



# Risks Associated with Treated Wastewater in Greenhouse Cooling System

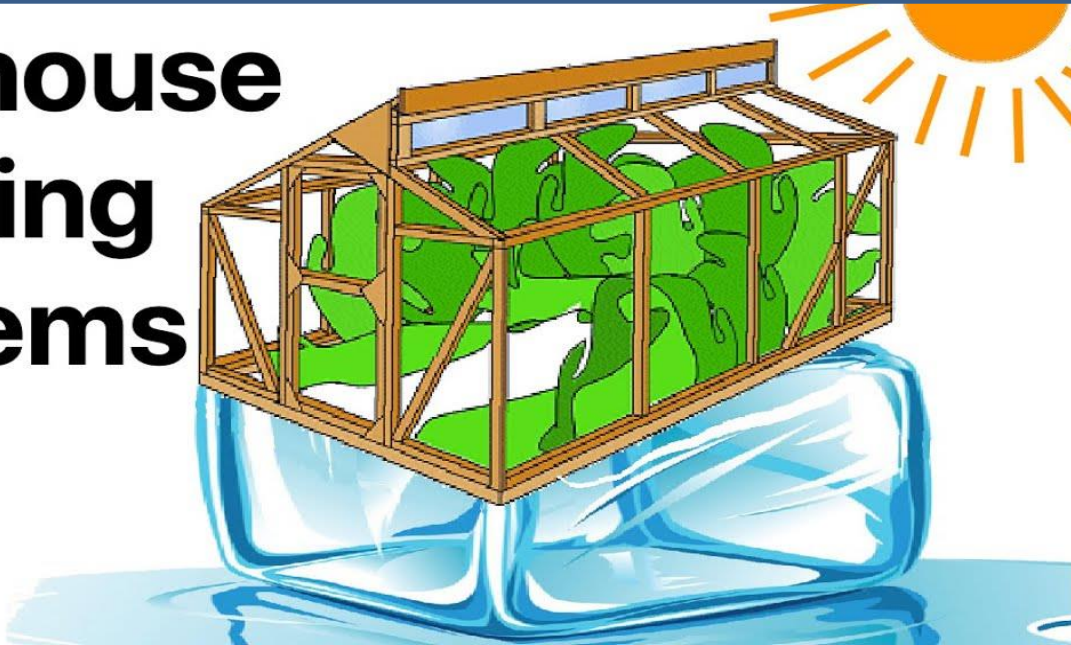


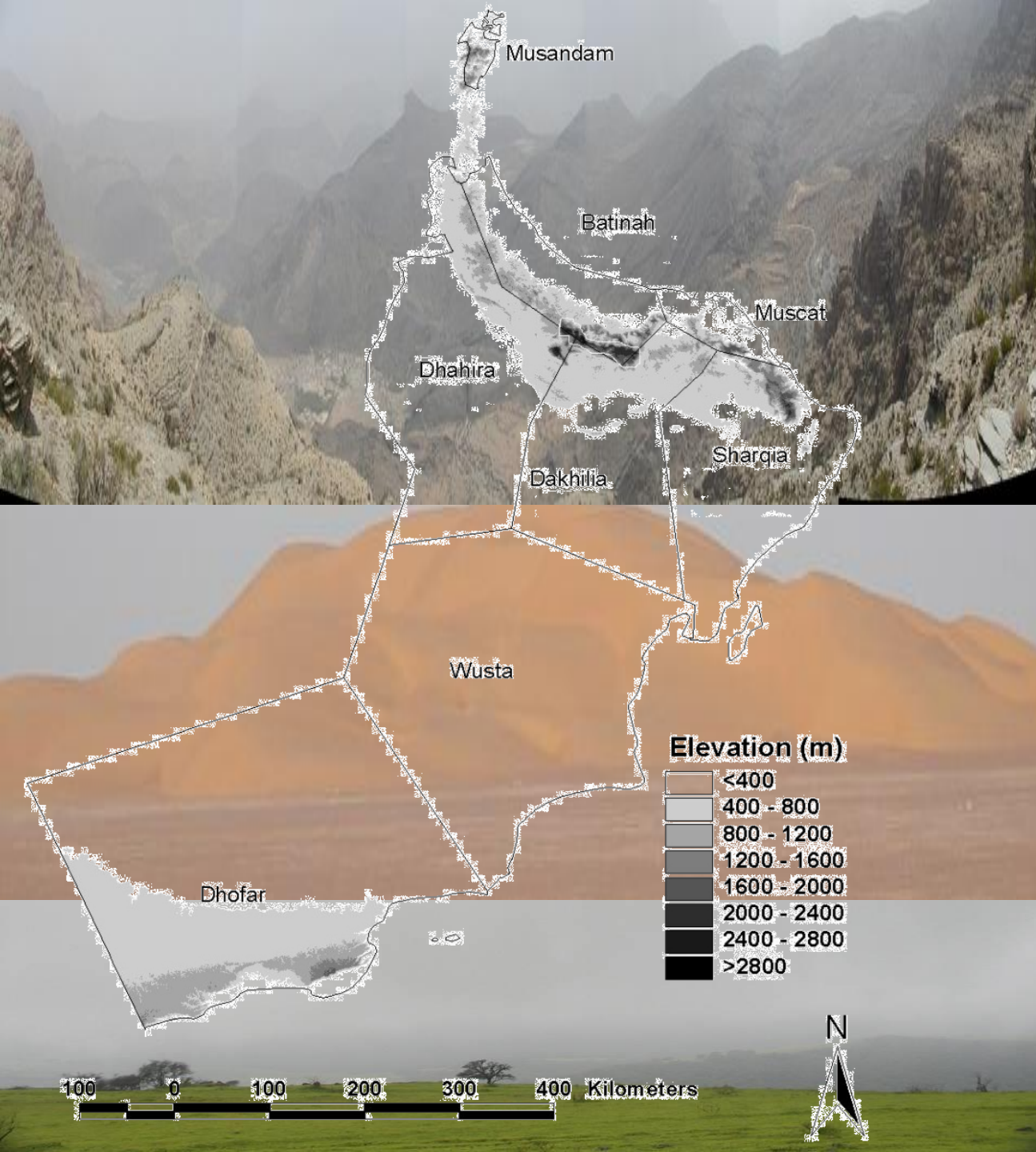
Dr. Ahmed Al-Busaidi

Researcher, Sultan Qaboos University

[ahmed99@squ.edu.om](mailto:ahmed99@squ.edu.om)

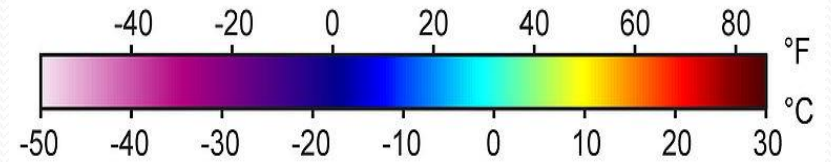
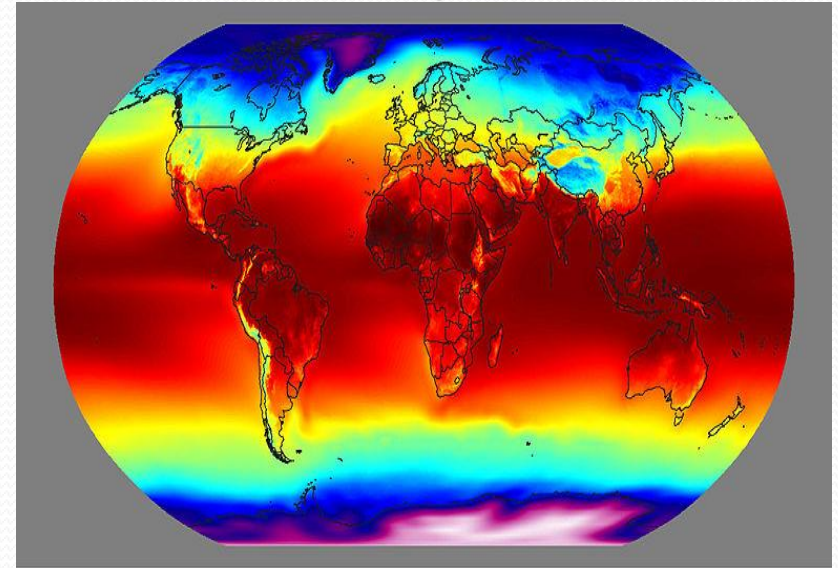
## Greenhouse Cooling Systems





# Hot Climate

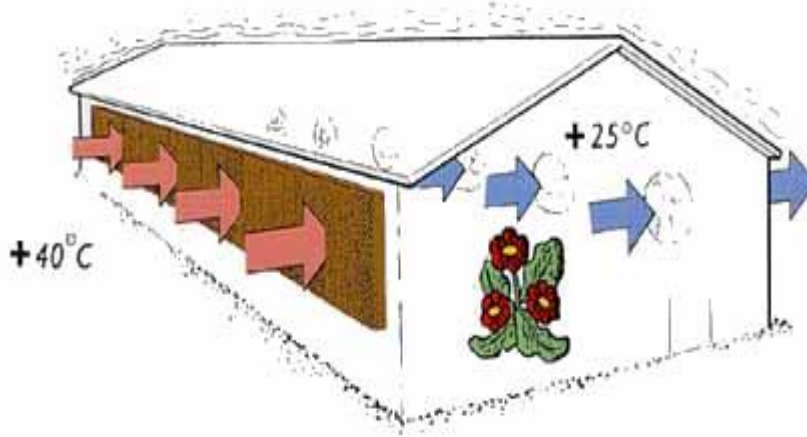
Area: 309,500 Km<sup>2</sup>



**Annual Mean Temperature**

- \* Arid Country with annual rainfall of 100 mm
- \* Annual Evaporation: 7,714 MCM
- \* Groundwater is the main source of water

# Greenhouses



Cooling Water  
**2-3 times higher**  
**than**  
Irrigation Water

- Improve the quality and quantity of crops through a controlled environment in greenhouses
- There is an increase of greenhouses number from (782) in 2001 to 2491 in 2008.
- Cooling system *consume significant quantities of water to maintain the greenhouse climate* (about 60% of water used for greenhouse).
- **Growing tomato inside the greenhouse consumed 62 L of water for cooling purposes, whereas, 15 L for irrigation water.**

استراتيجية استغلال المياه المعالجة خارج محافظة مسقط  
- إجمالي الإنتاج السنوي حسب الموسم

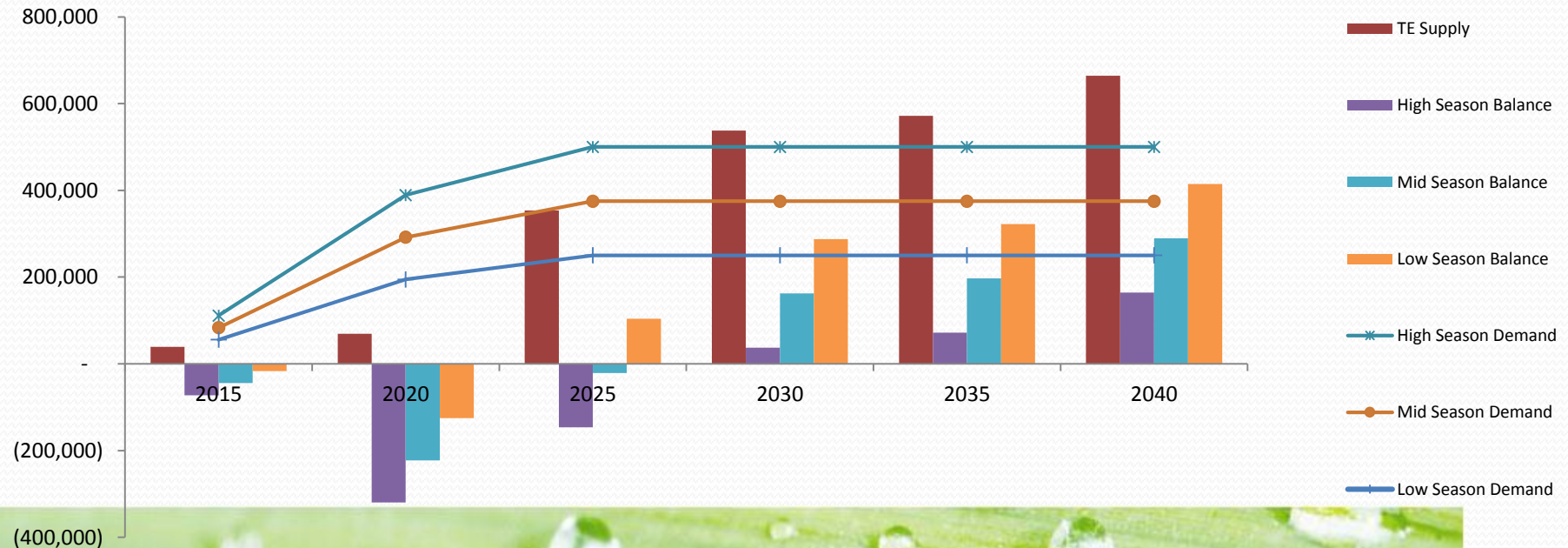
DID YOU KNOW?

You would have to flush your toilet around **six million** times to generate the same volume of wastewater that the city's two treatment plants receive every day.



## Treated Wastewater outside Muscat

العالم / الإنتاج اليومي (متر مكعب / اليوم)	2015	2020	2025	2030	2035	2040
<b>Total production</b> الإنتاج السنوي (m3/day)	<b>38,861</b>	<b>69,129</b>	<b>353,998</b>	<b>537,773</b>	<b>572,137</b>	<b>664,706</b>

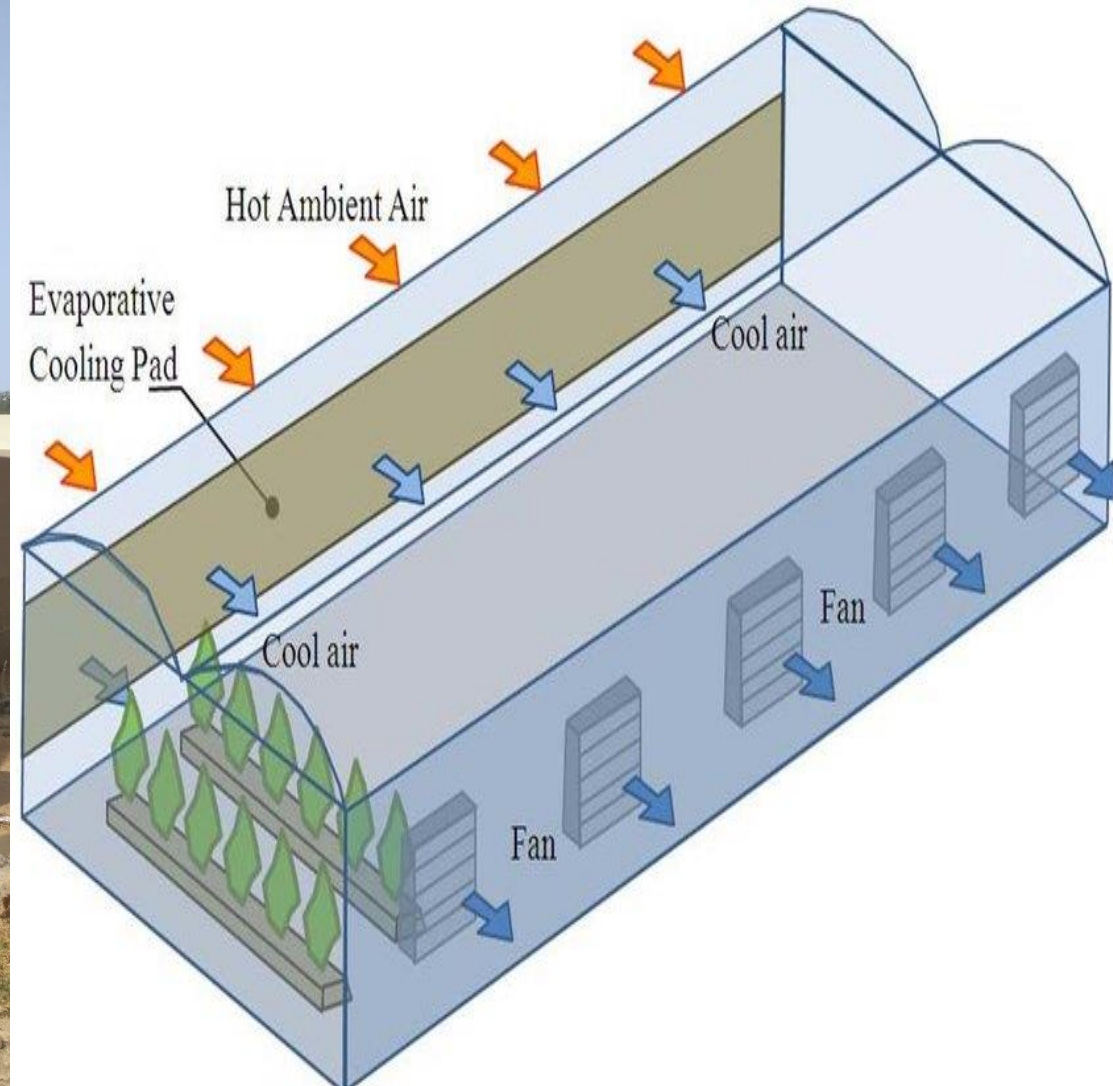


# TREATED WATER QUALITY

Parameter	Unit	Concession Agreement		** MD 145/93		*** MD 159/05
		* Group 1	Group 2	Std. A	Std. B	
Biochemical Oxygen Demand (BOD <sub>5</sub> )	mg/L	< 15	< 15	15	20	20
Chemical Oxygen Demand (COD)	mg/L	-	-	150	200	200
Total Suspended Solids (TSS)	mg/L	< 15	< 20	15	30	30
Total Kjeldahl Nitrogen (TKN)	mg/L	-	-	5	10	5
Ammonia Nitrogen (NH <sub>3</sub> -N)	mg/L	-	-	5	10	1
Total Nitrogen	mg/L	< 15	< 40	-	-	15
Nitrate (as NO <sub>3</sub> )	mg/L	-	-	50	50	15
Total Phosphorus (TP)	mg/L	< 30	< 30	30	30	2
Oil & Grease (O&G)	mg/L	< 5	< 5	0.5	0.5	15
pH		-	-	6 ~ 9	6 ~ 9	6 ~ 9
Fecal Coliform	MPN/100 mL	< 200	< 200	200	1,000	10,000
Nematode Ova	Ova / L	< 1	< 1	< 1	< 1	< 1

# Objectives

- Evaluate the possibility of using treated wastewater in greenhouse cooling system.
- Asses any potential risk to the environment that could affect human health and crop quality.



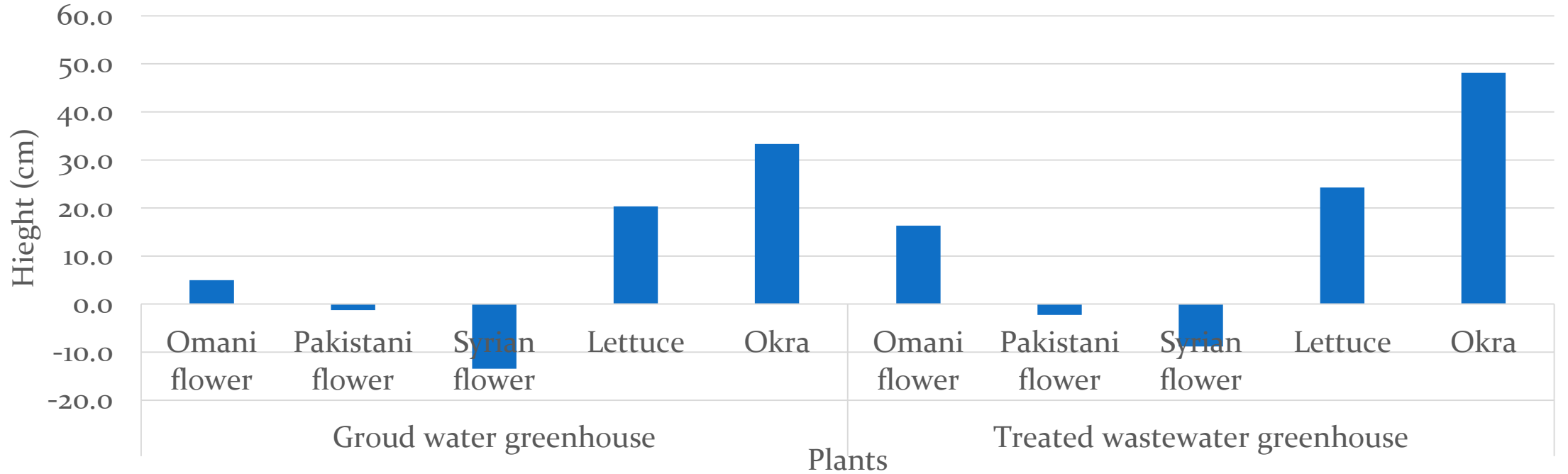
# Materials and Methods

# Cooling Greenhouse with Treated Wastewater



# Plant growth

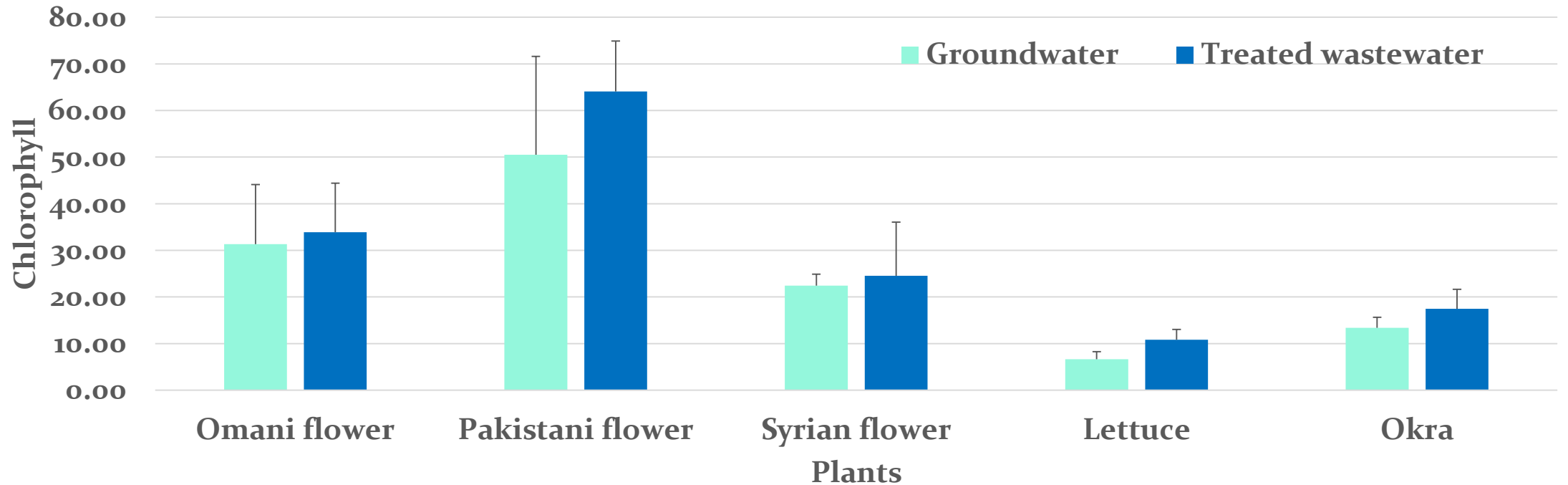
The average increase and decrease in plants heights in GW and TWW



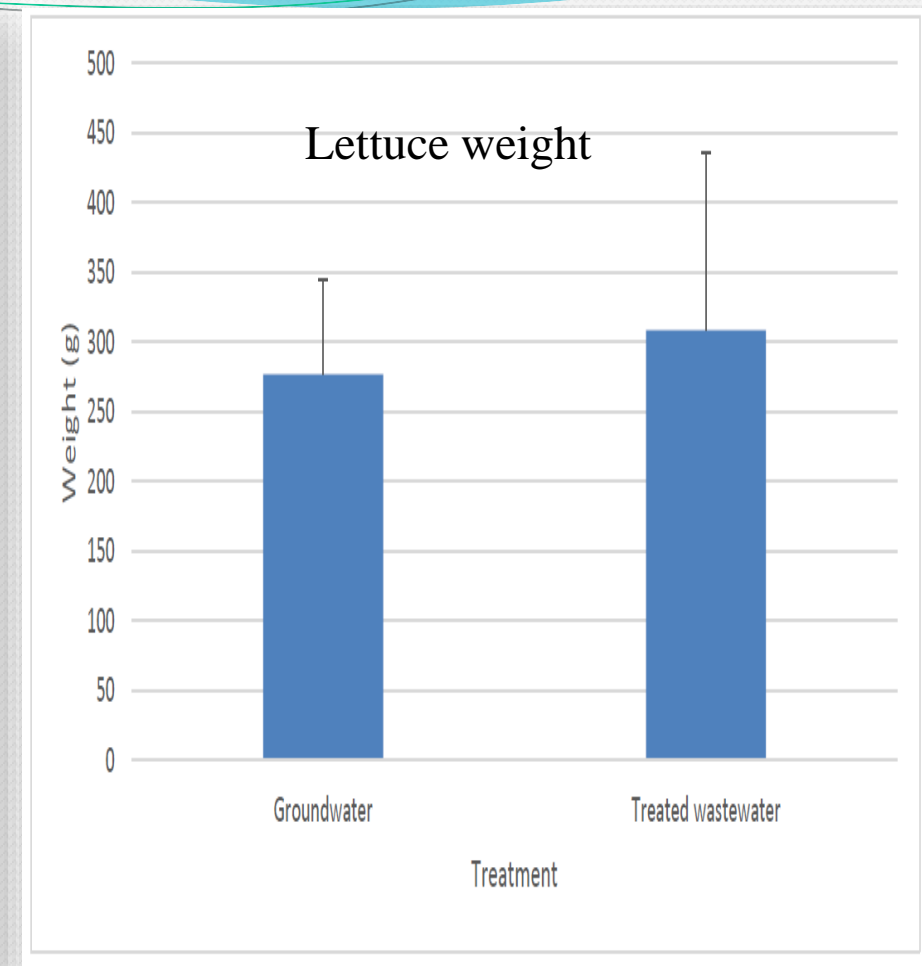
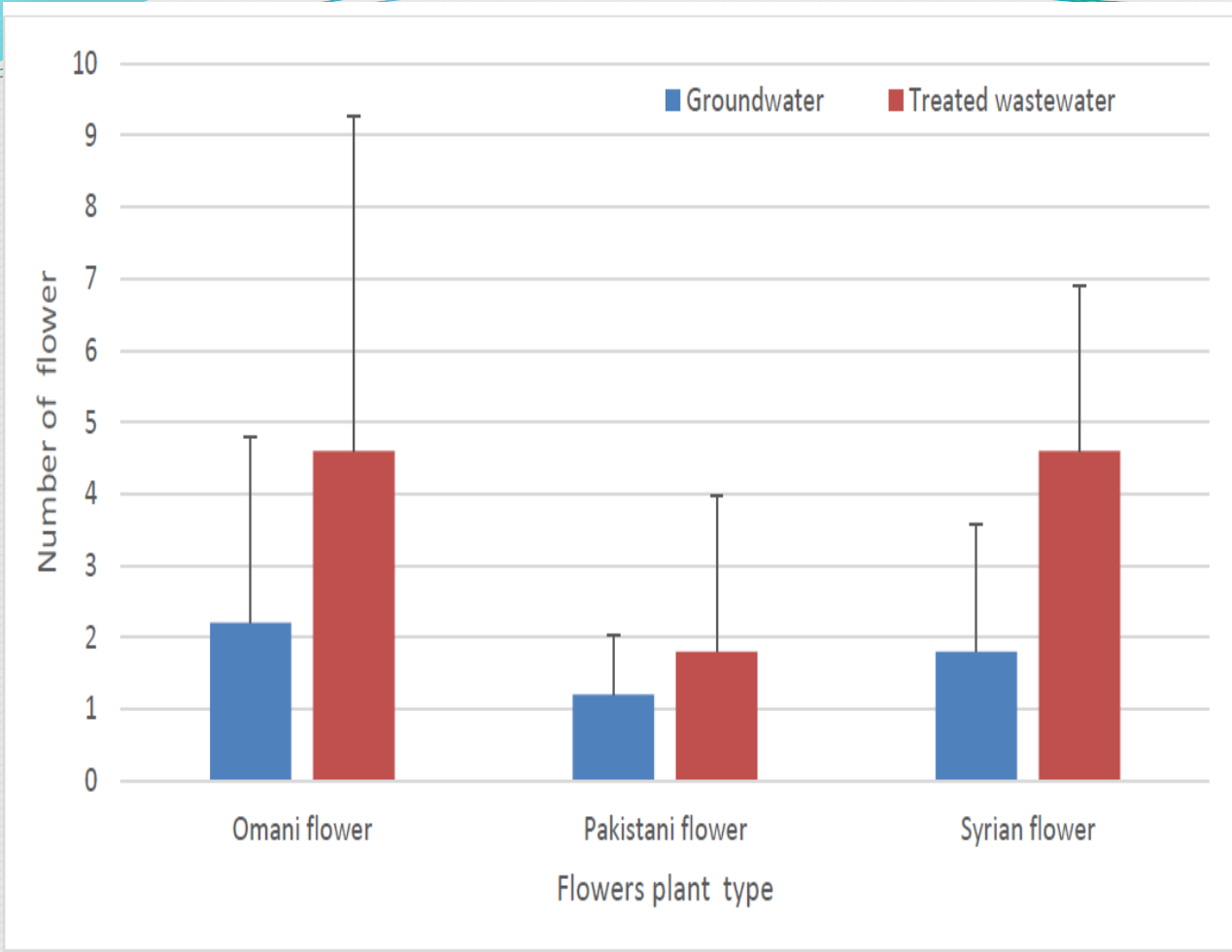


# Plant chlorophyll

Plants chlorophyll (average chlorophyll and standard error of mean) in GW and TWW



# Plant weight



Treated wastewater is rich of different elements. Therefore, it was expected to have better growth of different flowers under treated wastewater irrigation compared to groundwater and Same observation was noticed with lettuce growth.

# Biofouling (Algae growth)



At the beginning



At the middle



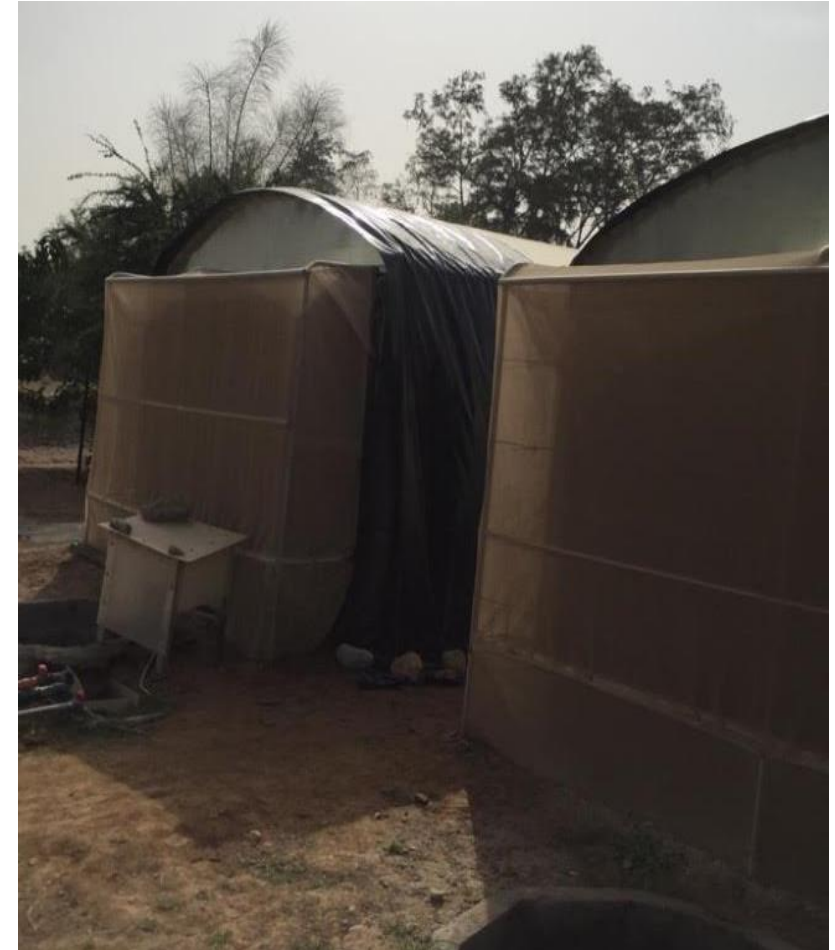
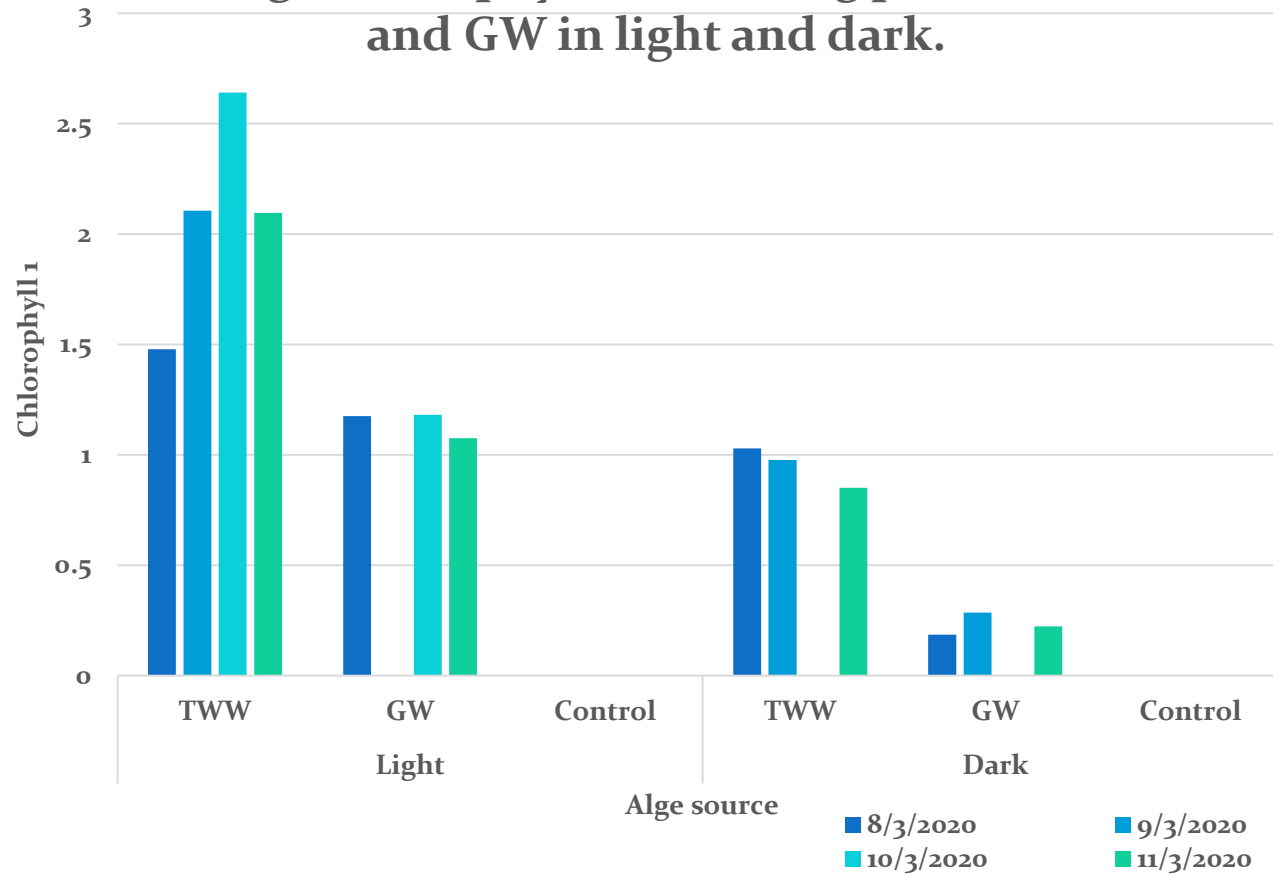
At the end

- Negative impacts on cooling system:
  - Blocks the cooling pads.
  - Reduce the efficiency of the cooling system.
  - Reduce the lifetime of cardboard.



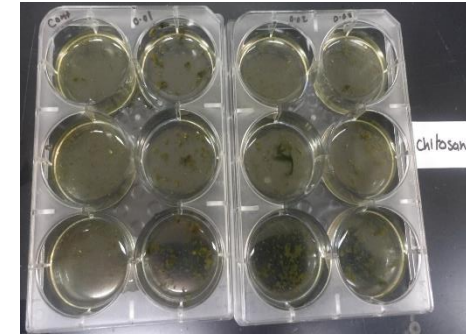
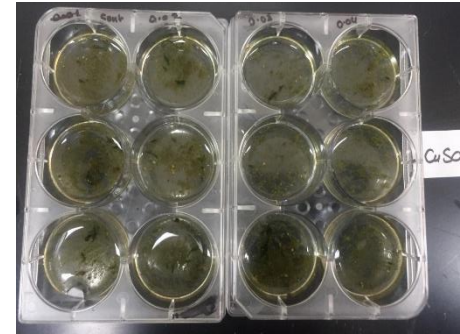
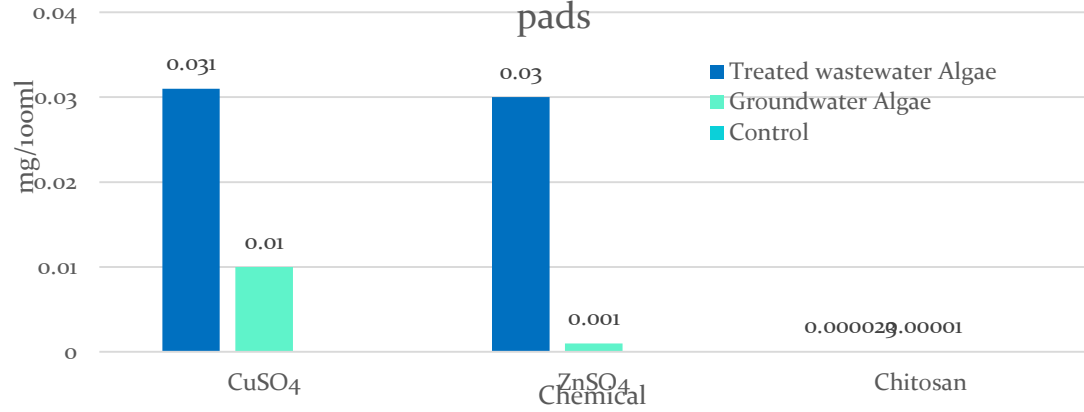
# Antifouling (Dark and light test)

Average chlorophyll a of cooling pads in TWW and GW in light and dark.

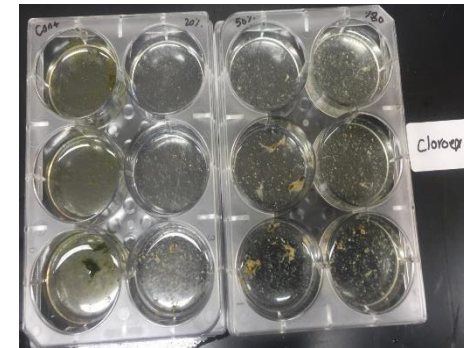
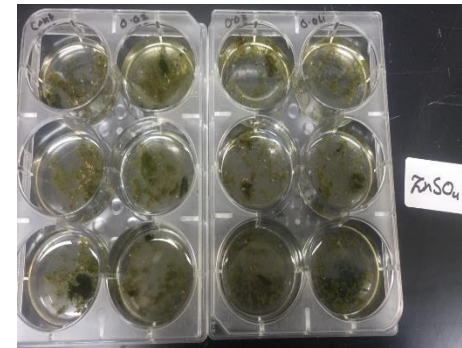
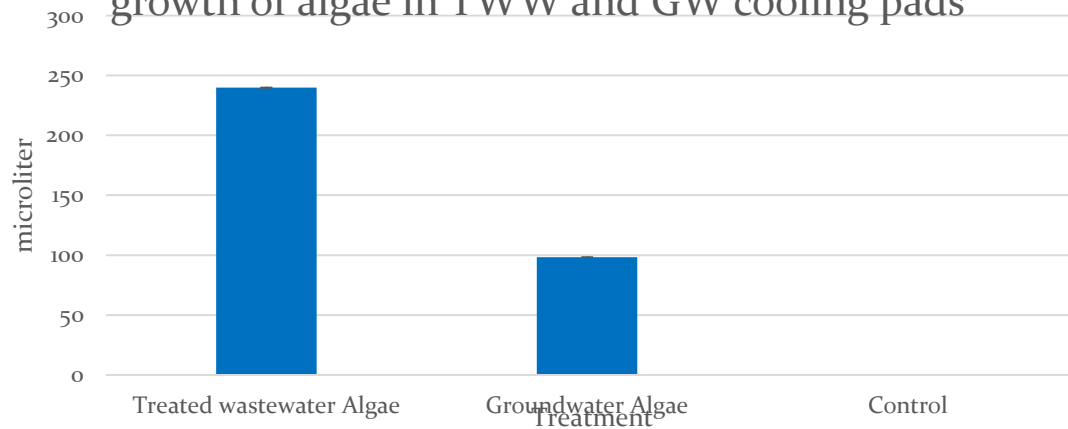


# Antifouling (chemical test)

Lethal concentration (LC 50) of  $\text{CuSO}_4$ ,  $\text{ZnSO}_4$  and Chitosan in growth of algae in TWW and GW cooling pads



Lethal concentration (LC 50) of Clorox in growth of algae in TWW and GW cooling pads



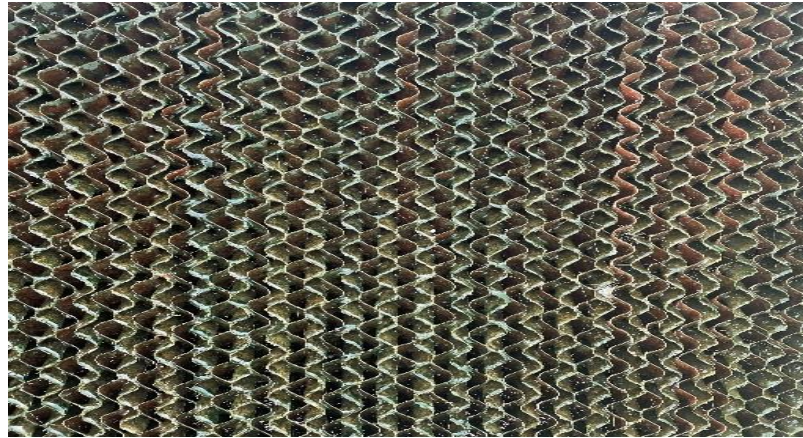
Before

# *Cleaning Effect*

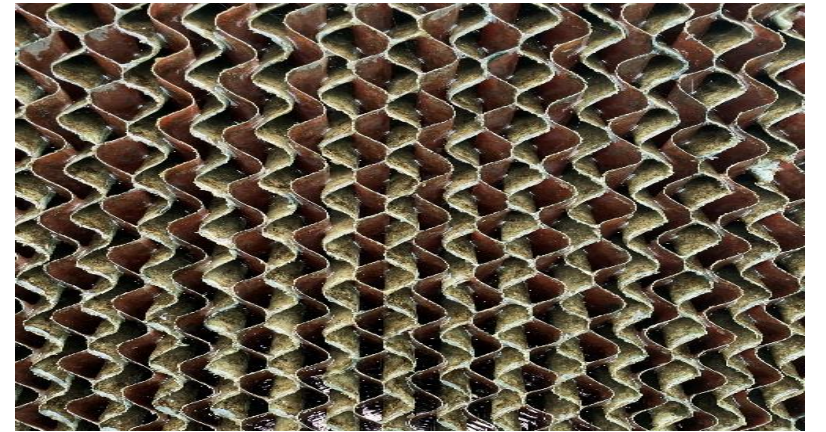
After



TWW



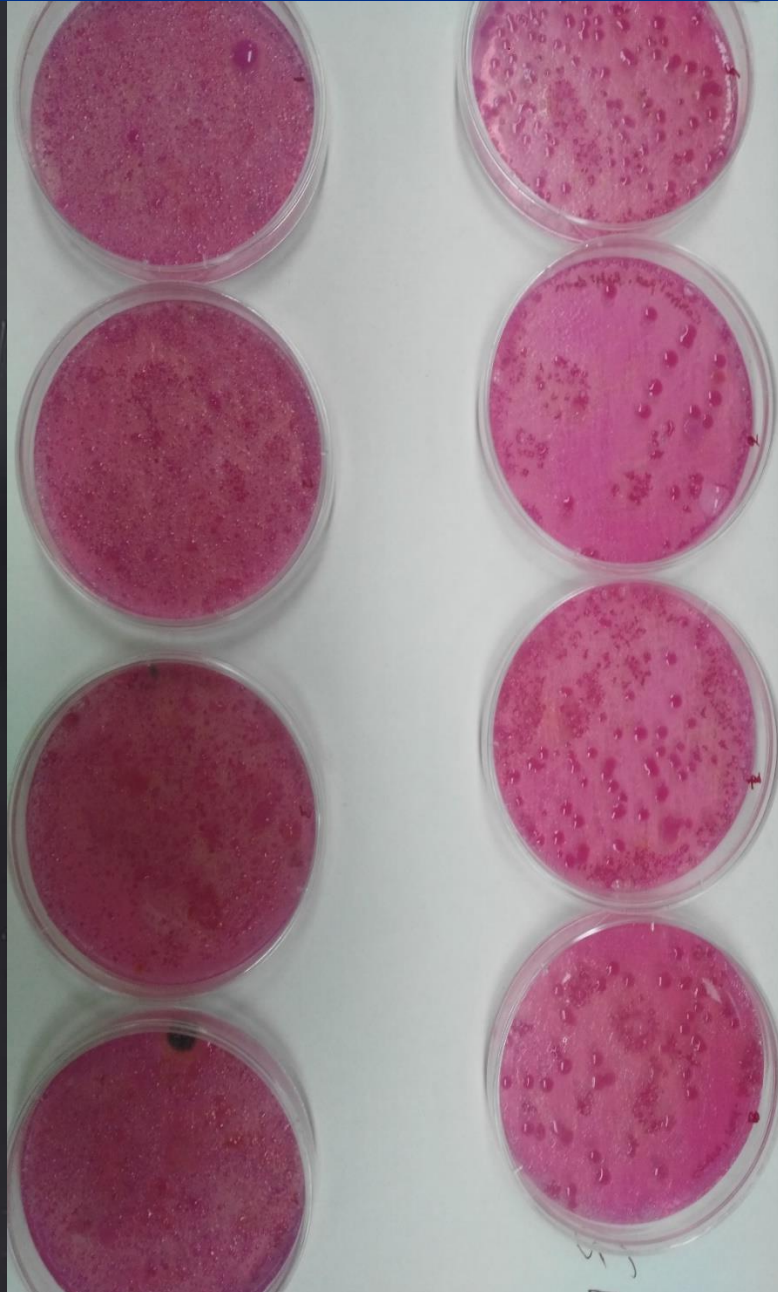
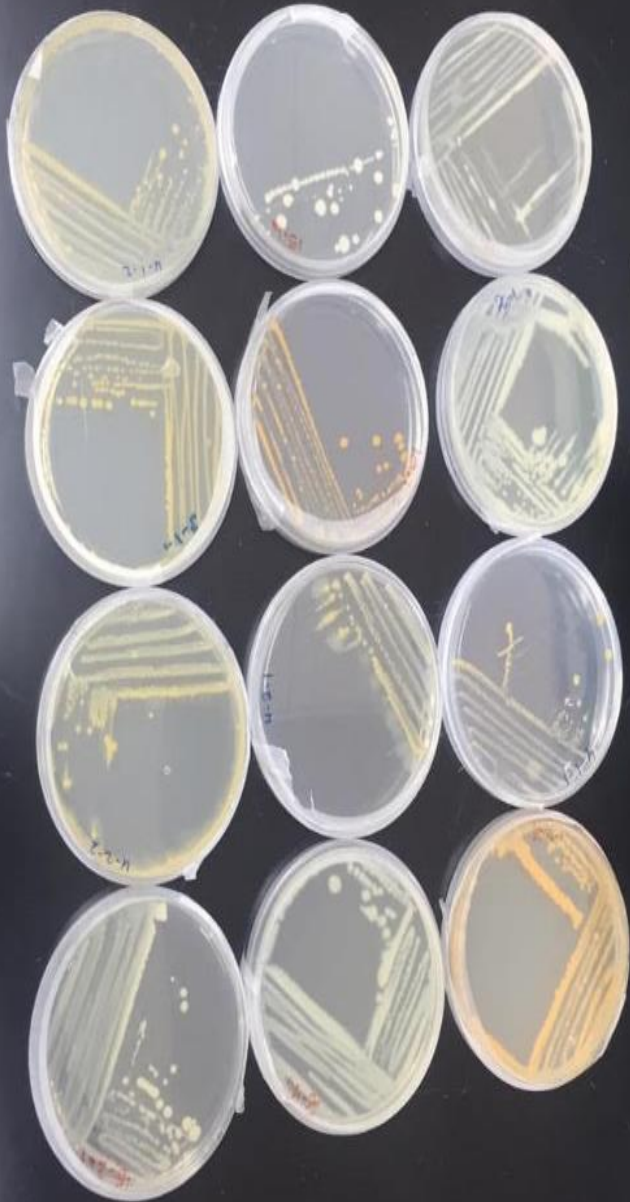
GW



Plastic



# Identification of bacteria in water and air

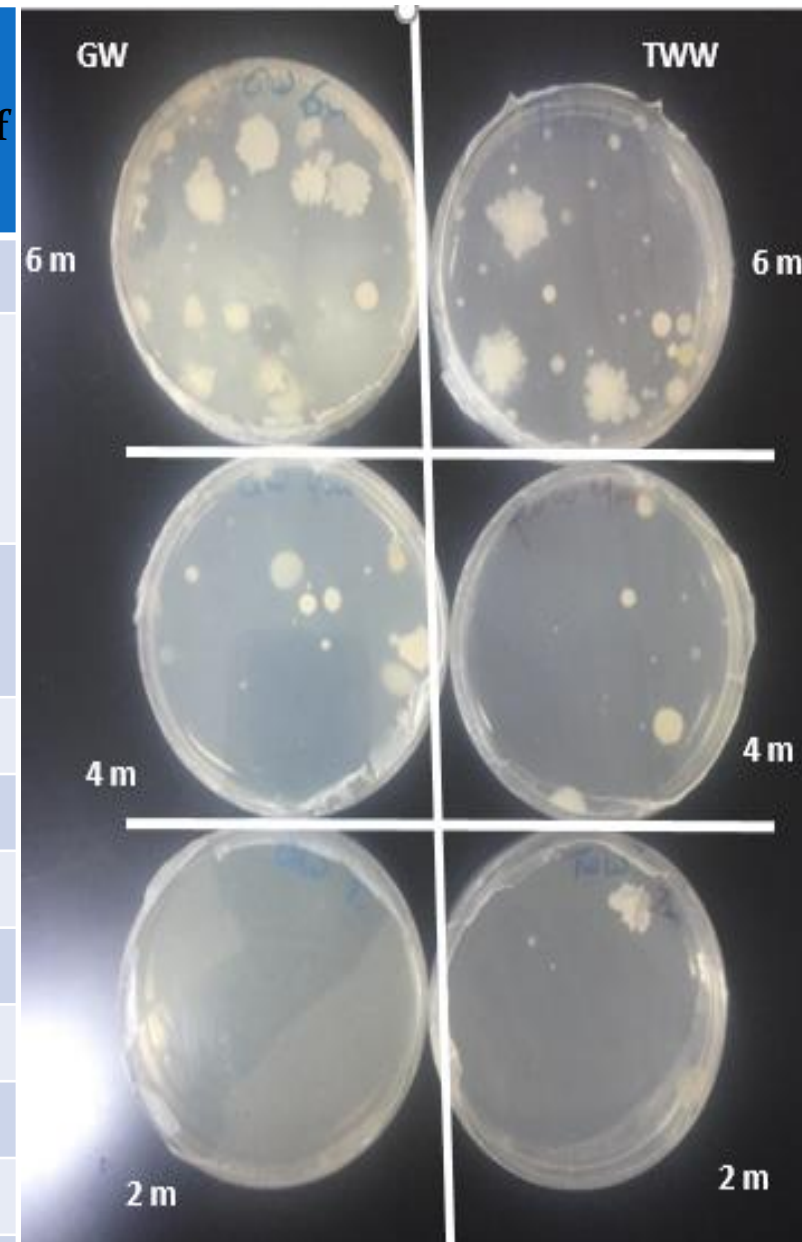


# Bacteria in water and air

## Bacteria in water

Name of bacteria	Treated wastewater	Cooling system of treated wastewater	Cooling system of groundwater
<i>Pseudomonas mendocina</i>	+	+	
<i>Stenotrophomonas maltophilia</i> ( <i>Pseudomonas beteli</i> #)	+		
<i>Microbacterium liquefaciens</i>	+		
<i>Pseudomonas stutzeri</i>	+		+
<i>Aeromonas hydrophila</i>		+	
<i>Bacillus infantis</i>		+	
<i>Aeromonas jandaei</i>		+	
<i>Enterobacter asburiae</i>		+	
<i>Enterobacter kobei</i>		+	
<i>Enterobacter ludwigii</i>		+	

## Bacteria in air

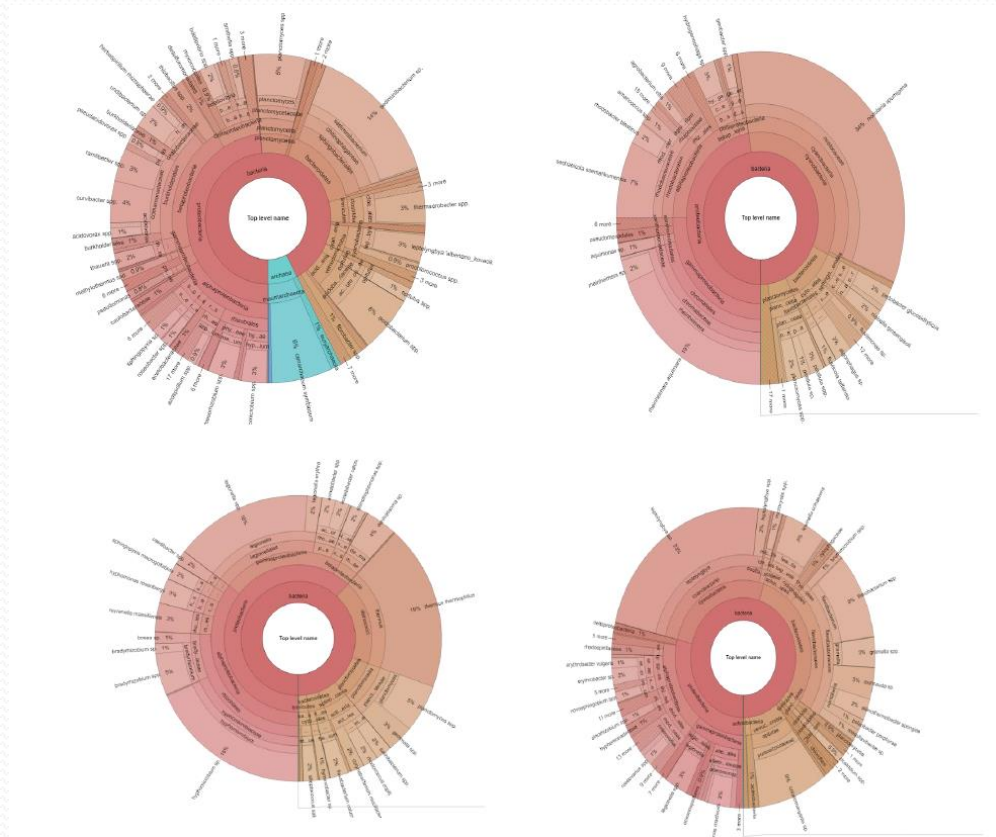




# Deep Investigation in the Impact of Using Treated Wastewater in Greenhouse Cooling System

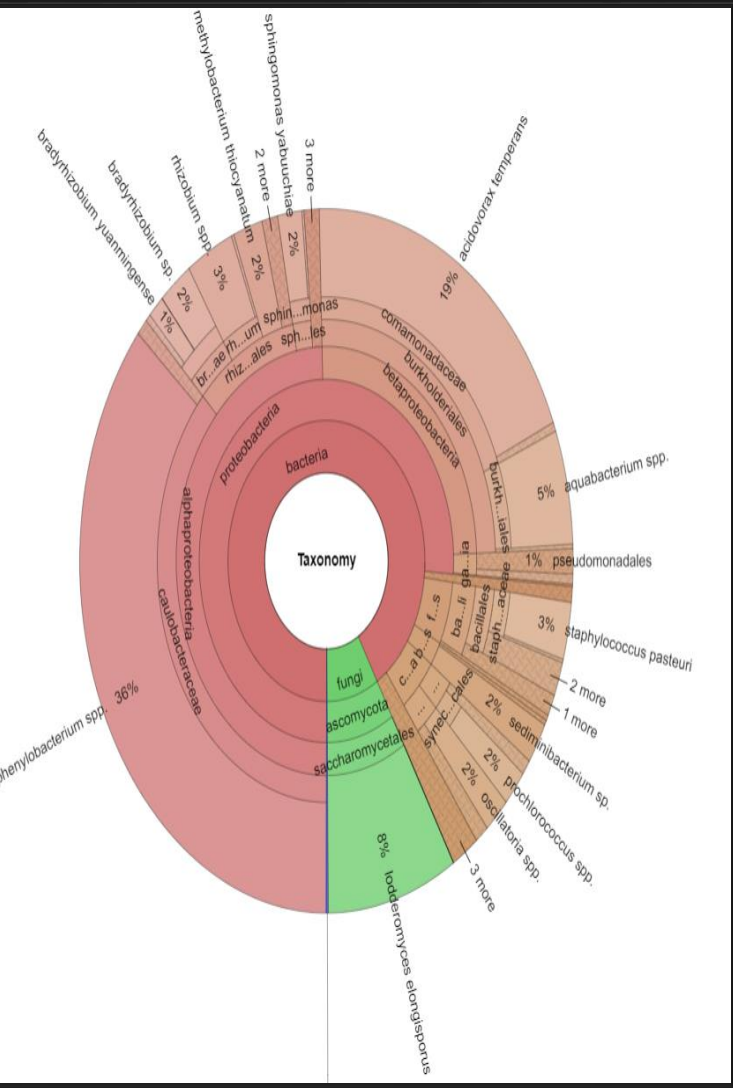
Pathogenic bacteria found in all collected samples

Pathogen	Health significant	Treated water Pads	Ground water Pads	Treated water	Ground water
<i>Burkholderia pseudomallei</i>	High	present	present	present	present
<i>Campylobacter jejuni, C. coli</i>	Low	Absent	Absent	Absent	Absent
<i>Francisella</i>	-	absent	absent	absent	absent
<i>Legionella</i>	High	present	present	present	present
Mycobacteria (non-tuberculous)	-	absent	absent	absent	absent
<i>Salmonella typhi</i>	-	Absent	Absent	Absent	absent
<i>Shigella</i>	-	Absent	Absent	Absent	Absent
<i>Vibrio</i>	High	present	present	present	present

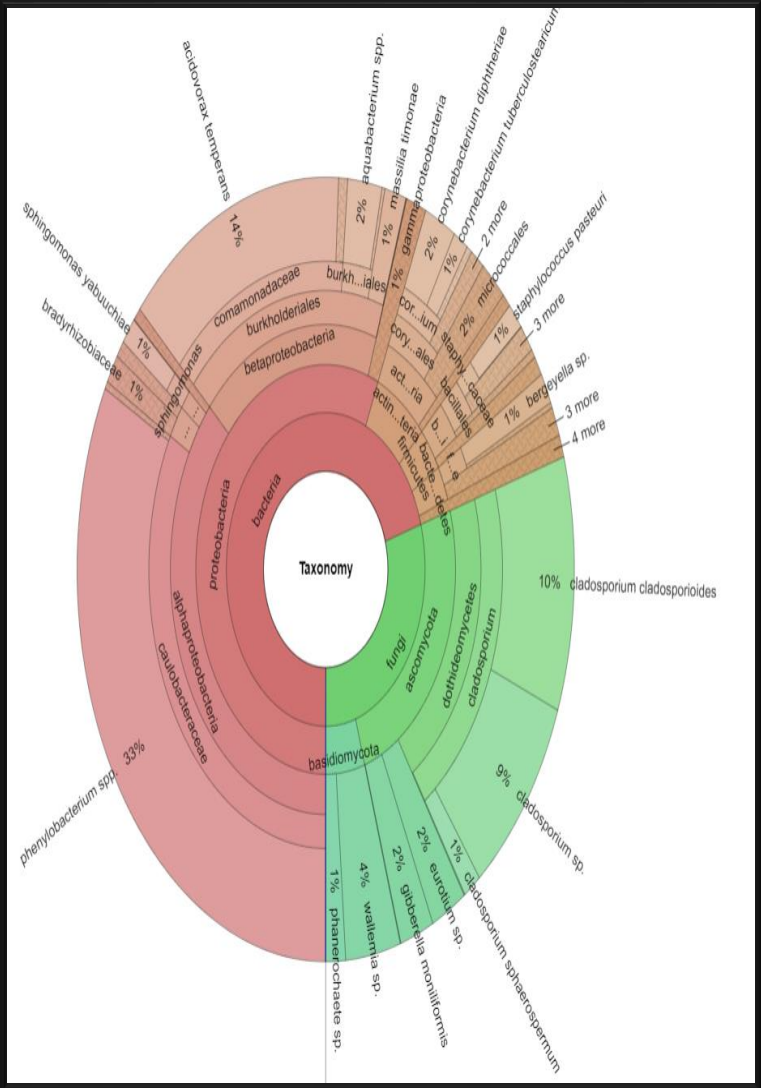


community of pathogenic bacteria in treated wastewater (top) and groundwater (bottom) samples and cooling pads

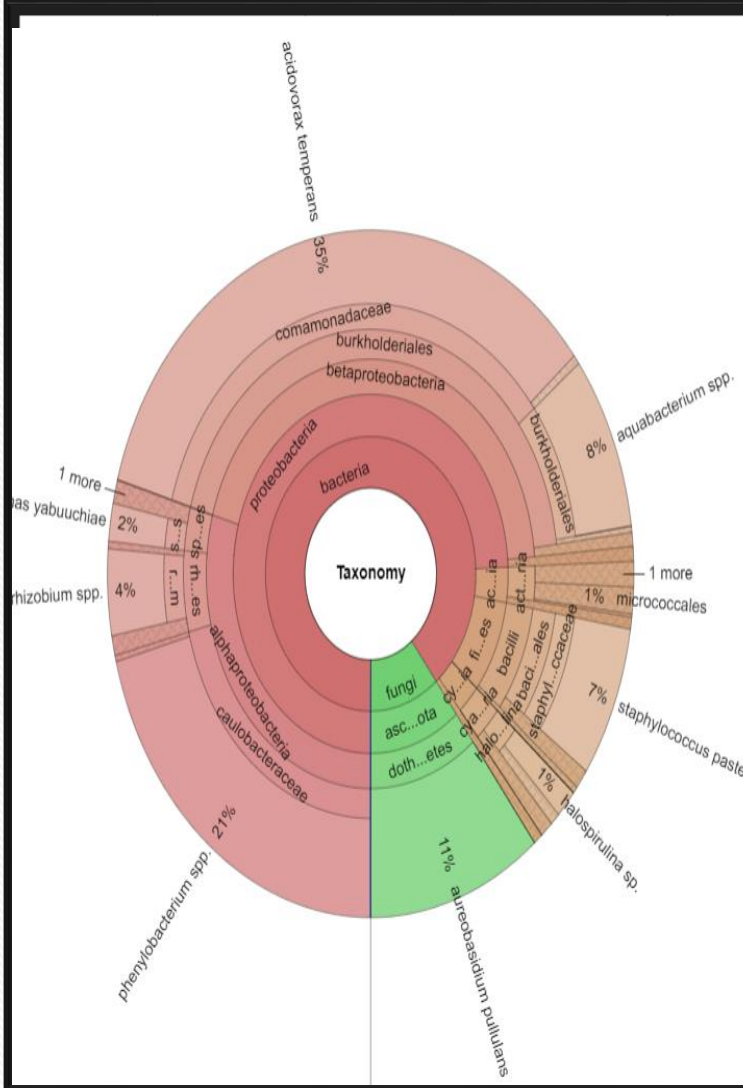
Data of the DNA samples were analyzed using **Krona program** to create a special Pie chart



**Cardboard-UGW**



**Cardboard-TWW**



**Plastic - TWW**

Bacterial species	Type of ECP	Pathogenecity
<b><i>Bacillus subtilis</i></b>	Cardboard-TWW , Plastic - TWW	ubiquitous , nonpathogenic
<b><i>Bacillus infantis</i></b>	Cardboard-TWW	<ul style="list-style-type: none"> <li>- isolates in a case of sepsis in a newborn child</li> <li>- not reported to be linked with human diseases</li> </ul>
<b><i>Bacillus megaterium</i></b>	Plastic - TWW	nonpathogenic and a useful vector in biotechnology since they carry multiple plasmids
<b><i>Pseudomonas oryzihabitans</i> *</b>	Cardboard-TWW, Cardboard-UGW	<ul style="list-style-type: none"> <li>- rare pathogenic to human</li> <li>- associated with indwelling catheters or prostheses</li> </ul>
<b><i>Pseudomonas luteola</i></b>		<ul style="list-style-type: none"> <li>- infrequently detached from pus, wounds, peritonitis and first isolated from blood of septicemia</li> <li>- immune-disorder patients *</li> </ul>
<b><i>Pseudomonas stutzeri</i></b>	Cardboard-UGW	<ul style="list-style-type: none"> <li>- opportunistic pathogen</li> <li>- infection to immunocompromised / serious diseases</li> <li>- highly resistance to different antibiotics</li> </ul>

**Therefore,** our recommendations are :

- **Further studies are needed to confirm how pathogenic they are through :**
  - Amplification of the related genes ( PCR)
  - Screening of those bacteria by staining and subculture.
  - Screening in different seasons, geographic area contamination
- **Public Health Centre and The Ministry of Municipality must be informed.**

# TWW Products



TWW Products



TWW Products



*Water quality*  
*Fruit quality*  
*Public acceptance*





*Public Trust*  
*Selling Treated Wastewater products in*  
*Fruits and Vegetable Market*





# Project Partners



Ministry of Health  
Sultanate of Oman

Diwan of Royal Court  
Million Date Palm Plantation Project



ديوان البلاط السلطاني  
المديرية العامة لمشروع زراعة المليون نخلة

Thank You

