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Assessment of Wastewater Irrigation Practices and Soil Properties in the Gazipur District of Bangladesh

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Abstract **Original Research Article**

The study deals with the assessment of wastewater irrigation practices and soil properties in connection with demographic information, availability of water sources, health hazards and the benefit-cost analysis in the Gazipur district of Bangladesh. A questionnaire survey was carried out to collect data on farmers' perceptions and responses to mainly agricultural production issues. It found that most respondents used wastewater because they had no alternative sources and sank their land during rush hour as well as the rainy season due to the lack of a proper wastewater disposal system by adjacent industries. The majority of respondents had skin problems from working with wastewater. No significant benefits were found from using direct wastewater in the fields. Irrigation costs could be reduced, however, fertilizer costs as well as the total cost of plant production were not adequate. The farmers did not get as much grown grain as they wanted. In addition, indirect wastewater users were rated better compared to direct users from the drainage canal. Farmers' perception showed that no major impact on the consumption of crops was noted, but rather the long-term use of wastewater in the field, which gradually reduced crop production and affected soil fertility. To evaluate Ca ++, Mg ++, K +, N, P, Cu, Pb, Cd and Ni from the investigation area; It was examined that the concentration of N, P and Cd was much higher than the standard limit. The heavy metal concentration series were as follows: Cd <Cu <Ni <Pb. In summary, the overall results of the study suggest that untreated or partially treated wastewater will slowly affect land and crop production in the long run.

Keywords: Wastewater irrigation, farmers' perception, health hazards, soil properties, agricultural production.

1. INTRODUCTION

Bangladesh is a developing country whose economy depends mainly on agriculture. The population of our country is growing day by day. To meet the growing demand for food, more crops need to be grown. Agriculture consumes a lot of water around the world. Almost 93 percent of the water was used in irrigated agriculture and only 7 percent of the water was used for other purposes (Alderwish, 2009). The growing demand of the population and climate change will make the availability of water in sufficient quantity and quality in Bangladesh even more difficult for the next generation. The demand for water has increased three times since the 1950s (Brown, 2003). The study was carried out by the International Food Policy Research Institute (IFPRI) and the International Water Management Institute (IWMI) and suggests that if the current conditions of increasing use of water for urbanization and food production worldwide continue, so will the availability of water by 2025 for irrigation. Scott *et al*. (2004) reported that this type of water consumption will cause an annual loss of around 350 million tons of food production worldwide. However, it is better to use another source of water for our agricultural production. Alternative water sources can be used to expand irrigation and to use water more efficiently (Pereira *et al.*, 2002).

Wastewater has become an important source of water and nutrients for irrigated agriculture, especially in developing countries, but not only in arid and semi-arid areas (Jimenez, 2006). According to a survey report, 20 million hectares (approx. 7%) of land worldwide are irrigated through the use of wastewater (SAI platform, 2010). Urban wastewater can contain all dangerous substances, including higher trace elements, heavy metals and pathogenic microorganisms (Siebe & Cifuentes, 1995). The amount of these substances varies from place to place and region to region, depending on the amount and source of the wastewater, the treatment before use and the management of the wastewater both at its source and at the level of agricultural use

(Drechsel & Evans, 2010). According to UNESCO 2003; More than 80% of the wastewater produced in developing countries is discharged directly into the environment without adequate treatment, and around 50% of the population depends primarily on these polluted water sources for its daily use, including irrigation. Untreated or partially purified wastewater can be harmful to both aquatic and terrestrial creatures by affecting the natural ecosystem and causing long-term health effects (Khan & Malik, 2013). Zhang & Shen (2017) reported that population growth, social and economic development, and water scarcity are becoming serious facts around the world. It has been suggested by many researchers and specialists to use sewage irrigation, but sewage in irrigated agriculture has both positive and negative effects on crop production, public health, soil resources and ecosystems (Hussain *et al.*, 2002; Scott *et al*., 2004). Irrigation requires sewage to be properly treated. According to the WHO (2006), only 10 percent of the world's population consumes food produced by sewage irrigation.

There were many industries around the study area and a lot of wastewater is produced by them. With proper treatment, this wastewater can be used as an alternative source of irrigation. Wastewater can contain organic matter and mineral nutrients that are beneficial for crop production and reduce fertilization costs (Hoek *et al*., 2002). Proper impact assessment is required before using wastewater to take advantage of both positive and negative impacts. Failure to do so could result in negative human health and environmental effects that could harm the effects of climate change on the whole world. Roy *et al*. (2013) identified the benefits, negative effects, social acceptability and long-term effects of reusing industrial wastewater in the greater Tejgaon area of Dhaka city. Due to the increasing scarcity of fresh water, the reuse of wastewater for irrigation had gained in importance in Bangladesh than suggested by Mojid *et al*., 2016. Ahmed *et al*. (2019) examined heavy metals such as chromium (Cr), copper (Cu), zinc (Zn), arsenic (As), cadmium (Cd) and lead (Pb) in irrigation, soil and vegetables in dry and rainy seasons from a multi-industrial zone in Bangladesh. Nonetheless, the present study is necessary to assess wastewater irrigation practices and soil properties in a particular region in Bangladesh. The research objectives were (i) the assessment of the farmers with regard to sewage irrigation, (ii) the analysis of the cost-benefit ratio of plant production with sewage and (iii) the quantification of the physico-chemical parameters of the soil irrigated with sewage.

2. METHODOLOGY

2.1 DESCRIPTION OF STUDY AREA

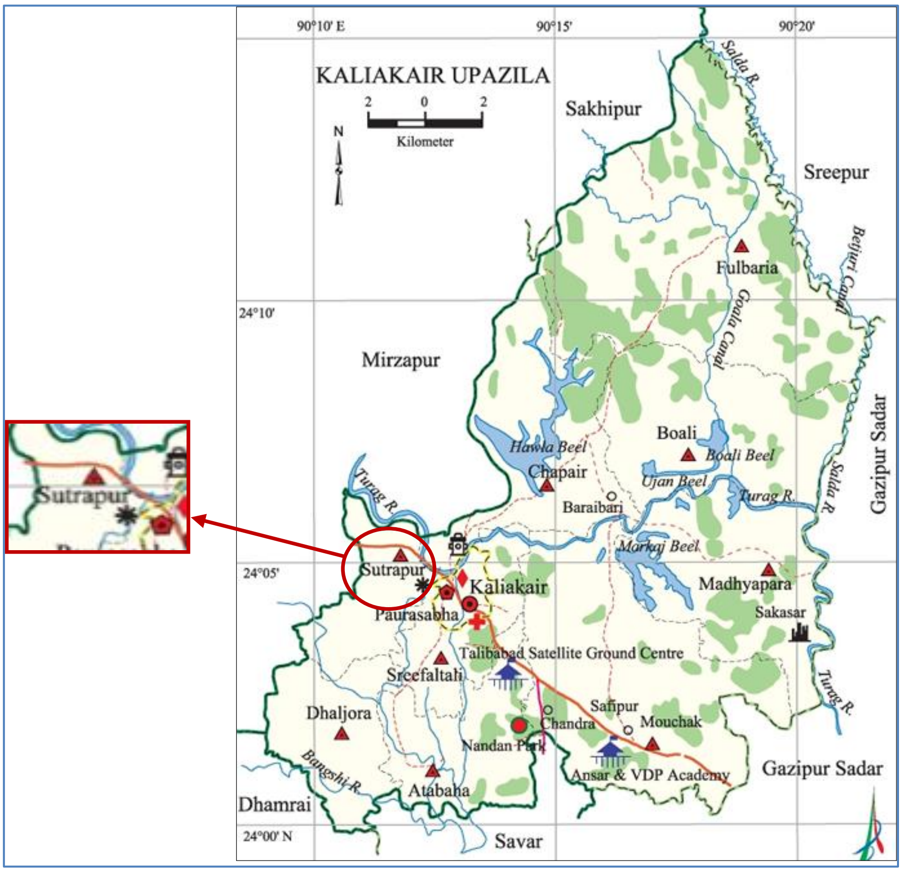

Fig-1: Map showing the study area

Kaliakair upazila is one of the exceptional areas in the Gazipur District of Bangladesh, where most of the industries are located and huge amounts of wastewater are regularly disposed of. The area of Kaliakair upazila is 314.14 km². It is between 24°00' and 24°15' north latitudes and between 90°09' and 90°22' east longitude. It is bordered by Mirzapurand Sakhipurupazilas in the north, Savarand Dhamrai Upazilas in the south, Gazipur sadar and Sreepurupazilas in the east, and Mirzapur Upazila in the west. Figure 1 shows the Turaq, Bangshai and Salda rivers; Boali, Hawla, Ujan, and Markaj Beel; and the Goala and Betjuri canals are the main bodies of water. The total population is approximately 2, 67,003; of these, 1, 38,240 and 1, 28,763 are male and female. The Upazila consists of 9 unions, 181 mouzas, 283 villages, 9 districts and 18 mahallas. The average population of Union, Mauza, and Village is 25,879; 1,287; and 823, respectively (BBS, 2011).

2.2. Survey data collection procedure

In this study the primary data and the secondary data were used. The secondary data such as statistical information, demographic information and geographic information were collected from the website of the relevant government office such as Kaliakair upazila, district statistics and population and housing censuses. Some data were collected directly from the Upazila Agricultural Extension Office through a conversation with the relevant official. Primary data was collected by visiting the study area such as the industrial sewer and agricultural fields. Another primary data source was collected through a questionnaire survey among farmers who have used and worked with wastewater. The most important part of this research was the sewage flow system in the study area, which was initiated by physical observations. The method of selecting the respondents was targeted sampling and the total number of respondents was 41 who are directly involved in the use of wastewater for crop production. The field survey was conducted to collect the following information: questionnaire on the demographic pattern of respondents; questionnaire on farmers' perception of the use of wastewater; questionnaires on the availability of natural resources such as irrigation sources; questionnaire on health hazards when working with wastewater, irrigation and crop consumption; questionnaire on irrigation and fertilizer costs, as well as total production costs.

2.3. Collection of soil sample

The soil samples were collected at four different locations during the *Boro* season in the study area. The sample collection depth was 15-20 cm from the top soil where plants were grown with wastewater. Four polyethylene bags were used to separate the sample. All other substances such as dry roots and grasses etc. were removed from the samples. Approximately 1 kg of the homogenized composite samples for each depth was stored below a temperature of 40°C. All samples were mixed together to give an average result. The physical and chemical analysis of the collected soil samples was carried out in the laboratory of Soil Science, Bangladesh Agricultural Research Institute (BARI), Gazipur.

2.4. Analysis of soil sample and survey data

The collected soil samples were analyzed for various physicochemical parameters such as calcium ion (Ca ++), magnesium ion (Mg ++), potassium ion (K +), nitrogen (N), phosphorus (P), copper (Cu), lead (Pb.), Cadmium (Cd) and Nickel (Ni) according to the standard method of the laboratories of Soil Science, Bangladesh Agricultural Research Institute (BARI), Gazipur. The MS Excel package was used to analyze the questionnaire survey data.

3. RESULTS AND DISCUSSION

3.1. Farmers' perception on wastewater irrigation

3.1.1. Description of respondents with cultivation status

Of all respondents, around 85 percent of the population was mainly engaged in agriculture and only 15 percent in non-agriculture, as shown in Table 1. About 62 percent of the respondents were uneducated with regard to their educational status. In another family size question, about 12 percent of farmers were small families, 52 percent middle families, and 36 percent large families, based on the number of family members. The cultivation time with wastewater irrigation was 0-5 years for 2 percent of the farmers, 6-10 years for *32* percent of the farmers, 11-15 years for 59 percent of the farmers and 16-20 years for 7 percent. Some farmers work their own land and others are grown on leased land. The study found that the 41 percent of farmers farmed up to 50 decimal places, 34 percent of farmers farmed between 51 and 100 decimal places, and only 8 percent of farmers farmed more than 100 decimal places, or 1 acre of land. A similar type of study was carried out by Roy *et al*. (2013) and found that most farmers (around 84.38%) used wastewater irrigation from exposed sites and only 15.63% had controlled sites. Michetti *et al*. (2019) reported that around 17 percent of respondents only had primary school education (five years of schooling) and the same percentage was over 65 years of age.

Table-1: Respondents' description who participated on the questionnaire survey

Indicators	Variable	Percentage (%)
Main occupation	Agriculture (=yes)	85
Education status	Uneducated (=yes)	62
Family size (persons)	0-3	12
	4-6	52
	7-10	36
Duration of cultivation (years)	0-5	2
	6-10	32
	11-15	59
	16-20	7
Field size (decimal)	0-50	41
	51-100	34
	100+	25

3.1.2. Statement by the respondents on the use of wastewater

Most of the farmers (around 71%) in the study area did not have a choice to irrigate the field with fresh water, but some did have the option to use fresh water. According to the respondents, around 90 percent of them used surface water irrigation and only 10 percent used groundwater for irrigation, as shown in Table 2. Almost all farmers stated that they used wastewater from surface sources for irrigation and this wastewater was disposed of from various industries around the study area. All industries dumped their waste in canals carried across the agricultural fields by the Bangshai and Turag rivers. Many of them (around 68%) were used directly from the sewer and the rest indirectly by storing the sewage in a hole and then using it for irrigation. The most important thing was that the wastewater was distributed over the agricultural land during the rainy season and the industrial peak season of waste disposal. During these two periods, all farmers reluctantly used sewage. The reasons for the use of wastewater are shown in Fig. 2. Some farmers had the option to use groundwater, but they also used wastewater for two main reasons: a) to reduce irrigation costs; and b) their land had been flooded during rush hour and rainy season. About 29 percent of farmers were able to use groundwater for irrigation, but only 10 percent of farmers were able to use groundwater. For the above reason, the farmers could not use their available water sources. They had mentioned that if the sewage didn't flood their land, they could use an alternative source of irrigation. All farmers gave their opinion that the source of the wastewater was industry and that it should be used in their field. Similar research was carried out by Kumar *et al*. (2008) and the results showed that the majority of the responders (approx. 90 percent) were not confronted with water scarcity, since wastewater was available as was sufficient at exposed locations throughout the year. But only 10 percent of farmers who lived at the bottom of the sewers said they experienced minor water scarcity during the main growing season in the March to April.

Table-2: Respondent's statement about the sources and causes of using wastewater

Indicators	Variable	Percentage (%)
Water availability	Ground water (=yes)	29
Types of water used	Surface	90
Types of surface water	Wastewater (=yes)	100
Sources of wastewater	Industrial (=yes)	100
Causes of using wastewater	No alternative sources	71
	Sinking out during peak hour	100
	Sinking out during rain	100
	Other reason	29
Way of using wastewater	Directly	68
	Indirectly	32

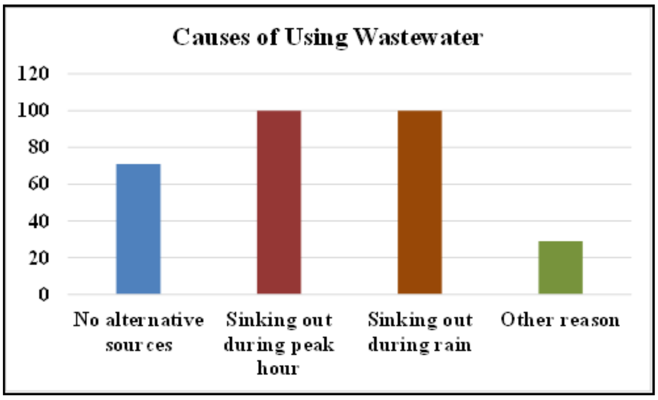

Fig-2: Causes for the use of sewage irrigation in the study area

3.1.3. Farmer's ideas about wastewater use and work with wastewater

Table 3 shows that the farmers are aware of the wastewater use and that all farmers believe that the wastewater is polluted. Almost all farmers stated that the source of sewage was industry and 27% also stated that the industrial sewers are connected to the waste disposal system. The sewage appeared worst in color and had the bad smell. All farmers said the wastewater is not good for agricultural production, although they grow rice with sewage and also 12% of the farmers grow various vegetables in their fields. Most of them had difficulties (see Fig. 3) when working with wastewater such as skin diseases, suffered from breathing problems, etc. Only 5% of the farmers remarked that on the day they worked on their land, because they had the worst smells and gases in the sewage. All farmers agreed with the statement that the use of sewage irrigation in crop production has long-term effects on agricultural land by reducing crop production and soil fertility. They didn't think the sewage had any beneficial effect on their crop production. A study by Roy *et al*. (2013) and reported that for the pollution of the water of the river, that of the usual masses (approx. 85 percent) during irrigation. About 46.25% of farmers said the wastewater was not good for crop production, but most of them (79.7%) used wastewater to save fertilizer costs. On the other hand, 53.75 percent of those surveyed said that reusing wastewater for crop production is reliable. Finally, 60 percent of those surveyed at the exposed locations suggested growing vegetables rather than other plants due to the environmental conditions. Michetti *et al*. (2019) reported that the perception of water quality was evoked by a qualitative response from farmers who could choose one of the following options: 1) good, 2) sufficient, 3) bad, (4) very bad; or (5) don't know. By analyzing the value of the qualitative categorical variables, they observed that the water quality in the area was perceived as good by 57 percent of the sample; 43 percent of farmers said it was of poor or very poor quality. Another study by Kumar *et al*. (2008) reported that the vegetables were the most frequently chosen crop by 70 percent of the farmers in control locations, while rice was the most frequently chosen crop for the farmers (around 40 percent) in exposed locations. About 90 percent of those surveyed said that reusing wastewater as irrigation for their plants is reliable.

Table-3: Perception of farmers about the use of wastewater and about working with wastewater

Indicators	Variable	Percentage (%)
Does wastewater be polluted?	Polluted water (=yes)	100
Sources of pollution	Industrial waste	100
	Sewerage waste	27
Is wastewater good for agriculture?	No (=yes)	100
What types of crops are grown in study area	Rice	100
	Vegetables	12
Facing any difficulties due to working with wastewater	Facing difficulties (=yes)	100
Types of problems they are facing	Skin	100
	Respiratory	20
	Irritation	5
Does it have any long-term effect on land?	long term effect (=yes)	100

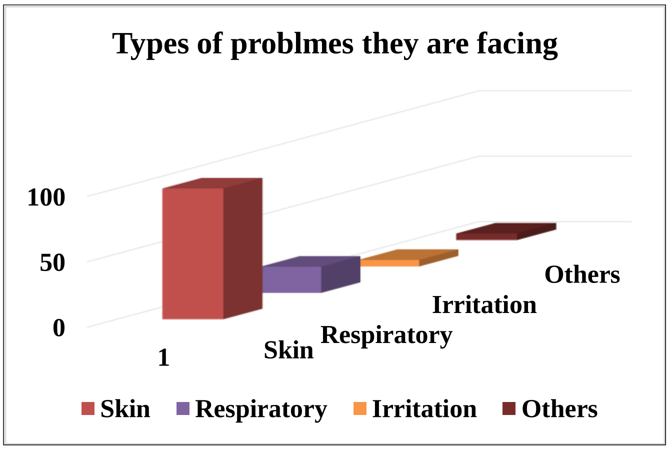

Fig-3: Types of problems in the use and processing of wastewater by farmers

3.1.4 Feedback from farmers on the consumption and sale of the crops grown with wastewater

Those who used wastewater for plant production consumed all of the crops listed in Table 4. About 12 percent of farmers complained that they encountered difficulties with wastewater after consuming the crops. Cooked rice tasted different from fresh source. Most of them (around 78%) sold their grown crops to the local market and others after consuming them. Only 10% of farmers said they had negative feedback from customers who bought and consumed crops from them. According to farmers, about 5% of farmers complained about taste problems and the same percent had minor odor problems. Another study was done by Michetti *et al.* (2019) and reported that a group of just four farmers, 50 percent of whom believed the wastewater treatment process had an impact on the aquatic environment, but a larger group of 50 farmers believed it had no impact.

Table-4: Feedback from the farmers on the consumption of the cultivated crops

Indicators	Variable	Percentage (%)
Consumption of cultivated crops	Consumption (=yes)	100
Do they face any problem after consuming the cultivated crops?	Facing problem (=yes)	12
Types of difficulties they are facing	Taste problem	12
Do they sell the cultivated crops?	Sell (=yes)	78
The place of selling the cultivated crops	Local market	95
	Super shop	5
Does customer face any difficulties after consuming the cultivated crops?	Facing difficulties (=yes)	10
Types of difficulties the consumers are facing	Taste problem	5
Does bad smell come from crops?	Having bad smell (=yes)	5

3.2 Cost-benefit analysis of crop production with wastewater

According to respondents, around 54% of respondents said that using wastewater was no more cost-effective than other sources of irrigation listed in Table 5. In addition, the health of the plant was good, but the plant final production did not meet their expectations. Almost 93 percent of farmers agreed to the falling irrigation costs because they didn't have to pay for irrigation. In some cases, fertilizer costs increased or decreased depending on the physical condition of the plants. About 46% of respondents said that fertilizer costs have increased due to sewage irrigation. If they stopped applying fertilizer, the physical condition of the plant would not be good and production would decline. However, the total cost of the project increased (49% informed farmers) as they had to use more fertilizer for plant growth or livelihood but did not get proportionally more harvests, which is shown in Fig. 4. Therefore, Hoek *et al.* (2002) reported that partially purified or untreated wastewater increased plant production and that water and fertilizer costs could be minimized. Another study by Michetti *et al.* (2019) found that around half of those surveyed believed that using purified water had benefits. A large number of farmers believed they had benefited from wastewater irrigation, but a group of few farmers did not expect any benefit from sewage irrigation. Kumar *et al.* (2008) found that the cost of fertilization at the control sites was much higher than at the exposed sites.

Table-5: An overall cost analysis of crop production with wastewater

Indicators	Variable	Percentage (%)
Is it cost effective using wastewater than others?	No	54
Does the production be changed?	Decreased	66
What is about the irrigation cost?	Decreased	93
After using wastewater, does the fertilizer cost be changed?	Increased	46
Overall cost of the project	Increased	49

3.3. Soil properties of the study area

The result of the collected soil samples is shown in Table 6. Considering the nutrient content in the soil, it was found that the nutrient concentrations such as calcium (Ca), magnesium (Mg), potassium (K), nitrogen (N) and phosphorus (P) were 1.24 meq/ml, 0.35 meq/ml, 0.72 meq/ml, 0.028% and 55.0 ppm, respectively. From the analysis, except for N and P; all other nutrient contents were within the permissible range of the soil. Nitrogen (N) influences the amino acid composition of the protein and its nutritional quality. Increasing nitrogen input usually improved core integrity and strength, which resulted in improved grinding properties of the grain. However, the excessive nitrogen supply decreased the relative proportions of lysine and threonine; this reduces the biological value of the protein (Blumenthal *et al*. 2008). An increased supply of nitrogen improved the concentration of nitrate, nitrogen and carotene; however, reduced the concentration of dry matter, potassium, sucrose, vitamin C and dietary fiber in leaf vegetable crops (Sorensen *et al*. 1999). While phosphorus (P) is considered to be one of the most important nutrient elements (after nitrogen) that limits agronomic production in most regions of the world (Holford, 1997). Increased amounts of phosphorus made a positive contribution to plant development and a higher grain yield (Rogerio *et al*. 2013). Increasing the phosphorus intake brought the greatest improvement in the length of the outer hyphae per centimeter of infected root and decreased the formation of vesicles within infected roots (Abbott *et al*. 1984). However, the concentration of the heavy metals copper (Cu), lead (Pb), cadmium (Cd) and nickel (Ni) were 2.37 ppm, 15.9 ppm, 1.40 ppm and 12.0 ppm, respectively. The heavy metal Cd from Cu, Pb and Ni was found to be higher than the standard limit. The heavy metal concentration was in the order Cd <Cu <Ni <Pb series. According to the analysis, Pb was found higher and Cd was found lower. Cadmium (Cd) is a heavy metal that occurs naturally in soils and can be added to the soil as a pollutant in fertilizers, sewage sludge and from air deposits (Grant *et al*. 1997). Cadmium can be stored in the human body for many years. Therefore, the consumption of foods with a high Cd content can cause chronic toxicity (Jackson & Alloway 1992; FAO / WHO 1995).

Table-6: Status of the nutrient and heavy metal analysis of the study area

Parameter	Value	Maximum Limit
Calcium (Ca)	1.24 meq/ml	0.984-1.857[1]
Magnesium (Mg)	0.35 meq/ml	1.20[2]
Potassium (K)	0.72 meq/ml	-
Nitrogen (N)	0.028 %	0.0125[3]
Phosphorus (P)	55.0 ppm	50[4]
Copper (Cu)	2.37 ppm	36[*]
Lead (Pb)	15.9 ppm	85[*]
Cadmium (Cd)	1.40 ppm	0.8[*]
Nickel (Ni)	12.0 ppm	35[*]
Source: Mahmood *et al.* (2020) [1], FDA[2], soilquality.org.au[3], Pennsylvania Nutrient Management Program[4], [*]Denneman and Robberse 1990; Ministry of Housing, Netherland		

4. CONCLUSION

The present study showed that most farmers had to use wastewater because of the scarcity of fresh water available. However, farmers are forcibly used wastewater as it floods their entire agricultural area at peak industrial waste disposal times as well as during the rainy season. While they were able to minimize irrigation costs, the crop production was not satisfied. The farmers who used the wastewater straight from the wastewater had to face some difficulties like breathing problems due to bad smell and skin problems and lower production costs. But those who used wastewater after storing it in a certain hole had no problem, and its production was good too. The user did not have a clear understanding of the benefits of using fully disinfected sewage for irrigation. However, they had to use large amounts of fertilizers, chemicals, and insecticides; they could not get the expected number of harvests proportionally. The physico-chemical parameters of soils including heavy metal analysis were carried out to check the fertility of the soil and the suitability of industrial wastewater irrigation for crop cultivation with the comparison of the prescribed standards for safe irrigation and sustainable development. The sample size was comparatively small due to the lower availability of respondents and it was difficult to find farmers together. Many of the respondents were not ready to give the interviews. First of all, the study on the physical, chemical and biological quality of disposed industrial wastewater should be carried out in order to find sustainability for irrigation and other uses.

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CONFLICT OF INTEREST

The author(s) have not declared any conflicts of interest with the research, authorship or publication of this article.

ETHICAL APPROVAL

This research does not involve any human or animal testing.

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