Presentation of Local evidence on the impact of irrigating vegetable crops from Ablah WWTP

ReWater MENA: More and safer water reuse in the Middle East and North Africa

Output 2: (2.7) LARI Demonstration site in Bekaa valley in support of the reuse standards dialogue in output 3

Marie Therese Abi Saab

15 March 2022

Background

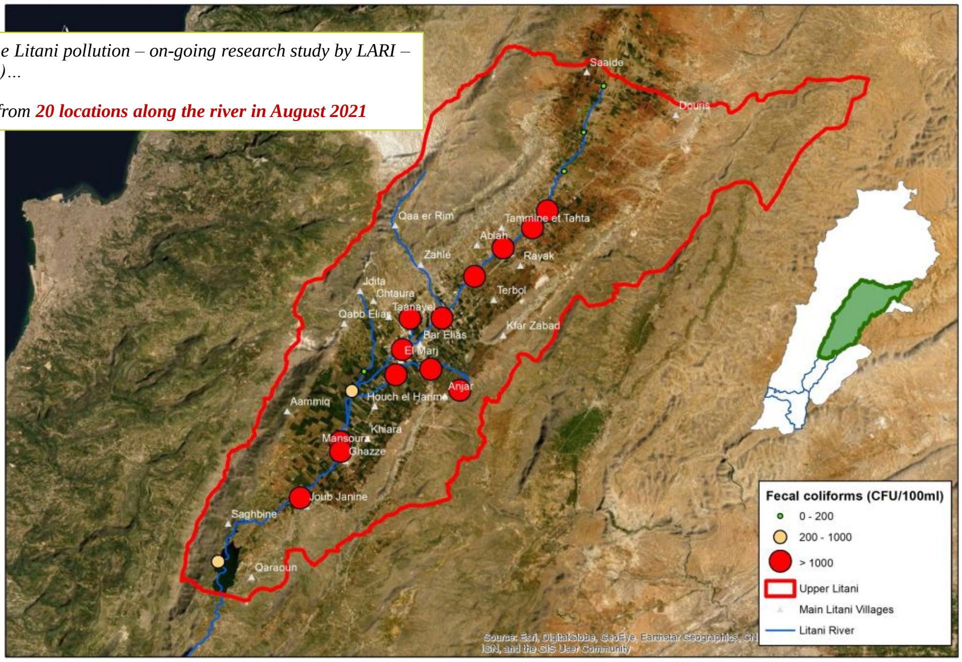
- **Safe use of reclaimed water** is increasingly being recognized by governments and international organizations as **part of the solution to water scarcity and pollution.**
- The use of reclaimed water becomes particularly **attractive when alternative freshwater resources are contaminated.**
- This is **the case of the Litany River Basin**…

uncontrolled disposal of liquid and solid wastes including industrial, municipal and even agronomical wastes

Upper Litani Watershed_Fecal coliforms

Recent evidence on the Litani pollution – on-going research study by LARI – (Abi Saab et al., 2021)…

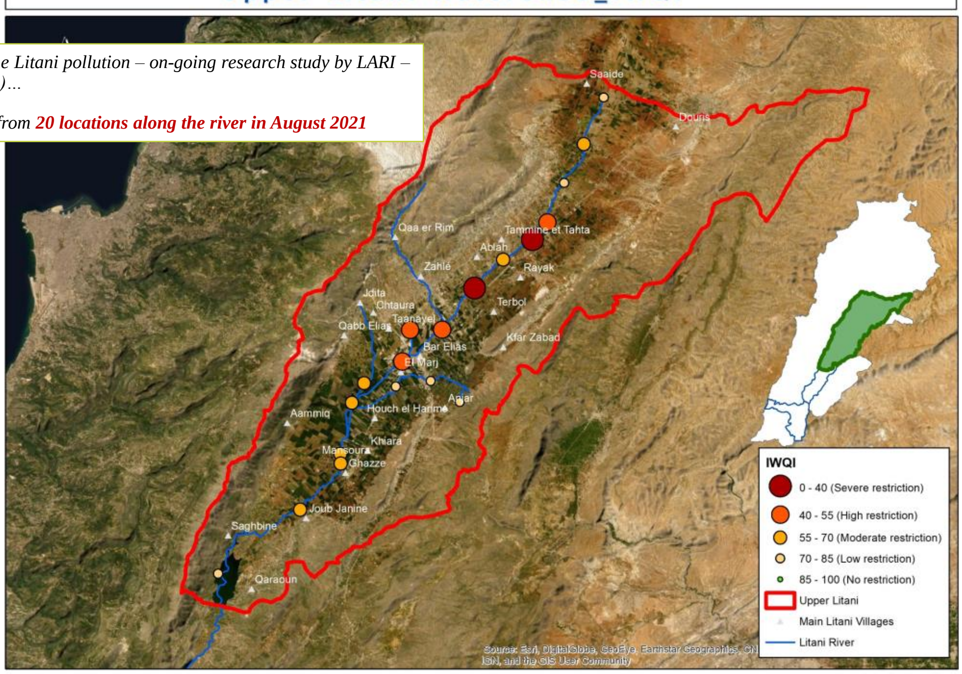
Water samples taken from ***20 locations along the river in August 2021***



Upper Litani Watershed_IWQI

Recent evidence on the Litani pollution – on-going research study by LARI – (Abi Saab et al., 2021)…

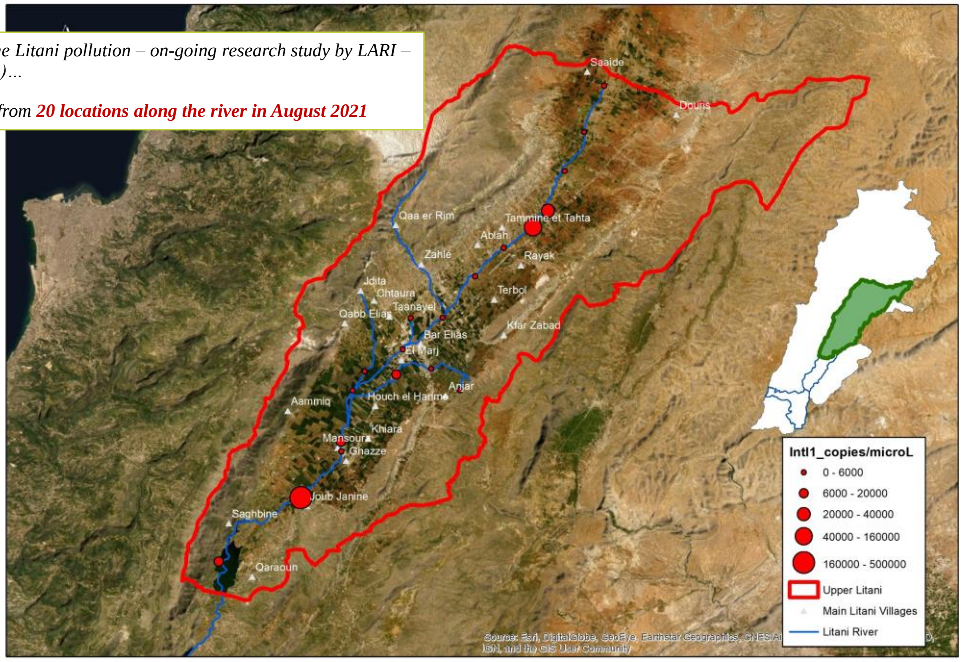
Water samples taken from ***20 locations along the river in August 2021***



Upper Litani Watershed_Intl1

Recent evidence on the Litani pollution – on-going research study by LARI – (Abi Saab et al., 2021)…

Water samples taken from ***20 locations along the river in August 2021***



Background

***Dead river (Shaban & Hamzé,** 2018)*

low water quality (SDG 6.3)
inefficient water use (SDG 6.4)
slow progress on achieving IWM (SDG 6.5)
(Darwish et al., 2021)

Pollution levels exceeded most of the time the international norms (Abi Saab et al., 2018; Mcheik et al., 2018; Nemeh and Haidar, 2018; Fadel et al. 2016; Darwich et al. 2008)

Limited studies in Lebanon on the agricultural use of **treated water**

Table grapes (Abi Saab et al., 2020; Mcheik et al., 2017)

Eggplant (Abi Saab et al., 2021)

Spinach (Mcheik et al., 2018)

Are freshwater and reclaimed water safe for vegetable irrigation?

Empirical evidence from Lebanon

Investigating the real threats on public health, environment, food security, and safety is necessary

Background

	E. Coli or Faecal Coli /100ml	Nematode eggs/l	Total Suspended Solids TSS mg/lit	Crops eaten uncooked is allowed	Code of practice
WHO	1000	<1	-	Yes	Yes
LEBANON	<200	<1	60	No	No

Proposition for wastewater reuse guidelines in Lebanon

Parameter	Category		
	I	II	III
BOD_5 (mg/l)	25	100	100
COD (mg/l)	125	250	250
TSS (mg/l)	60	200	200
pH	6 – 9	6 – 9	6 – 9
Cl_2 residual (mg/l)	0.5 -2	0.5 -2	0.5 -2
F. Coliforms (in 100ml)	<200	<1000	None required
Helminth ova (in 1 lit)	<1	<1	<1

Proposed by FAO within a local project year 2010/2011

Vegetables eaten raw cannot be grown

Background

Trial 1:

Assessing the productivity, the quality and (agronomic, environmental and health) risks of the use of different (waste)water qualities to irrigate various crops under different farm irrigation practices.

Trial 2: Assessing the time to withheld irrigation water before harvest as a farm-level option for minimizing health risks in vegetable production

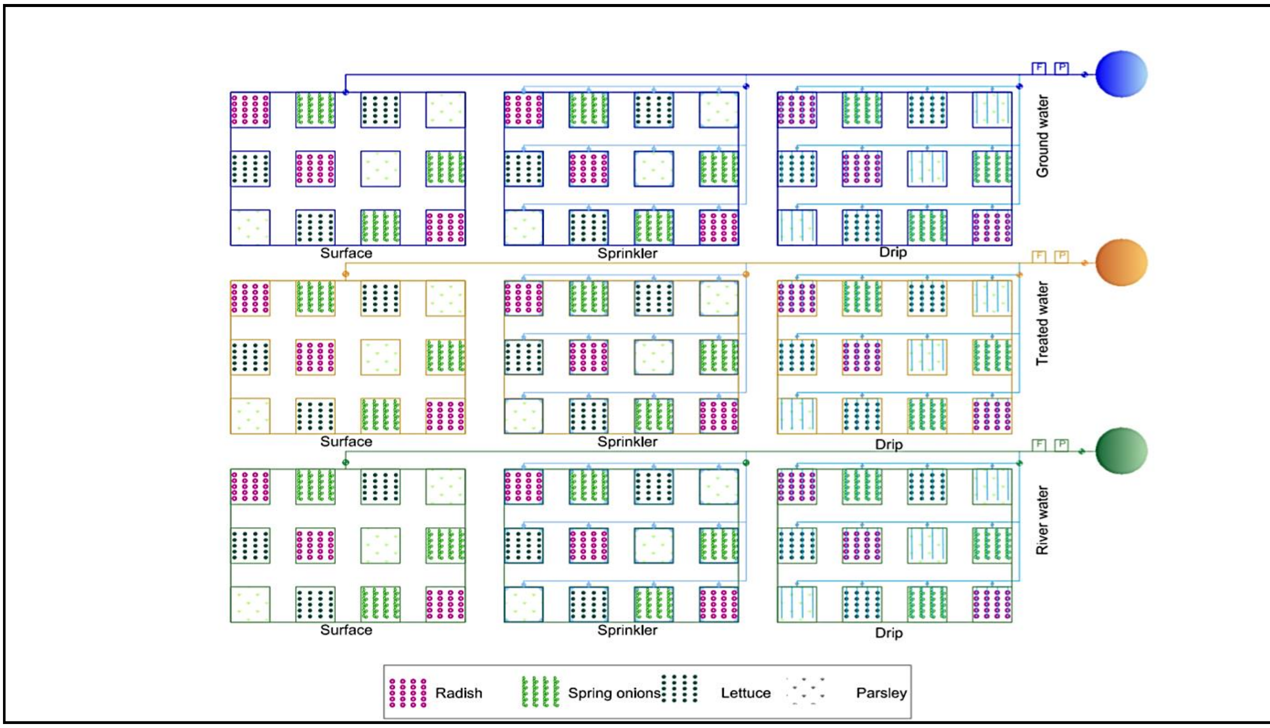
2 growing seasons: 2019 and 2020

LOCATION OF LARI FIELD TRIALS

Trial 1:

- Experimental site
  - LARI field close to Ablah WWTP and the Litani River.
- Experimental design
  - Split split plot design
  - 36 treatments
  - 3 replicates/treatment
  - Total of 108 plots

- Water sources
  - GW- groundwater abstracted from LARI well at LARI
  - TW- treated wastewater from Ablah WWTP
  - RW- surface water from the Litani River
- Types of irrigation methods
  - Dr- Drip irrigation,
  - Sp- Sprinkler irrigation
  - Sr- Surface irrigation
- Types of crops
  - parsley, lettuce, radish and spring onions.


Ground water
Treated water
River water
Surface
Sprinkler
Drip
Surface
Sprinkler
Drip
Surface
Sprinkler
Drip
Radish
Spring onions
Lettuce
Parsley


LARI &
IWMI
TRIAL 1


G2
24.09.2019 12:34


LARI &
IWMI
TRIAL 1
24.09.2019 12:33

Lettuce

Spring onions

Parsley

Radish

Drip irrigation

Sprinkler irrigation

Surface irrigation


G6
G2
T10
24.09.2019 12:56


LARI &
IWMI
TRIAL 1
24.09.2019 12:33


27.08.2019 13:03


04.10.2019 07:29

Trial 1:

Data collection

- **Soil sampling and analysis**: Before and after each growing season,
- **Water analysis:** physico-chemical characteristics, pathogen and metal presence.
- **Yield quantitative parameters** (fresh and dry yield, etc.).
- **Yield qualitative parameters:** (plant mineral analysis), etc.
- **Microbial contamination of fruits:** pathogenic loading in edible parts of vegetables (*E. coli, salmonella, helminth eggs, etc*.).
- **Metal contamination:** heavy metals accumulation in edible parts of the vegetables.

Trial 1:

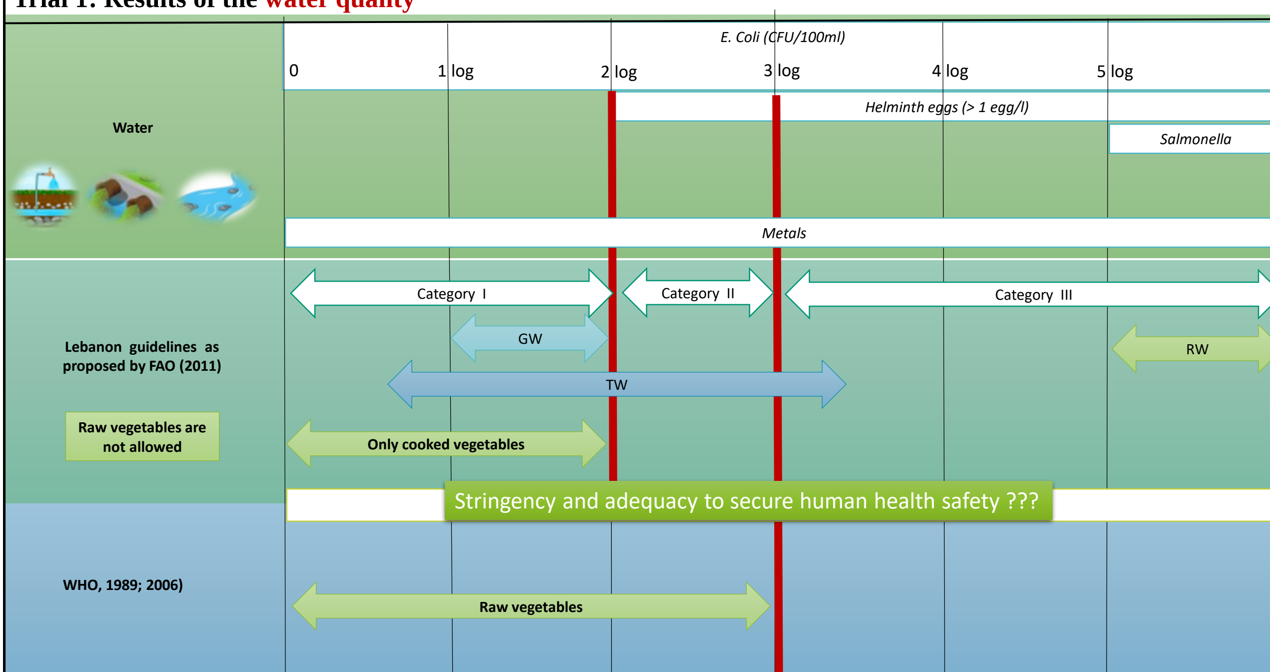
Data analysis

- **Water quality**
- **Yield and nutritional value of crops**
- **Bioaccumulation factor of metals in crops (BAF)**
- **Estimated daily intake (EDI) of heavy metals for adults and children** *(index value less than unity (1.0) shows safe levels while the values higher than1.0 are associated with adverse health effects)***.**
- **Health risk assessment: Health Risk Index (HRI) and Target Hazard Quotients (THQ)**
- **Agronomic risk assessment: soil salinity buildup, metal contamination of the soil.**

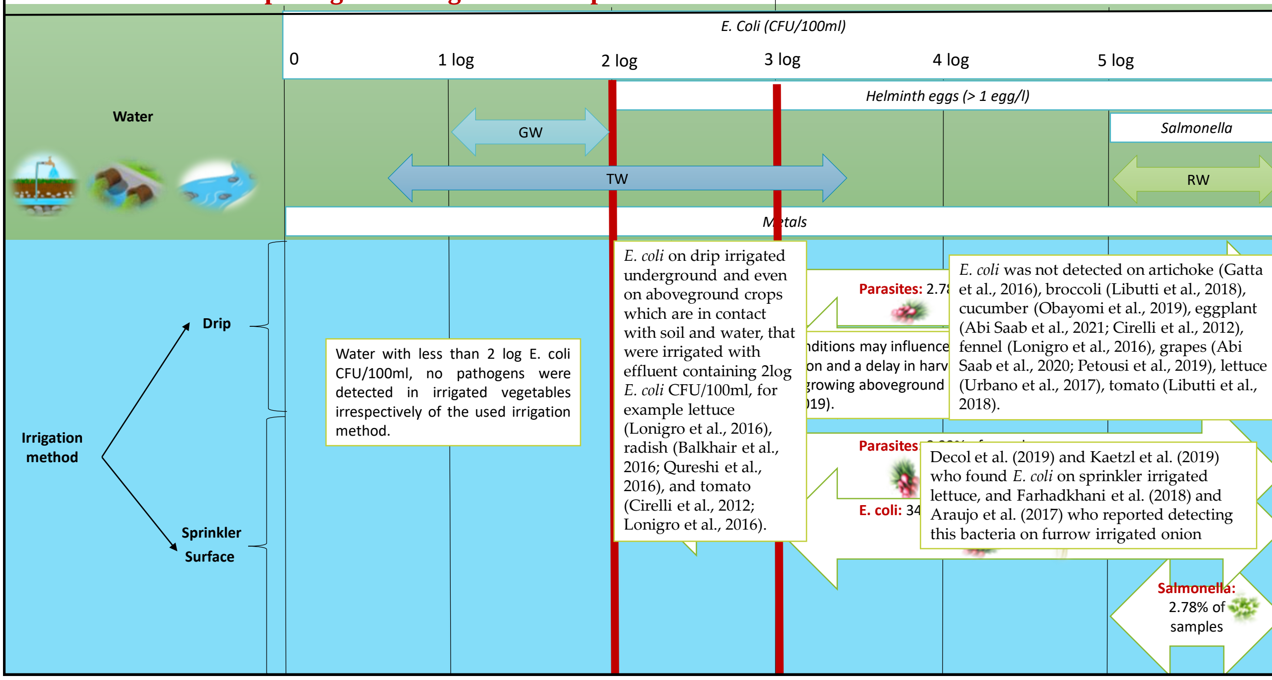
Trial 1: Results of the water quality

	GW				TW				RW				Allowable limits *		
	2019		2020		2019		2020		2019		2020				
	Value	STDEV	Value	STDEV	Value	STDEV	Value	STDEV	Value	STDEV	Value	STDEV	Category I	Category II	Category III
Physico-chemical parameters (mg.L^{-1})															
pH	7.21	0.14	7.80	0.21	7.72	0.30	7.68	0.19	7.31	0.18	7.62	0.12	_	_	_
Electrical conductivity (dS.m^{-1})	0.78	0.16	0.92	0.09	1.14	0.15	1.01	0.11	2.29	0.81	2.73	0.74	_	_	_
COD	36.33	11.74	20.24	18.21	66.95	19.51	20.13	18.82	105.25	34.02	**273.12**	219.21	125	250	250
BOD_5	16.83	2.64	6.33	9.81	**27.00**	8.65	20.01	14.79	**47.33**	15.63	**79.67**	61.83	25	100	100
Total Suspended Solids	4.11	1.47	3.40	2.96	27.51	6.34	3.93	2.13	33.55	7.90	13.83	4.36	60	200	200
Nitrates	26.93	6.90	20.42	8.11	14.96	4.79	16.50	13.83	9.66	4.73	9.12	11.40	30	30	30
Phosphates	0.24	0.56	0.01	0.01	0.77	0.30	2.09	2.64	4.88	3.83	3.01	1.63	_	_	_
Potassium	2.33	0.55	1.67	0.66	28.58	12.47	14.68	14.64	78.56	13.87	38.63	7.64	_	_	_
Sodium	15.96	2.55	14.78	1.10	26.00	3.15	29.02	17.04	115.59	5.20	90.93	26.55	_	_	_
Pathogens in water															
E. coli (CFU/100 mL)	6.58E+01	3.53E+01	1.84E+02	1.06E+02	**1.57E+03**	5.75E+02	9.67E+00	1.15E+00	**1.78E+05**	1.65E+05	**4.84E+05**	6.00E+05	<200	<1000	_
Salmonella	Absence	_	Absence	_	**Sometimes present**	_	Absent	_	**Sometimes present**	_	**Sometimes present**	_	Absent	Absent	Absent
Parasites (ova//L)															
Ascaris	0.00	0.00	0.00	0.00	**2.00**	2.76	0.00	0.00	**2.67**	3.67	**1.00**	1.00			
Chilomastix mesnili	0.50	0.55	**1.00**	1.00	0.83	0.98	0.00	0.00	**1.50**	1.97	**1.00**	2.00	<1	<1	<1
Blastocystis	0.67	0.52	**2.00**	1.00	**1.00**	1.55	0.55	0.30	**1.67**	2.73	**1.00**	2.00			
Endolimax nana	0.00	0.00	**1.00**	2.00	0.67	1.03	0.00	0.00	**1.00**	1.67	**2.00**	2.00			
Trace metals (mg.L^{-1})															
Cr	1.15	0.00	0.25	0.36	1.16	0.01	0.10	0.13	1.15	0.01	0.13	0.17		2	
Ni	0.20	0.00	0.03	0.08	0.21	0.00	0.13	0.22	0.22	0.01	0.04	0.08		0.5	

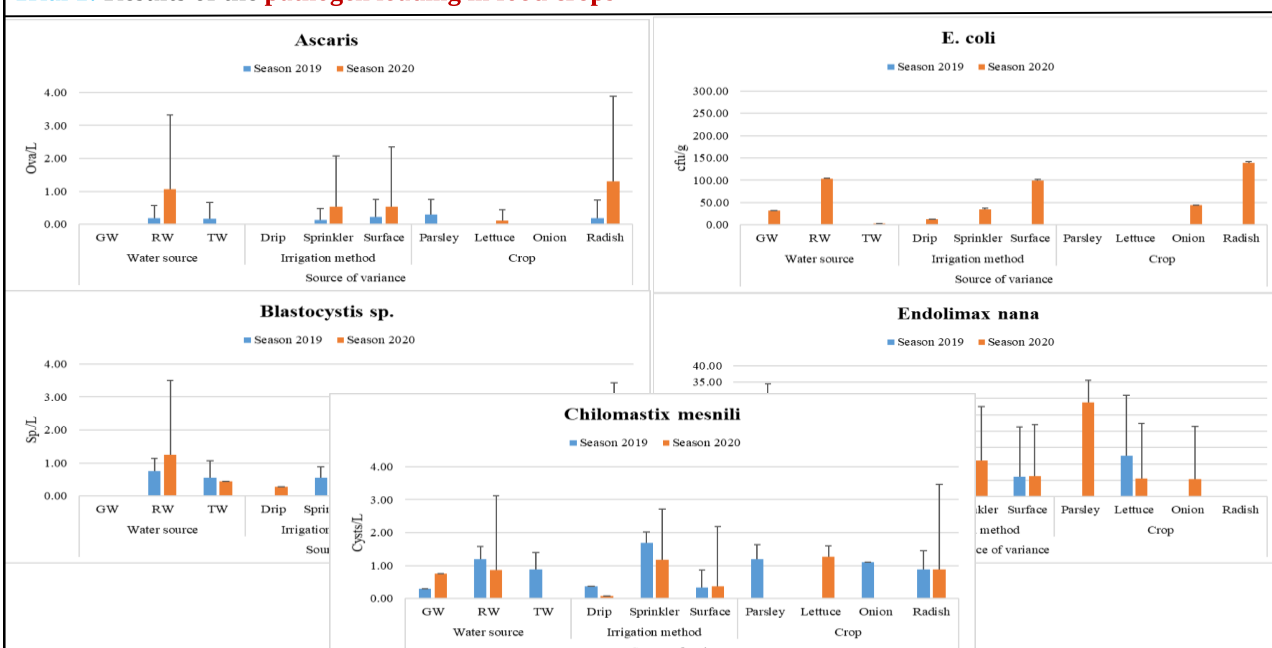
Trial 1: Results of the water quality



Trial 1: Results of the pathogen loading in food crops



Trial 1: Results of the pathogen loading in food crops



Trial 1: Results of the yield and nutritional value of crops

Treatment	Fresh weight (Kg. m^{-2})		N (mg. 100 g^{-1} FW)		P (mg. 100 g^{-1} FW)		K (mg. 100 g^{-1} FW)		Ca (mg. 100 g^{-1} FW)		Mg (mg. 100 g^{-1} FW)	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Water sources												
Groundwater	2.59 ± 2.29 b	2.76 ± 2.43 b	146.52 ± 26.14 a	78.12 ± 15.96 a	22.97 ± 7.92 b	11.76 ± 7.56 b	164.74 ± 27.72 b	259.56 ± 64.66 b	60.19 ± 21.38 b	106.68 ± 56.28 b	21.38 ± 7.92 b	26.88 ± 25.2 b
River - Litani	2.73 ± 2.82 a	3.49 ± 2.59 a	63.018 ± 28.00 c	70.05 ± 21.1 c	28.79± 7.78 a	14.35 ± 13.50 a	210.06 ± 42.79 a	285.27 ± 227.88 a	83.25 ± 14.78 a	124.91 ± 91.99 a	29.56 ± 5.45 a	37.98 ± 49.78 a
Treated water - Ablah	2.65 ± 2.70 b	3.45 ± 2.63 a	126.55 ± 30.68 b	74.802 ± 32.88 b	31.45 ± 10.74 a	11.50 ± 10.68 b	213.226 ± 88.97 a	279.19 ± 234.27 a	80.54 ± 16.88 a	121.66 ± 69.05 a	29.91 ± 6.14 a	32.13 ± 23.84 ab
Irrigation methods												
Drip	4.34 ± 3.27 a	3.70 ± 2.70 a	119.92 ± 37.95 a	76.12 ± 19.03 a	30.36 ± 8.35 a	12.71 ± 9.08 ab	214.80 ± 78.18 a	289.66 ± 207.93 ab	81.21 ± 14.42 a	99.91 ± 66.61 b	30.36 ± 6.07 a	40.44 ± 17.46 a
Sprinkler	2.34 ± 1.77 b	3.34 ± 2.61 a	100.50 ± 38.43 b	66.97 ± 27.15 b	25.12 ± 8.13 b	8.72 ± 6.35 b	187.94 ± 56.21 c	237.90 ± 168.90 b	66.51 ± 14.78 b	115.31 ± 56.30 b	23.65 ± 6.65 b	23.53 ± 12.67 c
Surface	1.30 ± 1.35 c	2.64 ± 2.27 b	114.94 ± 57.90 ab	88.98 ± 27.24 a	29.36 ± 12.59 b	18.10 ± 15.38 a	184.75 ± 45.08 b	329.42 ± 237.11 a	75.51± 29.37 b	152.95 ± 97.74 a	26.85 ± 7.39 b	29.06 ± 20.08 b
Crops												

Results highlights

- **Vegetables irrigated with TW are of good nutritional quality, as those irrigated from other water sources.**
- Drip method presented the highest yield
- Parsley showed the highest content of minerals followed by onion, lettuce and radish.
- Results on the mineral content of the grown crops were **in agreement to those reported by the USDA National Nutrient Database for Standard References** (Haytowitz et al., 2019; USDA, 2020).

Trial 1: Results of the metal contamination in food crops

- The concentrations of most metals in vegetables were significantly lower than the safe limits of the FAO/WHO of the Food Standards Programme Codex, except for Zn and Cr.
- Parsley and onion showed the highest metal contamination.
- The trends in the bioaccumulation factor (BAF) as well as the estimated dietary intakes (EDI) of metals were in the increasing order of Cu< Cd<Ni<Cr<Zn.
- The THQ values for all metals were lower than 1.0.

Trial 2:

Assessing the optimal time to withheld irrigation water before harvest as an on-farm practice in lettuce production with reused water

- Experimental site

  LARI field close to Ablah WWTP and the Litani River.

- Experimental design

  RCBD

  4 treatments

  3 replicates/treatment

  Total of 12 plots

To minimize risks of produce contamination with helminth eggs, E. coli, salmonella and other pathogens that are harmful to human health.

Trial 2:

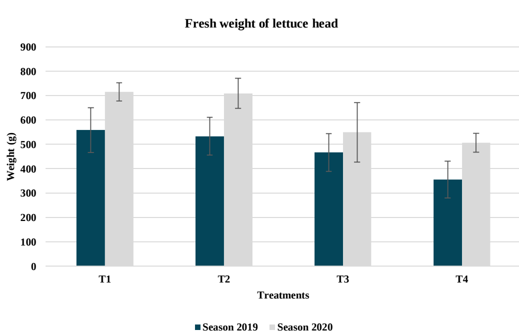
Data collection

- **Water analysis:** physico-chemical characteristics and pathogens.
- **Microbial contamination of produce:** pathogenic loading in edible parts of the vegetables (E. coli, salmonella, helminth eggs, etc.).
- **Yield quantitative and qualitative parameters**

Data analysis

- **Optimal irrigation withholding time** under Beqaa weather conditions with maximum pathogen removal at minimum yield or quality loss

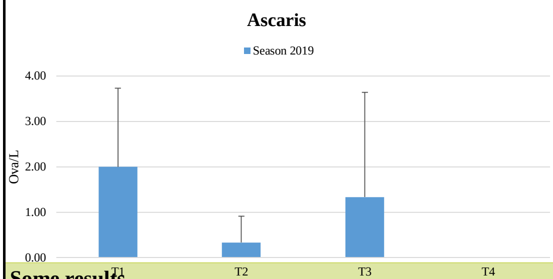
Trial 2: Assessment of the fresh yield and dry matter content of lettuce heads

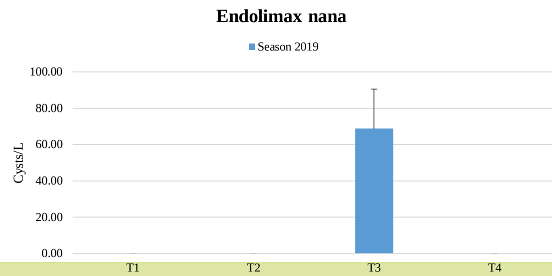


Some results

- The results are also very close to those reported by Keraita et al. (2007), particularly after 6 days of irrigation cessation. In fact, that study found that about **5% of the yield of lettuce was lost daily** from cessation of irrigation before harvesting in dry season.
- Irrigation can be **withheld for 2–4 days before harvesting** to reduce contamination with little loss of yield.
- The mineral content of the grown crops were also in agreement to those reported by the USDA National Nutrient Database for Standard References (Haytowitz et al., 2019; USDA, 2020).

Trial 2: Pathogen loading in food crops





Some results

- In season 2019, Ascaris (5.00 % of total samples) was the most encountered parasitic contaminant on lettuce, followed by Endolimax nana (3.33%). In this study, it is obvious that the occurrence of pathogenic parasites (mainly Ascaris) were low on irrigated lettuce and were not affected by the time to withheld irrigation at harvest.
- In season 2020, there was no parasites detected on the collected lettuce heads which could be explained by the fact that the treated effluent used for irrigation was of better quality than in season 2019 and it was free from parasites.
- In both seasons, there was no bacterial loading on harvested crops in terms of E. coli and Salmonella. It should be also mentioned that, in season 2020, the collected lettuce heads were also analyzed for the presence of E. coli 0157 and Listeria monocytogenes. The results showed that such pathogenic bacteria were not present on the crops.
- **Sanitary risk associated with irrigation practice, although very low, is always present.**

Conclusion

- In Lebanon, the food chain remains an important exposure pathway to contaminants due to widespread pollution of soils and waters.
- Empirical evidence from Lebanon showed, through this study, that the quality of irrigation water, the crop selection, the choice of irrigation method, but also the local environmental conditions would all influence produce safety.
- Therefore, the elaboration and implementation of sustainable policy for the monitoring and management of water quality leading to its protection and sustainable use is urgently needed.
- Of particular importance is the **development of irrigation water quality standards** (or, more broadly, **water reuse standards**) that **promote health protection and food safety at affordable costs.**

Conclusion

- Our research has shown that **the adoption of drip irrigation with water of less than 3log E. coli CFU/100ml has shown to be safe even for vegetables consumed raw**, with the exception of underground crops (such as onion or radish) that **should not be irrigated with water having more than 2log E. coli CFU/100ml.**
- Additionally, TW showed not to have an adverse effect on vegetables quality as compared to vegetables irrigated with other water sources.
- These results deserve to be considered in the **formulation of the first Lebanese standards for water reuse** with the aim of realistically protecting human and environmental health while making a more productive and efficient use of water resources.

Conclusion

Proposition for wastewater reuse guidelines in Lebanon

Drip irrigated vegetables eaten raw are allowed (Category I)

Drip irrigated vegetables eaten raw are allowed except those grown underground (Category II)

Vegetables eaten raw cannot be grown (Category III)

Parameter	Category		
	I	II	III
BOD_5 (mg/l)	**25**	**100**	**100**
COD (mg/l)	125	250	250
TSS (mg/l)	60	200	200
pH	6 – 9	6 – 9	6 – 9
Cl_2 residual (mg/l)	0.5 -2	0.5 -2	0.5 -2
F. Coliforms (in 100ml)	**<200**	**<1000**	**None required**
Helminth ova (in 1 lit)	**<1**	**<1**	**<1**

Proposed by FAO within a local project year 2010/2011

More barriers??? *cessation of irrigation before harvesting*

MDPI

Article

Are freshwater and reclaimed water safe for vegetable irrigation? Empirical evidence from Lebanon

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Abstract:

In Lebanon, irrigation water is threatened by pollution, particularly in the Litani River basin. Therefore, the potential health risks were evaluated for vegetables irrigated from existing water sources (Groundwater-GW, River water-RW, and treated wastewater-TW) and grown under different irrigation methods (drip, sprinkler and surface) over two growing seasons: 2019 and 2020. Water, crop and soil samples were analyzed for different physico chemical parameters, pathogens and metals. In addition, the bioaccumulation factor (BAF) as well as the Estimated Dietary Intakes (EDI), the Health Risk Index (HRI) and Target Hazard Quotients (THQ) were calculated in order to

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Table grapes irrigation with treated municipal wastewater in a Mediterranean environment

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Keywords
effluent reuse; fruit quality; microbiological status; mineral analysis.

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Abstract

This study investigated the effect of different water quality regimes [Freshwater (FW), treated wastewater (TW) and alternating FW and TW (FW-TW)] on drip-irrigated table grape yield, quality and microbial contamination. Water and soil samples were analysed. In addition, grape samples were harvested for quantitative and qualitative evaluation. The results showed that the plants irrigated with TW and

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Treated municipal wastewater reuse for eggplant irrigation

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Assessing the performance of constructed wetland for water quality management of a Southern Mediterranean river

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Keywords
bacterial pollution; Mediterranean watersheds; metal pollution; water treatment.

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doi:10.1111/wej.12348

Abstract

Most of Southern Mediterranean water courses suffer from numerous types of pollution. This study presents a comprehensive performance assessment of a pilot CW system for removing various contaminants from the Litani River, Lebanon. The physico-chemical, pathogens and trace metal parameters were analyzed for river water as well as for the wetland effluent. Results revealed that the average removal efficiencies were 87.01% for COD, 64.99% for BOD_5, 86.18% for TSS, 43.11% for NO_3—N, 34.82% for NH_4—N, 55.07% for PO_4—P and 73.05% for K. The removal efficiency of faecal coliforms was around 99.84%. Influent and effluent heavy metal pollution (Cu, Pb, As and Ni) concentrations greatly exceeded the range of the environmental limit values due to industrial emissions in river water. CWs seem to be a promising green technology for Lebanon for the reduction of bacterial contamination. Further studies are required to improve treatment modules for different pollutants, including metals.

Working team from LARI

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Virology Lab	Jeanne El Haj
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Thank you