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Sustainable management of wastewater use in agriculture: a systematic analysis

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Due to changes that have occurred in ecological conditions, the requirement to use wastewater has been considered more seriously in the agricultural sector, because agriculture is the source of human nutrition, health and security. Based on this, the purpose of this research was to systematically analysis the components affecting sustainable management of wastewater use (SMWWU) in the viewpoint of critical theory paradigm. Inductive qualitative content analysis (IQCA) was used for systematic analysis. In this regard, the software used was MAXQDA. The statistical population included valid scientific articles and knowledgeable experts in wastewater management in the agricultural sector in Tehran province, Iran. The sampling method for articles was by searching based on keywords and for experts by purposeful method until theoretical saturation was reached. The results of IQCA in the form of a model showed that the six main components "economic," "environmental," "contextual," "individual," "management and planning" and "education and extension" affect SMWWU. Each of these components also includes several factors and variables that can strengthen SMWWU and reduce the water crisis by paying attention to them. The obtained model can be used by policy makers and interested parties in making decisions and planning water protection measures.

KEYWORDS
water scarcity, farmers, water recycling, sustainability, wastewater

1 Introduction

The scarcity of available water resources, the shortage of rainfall, and recent droughts, have obliged the water policy makers to consider all conventional and non-conventional sources that can be effectively and economically available in the planning of water resources development (Ahmadi et al., 2019). On the other hand, the increase in urbanization and industrialization has resulted into a sudden increase in wastewater produced around the world. The problems caused by the lack of wastewater treatment on the environment have made this aim as an imperative need (Torabian and Moumeni, 2003). Nowadays, treated municipal wastewater can be one of the significant alternative water sources (Agrafioti and Diamadopoulos, 2012), treated wastewater can be a reliable source of water in some fields such as agriculture, because it is produced throughout the year, and although the efficient methods of water management in the farm, saving methods of water consumption and desalination are some of the strategies to cope up with water scarcity. However, the reuse of purified wastewater can be a more successful solution to recover part of water transferred to the agricultural sector (Ahmadi and Merkley, 2009). The reuse of wastewater and biosolids in agriculture has many social and economic benefits and promotes the sustainability of agriculture and the environment (Fu et al., 2019). Today, due to the transfer of human sewage to underground and surface water tables, dumping domestic sewage and the creation ugly and unpleasant environmental landscapes namely in Iran (Esmaeilian et al., 2021), if not being truly managed, planned and not good decision is made, it will bring adverse environmental consequences. Wastewater management is necessary not only to prevent much damage to sensitive ecosystems and the environment, but also to emphasize that wastewater is a useful resource (usable water as well as nutrients for agricultural use). From the view point of the world water council, the balance between existing water resources and cultivable land, water reuse in all sectors, implementing new methods to improve the quality of water resources, developing standards and creating a long-term balance between supply and demand are among the most important quantitative and qualitative indices of water resources sustainable management (Rezaie et al., 2013). Thus, the use of wastewater in agriculture is a strategy towards sustainable management as the use of municipal wastewater for irrigation mitigates the use of fertilizers and enhances soil fertility (Galvis et al., 2018) and it also reduces the pressure on water resources (Rezaee and Sarrafzadeh, 2017). Accordingly, sustainable management of wastewater use (SMWWU) in agriculture and their reuse is required to reduce water consumption and prevent water scarcity crisis. As an arid and semi-arid country where more than 70% of fresh water is used in the agricultural sector, Iran should focus on SMWWU. Although studies have been performed in different countries of the world on the use of wastewater in agriculture, their main focus has been on the treatment method, and less research has been done on the sustainable management of the wastewater, namely in the agricultural sector. Hence, the present study is aimed to have a systematic analysis of the components affecting SMWWU. Focusing on Iran's agricultural sector, the novelty of this research is the use of systematic analysis in the form of content analysis.

Like any other study, this study was conducted in the form of three types of questions: "ontology," "epistemology" and "methodology." In other words, ontology is about what types of things or essences exist in the world and refers to a range of entities and relations that are accepted within a specific field of knowledge and scientific expertise. In scientific investigations, the three paradigms of positivism, interpretivism and critical theory have been dominant and widely applied. Indeed, epistemology is the study of how and what can be known, and methodology is the method of examining and analyzing the way research is performed (Ahmadi et al., 2019; Sadeghi, 2019). From the view of positivism, the objective existence of truth and its tangibility is the only issue that can be recognized. In interpretivism, the truth is socially constructed. For this reason, the social world cannot be investigated in the same way as the natural world, and based on critical theory, the difference between the social world and the natural world is to consider the subjectivity while considering the socio-economic structures (Shafiei Sabet and Sedighi, 2018). From a methodological point of view, positivism emphasizes the unity of the scientific method and its approach is quantitative. In interpretivism, instead of focusing on precise empirical observation, they consider the quantitative measurement of human behavior, the meaning of human behavior or action. In critical theory, social science is a critical process that goes beyond the deceptive appearances of the social world to discover and reveal the real constructs of the material world and the social world, and in this way by increasing awareness about the unequal constructs and relations helps to create changes in relationships and social constructs (Ahmadi et al., 2019).

As it was mentioned, the present study attempted to employ the principles of ontology of the critical theory paradigm, by careful study of the existing documents and use the opinions of subject experts with a systematic analysis to investigate SMWWU. Thus, this study answers the following questions.

- What is the form and nature of SMWWU reality and what should be known about it? (Ontology).
- What is the nature of the relationship between the research subject (SMWWU) and reality (epistemology)? And how to know the methods related to SMWWU?
- How can this issue be examined and what are methods of coping up with the crises and problems in SMWWU? (Methodology).

2 Materials and methods

The research is qualitative in terms of research paradigm, applied in terms of research type and descriptive in terms of research method. In order to identify the dimensions and components of SMWWU, the present study applied systematic analysis with inductive qualitative content analysis (IQCA) method was used. In this method, articles of the factors affecting SMWWU were first analyzed, and then, in order to match the identified factors with the existing conditions, interviews were carried out with the experts of Jihad-e Agriculture and water and sewerage Company of Tehran Province, Iran. Content analysis is a method by which specific features of the message are clearly and exactly identified for scientific inference. In the analysis of the content of the text, four approaches can be referred. First, quantitative text analysis is widely used to count the explicit elements in the text and requires the selection of data using random sampling. However, qualitative content analysis is extended to discover the main hidden meanings in the text and normally purposeful text samples are selected among the texts which are appropriate to answer the research questions. Content analysis can be performed by deductive method and answer questions that are extracted from theories or empirical researches. On the other hand, inductive content analysis investigates topics and themes in their context and extracts good conclusions.

Like any other research, in qualitative content analysis, two concepts of validity and reliability of the research are taken into consideration. Thus, in the 1980s, Guba and Lincoln utilized the concept of trustworthiness to replace the validity and reliability of qualitative research (Akbari, 2018). This concept consists of four criteria: credibility, transferability, dependability and confirm ability. Credibility emphasizes sampling until data saturation is reached, long engagement in the setting, and multidimensionality of data. Validity refers to activities that increase the probability of obtaining valid findings. Dependability is the inspection, documentation of data, methods, and researcher decisions. Confirm ability means parallel examination of the results and reflexivity, and transferability means a detailed description of the environment and participants and the variety of perspectives and experiences of the interviewees (Lotfi et al., 2022). In the present research, the mentioned elements were used to be ensured of the accuracy and quality of the research as follows.

Abbreviations: SMWWU, sustainable management of wastewater use; IQCA, inductive qualitative content analysis.

- Credibility: The concepts extracted from the citations and interview questions of the research were examined and verified by a group of experts from Jihad-e Agriculture and the consulting company for water treatment projects.
- Dependability: In order to rely on the study findings, the content of the interviews was recorded and after the interview, it was transcribed.
- Transferability: Due to the diversity of perspectives and characteristics of documents and participants, efforts were made to investigate them with the aid of the research team.
- Confirmability: Various methods such as document review, interview and interview recording were used to verify the results.

The current study used MAXQDA software to analyze the texts of articles and interviews. MAXQDA is a highly reliable and powerful software program that is widely used for qualitative data analysis, including inductive qualitative content analysis (IQCA) like the one utilized in this study. MAXQDA allows researchers to systematically organize, code, and analyze large amounts of qualitative data, such as scientific articles and expert interviews, in a structured and efficient manner. It provides a user-friendly interface that facilitates the process of data management, coding, and interpretation, helping researchers to identify patterns, themes, and relationships within the data. In the study, MAXQDA was instrumental in organizing and coding the collected data from scientific articles and expert interviews, enabling to conduct a systematic analysis of the components affecting sustainable management of wastewater use in agriculture. The use of MAXQDA ensured the rigor and transparency of our analysis by allowing for a structured and comprehensive approach to data interpretation. By utilizing MAXQDA, it is possible to generate a model that clearly outlines the key components influencing sustainable management of wastewater use, providing valuable insights for policymakers and stakeholders.

Generally, after reviewing the papers, the participants were selected based on the purposeful sampling method from among the related experts and professionals, especially the consulting and executive companies of water and sewage and the experts of Jihad-e Agriculture. As in the qualitative part of researches, saturation of information is more important than the number of individuals or articles under study, thus the sample size was continued until theoretical saturation was reached. Indeed, the sampling continued until the researcher realized by asking questions repeatedly that the new data did not reveal any new insights. Data analysis was performed using the qualitative content analysis approach via coding, and finally, the final model was prepared by summarizing the information extracted from the articles and interviews.

2.1 Statistical population and sampling method to identify the components and dimensions of SMWWU

The first statistical population of this study includes articles related to SMWWU, which were selected using a purposive sampling method. Thus, to search for valid international articles from reliable journals in the fields of agriculture, ecosystem and environment, water resources research, water management in agriculture, environmental sciences and sustainable development, keywords water scarcity, water recycling, sustainability, wastewater, etc. were identified through searching in search engines such as Google Scholar and databases including Scopus, ScienceDirect, and ResearchGate in the relevant articles. Also, for using local sources and articles (in Farsi) in the process of content analysis, articles related to the topic were selected and investigated as foreign sources by searching in databases such as Magiran, Noormags, SID and Elmnet.

At first, 172 articles were identified via the related title, and then the articles that had related abstracts and keywords were investigated. Finally, 68 articles entered the content analysis. The review started from the most relevant and most cited articles and continued until theoretical saturation was reached (Table 1).

The second statistical population included the experts of Jihad-e Agriculture and the consulting and executive companies of water and sewage projects, who were selected using a purposeful and snowball method. Also, during the initial interviews, the information needs of the research were used to properly cover the research themes, diversity and variability in the conditions of the respondents and the introduction of previous people as the basis to select the next sample. So, the sample size was 13 after performing interviews and data analysis and finally reaching theoretical saturation (Table 2).

3 Results and discussion

After identifying relevant articles and interviewing experts, the process of data analysis was started Investigations were began based on the research question "What factors and components affect SMWWU ". All the extracted factors were reinvestigated to categorize and classify to separate the main components, factors and variables. Finally, five main components, "Economic," "Environmental," "contextual," "Individual" and "Management and Planning" were extracted, as these factors cover political, social, cultural, religious and individual characteristics and opinions. Table 3 and Figure 1 show the extracted components, and the factors and variables of each, as well as the frequency of different variables in the articles and interviews.

The results of the review of the articles indicated that 495 times the relevant concepts were mentioned and emphasized in the papers based on different methods. The highest frequency is related to the reduction of water scarcity and the protection of surface and underground resources and the storage of fresh water, which is a sub-component of the environmental component that is stated in 31 articles. As mentioned in the articles, the survival of part of the wastewater produced by urban accumulations may mitigate the pressure on water resources (Bolinches et al., 2022). Also, the reuse of treated water for irrigation of agricultural products has been developing in recent decades in areas with severe water scarcity (Feder, 2021) and the use of treated wastewater has mitigated water use and enhanced its saving (Galvis et al., 2018). Regarding other concepts related to the environment, important issues have been considered, such as: irrigation with wastewater increases soil salinity (Agrafioti and Diamadopoulos, 2012) and treated wastewater may contain a high concentration of salts including chlorine, sodium, and heavy metals which may influence the physical and chemical characteristics of the soil (Hassena et al., 2021). Also, studies demonstrated that microbiological contamination can be the main challenge for the reuse of treated wastewater in agriculture (Gatta et al., 2015). On the other hand, the possible accumulation of

TABLE 1 Sources of content analysis in the explanation of factors affecting SMWWU.

No.	Journal	IF (2021)	Publisher	h-index	Country	Subject area	No. of articles	No. of pages	Sources
1	Agricultural Water Management	6.611	Elsevier	152	Netherlands	Science, Economics, and Policy of Agricultural Water Management	27	311	Oron et al. (1999); Rojas-Valencia et al. (2011); Agrafioti and Diamadopoulos (2012); Jang et al. (2012); Sato et al. (2013); Trinh et al. (2013); Neji and Turki (2015); Gatta et al. (2015); Elgallal et al. (2016); Jeong et al. (2016, 2020); Galvis et al. (2018); Libutti et al. (2018); Licciardello et al. (2018); Nejatijahromi et al. (2019); Sathaiah and Chandrasekaran (2020); Deh-Haghi et al. (2020); Pedrero et al. (2020); Cakmakci and Sahin (2021); Feder (2021); Gao et al. (2021); Hassena et al. (2021); Hristov et al. (2021); Zolfaghary et al. (2021); Bolinches et al. (2022); Perez-Mercado et al. (2022); Yu et al. (2022)
2	Agriculture, Ecosystems & Environment	6.576	Elsevier	200	Netherlands	Environmental implications of agricultural land use and land use change, …	10	103	Lucho-Constantino et al. (2005); Mapanda et al. (2005); Palese et al. (2009); Chartzoulakis et al. (2010); Segal et al. (2011); Belaid et al. (2012); Vivaldi et al. (2013); Christou et al. (2014); Rodríguez-Liébana et al. (2014); Orlofsky et al. (2016)
3	Water Resources Research	6.159	Wiley-Blackwell	248	United States	Environmental Science (Water Science and Technology)	10	188	Axelrad and Feinerman (2010); Genius et al. (2012); Brown et al. (2015); Cosgrove and Loucks (2015); McLaughlin and Kinzelbach (2015); Rahav et al. (2017); Assouline et al. (2020); Bass et al. (2022); Cai et al. (2002); Kramer et al. (2022)
4	Water Research	13.4	Elsevier	354	Netherlands	Agriculture, Biology & Environmental Sciences	5	58	Murray and Ray (2010); Christou et al. (2017); Farhadkhani et al. (2018); Caicedo et al. (2019); Tisler et al. (2022)
5	Environmental Science & Technology	11.357	American Chemical Society	456	United States	It covers research in environmental science and environmental technology	4	33	Goldstein et al. (2014); Malchi et al. (2014); Wu et al. (2014); Fu et al. (2019)

(Continued)

TABLE 1 (Continued)

No.	Journal	IF (2021)	Publisher	h-index	Country	Subject area	No. of articles	No. of pages	Sources
6	Journal of Water and Sustainable Development	0.203 ISC	Ferdowsi University of Mashhad	–	Iran	Irrigation and Agriculture Risk, Sustainability and Resilience Surface and Groundwater Resources	6	56	Malek Jafarian and Mohseni (2015); Davoodabadi et al. (2018); Dindarlou and Dastourani (2018); Tabrizi et al. (2018); Zafari-Holoukhi et al. (2021); Esmaeilian et al. (2021)
7	Journal of Rural Research	–	University of Tehran	–	Iran	In the broad fields of rural research, including rural development, rural tourism, rural participation, spatial analysis, sustainable rural development, rural management, rural–urban linkages and other related areas.	1	14	Ahmadi et al. (2019)
8	International Journal of Recycling of Organic Waste in Agriculture	0.213 ISC	Islamic Azad University-Isfahan (Khorasgan)	32	Iran	Agricultural waste, Animal manure, Biochar, Compost, Food waste, Organic waste, Plant growth, Soil amendment, Vermicompost, Wastewater treatment	1	28	Tabatabaei et al. (2020)
9	Journal of Water Resources Engineering	0.267 ISC	Marvdasht Branch, Islamic Azad University	–	Iran	Water resources management, climate change, water resources management in agriculture and industry, hydraulic and hydraulic structures, environmental studies related to water resources, water and wastewater engineering	1	10	Hassani et al. (2017)

(Continued)

TABLE 1 (Continued)

No.	Journal	IF (2021)	Publisher	h-index	Country	Subject area	No. of articles	No. of pages	Sources
10	Iran-Water Resources Research	0.745 ISC	Iranian Water Resources Association	–	Iran	Climate Change, GIS, Groundwater, Hydraulics, Hydrology, Hydropolitics, Meteorology, Optimization, Urban Water, Water Economy, Watering, Water Law, Water Quality, Water, Resource Management, Water Sociology	1	14	Rezaee and Sarrafzadeh (2017)
11	Geography and Development	0.686 ISC	University of Sistan and Baluchistan	–	Iran	Geography, Rural development, Urban development, Regional geography, Cartography of Iran and the Iranian plateau, Cultural geography, Development, Environmental, …	1	18	Talebi Somesarayee et al. (2016)
12	Journal of Urban Research and Planning	0.843 ISC	Islamic Azad University of Marvdasht	–	Iran		1	22	Fattahi and Behroozi (2018)
Total							68 articles	855	

TABLE 2 People interviewed in the IQCA process.

Expertise/responsibility of the interviewee	Number
Member of the environmental community-based association	2
Technical and executive vice president of Jihad-e Agriculture	1
Soil and water expert	2
Plant breeding expert	1
Livestock expert	1
Agricultural extension and education expert	2
Agronomy expert	2
Executive expert of water and sewage consulting company	2
Total	13

emerging pollutants in the human diet when wastewater is used in agriculture can be the main concern (Wu et al., 2014). Although the presence of these materials in the environment and their potential ecological impacts are generally problematic, their concentration in water sources and other environmental receptors have been little, and many of these pollutants have the potential for short environmental half-lives (Elgallal et al., 2016). In addition, reuse of wastewater enhances soil fertility and increases organic matter and macronutrients such as nitrogen, phosphorus, and potassium; thus, it limits using chemical fertilizers (Galvis et al., 2018), as this has economic benefits, besides improving environmental conditions. Out of 100 categories related to economic issues, 27 articles have emphasized this issue. For example, it has been stated that the presence of macronutrients in wastewater can lead to a decline in the cost of fertilizing agricultural products (Bolinches et al., 2022). In general, by stating that irrigation with recycled wastewater increases the content of macro and micro elements in plants and soil (Cakmakci and Sahin, 2021), researchers have referred to the fact that this type of water increases productivity due to the supply of

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TABLE 3 Components extracted from concepts along with the frequency of different variables in articles and interviews.

	Sustainable management of wastewater use (SMWWU)				
	Component affecting SMWWU	Variables	Sources	Frequency	
				In articles	In interviews
	Economic	Unaffordability of alternative cultivation	Interviews	0	1
		Education and extension funding for the use of wastewater	Interviews	0	1
		Economical use of wastewater in agriculture compared to industry	Malek Jafarian and Mohseni (2015)	1	0
		Decreased willingness to pay for agricultural crops irrigated with wastewater	Bass et al. (2022)	1	0
		Reducing water pumping costs to use groundwater resources	Galvis et al. (2018); Sathaiah and Chandrasekaran (2020)	2	0
		Reducing sewage disposal costs	Trinh et al. (2013); Galvis et al. (2018); Libutti et al. (2018); Sathaiah and Chandrasekaran (2020)	4	0
		Water purchase costs	Sato et al. (2013); Deh-Haghi et al. (2020); Zafari-Holoukhi et al. (2021)	3	0
		Investment for the construction and operation of a refinery or surplus treatment	Oron et al. (1999); Elgallal et al. (2016); Galvis et al. (2018); Zafari-Holoukhi et al. (2021); Hristov et al. (2021); Bolinches et al. (2022)	6	1
		Employment	Genius et al. (2012); Davoodabadi et al. (2018), Sathaiah and Chandrasekaran (2020); Esmaeilian et al. (2021)	4	0
		Distance between agricultural land, land slope and intermediate infrastructure (roads)	Genius et al. (2012); Galvis et al. (2018); Libutti et al. (2018); Hristov et al. (2021); Zolfaghary et al. (2021); Bolinches et al. (2022); Yu et al. (2022)	7	0
		Reducing costs required for fertilizing and providing nutrients	Lucho-Constantino et al. (2005); Chartzoulakis et al. (2010); Murray and Ray (2010); Rojas-Valencia et al. (2011); Belaid et al. (2012); Jang et al. (2012); Sato et al. (2013); Trinh et al. (2013); Christou et al. (2014); Rodríguez-Liébana et al. (2014); Cosgrove and Loucks (2015); Gatta et al. (2015); Elgallal et al. (2016); Rahav et al. (2017); Dindarlou and Dastourani (2018); Galvis et al. (2018); Libutti et al. (2018); Deh-Haghi et al. (2020); Jeong et al. (2020); Pedrero et al. (2020); Sathaiah and Chandrasekaran (2020); Cakmakci and Sahin (2021); Feder (2021); Gao et al. (2021); Zolfaghary et al. (2021); Bolinches et al. (2022); Yu et al. (2022)	27	3
		Wastewater purchase costs	Oron et al. (1999); Galvis et al. (2018); Deh-Haghi et al. (2020); Zafari-Holoukhi et al. (2021); Esmaeilian et al. (2021); Hristov et al. (2021)	6	2
		Installation and maintenance costs	Agrafioti and Diamadopoulos (2012); Brown et al. (2015); Davoodabadi et al. (2018); Esmaeilian et al. (2021); Hristov et al. (2021)	5	0
		Costs due to wastewater transfer to farms	Galvis et al. (2018); Hristov et al. (2021); Bolinches et al. (2022)	3	0

(Continued)

TABLE 3 (Continued)

	Sustainable management of wastewater use (SMWWU)				
	Component affecting SMWWU	Variables	Sources	Frequency	
				In articles	In interviews
		Wastewater fees and tariffs	Malek Jafarian and Mohseni (2015); Zafari-Holoukhi et al. (2021)	2	0
		Reduction of crop yield, plant growth and degradation	Segal et al. (2011); Elgallal et al. (2016); Jeong et al. (2020); Pedrero et al. (2020)	4	0
		Increase performance and product improvement	Murray and Ray (2010); Segal et al. (2011); Rojas-Valencia et al. (2011); Gatta et al. (2015); Elgallal et al. (2016); Davoodabadi et al. (2018); Farhadkhani et al. (2018); Libutti et al. (2018); Pedrero et al. (2020); Sathaiah and Chandrasekaran (2020); Cakmakci and Sahin (2021); Feder (2021); Gao et al. (2021); Hristov et al. (2021); Zolfaghary et al. (2021); Yu et al. (2022)	16	1
		Decrease in economic performance	Gao et al. (2021)	1	0
		Farmer's profit – improvement of economic conditions (agricultural profitability)	Axelrad and Feinerman (2010); Sato et al. (2013); Neji and Turki (2015); Sathaiah and Chandrasekaran (2020), Hristov et al. (2021); Kramer et al. (2022); Yu et al. (2022)	7	3
		Income level of countries/farmers, etc.	Genius et al. (2012)	1	0
Individual	Individual characteristics	Level of education	Genius et al. (2012); Tabrizi et al. (2018); Deh-Haghi et al. (2020); Bass et al. (2022)	3	2
		Age		4	2
		Number of family members	Tabrizi et al. (2018)	1	0
		Experience		1	0
	Individual opinions	Willingness and interest in using wastewater	Rojas-Valencia et al. (2011); Neji and Turki (2015); Brown et al. (2015); Jeong et al. (2016); Tabrizi et al. (2018); Ahmadi et al. (2019); Deh-Haghi et al. (2020); Esmaeilian et al. (2021); Zolfaghary et al. (2021); Bass et al. (2022); Bolinches et al. (2022)	11	0
		Attitude and mentality	Tabrizi et al. (2018)	1	0
		People's knowledge and awareness of the consequences of using wastewater	Talebi Somesarayee et al. (2016); Fattahi and Behroozi (2018); Rezaee and Sarrafzadeh (2017); Tabrizi et al. (2018); Ahmadi et al. (2019); Deh-Haghi et al. (2020); Bass et al. (2022)	7	1
		Farmers' understanding of the water scarcity crisis and the use of wastewater	Cosgrove and Loucks (2015); Talebi Somesarayee et al. (2016); Deh-Haghi et al. (2020)	3	0
		Farmers' satisfaction with the quality and quantity of wastewater and government support	Neji and Turki (2015); Murray and Ray (2010); Ahmadi et al. (2019)	3	1

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TABLE 3 (Continued)

	Sustainable management of wastewater use (SMWWU)				
	Component affecting SMWWU	Variables	Sources	Frequency	
				In articles	In interviews
	Environmental	Reducing soil degradation	Interviews	0	1
		Use of untreated wastewater and health, environmental and sanitation risks	Palese et al. (2009); Vivaldi et al. (2013); Trinh et al. (2013); Jeong et al. (2016); Galvis et al. (2018); Esmaeilian et al. (2021); Yu et al. (2022)	7	3
		Reducing discharge (sewage) and contamination of receiving water sources	Jang et al. (2012); Trinh et al. (2013); Wu et al. (2014); Cosgrove and Loucks (2015); Galvis et al. (2018); Sathaiah and Chandrasekaran (2020)	6	0
		Emerging pollutants	Wu et al. (2014); Elgallal et al. (2016); Pedrero et al. (2020)	3	0
		Access to water throughout the year and during drought	Murray and Ray (2010); Sato et al. (2013); Christou et al. (2014); Rodríguez-Liébana et al. (2014); Elgallal et al. (2016); Davoodabadi et al. (2018); Jeong et al. (2020); Esmaeilian et al. (2021)	8	1
		Persistence of pesticides on the soil surface	Rodríguez-Liébana et al. (2014)	1	0
		Reducing the use of chemical fertilizers and improving the soil, elements and transfer to groundwater	Segal et al. (2011); Agrafioti and Diamadopoulos (2012); Jang et al. (2012); Trinh et al. (2013); Davoodabadi et al. (2018); Farhadkhani et al. (2018); Galvis et al. (2018); Fu et al. (2019); Sathaiah and Chandrasekaran (2020); Gao et al. (2021); Hassena et al. (2021); Zolfaghary et al. (2021); Bass et al. (2022)	13	0
		air pollution (odor)	Genius et al. (2012); Sathaiah and Chandrasekaran (2020)	2	3
		Pollution of soil sources, salinity, PH, heavy metals and microbes	Lucho-Constantino et al. (2005); Mapanda et al. (2005); Agrafioti and Diamadopoulos (2012); Genius et al. (2012); Vivaldi et al. (2013); Rodríguez-Liébana et al. (2014); Wu et al. (2014); Gatta et al. (2015); Elgallal et al. (2016); Rahav et al. (2017); Davoodabadi et al. (2018); Farhadkhani et al. (2018); Libutti et al. (2018); Fu et al. (2019); Nejatijahromi et al. (2019); Assouline et al. (2020); Pedrero et al. (2020); Sathaiah and Chandrasekaran (2020); Tabatabaei et al. (2020); Cakmakci and Sahin (2021); Feder (2021); Hassena et al. (2021); Gao et al. (2021); Zolfaghary et al. (2021); Kramer et al. (2022); Yu et al. (2022)	26	7
		Pollution of water sources (surface and groundwater, aquatic mortality, etc.)	Lucho-Constantino et al. (2005); Segal et al. (2011); Elgallal et al. (2016); Nejatijahromi et al. (2019); Deh-Haghi et al. (2020); Esmaeilian et al. (2021)	6	0

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TABLE 3 (Continued)

	Sustainable management of wastewater use (SMWWU)				
	Component affecting SMWWU	Variables	Sources	Frequency	
				In articles	In interviews
		Reduction of water shortage, protection of surface and groundwater resources and storage of fresh water	Oron et al. (1999); Palese et al. (2009); Murray and Ray (2010); Segal et al. (2011); Agrafioti and Diamadopoulos (2012); Jang et al. (2012); Trinh et al. (2013); Christou et al. (2014); Rodríguez-Liébana et al. (2014); Wu et al. (2014); Cosgrove and Loucks (2015); Gatta et al. (2015); Jeong et al. (2016, 2020); Orlofsky et al. (2016); Rahav et al. (2017); Rezaee and Sarrafzadeh (2017); Davoodabadi et al. (2018); Farhadkhani et al. (2018); Galvis et al. (2018); Libutti et al. (2018); Fu et al. (2019); Deh-Haghi et al. (2020); Sathaiah and Chandrasekaran (2020); Cakmakci and Sahin (2021); Feder (2021); Gao et al. (2021); Hristov et al. (2021); Bass et al. (2022); Bolinches et al. (2022); Kramer et al. (2022)	31	6
		Possible general risks for human health and the environment	Oron et al. (1999); Lucho-Constantino et al. (2005); Mapanda et al. (2005); Palese et al. (2009); Agrafioti and Diamadopoulos (2012); Vivaldi et al. (2013); Christou et al. (2014, 2017); Elgallal et al. (2016); Caicedo et al. (2019); Fu et al. (2019); Deh-Haghi et al. (2020); Pedrero et al. (2020); Sathaiah and Chandrasekaran (2020); Tabatabaei et al. (2020); Esmaeilian et al. (2021); Gao et al. (2021); Zolfaghary et al. (2021); Tisler et al. (2022); Yu et al. (2022)	20	1
		Possible health risks for consumers of products	Lucho-Constantino et al. (2005); Belaid et al. (2012); Malchi et al. (2014); Wu et al. (2014); Neji and Turki (2015); Orlofsky et al. (2016); Christou et al. (2017); Davoodabadi et al. (2018); Libutti et al. (2018); Caicedo et al. (2019); Fu et al. (2019); Nejatijahromi et al. (2019); Yu et al. (2022)	13	2
Contextual	Political	Place of life	Cai et al. (2002); Murray and Ray (2010); Sato et al. (2013); Neji and Turki (2015); Deh-Haghi et al. (2020); Bass et al. (2022); Tisler et al. (2022)	7	0
		Size, population and location of cities	Oron et al. (1999); Malek Jafarian and Mohseni (2015)	2	0
	Social	Increasing social capital and increasing participation of farmers in Water management	Tabrizi et al. (2018); Zolfaghary et al. (2021)	2	0
		Trust and social cohesion	Rezaee and Sarrafzadeh (2017); Tabrizi et al. (2018)	2	1
	Cultural and religious	Educating about wastewater	Interviews	0	1
		Development of communities and cultural development in agriculture	Oron et al. (1999); Agrafioti and Diamadopoulos (2012); Sato et al. (2013); Trinh et al. (2013); Elgallal et al. (2016)	5	0

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	Sustainable management of wastewater use (SMWWU)				
	Component affecting SMWWU	Variables	Sources	Frequency	
				In articles	In interviews
		Culture and religion of countries	Cosgrove and Loucks (2015); Bass et al. (2022)	2	0
Management and planning		Management and planning in crisis conditions	Interviews	Interviews	Interviews
		Applying fines based on the quality parameters of certain subscribers	Zafari-Holoukhi et al. (2021)	1	0
		Using local leaders and their recommendations	Tabrizi et al. (2018)	1	0
		Justice in water efficiency and (distribution of) wastewater	Cai et al. (2002); Murray and Ray (2010); Sathaiah and Chandrasekaran (2020)	3	0
		No need to have special skills to treat or use wastewater	Chartzoulakis et al. (2010); Licciardello et al. (2018)	2	0
		Use of sustainable methods (use of arbuscular mycorrhizal fungi)	Hassena et al. (2021)	1	0
		Cooperation between different sectors, including farmers and municipalities, etc.	Oron et al. (1999)	1	4
		Cooperation between people	Interviews	0	1
		Soil filter action (preventing the transfer of pollution to deeper layers)	Oron et al. (1999); Mapanda et al. (2005); Palese et al. (2009); Vivaldi et al. (2013)	4	0
		Knowledge and management and the effect of depth, quality, drainage, moisture and agricultural soil	Malchi et al. (2014); Neji and Turki (2015); Elgallal et al. (2016); Fu et al. (2019); Zolfaghary et al. (2021)	5	0
		Knowledge and management and the effect of choosing the type of soil (clay, sand, sand, etc.)	Mapanda et al. (2005); Goldstein et al. (2014); Elgallal et al. (2016); Dindarlou and Dastourani (2018); Davoodabadi et al. (2018); Assouline et al. (2020); Feder (2021); Gao et al. (2021); Perez-Mercado et al. (2022); Yu et al. (2022)	10	0
		Elimination of long-term unsustainable over-abstraction of groundwater	McLaughlin and Kinzelbach (2015)	1	0
		Considering the used part of the plant and the physical and chemical properties of the plant	Goldstein et al. (2014); Malchi et al. (2014); Wu et al. (2014); Elgallal et al. (2016); Christou et al. (2017); Licciardello et al. (2018)	6	2
		Management in the selection of crops and types of crops for irrigation with wastewater	Cai et al. (2002); Lucho-Constantino et al. (2005); Murray and Ray (2010); Agrafioti and Diamadopoulos (2012); Belaid et al. (2012); Genius et al. (2012); Sato et al. (2013); Christou et al. (2014); Wu et al. (2014); Neji and Turki (2015); Cosgrove and Loucks (2015); Gatta et al. (2015); Elgallal et al. (2016); Dindarlou and Dastourani (2018); Davoodabadi et al. (2018); Farhadkhani et al. (2018); Fu et al. (2019); Deh-Haghi et al. (2020); Pedrero et al. (2020); Sathaiah and Chandrasekaran (2020); Feder (2021); Gao et al. (2021); Hassena et al. (2021); Zolfaghary et al. (2021); Bolinches et al. (2022); Yu et al. (2022)	26	7

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TABLE 3 (Continued)

	Sustainable management of wastewater use (SMWWU)				
	Component affecting SMWWU	Variables	Sources	Frequency	
				In articles	In interviews
		Management of water addition (mixing with clean water) and washing and amount of incoming effluent	Elgallal et al. (2016); Assouline et al. (2020); Jeong et al. (2020); Feder (2021); Gao et al. (2021); Perez-Mercado et al. (2022)	6	3
		Management of the irrigation period and the time between irrigations and the amount of irrigation	Palese et al. (2009); Chartzoulakis et al. (2010); Belaid et al. (2012); Gatta et al. (2015); Elgallal et al. (2016); Orlofsky et al. (2016); Farhadkhani et al. (2018); Assouline et al. (2020); Hassena et al. (2021)	9	0
		Management of the distance between the last irrigation and the harvest and use of the product	Oron et al. (1999); Vivaldi et al. (2013); Farhadkhani et al. (2018); Pedrero et al. (2020); Perez-Mercado et al. (2022)	5	0
		Environmental and climatic conditions (temperature, humidity, etc.)	Sato et al. (2013); Trinh et al. (2013); Goldstein et al. (2014); Gatta et al. (2015); Elgallal et al. (2016); Jeong et al. (2016); Dindarlou and Dastourani (2018); Davoodabadi et al. (2018); Farhadkhani et al. (2018); Pedrero et al. (2020); Feder (2021); Gao et al. (2021); Hassena et al. (2021); Hristov et al. (2021); Zolfaghary et al. (2021); Perez-Mercado et al. (2022); Yu et al. (2022)	17	0
		Management at the treatment site (urban and rural)	Agrafioti and Diamadopoulos (2012)	1	0
		Management of public access to the site (agricultural land)	Agrafioti and Diamadopoulos (2012)	1	0
		Management in the type of irrigation (drip, irrigation, subsurface), design and technology	Oron et al. (1999); Cai et al. (2002); Palese et al. (2009); Agrafioti and Diamadopoulos (2012); Genius et al. (2012); Christou et al. (2014); Cosgrove and Loucks (2015); Gatta et al. (2015); Elgallal et al. (2016); Jeong et al. (2016); Dindarlou and Dastourani (2018); Farhadkhani et al. (2018); Libutti et al. (2018); Assouline et al. (2020); Deh-Haghi et al. (2020); Sathaiah and Chandrasekaran (2020); Tabatabaei et al. (2020); Gao et al. (2021); Bolinches et al. (2022); Perez-Mercado et al. (2022)	20	4
		Management in the way of using wastewater (periodic – full replacement)	Interviews	0	1
		Using new, useful and advanced health methods in purification and technology	Palese et al. (2009); Rojas-Valencia et al. (2011); Christou et al. (2014); Cosgrove and Loucks (2015); McLaughlin and Kinzelbach (2015); Elgallal et al. (2016); Bass et al. (2022); Bolinches et al. (2022); Yu et al. (2022)	9	0
		Management in the type of purification (degree and amount, quality and materials, system and method)	Agrafioti and Diamadopoulos (2012); Vivaldi et al. (2013); Goldstein et al. (2014); Gatta et al. (2015); Jeong et al. (2016); Dindarlou and Dastourani (2018); Licciardello et al. (2018); Caicedo et al. (2019); Hassena et al. (2021); Zolfaghary et al. (2021); Bolinches et al. (2022)	11	1
		Management and control of soil pH, amount of organic matter and soil modification and salinity	Elgallal et al. (2016); Pedrero et al. (2020)	2	1

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TABLE 3 (Continued)

	Sustainable management of wastewater use (SMWWU)				
	Component affecting SMWWU	Variables	Sources	Frequency	
				In articles	In interviews
		International policies and creating a legal framework on wastewater quality (guidelines)	Lucho-Constantino et al. (2005); Palese et al. (2009); Axelrad and Feinerman (2010); Chartzoulakis et al. (2010); Murray and Ray (2010); Vivaldi et al. (2013); Sato et al. (2013); Gatta et al. (2015); Dindarlou and Dastourani (2018); Galvis et al. (2018); Licciardello et al. (2018); Tabatabaei et al. (2020); Hristov et al. (2021); Zolfaghary et al. (2021); Bolinches et al. (2022)	15	4
		Monitoring and management in the use of wastewater (quality and health parameters)	Palese et al. (2009); Agrafioti and Diamadopoulos (2012); Christou et al. (2014); Gatta et al. (2015); Pedrero et al. (2020)	5	5
		Management of treated wastewater (no transfer to the sea, canal, etc.)	Agrafioti and Diamadopoulos (2012)	1	0
		Using wastewater in wet areas to improve performance	Sato et al. (2013); Feder (2021)	2	0
		Creating policies and programs in sustainable water and wastewater management and pollution prevention	Lucho-Constantino et al. (2005); Rojas-Valencia et al. (2011); Brown et al. (2015); Cosgrove and Loucks (2015); McLaughlin and Kinzelbach (2015); Davoodabadi et al. (2018); Ahmadi et al. (2019); Bass et al. (2022)	8	3
		Management with different methods (subsurface use of sewage, etc.)	Cakmakci and Sahin (2021); Feder (2021)	2	0
		Incentives and policies regarding the use of wastewater and encouraging farmers	Axelrad and Feinerman (2010); Jeong et al. (2016); Fattahi and Behroozi (2018); Deh-Haghi et al. (2020); Esmaeilian et al. (2021); Hristov et al. (2021)	6	2
		Available information and data regarding the amount of purification	Sato et al. (2013)	1	2
		Participation of stakeholders in decision-making and implementation of programs and interactive management	Genius et al. (2012); Neji and Turki (2015); Brown et al. (2015); Cosgrove and Loucks (2015); Talebi Somesarayee et al. (2016); Hassani et al. (2017); Rezaee and Sarrafzadeh (2017); Tabrizi et al. (2018)	8	0
	Education and extension	Dissemination of information	Genius et al. (2012); Tabrizi et al. (2018)	2	0
		Holding education and extension classes, managing and investigating problems and consulting	Cosgrove and Loucks (2015); Tabrizi et al. (2018)	2	1
		Continuous meeting of farmers benefiting from wastewater with change agents and experts	Tabrizi et al. (2018)	1	1
		Training farmers about sustainable agriculture	Rojas-Valencia et al. (2011); McLaughlin and Kinzelbach (2015)	2	0
		Educating citizens about the use of products produced with sewage	Murray and Ray (2010); Rojas-Valencia et al. (2011); Bass et al. (2022)	3	1
		Providing training to farmers regarding the use of wastewater	Murray and Ray (2010); Fattahi and Behroozi (2018); Deh-Haghi et al. (2020)	3	2
		Extension of sustainable agricultural methods using effluents and emphasis on benefits	Fattahi and Behroozi (2018); Bass et al. (2022)	2	0
Total				495	90

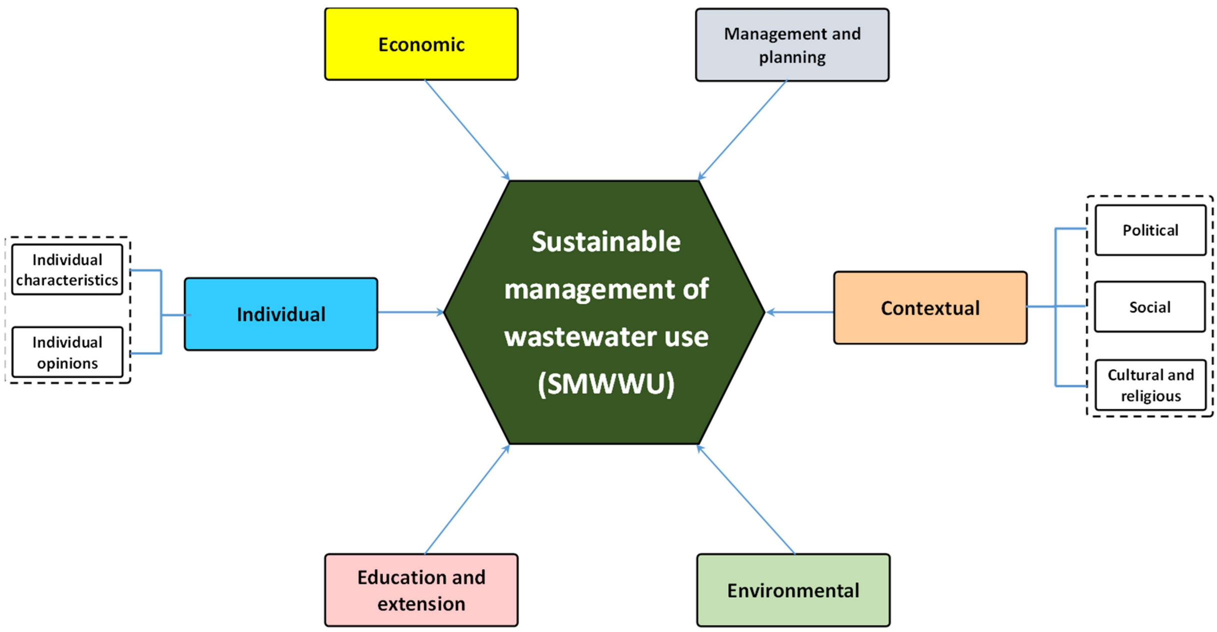

FIGURE 1
Content analysis model of factors affecting SMWWU.

nutrients for plant growth (Deh-Haghi et al., 2020). In fact, besides increasing available water causes farmers to switch from dry farming activities to irrigated farming (Hristov et al., 2021), wastewater can increase yield as much as or more than the combination of potable water and chemical fertilizers (Murray and Ray, 2010) in which 16 articles have referred to the increase in product yield. It is worth to mention that water scarcity is not the main reason to use sewage in most cases. For example, farmers in Latin America use wastewater because it provides a low-cost source of plant nutrients (Sato et al., 2013). On the other hand, despite the availability of water for the plant and the fertility of the soil by using recycled wastewater, the growth conditions of the plant can be affected positively, but the excess amounts of these mineral materials as well as other salts can have a negative impact on plant growth (Segal et al., 2011). Therefore, the necessity for basic management and planning in the use of wastewater in the agricultural sector is obvious, and in this research, the repetitions of concepts in the management and planning component is 190 times, which ranks first in terms of importance among other components. The most important concept of this topic is related to the management in the selection of the crop and the type of cultivation to irrigate with wastewater, the necessity of this issue has been discussed in 26 articles, and then the necessity of management in the type of irrigation (drip, surface, subsurface) and the design and technology of irrigation systems of farms have also been mentioned in 20 articles. Besides, in 17 articles, environmental and climatic conditions (temperature and humidity, amount of ultraviolet radiation, humidity and rainfall) have been considered by the researchers. In addition to management debates, concepts related to individual characteristics and opinions (individual component) have been emphasized in 34 researches, political, social, cultural and religious factors (contextual component) in 20 studies and extension and education concepts in 15 studies.

Just like the emphasis of the articles on the concepts of management and planning component, in the interviews, the concepts of this issue have been emphasized mostly. Indeed, in the interviews, there were 41 concepts related to this component. Then, the environmental, economic and the individual component have been mentioned and the only difference is in changing the position of the contextual and education component. By repeating the contextual component 20 times, the articles have given much emphasis before the educational component with 15 repetitions, but in the interviews conducted, the emphasis has been placed on extension and educational issues.

Finally, in the analysis of SMWWU, it is necessary to highlights the significance of utilizing treated wastewater in agriculture to address water scarcity issues, enhance soil fertility, and reduce reliance on chemical fertilizers. These benefits not only have environmental implications by conserving water resources and improving soil health but also offer economic advantages by potentially decreasing the costs associated with fertilization.

Furthermore, the discussion emphasizes the importance of proper management and planning in implementing wastewater reuse practices in agriculture. By selecting appropriate crops, irrigation methods, and considering environmental and climatic conditions, the potential risks associated with using treated wastewater can be effectively mitigated. This underscores the critical role of strategic decision-making and efficient resource allocation in ensuring the sustainability of wastewater use in agriculture.

Additionally, the discussion touches upon the individual, contextual, and educational components in relation to wastewater management. Understanding the personal characteristics, social factors, and cultural influences involved in adopting sustainable practices is crucial for successful implementation. Moreover, emphasizing extension and education can play a vital role in raising awareness, fostering behavioral change, and promoting best practices among stakeholders in the agricultural sector.

4 Conclusion

Since the anthropogenic actions and behaviors have caused problems in the field of SMWWU, and the measures taken to solve these problems have not been effective so far, dealing with the current challenges via the critical theory due to its critical view on issues and also examining and comparing the paths that have been employed so far to improve the conditions can make us reflect more on the current issues and the previous paths and achieve more effective solutions. Accordingly, in this paper, based on an approach in the form of critical theory paradigm, this issue was emphasized. As it was mentioned, and based on IQCA findings, the influencing factors on SMWWU were presented in the form of a model (Figure 1). Thus, the complexity of the issues in this field challenges different experts around the world to be able to create behavioral and structural changes among different stakeholders and decision makers. This research was performed using the IQCA method. Indeed, this topic can be examined with opposite quantitative, qualitative or mixed methods from the perspective of different scientific fields. It is worth to mention that the search for articles in this paper was in English and Farsi. To solve this limitation, in the future research, we can search the topic and factors affecting SMWWU from the results of other local researches. Also, besides articles and interviews with key experts, other upstream documents, laws and regulations, existing customs, norms and beliefs of people can be examined in the form of different research methods. However, as the present study is based on various previous researches, its results can be used in providing a comprehensive scientific insight for other researchers. The important point in the mentioned model is more emphasis on extension and educational issues. Hence, it is necessary to emphasize more education about the use of wastewater in agriculture. Because, as the results indicated, the most important step to raise awareness and stabilize the management and use of wastewater in agriculture is proper education. Now, various trainings are given to farmers in the government organizations of Jihad-e Agriculture, in accordance with different factors, such as: cultivation of gardens, family farms, dominant crops (wheat, barley, corn, and canola), etc., as well as skill classes, such as growing mushrooms and using unconventional water. In addition, it is required to prepare education and extension classes about heavy metals from wastewater. In fact, in addition to the quantity and quality of education, effective communication between farmers and change agents should be developed.

Author contributions

MG: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Writing – original draft. AN: Conceptualization, Methodology, Project administration, Supervision, Validation, Visualization, Writing – review & editing. MB: Conceptualization, Methodology, Project administration, Supervision, Validation, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The reviewer MS declared a past co-authorship with the author MB to the handling editor.

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