
5	32	1.8	40	10.94	82	92.7
6	19	1.8	30	14.74	87	90.8

Ozone Disinfection (Batch Tests)

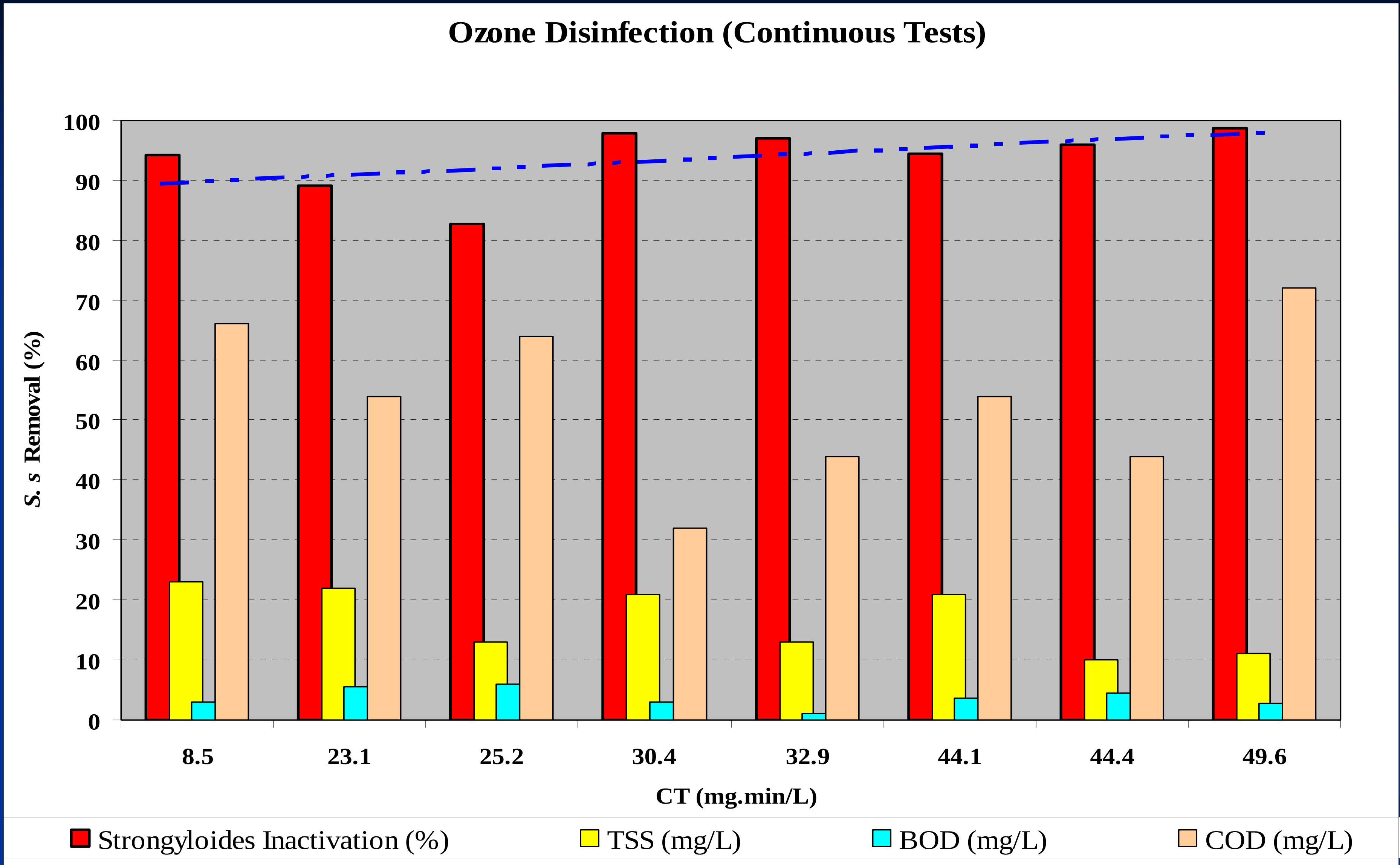




<u>Continuous experiments setup</u>

Summary of Sample Characteristics and Ozone Efficiency – Continuous Tests

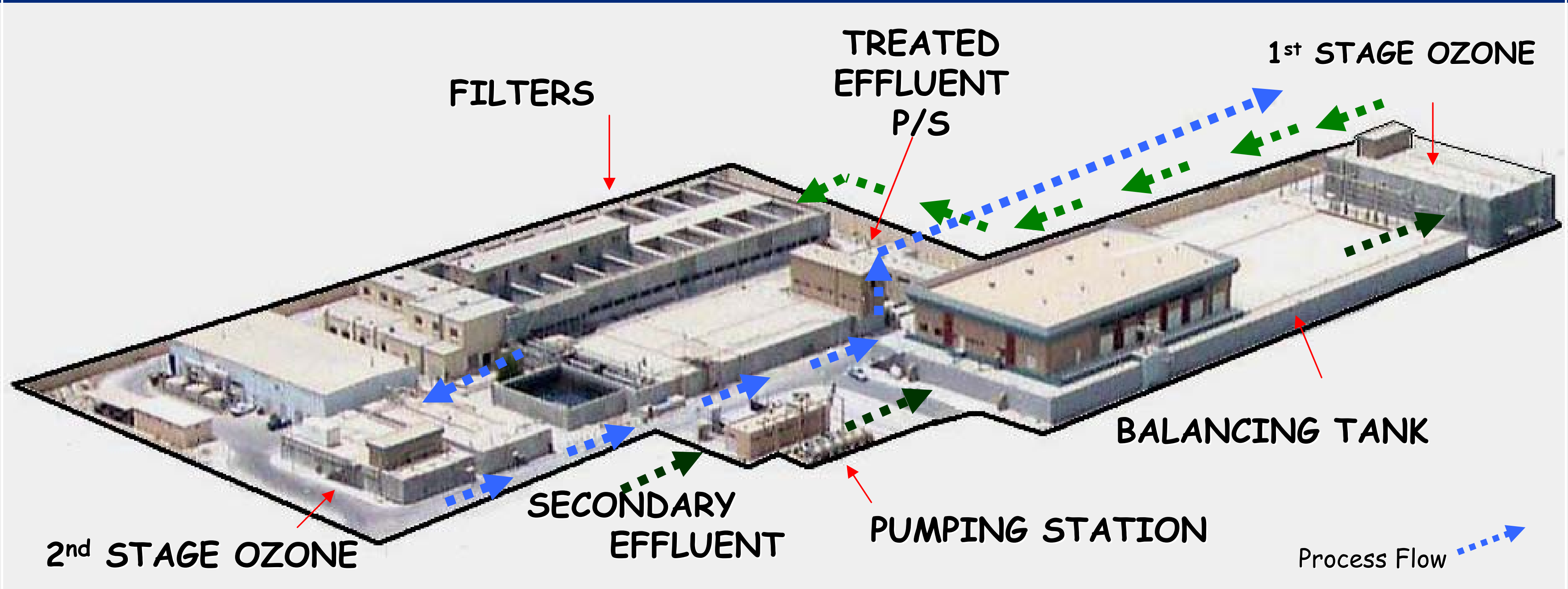
Test No.	Secondary Effluent Characteristics (mg/L)				CT (mg. min/L)	Strongyloides Count (Secondary Effluent)	Strongyloides Inactivation (%)
	TSS	NH_3	BOD	COD			
1	23	1.6	3	66	8.5	118	94.2
2	22	0.7	5.6	54	23.1	88	89.2
3	13	-	6	64	25.2	42	82.8
4	21	5	3	32	30.4	114	97.8
5	13	-	1	44	32.9	49	97.1
6	21	1.6	3.6	54	44.1	90	94.5
7	10	5.5	4.4	44	44.4	132	95.9
8	11	5.5	2.8	72	49.6	168	98.8


Ozone Disinfection (Continuous Tests)
100
90
80
70
60
50
40
30
20
10
0
S. s Removal (%)
8.5
23.1
25.2
30.4
32.9
44.1
44.4
49.6
CT (mg.min/L)
Strongyloides Inactivation (%)
TSS (mg/L)
BOD (mg/L)
COD (mg/L)

Results and conclusions of the ozonation tests:

- *Strongyloides stercoralis* removal of > 95% could be achieved using 10 mg/L of O_3
- Required contact time is around 30 minutes.
- The TSS should be < 10 mg/L to obtain the best results.
- O_3 could be applied before and after filtration. This will ensure high quality effluent.

Ozonation → Filtration → Ozonation



TERTIARY TREATMENT FLOW DIAGRAM

Major Effluent Quality Criteria (Actual):

Parameter	Unit	Allowable	Lab. Results	
			2004	2005
Ammonia	mg/L	3	1.2	0.2
Nitrate	mg/L	20	1.7	3.7
Phosphorus	mg/L	15	2.8	1.9
BOD	mg/L	10	1.0	0.7
Suspended Solid	mg/L	10	11.8	10.8
Fecal Coliform	1/100ml	2.2	2.2	0
Intestinal Nematodes	1/L	< 1	-	0.6

Reclaimed Water Production Cost

Cost of Secondary Treatment: 4 SR/m^3 (essential)

Cost of Tertiary Treatment: 2.5 SR/m^3

Cost of Transmission, pumping & Distribution: 2.5 SR/m^3

Total 5 SR/m^3

Potable Water approximate cost 30 SR/m^3

Thank You !