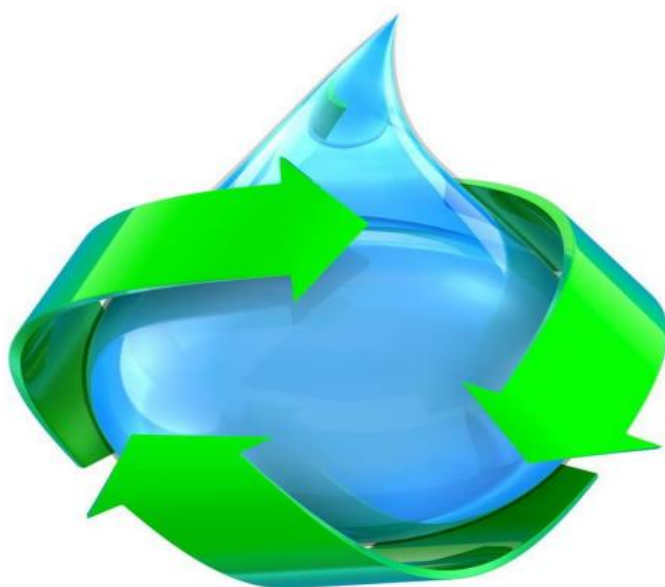




Recycling the wastewater for sustainable irrigation practices, by suitable treatment



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Abstract

The treated wastewater project focuses on addressing water scarcity in the Kurdistan Region and Iraq, exacerbated by climate change, population growth, and inefficient water management. It aims to utilize treated wastewater for irrigation, reducing pressure on freshwater resources while promoting sustainable agriculture and enhancing ecosystem health.

This initiative engages stakeholders through awareness campaigns, seminars, and training, addressing misconceptions about treated wastewater's safety and benefits. It highlights technological challenges and solutions while encouraging governmental and community support. Surveys and interviews indicate optimism for treated wastewater use, but barriers like safety concerns, community acceptance, and technological gaps remain. Recommendations include robust testing, education programs, and leveraging successful international practices to ensure wide adoption and long-term success.

Introduction

Climate change, induced by the greenhouse gas emissions from natural and human activities such as industries, transportation, agriculture, burning fossil fuels and deforestation, is a global phenomenon that impacts on the environment, societies, and economies. The global warming has led to frequent and severe weather events (IPCC, 2021). These outcomes pose significant risks to the entire world including biodiversity, water resources, food security, and human health. Efforts to mitigate climate change focus on reducing emissions through increase the reliability on renewable energy, energy efficiency, and reforestation, while adaptation strategies

aim to enhance the communities and ecosystems resilience to the changing climate (UNFCCC, 2020).

Climate change poses a significant challenge to Iraq, exacerbating existing environmental and socio-economic issues. The country is particularly endangered due to its arid climate, reliance on irrigation, and fragile political landscape. Rising in average temperatures, decreasing precipitations, and increasing the droughts and heatwaves are some of the major impacts observed in recent years. Iraq's mean annual temperature has increased and this warming trend is accompanied by a decrease in annual rainfall, leading to more severe water shortages. The Tigris and Euphrates rivers, crucial for the country's water supply, have seen reduced flow rates, impacting agriculture, drinking water, and electricity generation (World Bank, 2021).

The environmental challenges are further compounded by the legacy of conflict and instability, which hindering the country to respond effectively to climate change (IOM, 2021).

The agricultural sector in Kurdistan region of Iraq faces many irrigation challenges due to climate changes, water scarcity, and inefficient water use. The country's agriculture, which depend on irrigation, suffers from water shortages induced by upstream damming, climate change, and poor management practices. These challenges have led to decline in crop yields and increased soil infertility, threatening food security and livelihoods (World Bank, 2021). The use of treated wastewater offers a promising opportunity to replenish irrigation water supplies. Iraq can use treated wastewater to recycle and reuse water for agricultural purposes, thereby decreasing the pressure up on freshwater resources, improve water quality, helps in addressing water shortages, promotes sustainable agriculture, enhance crop productivity and more resilient environment (FAO, 2019; UNDP, 2020).

The objectives of conducting survey about using treated wastewater for irrigation were:

1. Addressing the education level of the public and stakeholders about the use of treated wastewater for irrigation
2. Showing the positive impacts of using treated wastewater on crop yields, soil health, and overall agricultural productivity, thereby encouraging its adoption.
3. Engaging community members and stakeholders in supporting and participating in wastewater treatment projects, fostering a sense of ownership and responsibility.
4. Raising awareness among policymakers and government officials to garner support for legislation, funding, and policies that promote wastewater treatment infrastructure and technologies.
5. Addressing common myths and misconceptions about wastewater treatment processes and the safety of treated wastewater for various uses.
6. Gaining a deep insight into the community's requirements and perspectives on wastewater treatment for irrigation will help tailor solutions that are both effective and acceptable.

Data Collection Activities:

○ **Questionnaires:**

- Number of questionnaires: [174]
- Target population: [all community were engaged specially youth category]



Summary: Questionnaire on wastewater treatment for irrigation to mitigate water scarcity issues offers several key benefits;

- Gather quantitative data
- Reaching wide audience.
- Identify knowledge levels regarding wastewater treatment for irrigation.
- Attitude and perception identification.

Interviews:

- Number of interviews conducted: [30]
- Interviewees:

Interviews were focused on people on charge with activities related to ecosystem conservation and water resource management directories such as directory of ecosystem reservation in Duhok and Zakho, Youth center directory, water resource

directory in Dohuk, University members, and activist in climate change issues. The interviews offer some key benefits;

- Access to specialized knowledge.
- Information validation.
- Identify best practice.
- Policy development discussion.
- Enhance innovation



○ **Focus Group Discussions (FGDs):**

- Number of FGDs conducted: [2]
- Participants: [12 person per FGD, different age, occupation, and academic levels]



Focus group discussion were conducted to;

- Collect diverse perspectives
- Identify key issues related to wastewater treatment challenges and future.
- Discuss solution to water scarcity.
- Enhance community engagements.
- Discuss policy and practice.

Results and discussion

1- Results of questionnaire

General trends regarding the participants of questionnaire survey;

A. Education levels

The bar chart (fig, 1) shows the education levels distribution among study population. We can conclude that the majority of the population is either high school or college students (30%, 30%) respectively, followed by those with a BSc (20%). The numbers decrease significantly for those with diplomas (10%), and the smallest groups are the illiterate (5%) and those with MSc. & PhD degrees (5%).

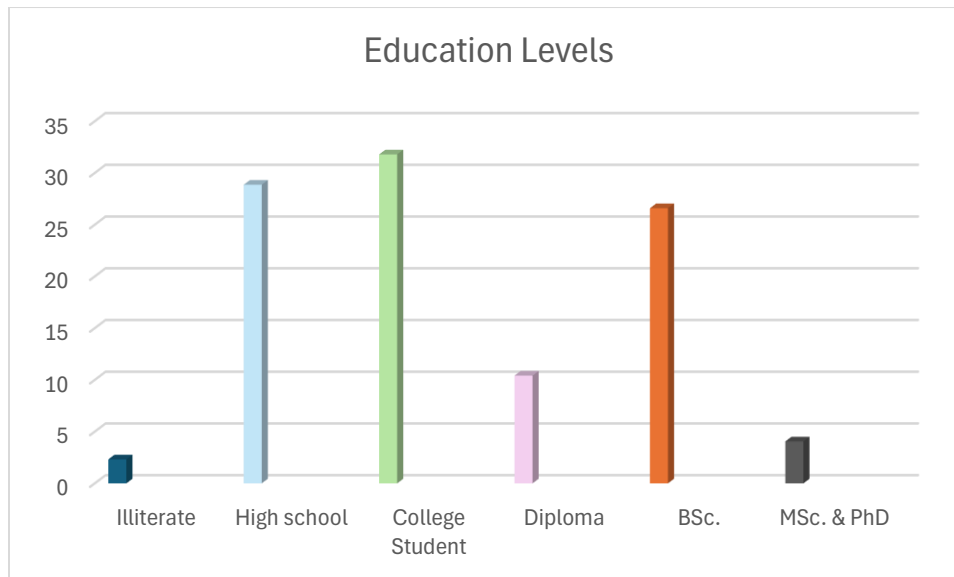


Figure 1: Education levels regarding questionnaire

B. Age categories

The pie chart (fig,2) shows the distribution of age categories in percentages. It shows that the majority of the respondents falls within the 16–30-year age range (68.79%), followed by the 31-45 year (26.01%), and a small percentage falls within the 46-60 year (5.2%).

A. Gender

Figure (3) shows the percentage of male to female in studied population. Results indicate that both genders were representing adequately in study with a slight difference. Hence, the female ratio was 54.9% in comparing to male 45.1%.

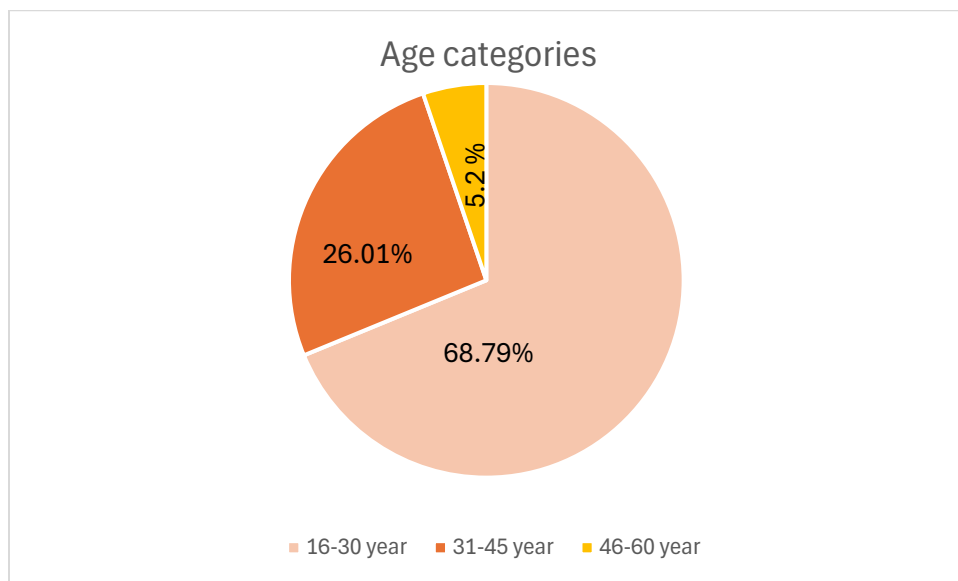


Figure 2: Age categories

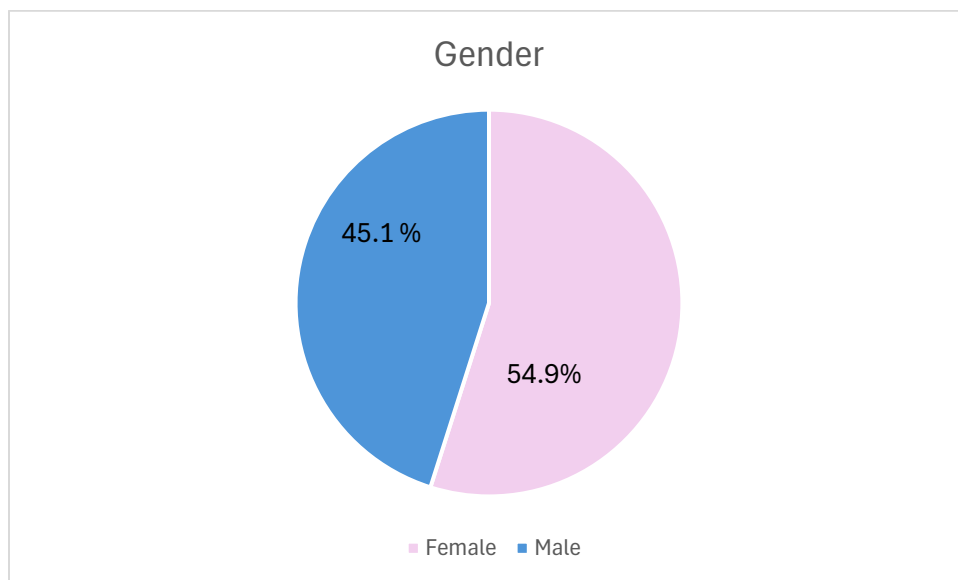


Figure (3) Gender

B. Source of Information

The bar chart represents the sources of information, along with their respective usage frequencies (fig, 4). It reveals that social media is the dominant source of information (110 respondents), followed by educational institutions (30 respondents), traditional media (35 respondents), professional training, and NGOs in descending order of usage (below 10 respondents each).

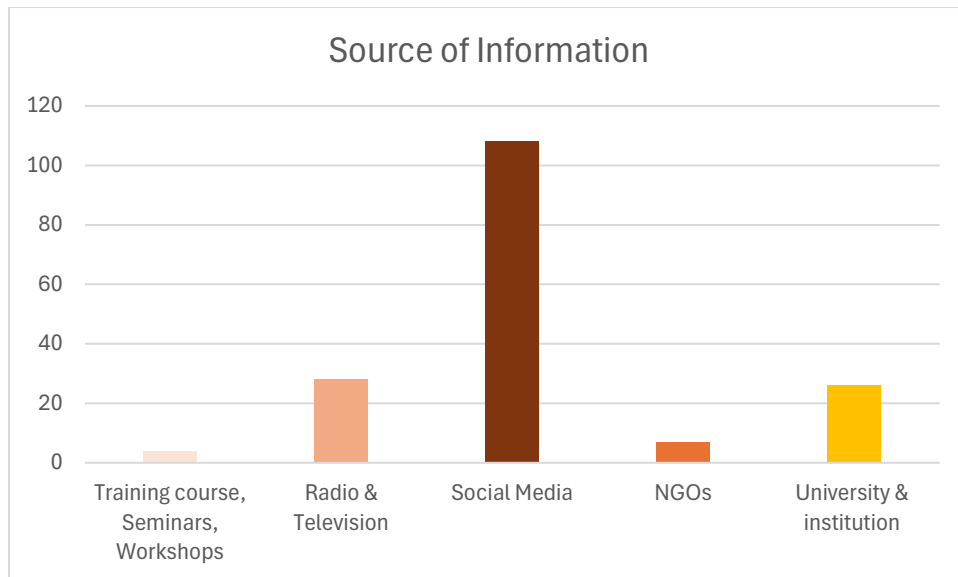


Figure 4: Source of Information

C. Level of awareness

The pie chart (fig,5) represents different levels of awareness, divided into three categories:

25-32 (low): This segment represents a small portion of the chart, indicating that a minor percentage of the population falls into the low awareness category.

33-40 (medium): This segment is larger than the low awareness segment but smaller than the high awareness segment, suggesting a moderate percentage of the population has medium awareness.

41-48 (high): This is the largest segment, showing that the majority of the population falls into the high awareness category.

The chart suggests that most individuals have a high level of awareness, with fewer individuals in the medium and low awareness categories.

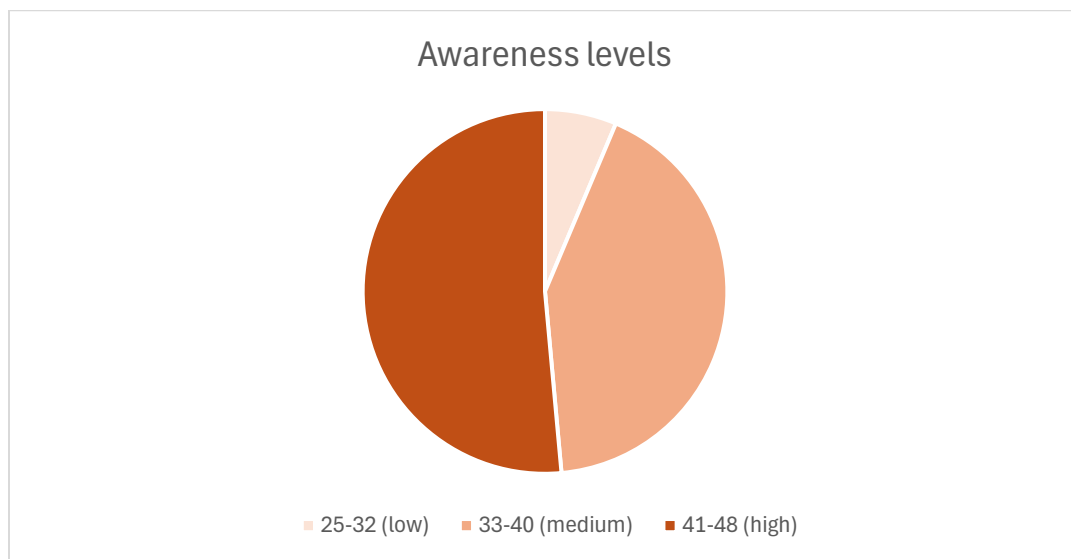


Figure 5: levels of awareness among studied population

The questionnaire included many close-ended questions and one open-ended question.

The open-ended question was **(In your opinion what changes or developments will increase the trust in using treated wastewater for irrigation? Any recommendation or advice do you have to ensure the wide spreads of such programs?).**

The majority of respondents indicated a lack of information on the topic, followed by a need for awareness programs and advanced treatment solutions. Other suggestions included proving the efficacy of TWW for irrigation, using proper filters, governmental support, and exploring alternative uses before direct

application in irrigation. A small number of respondents were completely opposed to using treated wastewater.

Table 1: Shows the Answers regarding open-ended question

Answers	Respondant	Percentages
I don't have information	51	31.67
Awareness programe	30	18.69
Advance treatment	23	14.28
Proving that this water is usefull for irrigation	12	7.45
Using proper filters in manucipal wastewater system	11	6.89
Govermental support and supervision	10	6.29
saving fresh water resources will enhance me to use T.W.W	8	4.99
firstly use this water for other purpose like car washing, road washing	4	2.48
Colabration by defferent sectors	3	1.86
Aportunity of using TWW in clean energy production	2	1.94
I will never use this kind of water in my life	2	1.94
Ecosystem reservation	2	1.38

Relationship Between Level of Awareness & Level of Education

Table 2: Relationship Between Level of Awareness & Level of Education

knowledge Level Level of education	(25-32) Low	%	(33-40) Medium	%	(41-88) High	%	X ²	rc
Illiteracy	0	0	1	0.578	3	1.734	13.743	0.019
secondary	2	1.156	20	11.561	21	12.139		
Academic student	4	2.312	25	14.451	26	15.029		
Diploma	3	1.734	6	3.468	9	5.202		
BSc.	2	1.156	19	10.983	25	14.451		
Institute or College	0	0.000	2	1.156	5	2.890		
Table value (rc): 1%=0.124036 5%=0.147558								

Relationship Between Level of Awareness & Gender

Results included in table (4) shows the relationship between awareness levels and gender.

Table (3): Relationship Between Level of Awareness & Information Sources

knowledge Level Information sources	(25-32) Low	%	(33-40) Medium	%	(41-88) High	%	X ²	rc
Training course	1	0.578	2	1.156	1	0.578	5.18	0.012
Radio & Tv	0	0.000	15	8.671	15	8.671		
Social media & Internet	10	5.780	41	23.69	55	31.792		

NGOs	0	0.000	3	1.734	4	2.312		
University and institution	0	0.000	12	6.936	14	8.092		
Table value (rc): 1%=0.124036 5%=0.147558								

Table 4: Relationship Between Level of Awareness & Gender

	(25-32) Low	%	(33-40) Medium	%	(41-48) High	%	X ²	rc
Male	6	3.468	44	25.434	47	27.168	0.8051	0.0051
Female	5	2.890	59	34.104	42	24.277		
Table value (rc): 1%=0.124036 5%=0.147558								

Relationship Between Level of Awareness & Age

Knowledge Level Age	(25-32) Low	%	(33-40) Medium	%	(41-48) High	%	X ²	rc
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(16-30)Years	7	4.046	56	32.370	56	32.370	4.0912	0.0114
(31-45)Years	3	1.734	14	8.092	28	16.185		
(46-60)Years	1	0.578	3	1.734	5	2.890		
Table value (rc): 1%=0.124036 5%=0.147558								

Table 5: Relationship Between Level of Awareness & Age

2- Results of Interviews

Results summarized in table (6) presents responses to different questions about the use of treated wastewater for irrigation and other purposes. When the interviewees asked about the reasons to use treated wastewater for irrigation 63.11% address climate changes and water scarcity as the main reason. The advantages of using treated wastewater for irrigation was expected to decrease the pressure on freshwater by the opinion of 41.67% of respondents.

There were different answers regarding the main challenges in implementing TWW project. Lack of awareness and poor knowledge was the viewpoint of 29.73%, others (24.32%) suggests that technological barriers is the main challenge.

The most chosen factor that motivate farmers to adopt TWW for irrigation was ensuring the safety by 33.33%/. Awareness program shown to have a high influence in motivate the farmer to use TWW (28.57%) and to address concerns regarding its use (50%). When interviewees questions about the expected outcomes of TWW project to Duhok city, the respondents shows that it will mitigate the water scarcity issue and enhancing ecosystems health (50%, 37.5%) respectively.

3. Results of Focus Group Discussion

The focus group discussion (FGD) (table 7) results on using treated wastewater (TWW) for irrigation reveal several insights into the participants' perceptions, concerns, and expectations. All participants (100% in both groups) mentioned that they have never used treated wastewater for irrigation. However, they expressed openness to using it if it, viewing it as a good option.

Participants recognized some benefits of using treated wastewater such as reserving fresh water (37.5% in FGD 1), saving money (12.5% in both groups), and using it for household purposes (12.5% in FGD 2).

Although Some participants showed willingness to use TWW for non-edible plants (50% in FGD 1), concerns were raised regarding doubts about safety (33.33% in FGD 1 and 42.86% in FGD 2) and lack of assurance (16.67% in FGD 1 and 14.29% in FGD 2).

Contamination by microorganisms and bacteria (28.57% in FGD 1 and 42.86% in FGD 2), lack of community acceptance (42.86% in FGD 2), and lack of technology (28.57% in FGD 1) were the key risks highlighted.

Community acceptance of TWW depends on awareness and knowledge-building efforts (e.g., training, seminars) – mentioned by 40% in FGD 1 and 16.67% in FGD 2. Time and resources required for community campaigns (40% in FGD 1). Expectations for widespread use of TWW for irrigation in next 5–10 years if implemented with high quality and safety (83.33% in FGD 1 and 78.57% in FGD 2). Suggestion for enhance the success of such project indicate learning from successful examples in nearby countries (50% in FGD 1), Initiating awareness campaigns (33.33% in FGD 1 and 3.33% in FGD 2), and Prioritizing water conservation (16.67% in FGD 1).

Table (6) presents interview about the use of treated wastewater for irrigation and other purposes

Interviews	
1- "What reasons would encourage you to use treated wastewater (TWW) for irrigation?"	
Answers	Percentages
Climate change and water scarcity lead to think about this kind of projects	61.11
Quality and safety standards	38.89
Ensure agricultural production	11.11
2- "Could you list the expected advantages of using treated wastewater (TWW) for sustainable irrigation?"	
Answers	Percentages
To reserve under ground water	25.00
To ensure irrigation in drought period	33.33
To reduce the increasing pressure on fresh water	41.67
3- "In your opinion, how could treated wastewater (TWW) help conserve water resources for a better ecosystem and enhanced food security?"	
Answers	Percentages
People will save fresh water for drinking and other personal purposes while using TWW for agriculture, lundry, and car wash which lead to a wis	31.58
Replenish water reserver	21.05
Sustainable agriculture	47.37
4- "What are the main challenges that could affect these projects? Is it technological, financial, or community-based challenges?"	
Answers	Percentages
People are not aware and have poor knowledge about TWW and recycling	29.73
Lack of technology	24.32
Lack the information about the severity of water scarcity ant its threats	5.41
Govemrntal actions are slow	10.81
Finantial challenges	21.62
Safety standards (contamination levels)	8.11
5- "If you had the opportunity to use treated wastewater (TWW), for what purpose would you use it?"	
Answers	Percentages
For Irrigation	63.33
Car wash	20.00
Landery	10.00
Drinking	6.67
6- "Do you believe that the current wastewater treatment processes are sufficient to ensure high-quality treated wastewater?"	
Answers	Percentages
70-100% safe water	73.68
It depends on the purpose of wastewater reusing (is it for irrigation or drinking,...etc)	26.32
7- "In your view, do national and international regulations impact the treated wastewater (TWW) project?"	
Answers	Percentages
yes it plays a vital role	71.43
Social acceptance and the relegious person will play main role	14.29
NGOs role will enhance project	14.29
8- "What factors would motivate farmers to use treated wastewater (TWW) for irrigation?"	
Answers	Percentages
Trust in treatment strategy	19.05
Research ensuring safety of TWW	19.05
awareness programme	33.33
Finantial aids to farmers	28.57
9- "As a planner, what strategies would you implement to encourage the use of treated wastewater (TWW)? How would you address public concerns or rejection?"	
Answers	Percentages
Conduct seminars and training courses about the beneficial effect of TWW	50.00
Support farmers with finantial aids	16.67
Well designed regulation	8.33
Showing evidence about the eligidability of TWW	25.00
10- "In your opinion, what are the expected outcomes of the treated wastewater (TWW) project for Duhok city?"	
Answers	Percentages
Increase green cover	12.50
Enhance ecosystem health	37.50
Matigate water scarcity	50.00

Table (7) presents focus group discussion results about the use of treated wastewater for irrigation and other purposes

Focus Group Discussion		
1- "Could you share your experience with irrigation practices? Have you ever used treated wastewater (TWW), or have you considered using it?"		
Answers	FGD 1 (%)	FGD 2 (%)
We didn't use it ever, but if it is available it will offer a good option for irrigation	100.00	100.00
2- In your opinion, do you think treated wastewater (TWW) could have positive outcomes? What are some of its potential advantages?"		
Answers	FGD 1 (%)	FGD 2 (%)
Reserving fresh water	37.50	0.00
offer good option for irrigation	37.50	62.50
saving money	12.50	0.00
Using in household for different purposes	12.50	25.00
Cant guarantee of using it		12.50
3- Would you consider using treated wastewater (TWW) if it were available? What concerns or doubts do you have about it?"		
Answers	FGD 1 (%)	FGD 2 (%)
I will use it for non-edible plants	16.67	0
Yes, definitely	33.33	42.86
Water scarcity has the key role of making me use TWW	33.33	14.29
I will use it but I am not sure about its safety	16.67	14.29
There is no such project and we lack technological support	0	28.57
4- What challenges do you think exist regarding the safety and quality of treated wastewater (TWW)?"		
Answers	FGD 1 (%)	FGD 2 (%)
Contamination level by microorganisms(bacteria & viruses)	28.57	14.29
Lack of technology	42.86	42.86
Lack of community acceptance	28.57	42.86
5- "Will the initial budget for this project impact its implementation? How do you assess the initial investment in relation to the long-term benefits of using treated wastewater (TWW)?"		
Answers	FGD 1 (%)	FGD 2 (%)
Yes, it will have a huge effect	20	33.33
No, this kind of beneficial projects deserve to spend money on it	20	50.00
It will affect the decision of establishing such projects but the expected outcomes is valuable	60	16.67
6- "Do you think treated wastewater (TWW) will be accepted by the community for use in irrigation? What are your thoughts on how to increase its acceptance?"		
Answers	FGD 1 (%)	FGD 2 (%)
People will accept it	40	33.33
Farmers will accept it if they gain a proper knowledge about the process (seminars, training courses,...etc)	20	33.33
Time needed to gain community acceptance by conducting tests for TWW and showing acceptable safety levels	40	16.67
A well designed campaign needed to gain community acceptance(social media campaign)		16.67
7- What do you expect treated wastewater (TWW) to have on environmental health? What are the potential positive and negative effects on soil health and water resource conservation?"		
Answers	FGD 1 (%)	FGD 2 (%)
It will affect soil positively if it is well designed by adding nutrient to soil	60	66.67
It will mitigate the effect of climate change and water scarcity	20	0.00
Save the ecosystem	20	0.00
I have doubt about its safety		33.33
8- In your opinion, what technologies could enhance the use of treated wastewater (TWW) for irrigation?"		
Answers	FGD 1 (%)	FGD 2 (%)
Testing machine to guarantee quality and safety	83.33	55.56
Smart irrigation system	16.67	
Social media will play a key role in enhancing the use of TWW		44.44
9- "What do you expect the future of treated wastewater (TWW) to be in your city over the next 5 to 10 years?"		
Answers	FGD 1 (%)	FGD 2 (%)
Wide spread use of TWW	83.33	78.57
TWW with high quality and safety will emerge	16.67	21.43
10- "In your view, what changes are necessary to enhance the use of treated wastewater (TWW) for irrigation?"		
Answers	FGD 1 (%)	FGD 2 (%)
Take a well knowledge about such project from nearby country that use this system	33.33	33.33
Community acceptance	50.00	33.33
reserve water	16.67	33.33

Conclusion

The findings highlight some significant trends about the opportunity of using treated wastewater for irrigation in Duhok and the people awareness levels regarding such projects. It clarifies the significance of digital platforms and traditional media in raising awareness. However, efforts to increase the impact of NGOs and training

courses could further enhance overall awareness levels. This underscores the need for targeted strategies that utilize high-impact sources effectively.

Higher education levels are strongly associated with higher awareness levels. Meanwhile, illiteracy and lower education levels (Secondary) are more associated with medium and low awareness. This emphasize the need for educational programs to improve knowledge and awareness, especially among less-educated groups through extensive awareness seminars, training courses, and workshops.

The overall results of study show optimism about using treated wastewater for irrigation, but some concerns about safety, community acceptance, and technological adequacy remain barriers. Solutions like education, testing technologies, and learning from other successful projects could drive acceptance and implementation.

Summary

In this research we tried to make our society aware that life cannot be without water and we must protect water better than anything else Therefore, with the increase in water use and excessive use of water today, there will be a need for a drop of water in 2050-2060. In order to better conserve fresh water for drinking and eating purposes, consider establishing a water treatment and reuse project in Duhok province, For agricultural work, car washing and other daily activities. In this research we worked on the importance of this project for the relevant parties, people and employees different classes and classes how much with the establishment of this project for the future of Duhok province.

As a result, we have reached the following conclusions:

1-Motivational courses should be opened.

2-This re-treated water should be properly tested and good assurance should be given to the citizens by the government and government institutions.3-The results of this project should be compared with the results of clean freshwater irrigation.

Challenges and Limitations:

-There was little time

-The budget was low

-They were with university experience

There were several other obstacles, but we were able to do the job and achieve good results.

Recommendation

1 - Educate and Raise Awareness through conducting seminars and workshops to highlight the importance of treated wastewater reuse for water security, environmental sustainability, and economic benefits.

2- Address Technological Challenges: Focus on common issues like energy efficiency, treatment technology selection, and maintenance challenges.

3- Engage Stakeholders: Encourage dialogue among different participants to identify their needs, concerns, and potential contributions.

4- Hands-On Demonstrations: Include case studies of successful wastewater reuse technologies.

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Appendices

Datasheets, pens and paper and distribution of leaflets, distribution of incentive videos and pictures and discussion of the project.

Acknowledgments

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