



# Perceptions on the use of recycled water for produce irrigation and household tasks: A comparison between Israeli and Palestinian consumers

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## ABSTRACT

Water scarcity has resulted in extensive wastewater recycling for agricultural irrigation in both Israel and the Palestinian Territories. However, minimal data have been collected regarding perceptions about wastewater recycling between the populations in these two areas. While geographically close and economically linked, these two populations differ in terms of governance, income, and access to technology for wastewater recycling. To address the data gap pertaining to perceptions of wastewater recycling, a survey was administered among a convenience sample of subjects ( $n = 236$ ) recruited from Eilat, Israel and Bethlehem, West Bank, from May to November 2018. The survey included questions addressing knowledge of water sources, water scarcity, and recycled water; willingness to use recycled water for produce irrigation and household tasks; and demographics. Israeli willingness to use recycled water for various purposes ranged from 8.3% to 55.1%, and more than half of Israeli respondents were willing to serve both raw and cooked produce irrigated with recycled water. Willingness to use recycled water ranged from 28.9% to 41.7% among the Palestinian respondents, and Palestinian respondents were more willing to engage in high-contact uses (i.e. drinking and cooking) than Israeli respondents. Among the Israeli respondents, experience or familiarity with wastewater recycling and water contamination were frequently significantly associated with willingness to use recycled water. In contrast, among Palestinian respondents, personal water contamination experience, home water safety testing, and trust in authorities to monitor recycled wastewater reuse were frequently significantly associated with willingness to use recycled water. Given the likely increasing water stress in both Israel and the Palestinian Territories, as well as the continued evolution of wastewater treatment technologies and the substantial amount of agricultural trade ongoing between Israel and the Palestinian Territories, it is important to identify effective and appropriate outreach and communication strategies to enable successful and acceptable water recycling.

## 1. Introduction

The use of recycled water (municipal wastewater that has been treated) in agricultural and domestic activities can elicit an emotionally-charged response in some communities (Dolnicar et al., 2011; Hurlimann and Dolnicar, 2010; Schwartz, 2015). As such, extensive stakeholder engagement is often critical for the acceptance and success of new wastewater recycling projects (Morgan and Grant-Smith, 2015; Rozin et al., 2015). Specifically, understanding community knowledge levels and concerns and responding with appropriate outreach and engagement is important for new wastewater recycling endeavors

(Dolnicar et al., 2010). However, in some highly water stressed regions, stakeholder engagement has not been fully developed despite ongoing wastewater recycling (Lipchin, 2006; Tal, 2006). This lack of stakeholder engagement represents a disconnect between wastewater recycling projects and the communities they are intended to serve.

In the Middle East, water scarcity has necessitated wastewater recycling for agricultural irrigation in many countries, including Israel and the Palestinian Territories (Friedler, 2008; McIlwaine and Redwood, 2011; McNeill et al., 2009). In Israel, about 90% of municipal wastewater is treated and recycled, and of that more than 80% is used for agricultural irrigation (Berman et al., 2017; Dotan et al., 2016). In

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contrast, the West Bank treats and recycles less than ten percent of its municipal wastewater (Dotan et al., 2016; McIlwaine and Redwood, 2011; Mizyed, 2013). However, in the Palestinian Territories the use of untreated wastewater for agricultural irrigation is a common practice (Bieler, 2016; Ezery, 2016).

Despite this ongoing and extensive use of recycled water, as well as significant transboundary trade between Israel and the Palestinian Territories (Bank of Israel, 2014; Venghaus, 2017), minimal data have been collected regarding knowledge and perceptions of wastewater recycling practices among Israelis and Palestinians. One Israeli survey assessed consumer acceptance of various uses of recycled water for both domestic and agricultural purposes, including but not limited to clothes washing, vegetable irrigation, and orchard irrigation (Friedler, 2008). In contrast, a moderate number of studies (Abu Madi et al., 2008; Al-Kharouf et al., 2008; Al-Sa'ed and Mubarak, 2006; Faruqi et al., 2000; Ghanem et al., 2010) have examined public opinions concerning the use of recycled water on food crops in the West Bank. However, to our knowledge, there are no surveys in the West Bank that have investigated water recycling applications other than those pertaining to agricultural irrigation.

These knowledge gaps, as well as the lack of studies using the same survey instrument to compare Israeli and Palestinian populations, demonstrate a need for more in-depth research on consumer willingness to use recycled water in this region. The similarity of climate and water resource challenges between Israel and the Palestinian Territories and the substantial amount of transboundary trade in agricultural products between the two, coupled with stark discrepancies in governance structures, income, and education across these populations, makes this an important comparison with implications for both development projects and future management of water resources in the Middle East. To address these issues, we administered a survey to evaluate perceptions regarding the use of recycled water for produce irrigation and household tasks among Israeli and Palestinian respondents.

## 2. Materials and methods

### 2.1. Study sites and population

This study included two sites: Eilat, Israel and Bethlehem, West Bank, Palestinian Territories (Supplemental Fig. 1). Eilat is a city of 50,072 in the south of Israel, with a mostly Hebrew-speaking, Jewish population (Israeli Central Bureau of Statistics, 2019). Bethlehem is a Palestinian city of 28,248 in the south-central part of the West Bank, with a primarily Arabic-speaking, Muslim population and an Arabic-speaking, Christian minority population (Palestinian Central Bureau of Statistics, 2019).

### 2.2. Recruitment and survey administration

We recruited a convenience sample of subjects from public locations in both study sites in May and June 2018. We provided a small incentive, and subjects either completed a paper-based survey or an online version of the same survey. A secure link to the online survey was also shared via social media, specifically through Southern Israel- and West Bank-specific Facebook Groups, in order to reach more residents of each area. The online survey was available from May to November 2018. The survey and study were reviewed and approved by the University of Maryland Institutional Review Board (Project number 1057839).

### 2.3. Survey instrument

The survey included 54 multiple-choice and open-ended questions. Questions covered food purchasing habits; knowledge of water sources and water scarcity in the region; knowledge about recycled water; willingness to use recycled water for produce irrigation and household tasks; and demographics. The study was initially designed in English and

then professionally translated into Hebrew and Arabic. During translation and beta testing, the framing or explanation of some survey questions was adapted to the cultural context of Israel and the Palestinian Territories. The Israeli version of the survey was available in both Hebrew and English to more fully capture the Israeli population. The online survey was developed and stored on the survey platform Qualtrics (Qualtrics, Provo, Utah, USA), and paper-based surveys were entered into the Qualtrics platform after collection.

### 2.4. Statistical analysis

Data were analyzed using descriptive statistics, Chi-squared tests, and Fisher's exact tests. Fisher's exact tests were used when the cell sample was small or unevenly distributed. We recategorized responses from a five-point Likert scale (Strongly agree, Agree, Neutral, Disagree, Strongly disagree) into two levels (Agree, Did not agree) based on the assumption that there is little meaningful difference between the two positive values (Agree and Strongly agree), and that the three neutral or negative values (Neutral, Disagree, and Strongly disagree) all mean that the respondent did not agree. Because our primary outcome of interest was agreement with using recycled wastewater, the recategorization allowed the analysis to focus on factors associated with agreement.

In general,  $p$ -values of  $<0.05$  were considered statistically significant. To test for within-group significance among demographic variables, residuals were calculated as a post-hoc analysis and a Bonferroni adjustment was utilized (Shan and Gerstenberger, 2017). Data analysis was conducted with SAS 9.4 (Cary, NC). Figures were created in R (Version 3.5.1, The R Foundation for Statistical Computing, Vienna, Austria), and the map was designed on ArcGIS ArcMap (Version 10.4.1, Esri, Redlands CA, USA).

## 3. Results

### 3.1. Population demographics

The study included a total of 236 survey respondents: 127 individuals were surveyed from Israel and 109 from the Palestinian Territories. 64.0% of respondents chose to respond via the paper-based survey. As shown in Table 1, the Israeli and Palestinian respondents differed significantly based on age, gender, religion, education, and income. For example, the Palestinian respondents were generally younger (75.9% were 30 or younger) than the Israeli respondents (45.3% were 30 or younger).

### 3.2. Comparison between Israeli and Palestinian responses

As shown in Fig. 1, there were significant differences between Israeli (IL) and Palestinian (PA) respondents with regard to their perceptions of and attitudes about issues related to both water and food. For example, Palestinian respondents were more likely than Israeli respondents to agree that their region had recently experienced water contamination ( $p$ -value = 0.0002), that they had personally experienced the effects of water contamination (e.g. water made someone sick or they had been exposed to warnings not to drink or bathe in tap water ( $p$ -value = 0.0002), and that they had tested the safety of the water in their home (e.g. lead test) ( $p$ -value = 0.002).

As shown in Fig. 2, there were fewer significant differences between the two populations regarding wastewater experience and perceptions. The only significant difference was that Palestinian respondents were more likely than Israeli respondents to agree that recycled water was more likely to pollute the soil than conventional irrigation water ( $p$ -value  $<0.0001$ ).

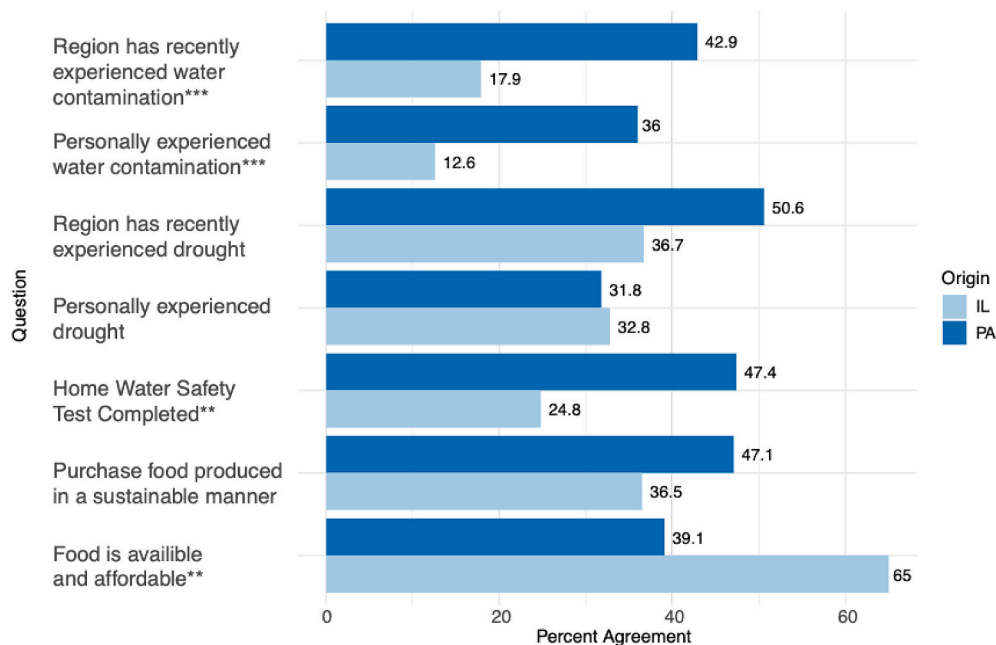
As shown in Fig. 3, the two populations differed significantly on their willingness to use recycled water in various contexts. Israeli respondents' willingness ranged from 8.3% to 55.1%, and more than half were willing to serve raw and cooked produce irrigated with treated

**Table 1**

Demographics of Israeli (n = 127) and Palestinian (n = 109) respondents of a wastewater recycling survey.

		Israeli	Palestinian	Total	Within-group p-value	Overall p-value
Age	18-20	20 (15.6)	29 (26.8)	49 (20.8)	0.02	<0.0001
	21-30	38 (29.7)	54 (49.1)	92 (40.0)	0.0007	
	31-40	21 (16.4)	13 (11.8)	34 (14.4)	0.2	
	41-50	7 (5.5)	8 (7.3)	15 (6.3)	0.3	
	51-60	16 (20.3)	2 (1.8)	18 (7.6)	0.001	
	61+	26 (20.3)	2 (1.8)	28 (11.9)	<0.0002	
	Total respondents	128	108	236		
Gender (N, % Female)		64 (58.7%)	31 (29.2%)	95 (44.2%)	N/A	<0.0001
	Total respondents	109	106	215		
Religion	Jewish	95 (80.5%)	0 (0%)	95 (42.4%)	<0.0002	<0.0001
	Muslim	0 (0%)	98 (92.4%)	98 (43.7%)	<0.0002	
	Christian	7 (5.9)	6 (5.5%)	13 (5.8%)	0.5	
	None	12 (10.2%)	2 (1.8%)	14 (6.2%)	0.005	
	Other	4 (3.4%)	0 (0%)	4 (1.8%)	0.03	
	Total respondents	118	106	224		
Education	Less than HS	0 (0%)	31 (28.7%)	31 (14.1%)	<0.0002	<0.0001
	High School	39 (34.5)	31 (29.2)	70 (32.0%)	0.2	
	Some College or Bachelor's Degree	37 (32.7)	39 (36.8)	76 (34.7%)	0.3	
	Graduate Degree	37 (32.7)	5 (4.6)	42 (19.2%)	<0.0002	
	Total respondents	113	106	219		
Household Income <sup>a</sup>	<3000 NIS	1 (1.1%)	33 (42.8)	34 (20.0%)	<0.0002	<0.0001
	3000–5000 NIS	7 (7.5%)	28 (36.4)	35 (20.6%)	<0.0002	
	5001–10,000 NIS	35 (37.6)	10 (12.66)	45 (26.5%)	<0.0002	
	10,001–20,000 NIS	34 (36.6)	2 (2.5)	36 (21.2%)	<0.0002	
	>20,000 NIS	16 (17.2)	4 (5.1)	20 (11.8%)	0.008	
	Total respondents	93	77	170		
Ethnicity	Ashkenazim/Eastern European/White	45 (72.6)	Bedouin Heritage	25 (36.8)	N/A	N/A
	Sephardim/Mizrahim	17 (27.4)	No Bedouin Heritage or unk	43 (63.2)		
	Total Respondents	62		68		

<sup>a</sup> USD equivalents: 3000 New Israeli Shekels (NIS) = 830 USD, 5000 NIS = 1400 USD, 10,000 NIS = 2800 USD, 20,000 NIS = 5600 USD.



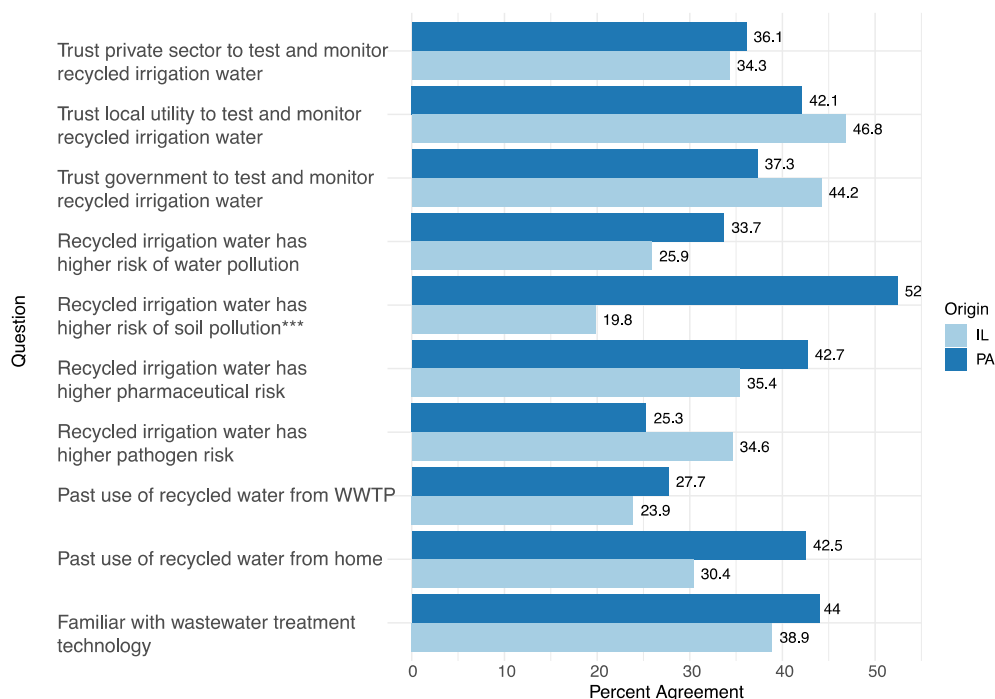
**Fig. 1.** Percentage of respondents agreeing with statements regarding food and water perceptions among a convenience sample from Bethlehem, Palestinian Territories (PA) and Eilat, Israel (IL). \*\* =  $p$ -value < 0.005, \*\*\* =  $p$ -value < 0.0005.

wastewater. Willingness among the Palestinian respondents was less varied (28.9%–41.7%) than willingness among Israeli respondents, and no recycling option garnered agreement from more than half the respondent population. Palestinian respondents were more willing than Israeli respondents to use recycled water for bathing ( $p$ -value = 0.0005), washing produce ( $p$ -value < 0.0001), cooking ( $p$ -value < 0.0001), and drinking ( $p$ -value < 0.0001). However, Israeli respondents were more willing than Palestinian respondents to serve cooked produce irrigated

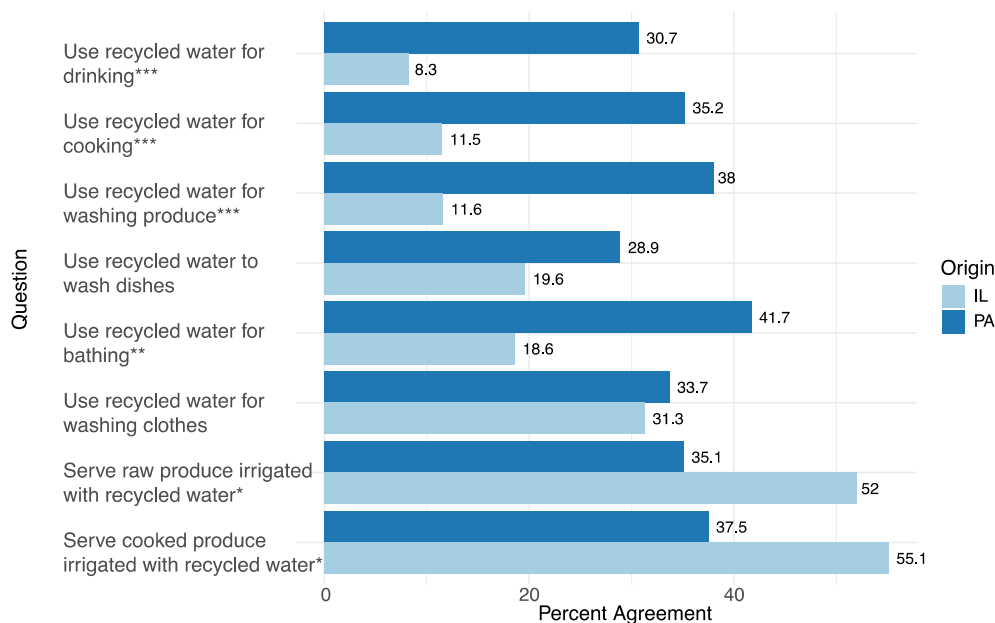
with recycled water ( $p$ -value = 0.01) and raw produce irrigated with recycled water ( $p$ -value = 0.02). For counts for each response, see [Supplemental Table 1](#).

### 3.3. Palestinian agreement with various uses of recycled water

The statistically significant associations of different factors with recycled water use agreement are reported in [Table 2](#). Three factors



**Fig. 2.** Percentage of respondents agreeing with statements regarding wastewater experience among a convenience sample from Bethlehem, Palestinian Territories (PA) and Eilat, Israel (IL). \*\*\* =  $p$ -value < 0.0005).



**Fig. 3.** Percentage of respondents agreeing with statements regarding willingness to use recycled water among a convenience sample from Bethlehem, Palestinian Territories (PA) and Eilat, Israel (IL). \* =  $p$ -value < 0.05, \*\* =  $p$ -value < 0.005, \*\*\* =  $p$ -value < 0.0005.

were consistently significant across wastewater recycling options among the Palestinian respondent population: personal water contamination experience, home water safety testing, and trust in authorities to monitor recycled wastewater reuse.

Those who did not agree that they personally had experienced the impacts of water contamination were more likely to express willingness to use recycled water for washing clothes ( $p$ -value = 0.03), and those who did not agree that their region had recently experienced water contamination were more likely to express willingness to use recycled water to wash produce ( $p$ -value = 0.03). Those who agreed that they had

tested the safety of their water at home were more willing to use recycled water for washing dishes ( $p$ -value = 0.002) and cooking ( $p$ -value = 0.02).

Those who were willing to serve cooked produce irrigated with recycled wastewater or bathe with recycled water ( $p$ -value = 0.04) were also likely to agree that they trusted their local utility/wastewater treatment system to test and monitor recycled irrigation water ( $p$ -value = 0.01). Those who were willing to serve raw produce irrigated with recycled wastewater were also likely to agree that they trusted the private sector to test and monitor recycled irrigation water ( $p$ -value =

**Table 2**

Statistically significant relationships between willingness to use recycled water and factors including attitudes toward recycled water, food purchasing habits, and water knowledge in Bethlehem, West Bank, Palestinian Territories.

		Cooked Produce		Raw Produce		Washing Clothes		Bathing		Washing dishes		Washing produce		Cooking		Drinking	
		% Accept	p-value	% Accept	p-value	% Accept	p-value	% Accept	p-value	% Accept	p-value	% Accept	p-value	% Accept	p-value	% Accept	p-value
Age	18-20	50.0	0.3	41.2	0.9	33.3	0.5	60.0	0.1	31.8	0.6	68.4	0.01	42.9	0.8	50.0	0.2
	21-30	38.6		32.6		30.9		31.2		33.3		27.1		39.1		23.4	
	31-40	27.3		30.0		18.2		41.7		18.2		27.3		27.3		25.0	
	>40	12.5		40.0		50.0		33.3		18.2		27.3		33.3		33.3	
I have tested the safety of the water in my home	Agree	50.0	0.1	30.8	0.6	50.0	0.05	46.7	0.9	53.6	0.002	44.8	0.6	65.5	0.02	38.7	0.4
	Did not agree	32.2		37.9		25.8		45.7		16.1		38.2		36.4		28.1	
I have used recycled water that I gathered at my own home	Agree	30.0	0.2	29.6	0.6	41.4	0.4	45.4	0.5	19.3	0.04	42.9	0.6	37.5	0.4	31.2	0.4
	Did not agree	45.9		35.3		30.8		37.2		42.5		36.8		46.3		41.5	
My region of the country has recently experienced water contamination	Agree	34.6	0.6	40.9	0.6	42.9	0.1	35.3	0.7	36.7	0.2	21.9	0.03	48.4	0.1	33.3	0.9
	Did not agree	40.5		34.3		24.4		39.5		23.8		46.1		31.7		34.2	
I have personally experienced the impacts of water contamination	Agree	50.0	0.1	30.0	0.5	15.4	0.03	53.8	0.07	20.7	0.07	38.5	0.9	38.5	0.9	28.0	0.4
	Did not agree	30.9		38.6		40.0		32.7		40.4		37.0		36.7		37.5	
Recycled irrigation water is more likely to pollute downstream waterways	Agree	35.0	0.8	19.0	0.07	26.1	0.2	29.6	0.1	23.1	0.2	30.8	0.4	37.0	0.6	17.4	0.04
	Did not agree	38.8		41.3		40.8		47.2		37.5		40.4		42.9		41.2	
I trust my local utility/wastewater treatment system to test and monitor recycled irrigation water	Agree	62.5	0.01	27.8	0.4	34.5	0.3	53.6	0.04	34.6	0.8	44.4	0.5	36.0	0.5	40.0	0.5
	Did not agree	29.7		39.5		22.6		29.3		32.4		35.9		44.7		31.6	
I trust the private sector to test and monitor recycled irrigation water	Agree	44.4	0.7	52.6	0.03	40.0	0.2	45.4	0.3	31.8	0.9	40.9	0.5	40.0	0.8	28.6	0.7
	Did not agree	38.2		23.7		23.7		32.5		32.5		31.6		37.5		33.3	

0.03).

Generally, demographic variables were not statistically significantly different among the Palestinian respondent population; statistical significance was only observed between age and washing produce. A higher percentage of those in the 18–20 age category were willing to use recycled water for washing produce ( $p$ -value = 0.01). Post-hoc analysis and a Bonferroni adjustment were also carried out on multi-level demographic variables that were overall not statistically significant, to assess if one level in particular was statistically significant. In this analysis, statistical significance was observed for the <3,000NIS income group for cooking ( $p$ -value = 0.003). For all non-statistically significant responses, see [Supplemental Table 2](#), and for statistically significant demographic post-hoc testing results see [Supplemental Table 3](#).

### 3.4. Israeli agreement with various uses of recycled water

The statistically significant associations of different factors with willingness to use recycled water among Israeli respondents are reported in [Table 3](#). The following topical areas were commonly associated with willingness to use recycled water among the Israeli respondent population: experience or familiarity with wastewater recycling and water contamination experience.

Those who agreed that they were familiar with the technologies used to treat and recycle wastewater expressed more willingness to use recycled water for washing clothes ( $p$ -value = 0.006), washing dishes ( $p$ -value = 0.009), cooking ( $p$ -value = 0.0005), washing produce ( $p$ -value = 0.01), and drinking ( $p$ -value = 0.002). Those who agreed that they had used recycled water gathered at their home expressed more willingness to serve raw produce irrigated with recycled water ( $p$ -value = 0.007), and to use recycled water to wash dishes ( $p$ -value = 0.003) and cook ( $p$ -value = 0.003). Those who agreed that they had used recycled water from a WWTP expressed more willingness to use recycled water for washing clothes ( $p$ -value = 0.001), bathing ( $p$ -value = 0.02), washing dishes ( $p$ -value = 0.01), cooking ( $p$ -value = 0.004), and drinking ( $p$ -value = 0.002).

Those who agreed that they had personally experienced the effects of water contamination expressed more willingness to serve cooked produce irrigated with recycled water ( $p$ -value = 0.04) as well as to use recycled water to bathe ( $p$ -value = 0.005), cook ( $p$ -value = 0.009), wash produce ( $p$ -value = 0.01), and drink ( $p$ -value = 0.001). Those who agreed that their region of the country had recently experienced water contamination expressed more willingness to use recycled water for washing produce ( $p$ -value = 0.047) and drinking ( $p$ -value = 0.03).

As with the Palestinian respondents, demographic variables were also generally not statistically significant among the Israeli respondents; statistical significance was observed between education attainment and serving raw produce ( $p$ -value = 0.002) and cooked produce ( $p$ -value < 0.0001); those with higher levels of education expressed more willingness than those with a high school education. Furthermore, when post-hoc analysis and a Bonferroni adjustment were also carried out on multi-level demographic variables which were overall not significant, a trend was observed regarding the religion variable. Those reporting no religion were significantly more likely to express willingness to serve raw produce ( $p$ -value = 0.006), cook ( $p$ -value = 0.004), and drink ( $p$ -value = 0.005) recycled water. For non-statistically significant responses, see [Supplemental Table 4](#), and for statistically significant demographic post-hoc testing results see [Supplemental Table 5](#).

## 4. Discussion

### 4.1. Summary of study findings

In this study, we compared Israeli and Palestinian populations with regard to perceptions, attitudes and knowledge about wastewater recycling for household tasks and agricultural irrigation. Overall, most recycled wastewater uses garnered less than 50% acceptance for both

populations; only Israeli respondents specifically were willing to serve raw and cooked produce irrigated with recycled water more than 50% of the time. This could be due to numerous factors including but not limited to experience with recycled wastewater, trust in those treating/monitoring the water, and familiarity with the technology used. Higher-contact uses (i.e. cooking, drinking) were more well-accepted among Palestinian respondents than Israeli respondents.

Among the Israeli respondents, experience or familiarity with wastewater recycling and water contamination experience were frequently significantly associated with increased willingness to use recycled water. Among the Palestinian respondents, experience with home water safety testing and trust in authorities to monitor recycled wastewater reuse were frequently significantly associated with increased willingness to use recycled water while an absence of perceived personal water contamination experience was associated with increased willingness to use recycled water.

One known Israeli survey assessed consumer acceptance of various uses of recycled water, including but not limited to clothes washing (45% acceptance), vegetable irrigation (48%), and orchard irrigation (53%) ([Friedler, 2008](#)). The percentage of Israeli respondents agreeing to these or similar uses in our study was roughly the same, with 31% agreeing with using recycled water to wash clothes and 52–55% agreeing to serve produce (raw or cooked) irrigated with recycled water.

In the literature from the West Bank, the percentage of respondents that accepted the use of recycled water for agricultural irrigation ranged from 25 to 90% ([Abu Madi et al., 2008](#); [Al-Kharouf et al., 2008](#); [Al-Sa'ed and Mubarak, 2006](#); [Faruqi et al., 2000](#); [Ghanem et al., 2010](#)). While this range of acceptance varies compared to our observed acceptance of recycled water for produce irrigation (35–37%), our findings were in agreement with a 2012 survey in the Bethlehem Governorate (42% acceptance), as well as a 2010 survey in the Hebron Governorate (Bethlehem's neighbor to the south) ([Ghanem, 2012](#); [Ghanem et al., 2010](#)). This survey in the Hebron Governorate also parsed out agreement with regard to cooked vs. raw produce and found that the cooked produce irrigated with recycled water was more acceptable to consumers (47% acceptance vs 32%, respectively) ([Ghanem, 2012](#); [Ghanem et al., 2010](#)). Overall, these findings indicate that both populations can be skeptical of wastewater recycling, and education and outreach need to be tailored to each population in order to appropriately address concerns and factors that play a role in acceptance.

### 4.2. Water contamination experience

While water contamination experience was highly associated with willingness to use recycled water among both Israeli and Palestinian respondents, the relationship was different. Overall a relationship between these two factors is expected given that [Hartley \(2006\)](#) lists "awareness of water supply problems in the community" as one of the key factors contributing to community acceptance of recycled water ([Hartley, 2006](#)). Among Israeli respondents, agreement with the statement that they had experienced water contamination was associated with agreement to use recycled water. It is possible that those who perceive that they have experienced contamination may see recycled water as a "cleaner" source, and thus, may be more willing to use it.

Interestingly, while water contamination experience was also significant within the Palestinian respondent population, the relationship was flipped. The relationship was significant for several potential uses, but those who did not agree that they had experienced water contamination personally or regionally were more willing to use recycled water. That being said, for other recycling applications, agreeing that a home water safety test had been conducted (which may indicate a suspicion of a water contamination issue) was also associated with willingness among Palestinian consumers. Perception of water contamination sources and solutions may warrant further investigation among these two populations.

Furthermore, it bears noting that the specific contaminants and

**Table 3**

Statistically significant relationships between willingness to use recycled water and factors including attitudes toward recycled water, food purchasing habits, and water knowledge in Eilat, Israel.

		Cooked Produce		Raw Produce		Washing Clothes		Bathing		Washing dishes		Washing produce		Cooking		Drinking	
		% Accept	p-value	% Accept	p-value	% Accept	p-value	% Accept	p-value	% Accept	p-value	% Accept	p-value	% Accept	p-value	% Accept	p-value
Education	High School	24.1	<0.0001	27.6	0.002	20.6	0.1	14.7	0.3	18.2	0.6	12.1	1.0	11.8	1.0	6.1	0.5
	Some College or Bachelor's	71.9		71.0		31.4		13.9		16.7		13.5		11.1		5.7	
Ethnicity	Graduate Degree	73.3	0.2	60.6	0.07	44.1	0.02	25.7	0.4	25.0	0.4	11.4	0.3	13.9	0.3	14.3	0.6
	Ashkenazi/Euro/White	67.6		66.7		41.9		14.0		20.9		14.0		13.6		9.5	
	Mizrahim/Sephardim	46.2		38.5		7.1		6.7		6.7		0.0		0.0		0.0	
I buy food that has been produced in ways that are sustainable for the environment	Agree	44.8	0.1	46.4	0.4	43.8	0.02	27.3	0.2	19.4	0.9	21.2	0.05	18.8	0.2	13.3	0.2
	Did not agree	61.0		55.7		22.1		16.2		20.3		7.3		8.7		6.0	
The food I want to buy is available and affordable for me	Agree	56.4	0.6	53.8	0.5	34.3	0.5	12.9	0.03	14.3	0.047	14.5	0.4	11.4	1.0	10.0	0.5
	Did not agree	51.4		47.1		27.5		29.3		30.0		7.3		12.2		5.4	
I am familiar with the technologies used to treat and recycle wastewater	Agree	57.9	0.9	57.9	0.5	47.6	0.006	29.3	0.06	34.1	0.009	21.4	0.01	26.2	0.0005	20.0	0.002
	Did not agree	56.6		50.9		22.2		14.0		12.7		4.9		3.2		1.6	
I have used recycled water that I gathered at my own home	Agree	67.7	0.1	73.3	0.007	32.4	0.9	29.4	0.08	42.9	0.003	20.6	0.1	26.5	0.003	16.1	0.1
	Did not agree	50.8		43.9		31.1		14.9		13.2		8.2		5.4		5.5	
My region of the country has recently experienced lack of water or drought	Agree	60.6	0.4	52.8	0.9	50.0	0.0004	26.3	0.07	28.2	0.046	18.9	0.05	17.9	0.1	10.8	0.5
	Did not agree	51.8		51.8		17.2		12.3		12.5		6.1		6.1		6.2	
My region of the country has recently experienced water contamination	Agree	43.7	0.5	46.7	0.8	18.7	0.6	18.8	0.7	31.3	0.1	25.0	0.047	18.8	0.2	20.0	0.03
	Did not agree	54.0		50.7		24.3		15.1		15.1		6.7		8.1		2.7	
I have personally experienced the impacts of water contamination	Agree	83.3	0.04	75.0	0.1	46.2	0.2	46.2	0.005	30.8	0.3	38.5	0.01	38.5	0.009	38.5	0.001
	Did not agree	51.3		51.2		30.1		14.0		17.4		8.7		8.6		4.4	
Recycled irrigation water is more likely to pollute downstream waterways	Agree	31.3	0.02	35.3	0.06	11.1	0.06	5.9	0.2	5.9	0.1	5.3	0.2	5.6	0.4	5.6	0.7
	Did not agree	64.9		61.4		33.9		21.7		25.0		20.3		16.7		13.8	
Recycled irrigation water is more likely to pollute the soil	Agree	33.3	0.04	20.0	0.003	14.3	0.1	0.0	0.06	14.3	0.7	13.3	1.0	7.1	0.7	7.1	1.0
	Did not agree	62.7		62.3		33.3		23.1		23.4		15.6		13.8		11.1	



levels of said contaminants present within treated wastewater differ between Israel and the Palestinian Territories due to differences in overall capacity to handle and treat wastewater. Israeli WWTPs use centralized wastewater treatment systems to provide high-quality irrigation water (Dotan et al., 2016). However, despite this treatment, previous research in Israel has noted that the increased use of treated effluent in agricultural irrigation contributes to salinization of soil, and treated wastewater has been noted to contain low levels of antibiotic-resistant bacteria, antibiotic resistance genes, and pharmaceutical compounds (Malchi et al., 2014; Marano et al., 2021; Tal, 2016). In the West Bank, due to the lack of capacity for large-scale reuse, small-scale, off-grid wastewater treatment solutions have been implemented (McIlwaine and Redwood, 2011). These systems have been noted for their high levels of bacteria (including bacteria exhibiting antibiotic resistance) as well as chemical contaminants including antimicrobial compounds (Craddock et al., 2020a; Craddock et al., 2020b).

#### 4.3. Future research

The findings of this survey could be used to inform a shorter, more targeted survey that could be more easily deployed to a larger population of respondents. Efforts should be made to further explore the population's willingness to engage in other forms of water reuse (i.e. assessing the public's willingness to eat meat from livestock that have grazed on wastewater-irrigated fodder, eat processed foods such as olive oil that were irrigated with recycled water, or wash floors with recycled water) (Al-Sa'ed et al., 2012; Kecinski et al., 2018; McIlwaine and Redwood, 2011). Furthermore, as stated above, the relationship between the perception of water contamination and willingness to use recycled water bears further in-depth investigation.

#### 4.4. Limitations

The primary limitation of this study was the convenience sampling methodology. In addition, respondents, especially in the Israeli population, frequently declined to fill in demographic details, which decreased our ability to assess statistical significance. However, as over 100 respondents from each population were sampled using the same survey instrument, this study serves as a foundation for future work which could provide more broadly applicable findings regarding these two populations. Additionally, when designing the survey, most information regarding potential explanatory variables was sourced from surveys outside of the Middle East. Thus, it is possible that, despite closely working with Palestinian and Israeli colleagues, some relevant questions may have been missed (Hartley, 2006; Hummer, 2017; Ross et al., 2014).

### 5. Conclusions

Our findings suggest that both Israeli and Palestinian populations are willing to some degree to use recycled water in multiple ways, although willingness varies based on the specific intended use as well as between the two respondent populations. Demographic characteristics, attitudes, and previous experiences that are significantly related to willingness to use recycled water also differed between our two respondent populations. Given likely increasing water stress in both Israel and the Palestinian Territories, as well as the continued evolution of wastewater treatment technologies and ongoing agricultural trade between Israel and the Palestinian Territories, it is important to apply these findings to identify and apply effective and appropriate outreach and communication strategies to help increase willingness to use recycled water. Both environmental and development goals can be achieved through innovative water management approaches like treatment and recycling, but these solutions will only have an impact if people are willing to use them.

### Credit author statement

Hillary A Craddock: Investigation, Writing – original draft, Writing – review & editing, Visualization, Formal analysis. Younes Rjoub: Investigation, Visualization, Writing – review & editing. Kristal Jones: Conceptualization, Writing – review & editing, Supervision. Clive Lipchin: Conceptualization, Writing – review & editing, Supervision, Project administration, and Funding acquisition. Amy R. Sapkota: Conceptualization, Writing – review & editing, Supervision, Project administration, and Funding acquisition.

### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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### Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jenvman.2021.113234>.

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