Biological and Clinical Sciences Research Journal
eISSN: 2708-2261; pISSN: 2958-4728
www.bcsrj.com
DOI: https://doi.org/10.54112/bcsrj.v6i2.1547
*Biol. Clin. Sci. Res. J., Volume, 6(2) **2025**: 1547*
Original Research Article

Wastewater Irrigation: A Study of Power Relations and Community Dynamics

Maria Khalid[1]*, Izhar Ahmad Khan[1], Naveed Farah[1] and Fahd Rasul[2]

[1]*Department of Rural Sociology, University of Agriculture, Faisalabad-38040, Pakistan*
[2]*Department of Agronomy, University of Agriculture, Faisalabad-38040, Pakistan*
*****Corresponding author email address: mariakhalid0786@gmail.com*

(Received, 5th January 2025, Accepted 25th February 2025, Published 28th February 2025)

Abstract *Wastewater irrigation has emerged as a critical practice in addressing canal water scarcity and enhancing agricultural productivity.* ***Objectives:*** *This study explores the socio-political implications of using untreated wastewater for irrigation, emphasizing the complex interplay between water management, governance, and social equity.* ***Methodology:*** *By analyzing case studies from various wastewater-using communities, the paper highlights how wastewater irrigation in vegetable production can alleviate and exacerbate existing socio-political tensions, particularly regarding access to water resources, public health concerns, and food sustainability.* ***Results:*** *The study examines stakeholders' perceptions and the farming community's responses to wastewater irrigation. It's shedding light on the governance challenges in managing this multifaceted issue. Ultimately, this paper argues the drawbacks of using wastewater and the need for effective irrigation practices that require technological innovations, inclusive political discourse, and community involvement to address the underlying power dynamics.* ***Conclusion:*** *The findings highlight the necessity for interdisciplinary approaches to manage wastewater and irrigation sustainably and equitably in the face of increasing wastewater and water demands for irrigation*

Keywords: Wastewater irrigation, perception, political dynamics, community relations.

[***How to Cite***: Khalid M, Khan IA, Farah N, Rasul F. "Wastewater Irrigation: A Study of Power Relations and Community Dynamics". *Biol. Clin. Sci. Res. J.*, **2025,** 6(1):1-11. doi: https://doi.org/10.54112/bcsrj.v6i1.1547]

Introduction

Wastewater irrigation has deep historical roots, spanning various civilizations and regions. Historically, the use of domestic wastewater for irrigation can be traced back to the Bronze Age (circa 3200–1100 BC) in regions such as China, Egypt, the Indus Valley, Mesopotamia, and Crete. It was a practical solution to enhance agricultural output in limited freshwater resources. For instance, in ancient China, human waste was systematically applied to fields, a practice that continues today under various forms of treatment and regulation (1). Water reuse is not a new technique or concept; knowledge of wastewater treatment and reuse has accumulated throughout humankind's history. Land application of human waste is an old practice, which has undergone several development stages from ancient to contemporary times (2). Similarly, the Greeks and Romans employed wastewater for crop irrigation around urban centers like Athens and Rome, which was crucial for sustaining agriculture in densely populated areas (1). The sewage farms utilized untreated wastewater to fertilize crops, effectively addressing agricultural needs and urban waste disposal challenges (1). As cities grew rapidly during the 19th century, similar systems were adopted across Europe and North America. For example, Mexico City's drainage canals were designed to collect wastewater for irrigation in the Mezquital Valley, which now supports extensive agricultural activities on approximately 90,000 hectares (1). The socio-political landscape surrounding wastewater irrigation is complex, involving stakeholders from government agencies to local farmers who must navigate regulatory frameworks, health risks, and public perceptions. Effective management practices are crucial to maximizing the benefits of wastewater use while minimizing potential health hazards associated with pathogens and contaminants (3). Water scarcity is a critical issue affecting agricultural practices globally, exacerbated by climate change, population growth, and inefficient water management. Approximately 70 percent of global freshwater withdrawals are used for agriculture, highlighting the sector's significant impact on water resources (4). In many developing countries, the combination of excessive water demand and limited freshwater availability has made wastewater an attractive alternative for irrigation. Utilizing treated wastewater not only conserves precious freshwater resources but also addresses the challenges posed by increasing agricultural demands (5). Wastewater often contains a variety of pathogens, including bacteria, viruses, and parasites. Agricultural workers and their families are at heightened risk due to direct exposure during irrigation activities. Epidemiological studies have shown that individuals exposed to wastewater are significantly more likely to suffer from diarrheal diseases and parasitic infections. For instance, a meta-analysis revealed an odds ratio of 1.65 for diarrheal disease and 5.49 for helminth infections among exposed agricultural workers and their families. Children and immunocompromised individuals are particularly vulnerable, facing higher risks of infection compared to healthy adults (1). The transmission pathways for these pathogens include direct contact with contaminated water, soil, and crops. Foodborne outbreaks linked to vegetables irrigated with wastewater have been widely reported, highlighting the potential for pathogens to enter the food chain (6). Contaminants such as fecal coliforms and enteric viruses can survive on crop surfaces long enough to pose a risk to consumers, especially when crops are consumed raw (4). Vulnerable populations such as low-income communities that rely heavily on agriculture for their livelihoods are disproportionately affected by these health risks. These communities often lack access to safe drinking water and sanitation facilities, compounding the dangers associated with wastewater irrigation (4). Irrigation and drainage departments manage water resources to optimize agricultural productivity while preventing environmental degradation. Their role includes promoting best practices for using treated wastewater in irrigation systems. Research highlights the benefits of integrating reclaimed water into irrigation strategies, which can improve soil fertility and crop resilience (7). Environmental protection authorities focus on the ecological impacts of wastewater irrigation. They set guidelines for

acceptable contaminant levels in wastewater used for irrigation and monitor compliance with these standards. The potential for heavy metal accumulation in soils and crops from wastewater irrigation has been documented, highlighting the need for stringent regulatory frameworks (8). Food authority departments are tasked withensuring food safety standards are met in agricultural practices involving wastewater. They monitor the quality of produce irrigated with wastewater and enforce regulations that prevent contaminated crops from reaching consumers. Studies have shown that crops irrigated with untreated or inadequately treated wastewater can harbor harmful pathogens, increasing the risk of foodborne illnesses (9). Water and sanitation agencies are integral to the treatment and management of wastewater used for irrigation. They establish treatment standards that wastewater must meet before being reused. For example, research indicates that treated wastewater can significantly enhance crop yields while reducing reliance on freshwater resources (10).

Many countries lack comprehensive guidelines for wastewater treatment and reuse in agriculture. Although, the World Health Organization's (WHO) established guidelines for safe wastewater use are often not implemented effectively at the local level (6). For instance, a review highlighted that despite the existence of WHO guidelines, many regions still permit the use of untreated wastewater due to inadequate monitoring and enforcement mechanisms (9). Many agricultural workers and their families are not fully informed about the potential dangers posed by pathogens in wastewater, such as helminth infections and other waterborne diseases (11). This lack of knowledge can lead to complacency in adopting safe practices, as farmers may prioritize crop yield over health considerations. Additionally, consumers may not be aware that their food has been irrigated with wastewater, further perpetuating the cycle of risk (12). Water scarcity in urban areas compels farmers to rely on available wastewater sources for high-value crops, as they may have no alternative irrigation options (6). The immediate economic benefits derived from increased crop yields can overshadow concerns about long-term health effects. Many farmers accept these risks as part of their daily lives, particularly when they lack access to adequate healthcare resources to address any resultant health issues (13). A meta-analysis indicated an odds ratio of 1.65 for diarrheal diseases and 5.49 for helminth infections among agricultural workers exposed to untreated or partially treated wastewater (9). Most of the studies discuss the perception of farmers in wastewater irrigation and the previous studies had focused on water management. Most of the studies showed the blames on the farmers but they neglect the farmer's viewpoints about the reasons for wastewater irrigation. In this study, we aim to explore the involvement of institutions in wastewater irrigation and in that community. Several studies have addressed the health and environmental implications of wastewater irrigation for vegetable production in various countries including Pakistan (14,15), but rigorous pragmatic studies have not been undertaken on role of institutions in wastewater irrigation in vegetable production. Other studies have however been undertaken on farmers perceptions and attitudes toward wastewater reuse and other sectors (16-18). A study by Carr et al. (16) focused on examining the underlying factors leading to either a positive or negative perception of reclaimed water. Mojid et al. (17) posit that the current status of wastewater for irrigation is based on farmers' knowledge and perceptions about wastewater irrigation. Notably, such studies have been limitedin their scope. Chaoua et al. (15) investigate the farmers' attitudes, toward economic, social, environmental, and health sustainability of wastewater irrigated farms. Sohail et al. (18) explored the knowledge of farmers about the impacts of wastewater reuse in agriculture and the adaptative behavior of various techniques regarding climate change. He emphasized that awareness among farmers about wastewater health risks and adaptation of good practices could be possible only through the involvement of government. The theme of the study is therefore relevant. Knudsen et al. (19) point out that the need for further insights into farmer's perception of risks and risk awareness when using human excreta and wastewater for agricultural production is very important to inform stakeholders on how to promote health programs and activities towards the education of farmers and consumers on untreated wastewater irrigation.

ection 2, presents a brief overview of wastewater, institutions, and power in the study area (Faisalabad, Punjab Pakistan), providing a review of farmers' perception of wastewater irrigation and relevant literature surrounding the politics of wastewater irrigation. Section 3, discusses the material and methods employed in this paper. Section 4, presents our main research findings, starting with an analysis of the role of formal and informal institutions with explicit attention to visible and hidden power, and authority and perception of farmers about wastewater health risks. Finally, we present a discussion followed by concluding remarks and policy recommendations (Section 5)

Material and Methods

Study area: The research was conducted in the adjacent villages of wastewater collecting drains Madhuana and Paharang drains of Faisalabad in the province of Punjab (Figure 1). Faisalabad, the 3rd largest city in Pakistan with a population of more than 9 million, is well known for having numerous industries in various sectors. Faisalabad is the major contributor to GDP of Pakistan i.e. over 20 percent. It is the center of the Textile industry in Pakistan constituting more than 65 percent of textile export market of Pakistan. All these production units produce wastewater in immense quantity therefore wastewater management and industrial effluent in particular is one of the major environmental issues of Faisalabad City (20). It's the best location to investigate wastewater irrigation's health risks. The Paharang drain in Faisalabad was once a stormwater carrying drain but presently it is highly polluted by industrial wastes (21). In these sites, vegetable cultivation has become the main livelihood for farmers (22). At Paharang drain, farmers had small landholdings and they were supported by labor work and agriculture work. Wastewater exposure has been linked to viral, bacterial, and protozoan diseases such as salmonellosis, shigellosis, cholera, giardiasis, amoebiasis, hepatitis A, viral enteritis, and other diarrheal diseases (23, 24).

Figure 1. The map showing the wastewater using sites of Faisalabad and study area. The different geographical location marks in figure (1) are wastewater using villages. This is drawn by using ArcGIS software.

Description of data:

Data was elicited through qualitative methodologies such as key informant interviews as well as focus group discussions(25). Qualitative data was collected primarily in the form of interviews which were completed after visits to wastewater using villages, newly developed residential areas and industrial areas (hosting a diverse range of small- and large-scale factories). Data was collected in winter and summer throughout the year from April 2023 to February 2024. The first phase allowed for a careful selection of communities from two main wastewater sites-here referred to as C1 Paharang, C2 Madhuana drains where wastewater is used as a source of irrigation water. Further key informant interviews were conducted involving government officials from the irrigation and drainage department, water and sanitation agency and health department. During the second phase, focus group discussions with wastewater using farmers of adjacent villages of two main sites (C1 and C2) were conducted to obtain more nuanced insights into wastewater irrigation's health impacts and community behavior towards health risk reduction strategies. Focus group discussions were conducted and the estimated time of each group discussion was comprised of 40 to 60 minutes. We positioned our inquiries in villages near Faisalabad's main drains where wastewater irrigation is practiced and informal conversations along with 16 FGDs with wastewater-using farmers in the study area took place. We asked the indigenous residents to describe about WWI, and to reflect on how problems have shifted over time. By way of an 'outward layering' of data sets, a process of learning was achieved that allowed the research to reveal the political dimensions of WWI. All questions were asked in the native language Punjabi with the help of two enumerators, trained for a few days before data collection. In the second phase, key informant interviews were conducted and for this purpose, prior consent from interviewees was obtained to participate in the study. Interviews were conducted at the participant's place of employment, in Urdu, and lasted between 60 and 90minutes. They were guided by interview guide questions focused on wastewater irrigation, health risks, health risks reduction strategies as well as the impact of each on farming community and hurdles in the implementation of these strategies.

Table 1. Characteristics of wastewater users at adjacent villages of both drains in Faisalabad.

Characteristics	C1	C2
Location	Paharang Drain	Madhuana Drain
Native language	Punjabi	Punjabi
History of wastewater usage	Since from last 2 decades	More than 2 decades ago
Source of Irrigation	Canal water, Wastewater & tube well water	Canal water, Wastewater & tubewell water

Finally, sixteen focus group discussions were conducted, with the help of community leaders identified in phase one, two focus groups with five to six participants per group from each community. Focus group participants yield by purposive sampling technique. The focus group consisted of wastewater vegetable growers and groups are formed on the base age like old and young and education. The groups were homogeneous inside but heterogenous when compared group to group. As per the culture of the communities, mostly males were involved in agriculture, so focus groups consisted on male participants. Questions were asked by the researcher's self but note-taking was made by the facilitator. All conversations were recorded through audio recorder and consent from participants was taken before the interview. Analysis of qualitative data generated through the focus group discussions and key informant interviews involved transcription and translation of field notes and audio recordings, identification of themes and sub-themes, rigorous coding, and triangulation with key questions (26, 27), using Alas. ti version 8.4.15.

Results

As context, we first provide farmer's perception of wastewater irrigation. This is followed by interviews and FGD results that detail the role of formal institutions (public and local domestic organizations and international organizations) and informal ones (e.g., traditional entities). The finding highlights specific initiatives and recommendations in Faisalabad, Pakistan. In the history of Faisalabad, based on the previous study Akhtar et al. (28) Approximately 140,000 cubic meters of wastewater is utilized daily for irrigation in the region. The insights from the key informant interviews and responses from FGDs, illustrate that wastewater irrigation in Faisalabad has started for many decades and the majority of the results showed it started in from last few decades.

Farmers perception of wastewater irrigation: Perception and awareness about wastewater irrigation were assessed through focus group discussion. For analysis, we used thematic analysis of the collected case studies. The variation in responses based on age and education was observed. The difference in perception of irrigation water quality is highlighted that shows mostly less educated farmers had a positive perception towards water quality. We also find differences in perception about the use of the same irrigation water in washing vegetables after harvesting. Perception of eating unwashed vegetables varies in both age groups. In a focus group discussion, a young age, less-educated farmer said;

"Wastewater in the village contains animal manure that is like an energy drink for earth's health and also enhances the crops' production and we don't consider it dirty and poor for vegetable production. It's the best and easiest way to earn money because it firstly passes near to my fields, that's why I have the authority to sell it. Therefore, I am earning money by selling it to my fellow farmers for irrigation."

FGD participants communicated a positive behavior for what they perceive about wastewater irrigation in vegetable production. The availability of wastewater is the best way to compensate for the need for water and most of them consider that it has nutrients that increase the rate of production. Farmers thought it's an easy and investment-free profit-earning source. They had no clear concepts about nutrients and they don't bother with the source of nutrients and just focused on the production of crops. As another focus group young age participants described below;

"Without its use, vegetables could not flourish and grow properly. Wastewater is essential just like calcium for the human body. Same as, it fulfills the desire need for nutrients in the soil and throats magical properties, it increases the rate of production of crops."

Figure 2. The figure highlight lack of awareness of health risks of wastewater irrigation and community's opposing behavior towards wastewater health risks reduction strategies in Faisalabad, Pakistan.

Perceptions towards eating unwashed vegetables and washing hands and vegetables with the same irrigation water were observed and assessed through focus group discussion. Their perception was different in both age groups. The old age participants have a positive perception of washing hands after irrigation with the same irrigation water as compared to young age farming groups. They had poor knowledge about quality matters in irrigation water and preferred their cultural habits and traditions. As an old age farmer replied;

"We always wash our hands with the same irrigation water as we had seen our forefathers do this. They always taught us that running water is considered pure and clean."

A significantly similar awareness about problems of eating unwashed vegetables was found in both age group participants. But, according to an average, educated persons showed a negative perception of eating unwashed vegetables. An old age focus group participant stated that;

"When we were young, we used to eat produce on the farm without washing. We had never encountered food poisoning. But now if we eat unwashed produce, we may suffer from poisoning."

We also analyzed to determine whether significant differences existed in perceptions and awareness towards irrigation water and wastewater irrigated vegetable consumption among farmers residing in different farming sites. No significant differences were observed among educational status and age groups. The results concluded that the young age group and more educated like high school persons had more knowledge of wastewater contamination and unwashed vegetables can cause illness as compared to the old and less educated group.

Power, community and wastewater irrigation: Understanding the roles of formal and informal institutions in the illegal use of wastewater, as well as power dynamics within and between them, is essential for examining the institutional arrangement process.

Formal institutions: The Punjab Food Authority in Pakistan, has completely banned the wastewater use in edible crops to sustain the health of the community. However, vegetable cultivation through wastewater still exists in various cities basically in Faisalabad. The farming community is not satisfied with the role of government and institutional bodies. On the other side of the card revealed in key informant interviews with the Food Authority department that the farming community behaved ill-mannered and non-cooperative towards the team of the food department. Even though they try to break the rules in which they banned the use of wastewater in vegetable production. The environmental protection officer stated that the wastewater management responsibilities fall under the Water and Sanitation Agency, suggesting a complexity in governance and jurisdiction that may hinder effective environmental protection. There is a gap in current practices or policies to mitigate risks associated with wastewater irrigation and its effects on soil or land health. The division of labor (between the environment protection officers and the water sanitation agency) can create gaps in consistent policies and actionable steps toward environmental health. As the environment protection officer stated;

"Wastewater irrigation is becoming popular day by day in Faisalabad. Basically, in dealing with the environment, we focus on three components such as land, water, and air. Either wastewater irrigation is destroying rivers' water quality and soil structure. However, due to some restrictions, wastewater is not under our jurisdiction. Water and sanitation agency dealing with wastewater. Although it negatively affects the land and soil's quality. Protecting groundwater and soil health from potential impacts of wastewater irrigation should be a shared priority, and we are not working on wastewater yet but necessary initial steps must be taken to minimize these risks".

The Water and Sanitation Agency (WASA) community mobilizer stated that they try their best to develop a non-supportive sense in the community about wastewater irrigation. For this, the need is to start from the school level to break the stigma of isolating community members who engage in or support wastewater irrigation, strong cultural beliefs, lack of information, fear of health risks, and traditional practices that favor certain agricultural methods over others. Effective governance in the context of environmental health requires active oversight, especially in areas where stigma and misinformation prevail. This can lead to a lack of accountability and ineffective management practices that may exacerbate public health risks. The acknowledgment of manpower challenges highlights a critical issue of resource allocation within the agency. It echoes broader sociological concerns about inequality in access to resources and the impact this has on the capacity to implement change. As the water and sanitation agency's community mobilizer stated;

"Managing the social stigma of wastewater irrigation within the community is an ongoing effort for us, and we strive to communicate the benefits and safety measures of solid waste management at the school level. Monitoring and oversight of wastewater irrigation are not essential aspects of our operations, but we are committed to continuing improvement and we are facing challenges of manpower to manage it".

The statement reflects a complex interplay of social stigma, education, oversight, and resource challenges in the management of wastewater within a community. Addressing these issues from a sociological perspective requires a multifaceted approach that emphasizes community

engagement, education, and adequate resource allocation. For effective wastewater management, it is essential to foster an inclusive dialogue that challenges stigma while promoting health and safety initiatives.

There is a significant gap in knowledge about food safety practices, particularly regarding the handling of vegetables grown with potentially contaminated water. This highlights the role of education in shaping consumer behavior and perceptions. Addressing these gaps is crucial as it can influence public health outcomes and consumer trust. There is a misconception among consumers that washing vegetables is sufficient to remove pollutants. This reflects cognitive dissonance, where individuals might hold onto beliefs (that washing is enough) despite evidence to the contrary (that pollutants may persist). Trust is necessary between the food authority and consumers but the aggressive reaction of the community towards the food authority's action showed there is minimum trust between both. As the Food agriculture officer stated;

There is a misconception among some vegetable consumers that washing vegetables is enough to remove pollutants. It's necessary to understand the importance of safe handling practices all over the supply chain of vegetables from farm to fork. We are planning to test the vegetables at the local city level but due to a lack of facilities, we are unable to do this. We also ban wastewater irrigation in all edible crops but people are still using it. We try forcefully to follow it but it's really difficult. Public awareness campaigns and education on the safety of vegetables and irrigation sources are required (KII-FAD)."

There is inadequate infrastructure that reflects societal inequalities; communities with fewer resources may face increased health risks. The absence of technological resources for ensuring food safety exacerbates existing vulnerabilities, particularly in lower-income regions. The introduction of floating wetlands in wastewater treatment ponds signifies a progressive and sustainable approach to managing wastewater, with potential ecological and economic benefits. However, considerations around effectiveness, maintenance, climatic factors, and community engagement are crucial for successful implementation. Balancing these factors will be key to optimizing the benefits of this innovative treatment method in Faisalabad and similar areas. As the chief scientist of NIBGE stated;

"We introduce floating wetlands at wastewater collecting ponds of Uchkera, Faisalabad to treat the wastewater and wastewater passes through step by step in these seven ponds. Treated water becomes feasible for crop plantation at the end and becomes feasible to irrigate the crops (NIBGE-Chief Scientist)."

Farming community and wastewater irrigation: The focus group participants emphasized the financial strain on small farmers, who often operate on tight budgets and have limited resources. As input costs rise, many farmers face difficult choices about how to sustain their livelihoods. Some farmers resort to using wastewater as a less expensive alternative. This reflects a larger issue where regulatory bodies may not fully understand or appreciate the challenges faced by small farmers. The lack of dialogue and support from the government can make farmers feel isolated and marginalized, leading to a sense of injustice about their situation. One of the respondents stated that;

"I am a poor farmer with a land holding of 2 acres. Due to inflation, agriculture expenses like spray, diesel to run a tubewell, and fertilizers are not affordable. Just because of it, I am using wastewater for irrigation. The Food Authority department always destroys our vegetable fields. Even though they ignore our struggle and hard work behind it for the whole season. Their behavior is painful". "The government has not informed us of the precautionary measures and has not told us its harmful effects. They have completely banned it, which greatly affects the lives of the poor and small farmers. Due to lack of financial resources, people were forced to beg".

It showed the farmers are facing economic loss due to the institution's poor role and mostly small land-holding farmers are target groups of such losses. Government is negligent to them and never informs them of the actual side effects of wastewater irrigation. Lack of transparency is the main reason in which farmers feel helpless and mostly uninformed. The results showed the farmers get less crop yield and reduced income. The government bans wastewater use which is affecting not only the farmers but also their families. Sudden change and plughing are not a solution to stop the farmers from using wastewater.

"There was a scheme to build an advanced canal system in areas where canal water did not reach, we have been meeting various institutions and officers to build it for our village because due to housing societies, our water channels were broken and there was a dire need to repair it. For this purpose, we pay the money to the government but no one took notice of it and neither our requests have been implemented"

The farmers expressed the inadequacy of existing water supply sources. The statement reveals that farmers are actively engaging with various institutions and officials to push for the necessary improvements in their water supply systems. In summary, this statement reflects the frustrations and hopes of farmers who are striving for better water management in their communities. It showcases their dedication to advocating for infrastructure improvements, their sense of injustice regarding unacknowledged contributions, and the need for more responsive governance that can effectively address the ongoing challenges posed by both urban development and agricultural viability. The farmers are seeking recognition and action from authorities to ensure their voices are heard and their needs are met.

Informal institutions: The potential value of wastewater according to the farming community particularly in resource-constrained environments has a gap in the government's role in adequate wastewater management because people claim the government never tries to educate them on the safe use of wastewater. The head's statement acknowledges that without proper management and education, the risks associated with pathogens and pollutants in wastewater could pose serious health risks. The head of the village (Numberdar in the local language) suggested that;

"*Wastewater should be treated and various young farmers supported the suggestion and said that government should take actions to treat wastewater for irrigation and it should be safe for all sort of crops and vegetables too."*

Table 2. Depicts the range of reasons behind wastewater irrigation supported by formal and informal institutional bodies, as identified through key informant interviews and focus group discussions. WASA= Water and Sanitation Agency, FAO= Food Authority Officer, EPA= Environment Protection Agency, IWD= Irrigation and Drainage Department, L= Leader of the community, F= Farmers

Reasons behind wastewater irrigation	**Formal and informal institutional bodies**					
Questions	**WASA**	**FAD**	**EPA**	**IWD**	**L**	**F**
Improper wastewater management			■	■	■	
Poor infrastructure in community	■				■	■
Negligence of the institutions			■		■	
Lack of man power	■	■			■	
Community's non-cooperative behavior	■	■				
Impartiality in rules implementation		■			■	
Neglecting behavior					■	■

The potential value of wastewater according to farming communities particularly in resource-constrained environments has a gap in the government's role in adequate wastewater management because people claim the government never tries to educate them on the safe use of wastewater. The head's statement acknowledges that without proper management and education, the risks associated with pathogens and pollutants in wastewater could pose serious health risks. To further explore the role of institutions and community's behavior towards wastewater irrigation in the selected area, we draw on key informant interviews and focus group discussions in the given below.

Discussion

The study highlights the role of the formal and informal institutions and farmers' perception in magnifying wastewater irrigation in Faisalabad, Pakistan. By focusing on it, we have shown how various institutions contribute to the safe use of wastewater irrigation and ineffective law implementation. Perception is influenced by a combination of personal factors that affect how one understands and reacts to issues (29). The voluntary nature of exposure, uncertainty about the consequences of exposure, and the ease of perception and understanding of the benefits associated with exposure may also influence perceptions towards risks (30). Irrespective of the depth and level, most farmers have a general awareness of irrigation water contamination. Young and educated groups were somehow less confident in the quality of irrigation water at both drains. The comparison between water and vegetable quality, both farming groups considered that wastewater irrigation does not affect the quality of vegetables. Despite the use of irrigation water, the farmers show a negative perception of the role of institutions and policymakers. Farmers were convinced that training and provision of alternative water sources could reduce the use of wastewater rather than the implementation of strict laws. However, it is striking that more young farmer groups show a positive perception towards institutions as compared to old age and less educated farmers. But, the young age, highly educated farmers also had negative perceptions and disliking behavior towards boycotting the wastewater irrigation law. Other surveys have not studied such issues yet and they could be studied in the future.

At both sites, the institutional authorities performed poor roles as they plough and destroyed the crops and vegetables of poor farmers and it was a discouraging factor towards the practice. Our results showed that farmers perceived solid wastes, industrial wastes, and household sewage water as important water contamination sources as the best nutrient-rich source for the irrigation of vegetables. These findings are relevant to some previous literature like (Mojid et al., 2010; Carr et al., 2011) that have examined the farmers' perception of irrigation water contamination. The farmers' viewpoint may also include a call for alternative solutions. Instead of a ban, they might advocate for the development of safe sewage treatment processes, training on how to use treated wastewater safely, or support programs to help farmers transition to sustainable practices without jeopardizing their livelihoods. In summary, from the perspective of wastewater-using farmers, this situation highlights a critical need for government engagement, education on safe practices, and sustainable alternatives that can protect their livelihoods while addressing health and environmental concerns as discussed in a study (31). It underscores the importance of dialogue between authorities and affected communities to find solutions that balance public health with the needs of vulnerable populations. As discussed in a study by (32) the stakeholder's acceptance of recycled water is considered a success for recycling projects. Results reflect the intersection of economic need, regulatory challenges, and emotional strain within the context of small-scale farming. It highlights the urgent need for supportive policies and acknowledgment of farmers' struggles, along with a call for collaborative approaches to address the challenges posed by inflation and the need for dependable water sources. The consequences reflect a common tension between urban expansion and rural agricultural practices, where the needs of one party often overshadow the other. Farmers are affected not only by the loss of infrastructure but also by the overall alteration of their environment. Educational initiatives targeting schools may help shape the next generation's understanding and acceptance of wastewater management practices, potentially altering long-standing stigmas. Participatory governance approaches could foster trust, improve compliance with safety measures, and enhance the overall effectiveness of wastewater management strategies. The acknowledgment of bans on wastewater irrigation that are not adhered to raises questions about enforcement, compliance, and community behaviors.

This suggests a need for greater accountability measures and community engagement to foster adherence to health regulations. Increasing public awareness involves shifting societal norms around food safety. Education campaigns should be culturally sensitive and tailored to the community's existing beliefs and practices. This requires collaboration with community leaders and stakeholders to implement changes in perception and behavior effectively. Promoting wastewater for urban gardening, fodder crops, and vegetable cultivation suggests a practical approach to enhancing local food security, especially in densely populated cities. By encouraging these practices, the statement seeks to address dual challenges: urban food scarcity and effective wastewater management. The call for collaboration among the government, farmers, and vendors indicates an understanding of the complexity of the wastewater issue. Effective management requires input and cooperation from multiple stakeholders across all stages, from harvesting to post-harvest. Promoting safe practices around the use of wastewater in agriculture is crucial to mitigate potential health hazards. This necessitates effective risk communication strategies that inform stakeholders about safe handling, treatment methods, and monitoring practices. Urban agriculture presents a viable solution for integrating wastewater management into community practices. By utilizing treated wastewater for irrigation, communities can close nutrient loops, enhance food security, and promote sustainable agricultural practices. This integration supports local economies and fosters a sense of community ownership over resources.

***Challenges and Considerations**:* The promotion of wastewater use must be balanced with careful consideration of health risks. Ensuring that wastewater is treated to acceptable standards before use in agriculture is essential to protect public health.

***Societal Acceptance**:* Any campaign promoting wastewater use must also address potential societal stigma and fears. Community involvement in the planning and implementation stages can enhance acceptance and foster a sense of ownership and responsibility.

Declaration

Acknowledgements

This work was supported by Medical Research Council (MRC) and United Kingdom Research and Innovations (UKRI). We wish to acknowledge the support of administrations and university of Agriculture, Faisalabad, Pakistan. We are also grateful to farmers for sharing their knowledge and experience about wastewater irrigation.

Competing Interests

Authors declare that there are no competing interests regarding the publication of this article.

Authors Contribution

Maria Khalid conducted the research and field surveys to wrote the manuscript. Fahd Rasul assist in sites identification and implementation of the layout. Izhar Ahmad Khan and Naveed Farah planned the research layout and finalized the manuscript. All the authors have read and approved the manuscript in its final form.

Ethics Approval and Consent to Participate

Not applicable.

Consent for Publication

The study was approved by authors.

Funding Statement

Not applicable

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