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Treated Wastewater Application in Urban Agriculture

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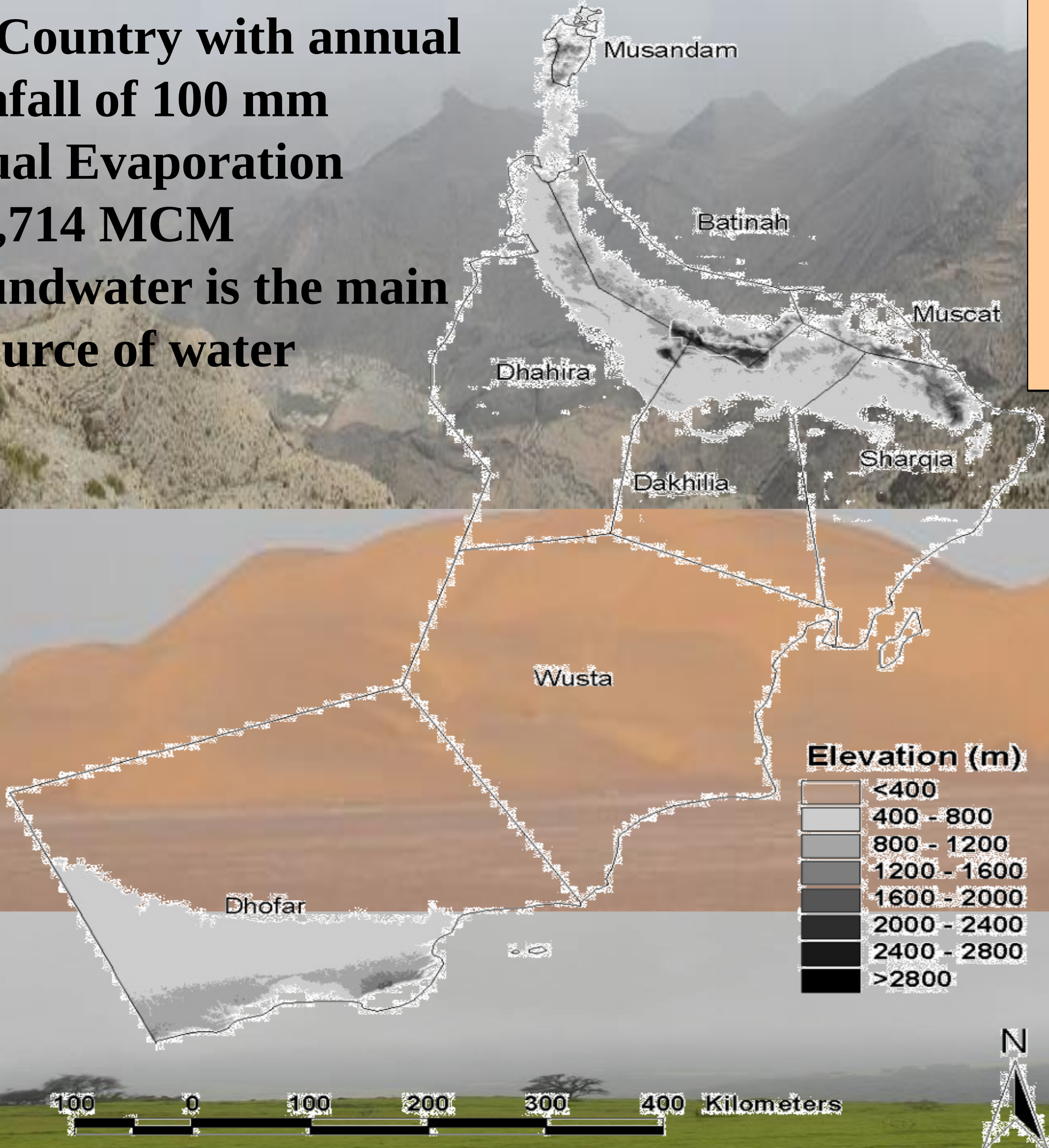
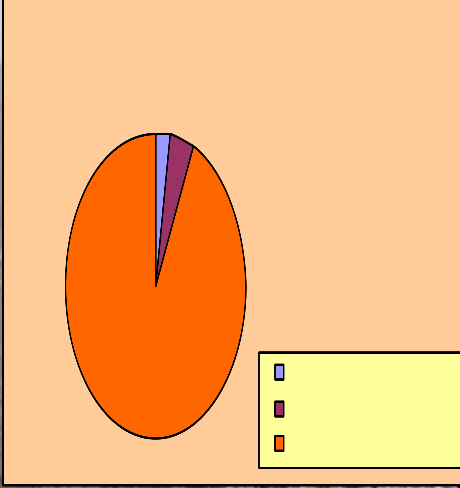
*Arid Country with annual rainfall of 100 mm

* Annual Evaporation 7,714 MCM

* Groundwater is the main source of water

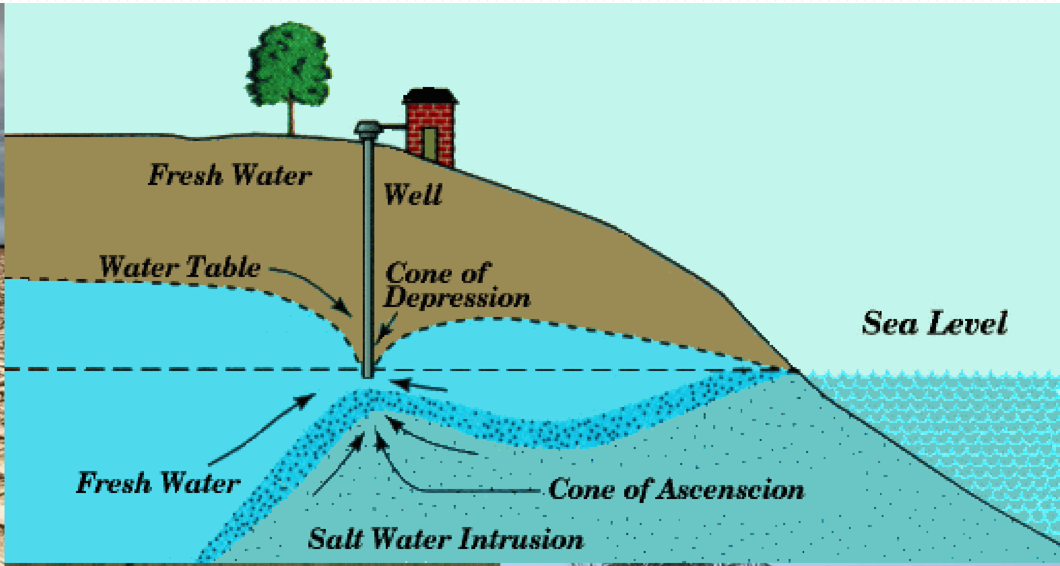




Challenges التحديات

1) **Water Shortage نقص المياه**

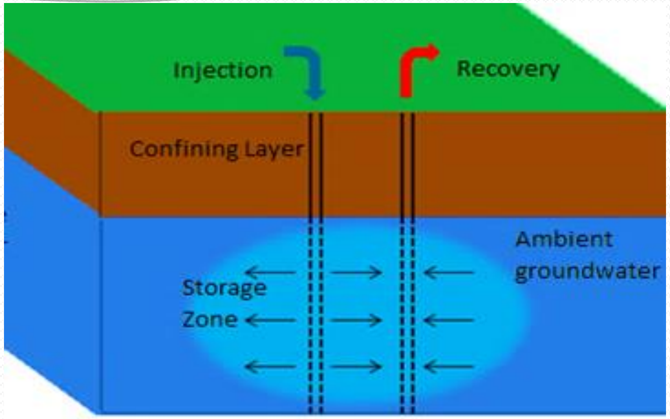
2) **Sea Water Intrusion (Salinity Problem) ملوحة التربه**



Wastes Management
3R Approach

Research Challenge: Treated Wastewater

- Running cost and disposal
- Seasonal fluctuations in production
- MAR for storage and recovery
- **Irrigation and Health Risks**



Emerging Contaminants

- Pathogens
- Heavy metals
- Nitrates
- Salts
- Emerging contaminants

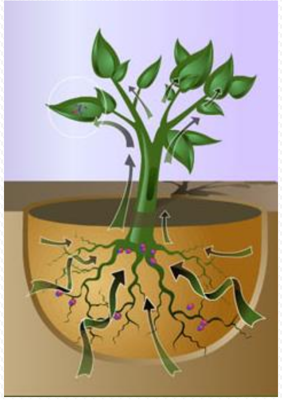
Potential risk ?

Micropollutants in treated wastewater


Sewage Treatment Plant (STP)

SAFE?


Human exposure

Plant uptake

Inorganics Standards for Wastewater Reuse (mg/l)

PARAMETER	STANDARDS	
	Class A	Class B
Aluminum (as Al)	5	5
Arsenic (as As)	0.100	0.100
Barium (as Ba)	1	2
Beryllium (as Be)	0.100	0.300
Boron (as B)	0.500	1
Cadmium (as Cd)	0.01	0.010
Chloride (as Cl)	650	650
Chromium (total as Cr)	0.050	0.050
Cobalt (as Co)	0.050	0.050
Copper (as Cu)	0.500	1
Cyanide (total as CN)	0.050	0.100
Fluoride (as F)	1	2
Iron (total as Fe)	1	5
Lead (as Pb)	0.100	0.200
Lithium (as Li)	0.070	0.070
Magnesium (as Mg)	150	150
Manganese (as Mn)	0.100	0.500
Mercury (as Hg)	.001	0.001
Molybdenum	0.010	0.050
Nickel (as Ni)	0.100	0.100
Ammonical (as N)	5	10
Nitrate (as NO_3)	50	50
Phenol (total)	0.001	0.002
Phosphorus (total P)	30	30
Selenium (as Se)	0.020	0.020
Silver (as Ag)	0.010	0.010
Sodium (as Na)	200	300
Sulphate (as SO_4)	400	400
Sulphide (total as S)	0.100	0.100
Vanadium (as V)	0.100	0.100
Zinc (as Zn)	5	5

Limitations:

Contains some Heavy Metals

↓

Monitoring is Required

Circular Approach for Treated Wastewater Application in Modern Agriculture

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Hydroponics system

Aquaculture system

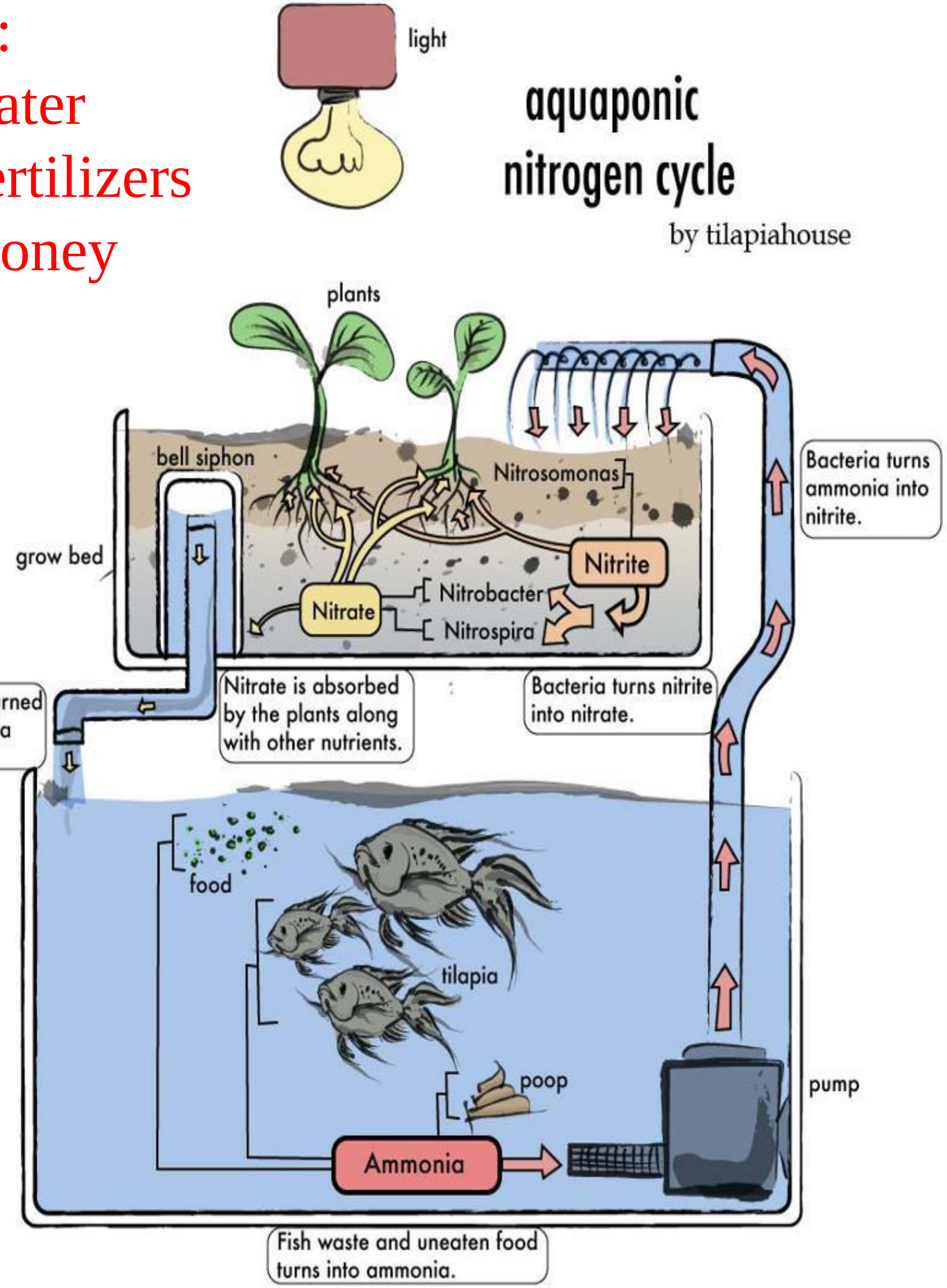
Aquaponics system

Aquaponics

Growing fish in integrated systems with hydroponic plant has become:

1) a channel for increasing the use of limited water resources
2) decreasing dependence on chemical fertilizers
3) providing a greater economic return per unit of water

Save:
1) Water
1) Fertilizers
2) Money

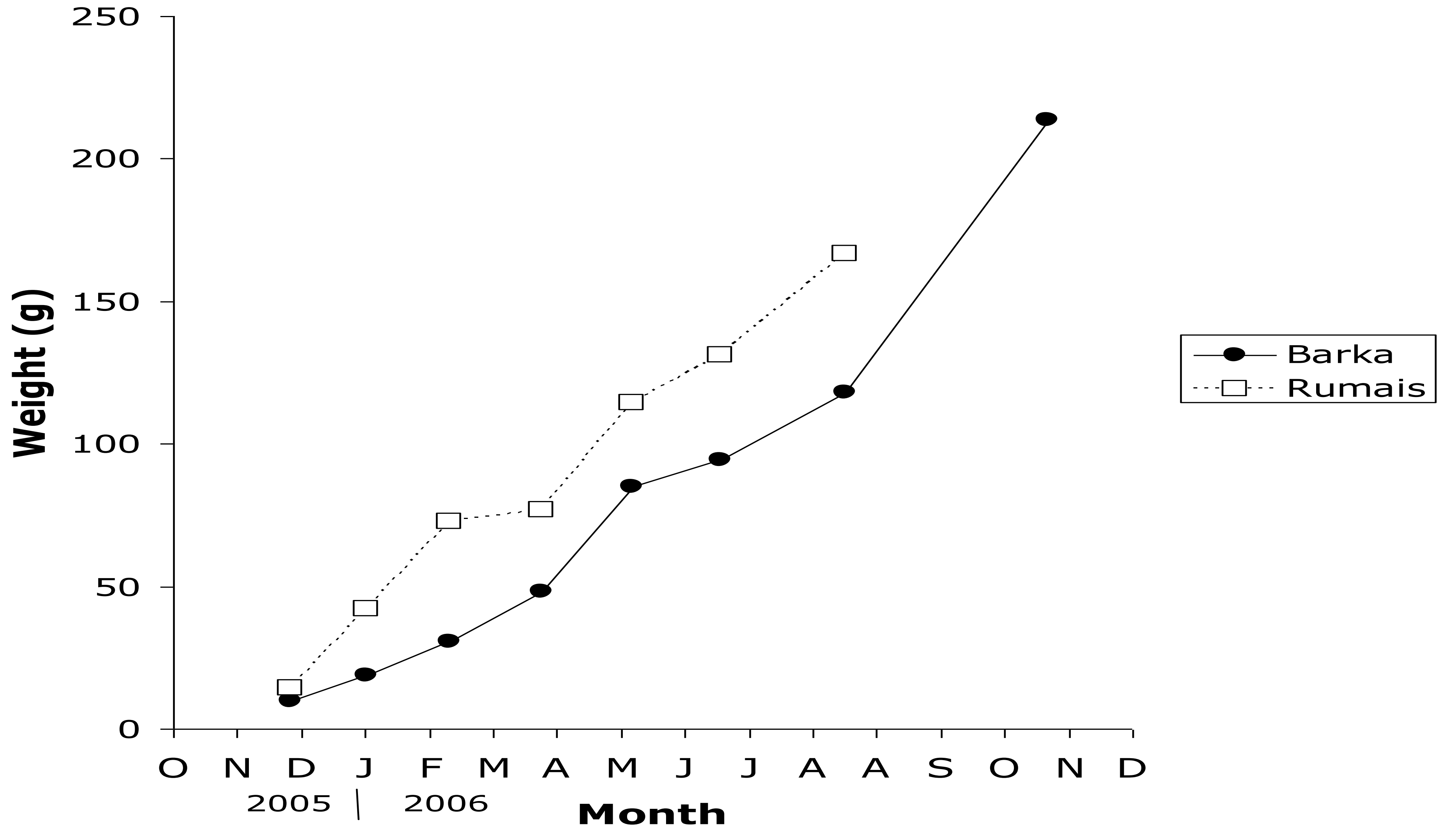


Tilapia culture

Brackish water - Barka

Fresh water tilapia farm, Sinaw, Oman

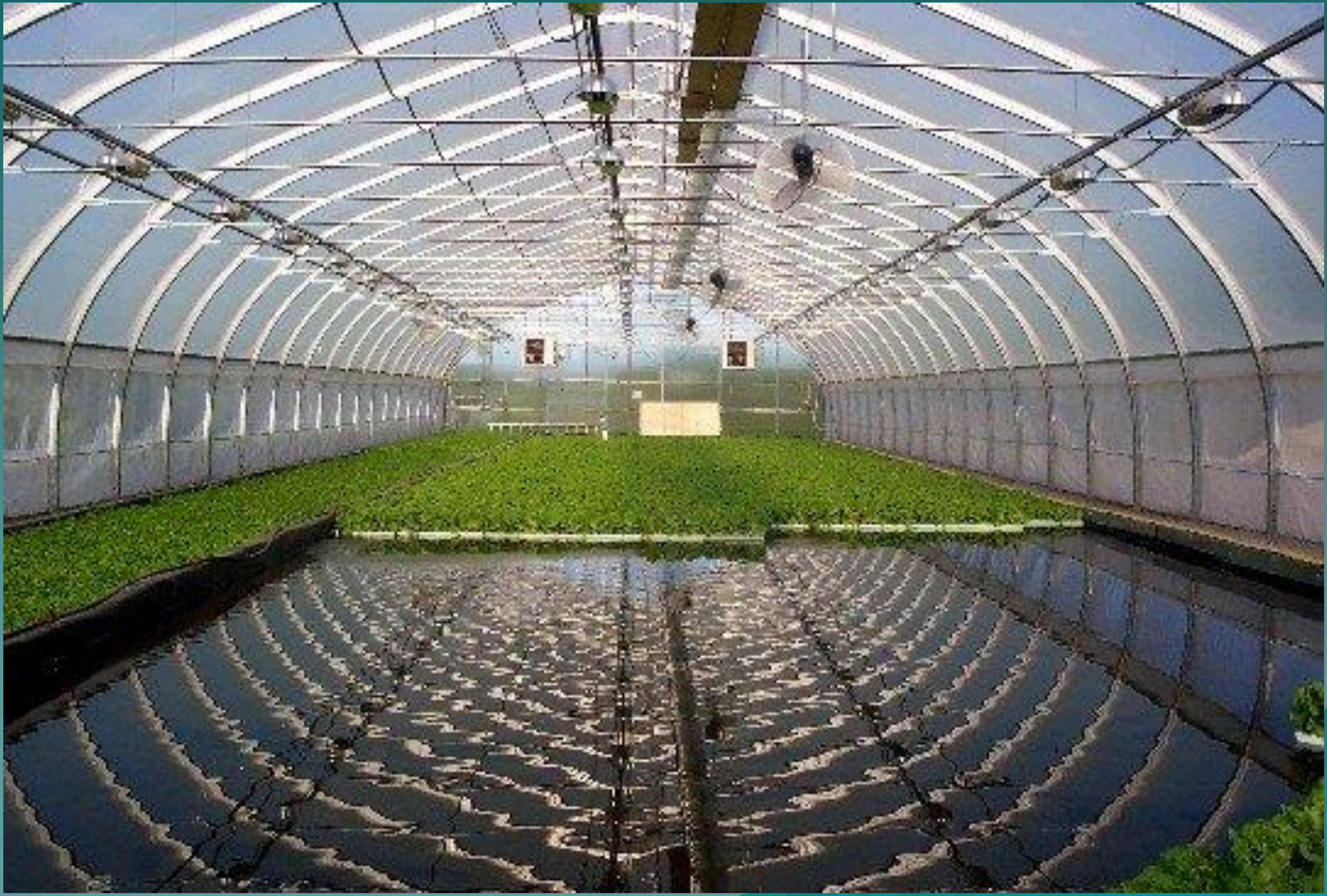
Comparative growth of Nile tilapia in freshwater (Barka) and at 10ppt salinity (Rumais)



Integrating Fish Culture with Freshwater Agriculture

Trial farm - Barka

Aquaponics for Smart Cities




Greenhouse Aquaponics

The combined growing of fish and greenhouse crops has been tested successfully in Oman. In 2010 a report was published by a group of scientists from Sultan Qaboos University and the Ministry of Agriculture and Fisheries for the combined production of tomatoes and red hybrid tilapia

Aquaponics: a promising method for growing fish and crops in Oman

By Dr Stephen Goddard

AQUAPONICS is the combination of fish production (aquaculture) with the soil-less production of plants (hydroponics). It operates within a closed-loop system and utilises minimal resources. Fish feed provides most of the nutrients required for healthy plant growth. These nutrients, excreted directly by the fish, or generated by the microbial breakdown of organic wastes, are absorbed by growing plants. Nutrient removal by the plants in turn treats the water by removing nitrogenous compounds, such as dissolved ammonia, which are harmful to fish. Water is then re-oxygenated and returned to the fish tanks. Fresh, potable water is added to the system, as necessary to replace evaporative loss.

Aquaponics Research in Oman

The combined growing of fish and greenhouse crops has been tested successfully in Oman. In 2010 a report was published by a group of scientists from Sultan Qaboos University and the Ministry of Agriculture and Fisheries for the combined production of tomatoes and red hybrid tilapia. The trials were conducted at the Rumais Agricultural Station. This research is now being extended with support from the Agricultural and Fisheries Development Fund, which is operated by the Ministry of Agriculture and Fisheries. New varieties of salad crops and various fish species will be grown in a climate-controlled greenhouse and the results will be made available to growers. The unit in Rumais will also function as a demonstration facility. The main research objectives are to examine the production and uptake of minerals and their effects on the growth of plant crops, fish and plant crop productivity, the potential costs/benefits for farmers and quality and safety issues.

Commercial Development

The commercial development of large-scale aquaponics is being pioneered in Oman by Water Farmers Canada in collaboration with the Al-Raid Business Corporation. Their initial project, developed on a site at Manuma, is now in its third phase of expansion and has the seen the production of commercial quantities of fruits, salads and vegetables in systems integrated with the production of tilapia.

Production systems

Two main systems are used in aquaponics. The first involves growing crops in shallow grow-beds, using media to provide support for root systems. Expanded clay balls are commonly used to provide the physical support necessary for the roots of tall or trellised plants. The system operates on a flood and ebb system, where each tank is filled with mineral-rich water and drained 2-3 times each hour. A second method, used for smaller plants such as herbs and salads, involves floating the plants in a styrofoam raft. The plants are grown in small coir pots and receive their necessary minerals from the fish tank via the water which circulates around their exposed roots beneath the floating rafts.

Aquaponic systems need to be run intensively for maximum benefit with carefully managed planting and harvesting cycles. This necessitates maintaining the necessary balance between the culture of fish and the growing of plants. This ensures adequate circulating minerals and maintenance of water quality. Whilst most benefits of aquaponics are normally derived from the sale of plants there is considerable interest in growing fish of high value.

Tilapia are hardy fish. They are able to survive high water temperatures and are a suitable species for aquaponics production in Oman. Other, more highly valued species, include the Asian sea-bass and koi carp, which are sold for aquaria and ornamental fish ponds.

Sustainability

The benefits of using soil-less culture techniques and water re-cycling provide considerable benefits for long-term sustainability. Water consumption is less than 10 per cent of normal levels for horticultural production and can be provided from potable supplies. This eliminates the risk of contamination with pathogens which may occur in ground-water supplies. Reduced water demand is clearly useful in a hot arid environment. There are no direct mineral or fertilizer costs since the primary mineral source is the fish feed, which is contributing also to fish production. Some small additions of alkaline salts, to maintain a stable, neutral pH and ferrous salts, to maintain the necessary iron content, are the only mineral additives used in aquaponics. The intensive nature of aquaponic production reduces the amount of land necessary for commercial production units. Additionally, aquaponic systems operate with a low energy footprint, by maximising the use of gravity for water flow.

Safety

Neither chemicals nor pesticides are used in aquaponic systems, which have a high level of environmental compatibility as they do not discharge effluents. Being the ideal closed loop system, all chemical and biological by-products of the system are naturally used and neutralised within the system itself. The systems can be initiated with potable water and there are no direct risks of contamination with coliform bacteria or salmonella, since these pathogens do not survive in cold-blooded animals, such as fish. As in all crop production systems cross-contamination is possible, but the risk is greatly reduced when compared with field crops or greenhouse production systems using soil. Major testing programmes on aquaponic produce in Canada and Hawaii have recommended normal washing procedures following harvest for raw salad crops and herbs. Farmers using aquaponic techniques also have opportunity to seek organic certification since no pesticides or chemicals are used during production and crops should remain free of any unwanted residues.

(Dr Stephen Goddard is the Director of the Centre for Marine Biotechnology at Sultan Qaboos University. All pictures were taken at the Al Raid Farm in Manuma, near Rumais).

Integrating Fish Culture with Saline Agriculture

Salinity tolerance of hybrid Tilapia

Strain evaluations for red hybrid *Tilapia (O.mossambicus x O.niloticus).* Evaluate for salinity tolerance and growth rate

Consumer preference

Integrating Fish Culture with Saline Agriculture

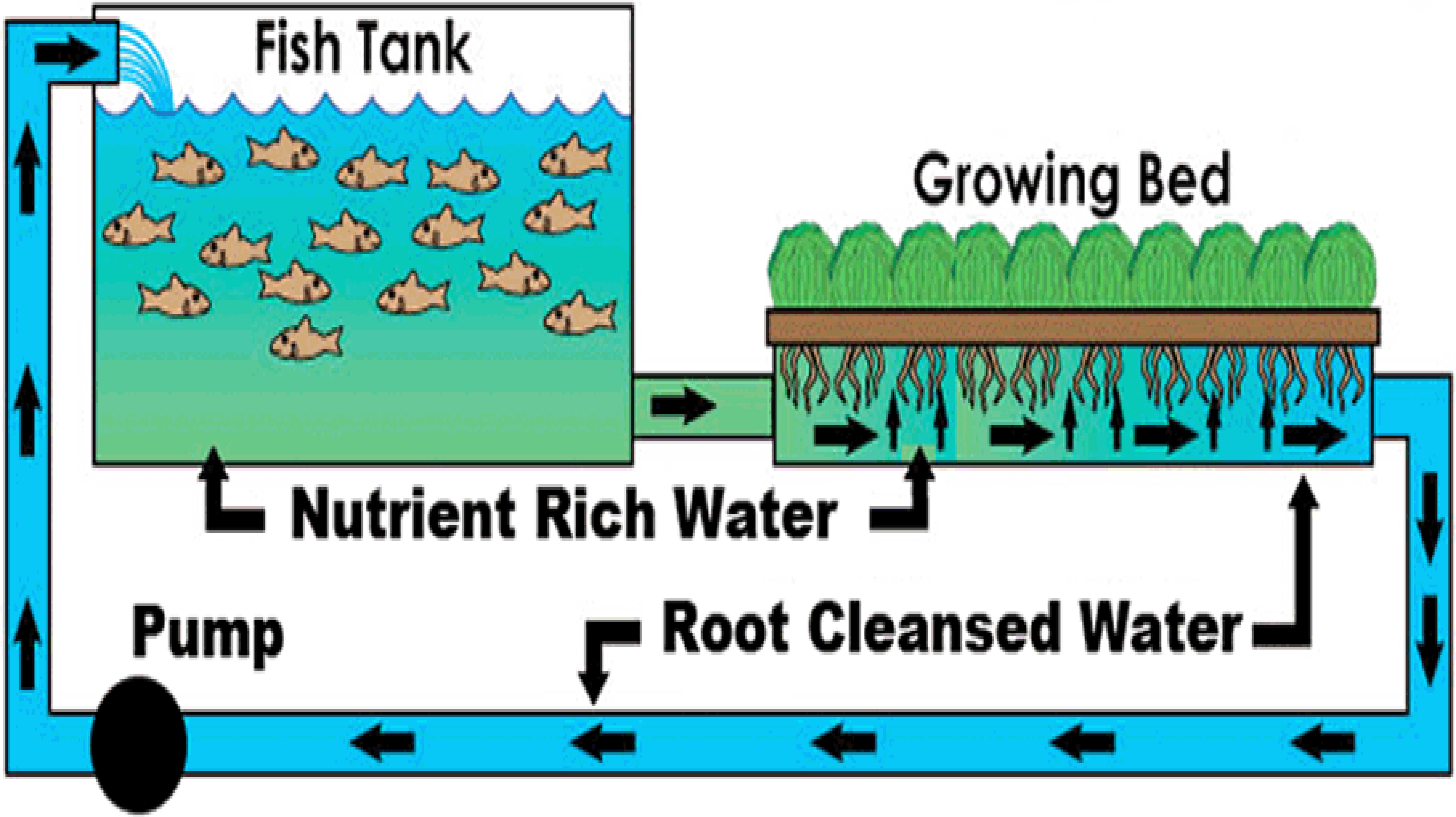
Result and discussion

Tomato plant growth at different irrigation water treatments, low saline fish effluent (3E), higher saline fish effluent (6E), low saline (S3), high saline (S6) and freshwater (FW).

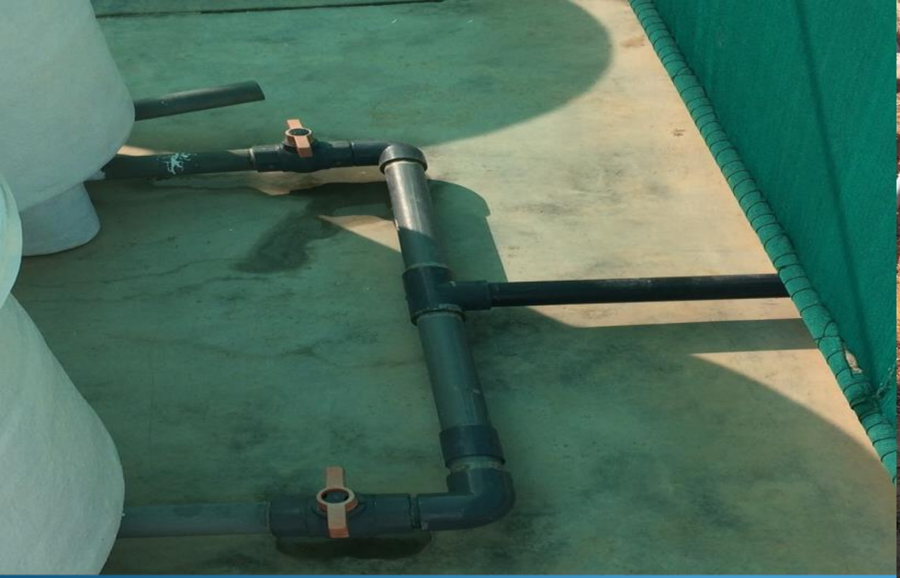
Treatment	Height (cm)	Fresh weight (g)	Leaf area (cm^2)	Root weight (g)
3E	39.80^{a}	25.40^{a}	9.33^{a}	11.20^{a}
6E	30.83^{b}	7.33^{b}	4.37^{bc}	6.67^{b}
S3	23.50^{d}	4.00^{c}	4.40^{bd}	3.75^{d}
S6	20.75^{e}	4.25^{c}	2.88^{e}	5.00^{c}
FW	28.25^{c}	6.00^{b}	3.75^{cde}	6.75^{b}

Mean values in each column followed by the same superscript are not significantly different (*P* > 0.05).

Maximizing Water Productivity by Integrated Approach of Aquaculture System using **Treated Wastewater**



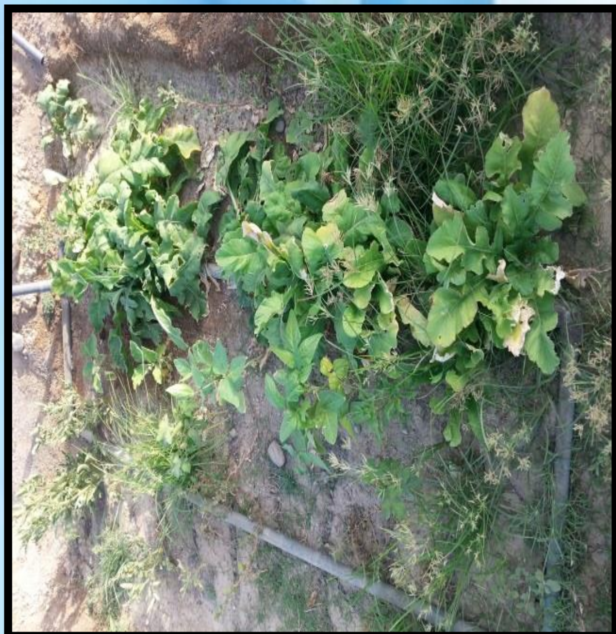
Integrated Aquaculture with TWW



Fish tanks connected to field crops

Irrigated crops: Radish, Bean & Hot pepper

Integrated Aquaculture with TWW



Ground water

Ground water with fish waste

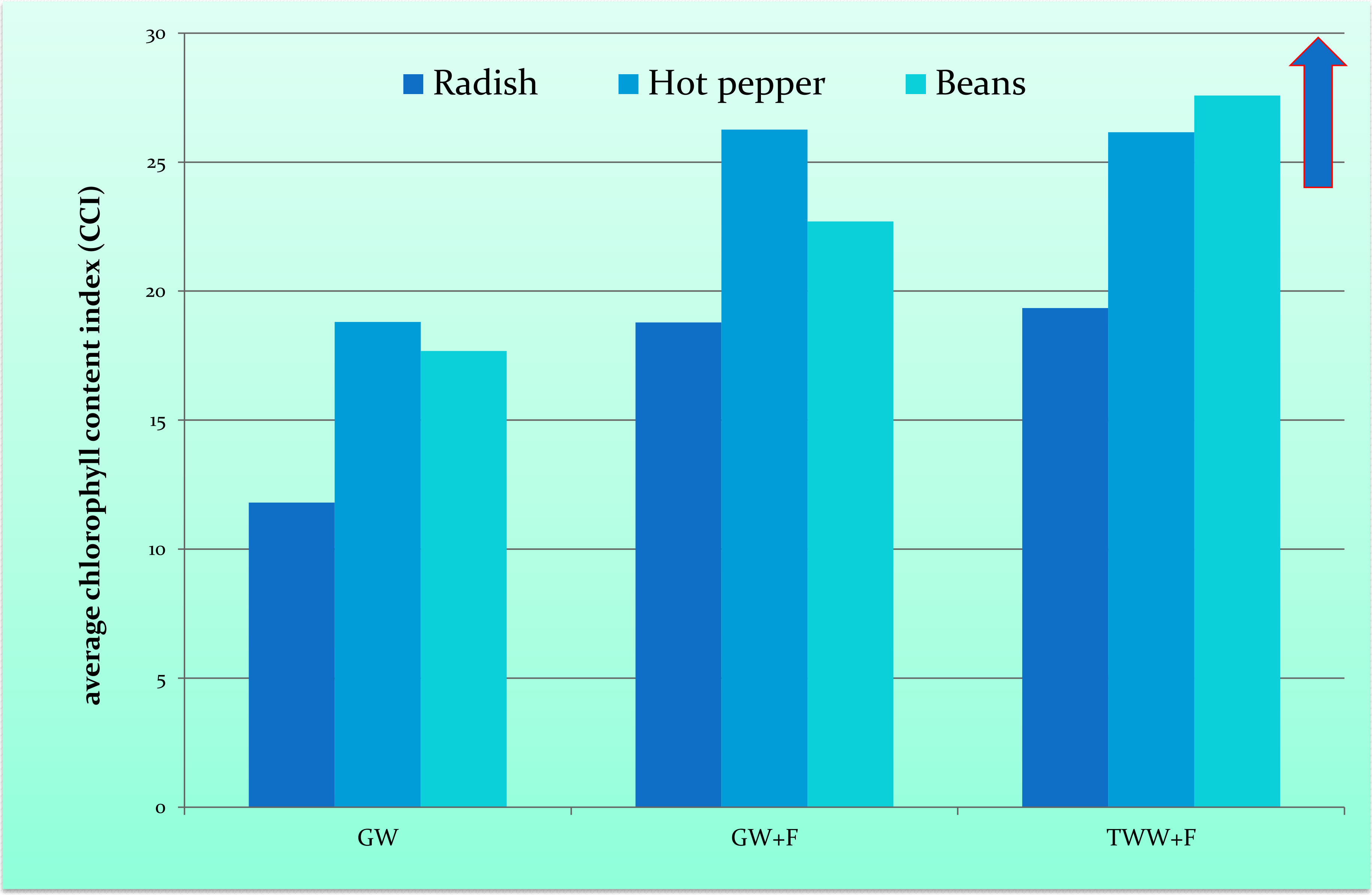
Treated waste water with fish waste

Water and Plant analysis's

	TWW	GW	TWW + FISH	GW +FISH
EC (mS/cm)	1.78	1.20	2.16	2.03

Sample	Na ppm	K ppm	Ca ppm
GW+Fish (Water)	700	43	28
TWW + Fish (Water)	650	52	41
TWW (Water)	520	81	55
GW (Water)	630	29	36
GW + Fish (Plant)	350	440	210
TWW + Fish (Plant)	570	825	280
GW (Plant)	225	195	60

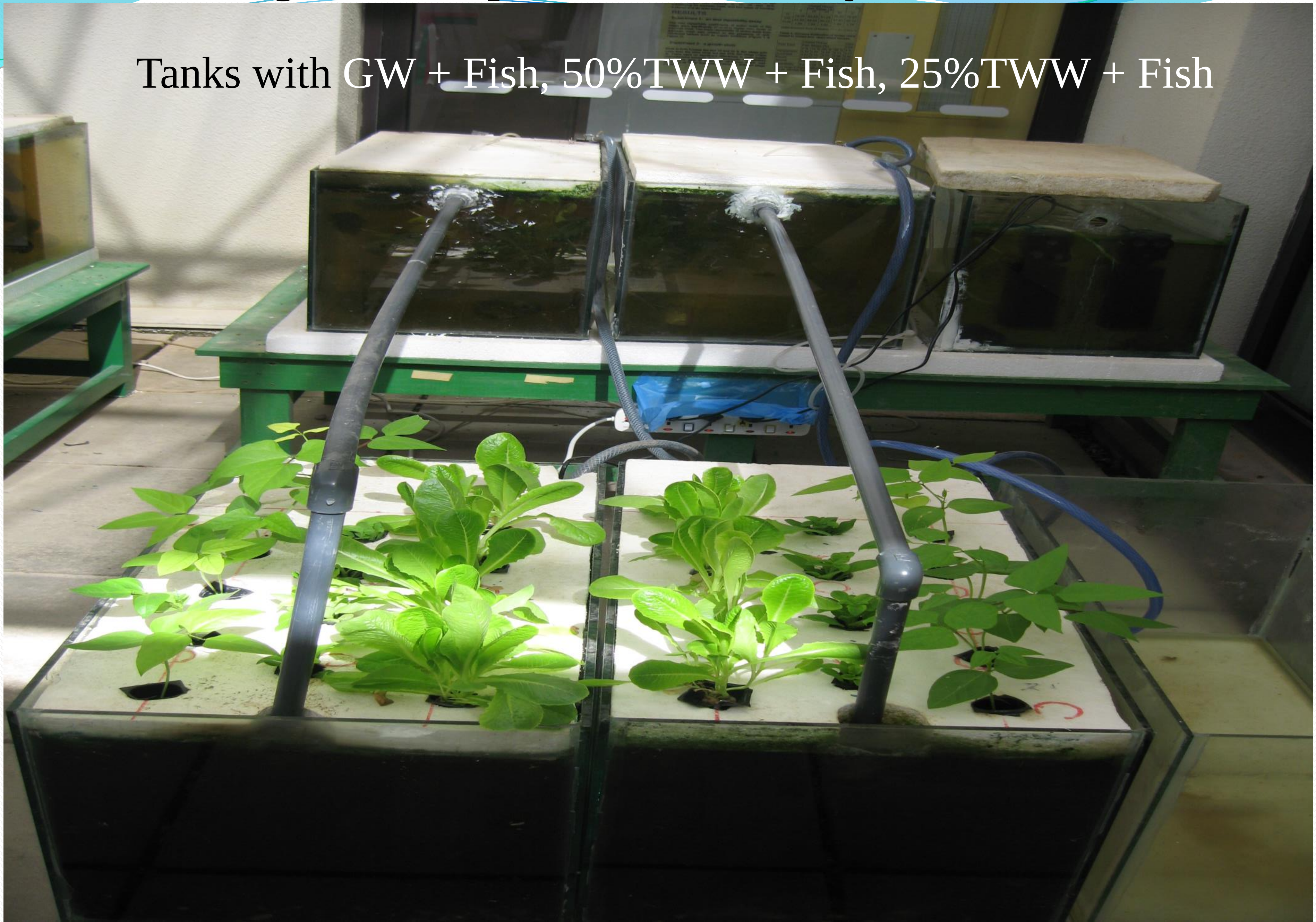
Chlorophyll content index (CCI) for the three crops



➢High Ammonia & **Nitrate**: affect fish life

Part 2: Integrated Aquaculture Study in Shade House

Tanks with GW + Fish, 50%TWW + Fish, 25%TWW + Fish



Integrated Aquaculture with TWW

Water analysis			
Parameter	25% TWW	50% TWW	Fresh water
Temperature (c°)	25.49	25.21	25.31
Salinity (ms/cm)	0.341	0.503	0.424
DO (mg/L)	4.32	3.11	4.69
pH	6.72	6.81	6.27

Integrated Aquaculture study in Shade House

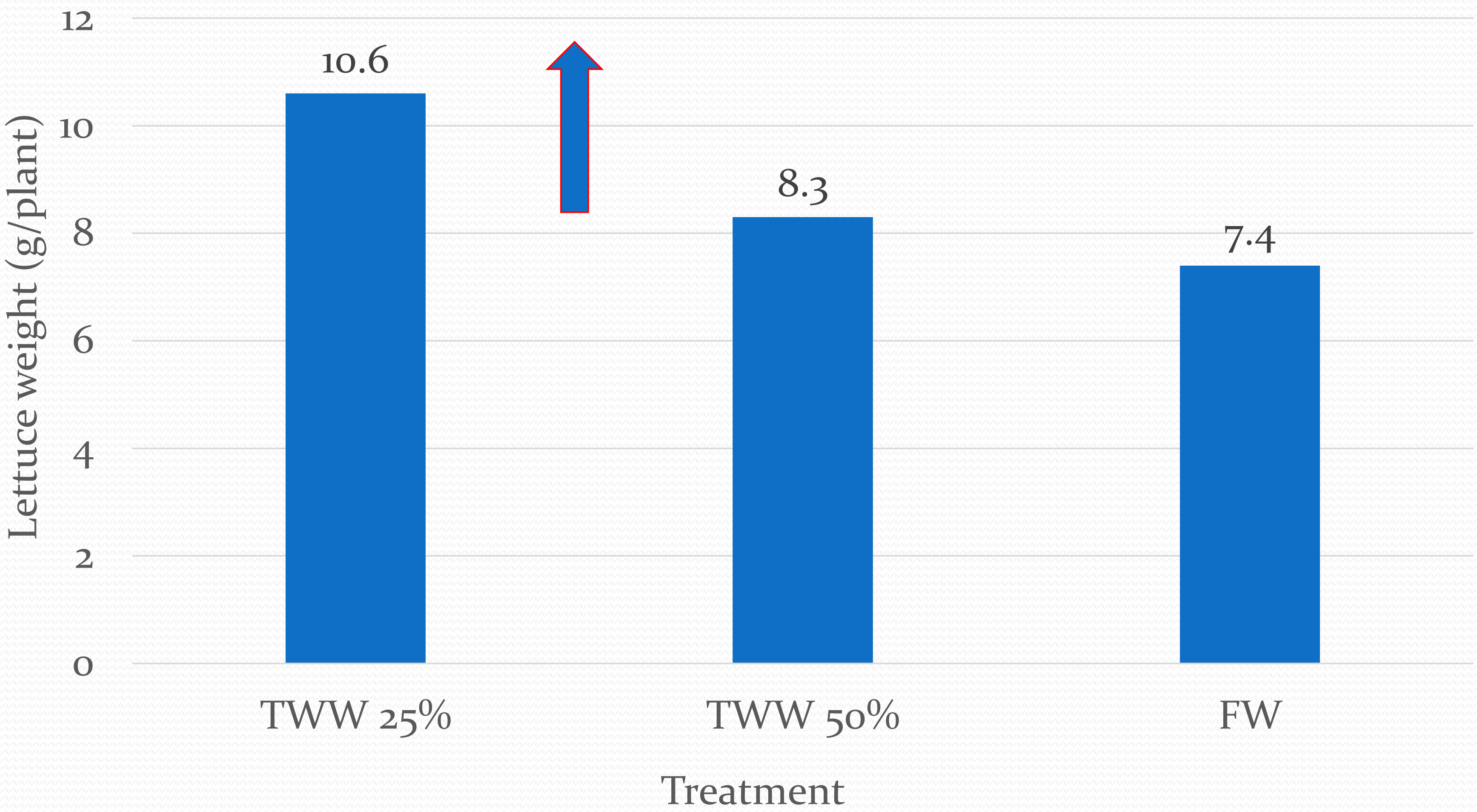
Plant analysis (Lettuce)

Treatment	CCM-200 (CCI)
Fresh water	8.4
TWW 25%	12.5
TWW 50%	14.8

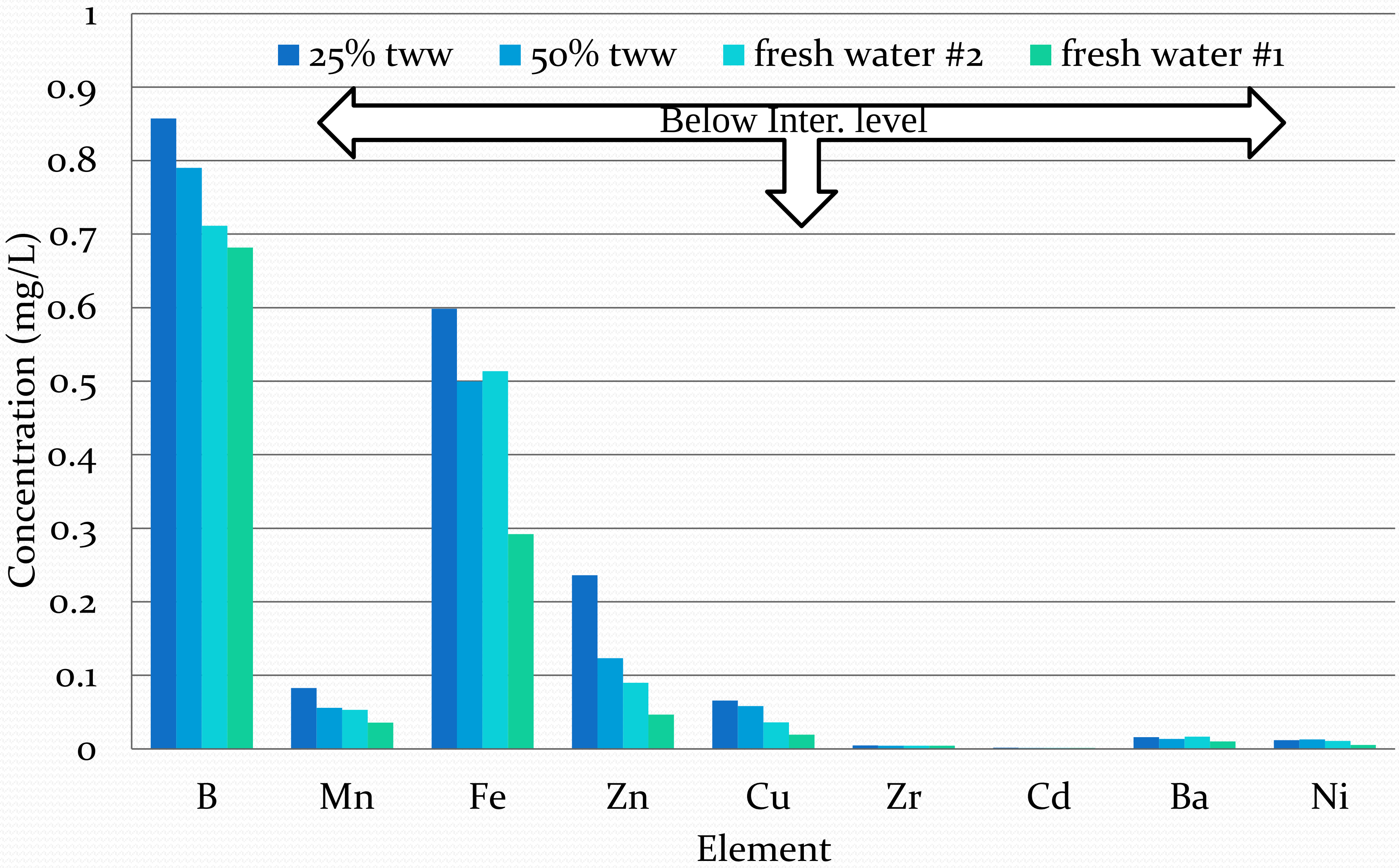
Treatment	Nitrogen analysis	
	samples	Nitrogen %
25% TWW	Lettuce shoot / A	2.54
	Lettuce shoot / B	3.64
50% TWW	Lettuce shoot /A	3.52
	Lettuce shoot / B	4.23
Fresh water	Lettuce shoot	3.56

Integrated Aquaculture with TWW

Lettuce growth as affected by different treatments



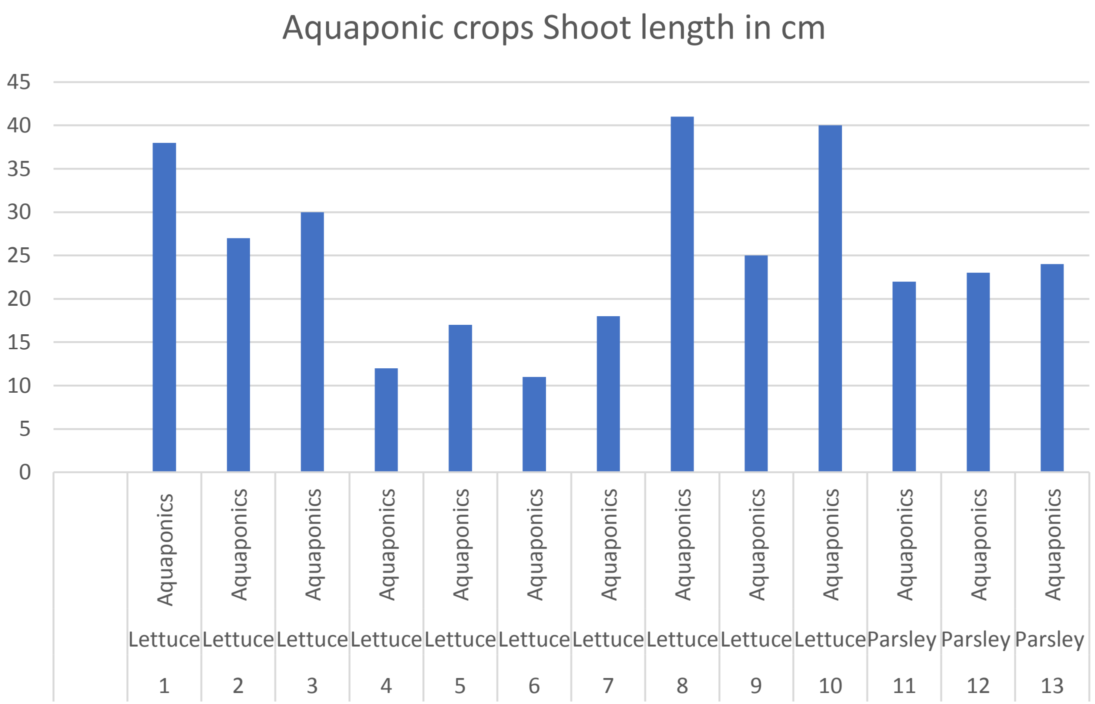
Average elements concentrations of all treatments



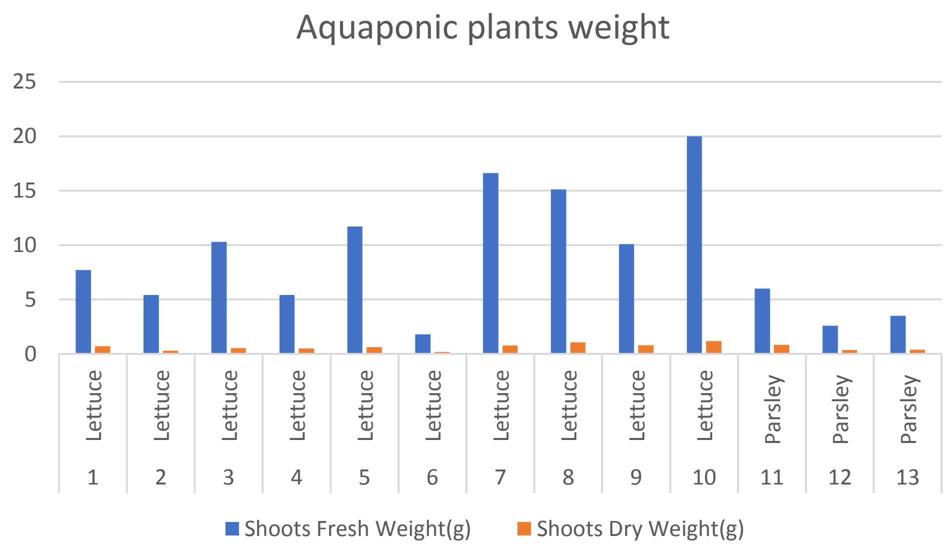
Guideline for safe limits of heavy metals in Plant

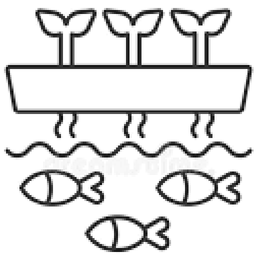
Element	Normal range in plants mg/Kg	Critical concentration in plant ***	
		a	b
Ag	0.1 - 0.8	-	1.0 - 4
As	0.02 - 7	5.0 - 20	1.0 - 20
Cd	0.1 - 2.4	5.0 - 30	4 - 200
Co	0.02 - 1	15 - 50	4.0 - 40
Cr	0.03 - 14	5.0 - 30	2.0 - 18
Cu	5.0 - 20	20 - 100	5.0 - 64
Hg	0.005 - 0.17	1.0 - 3	1.0 - 8
Mn	20 - 1000	300 - 500	100 - 7000
Ni	0.02 - 5	10 - 100	8 - 220
Pb	0.2 - 20	30 - 300	
Zn	1 - 400	100 - 400	100 - 900

2-Aquaponic plants length



Aquaponic plants weight





Plant Number	Plant type	Shoots	
		Fresh Weight(g)	Dry Weight(g)
1	Lettuce	7.7	0.7
2	Lettuce	5.4	0.3
3	Lettuce	10.3	0.53
4	Lettuce	5.4	0.49
5	Lettuce	11.7	0.62
6	Lettuce	1.8	0.17
7	Lettuce	16.6	0.76
8	Lettuce	15.1	1.06
9	Lettuce	10.1	0.79
10	Lettuce	20	1.17
11	Parsley	6	0.84
12	Parsley	2.6	0.37
13	Parsley	3.5	0.39

Heavy metals & micronutrients in plant leaves

ICP-OES Results Units in PPM														
Sample No	Sample Name	As	Zn	Pb	Co	Cd	Ni	Fe	Hg	Mn	Cr	Cu	B	Al
1	Aquaponic lettuce	ND	0.22	ND	ND	ND	ND	0.32	ND	0.16	ND	0.2	0.49	0.14
2	Soil lettuce	ND	1.97	ND	ND	ND	ND	1.23	ND	O.37	ND	0.2	0.55	0.41
3	Aquaponic parsley	ND	0.21	ND	ND	ND	ND	0.19	ND	0.11	ND	0.13	0.63	0.14

Smart Farming

Urban Agriculture: Vertical Farming


Water from Air for Urban Agriculture

Integrated Model


Thank You
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OMAN WATER SOCIETY