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Impact of Irrigation Water On the Quality Attributes of Selected Indigenous Plants

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Abstract: The present study was carried out to study the effects of irrigation water on the quality attributes of mango, banana, and mulberry collected from the nearby orchards located in peri-urban areas of Sahiwal (Pakistan). Due to freshwater scarcity in peri-urban areas, wastewater is used as a source of irrigation for orchards, which consequently increases heavy metal accumulation in the soil, leaves, and fruits. The physio-chemical attributes and accumulation of heavy metals were analyzed in different soil layers and fruit cultivars. Among the heavy metals, copper, lead, chromium, and cadmium contents were found to be in greater amounts in the effluent sample than in freshwater samples, according to WHO. Heavy metals such as copper, lead, and chromium were found to be in higher concentrations in soil and effluent samples. The concentration levels of copper in mango and mulberry were 0.005 and 0.002 mg/kg, respectively. The concentration levels of lead in banana and mulberry were 0.231 and 1.248 mg/kg, and the concentration of chromium in banana was found to be 1.203 mg/kg, which is higher than the allowed limit given by WHO. The interaction among the sources of irrigation and fruit cultivars was significant for copper accumulation in different soil layers, lead, and copper accumulation in fruit cultivars. The irrigation water quality index (WQI) of all effluent samples ranged from 63.5 to 63.57, which, according to WHO, can be used for irrigation purposes as it is non-drinkable water.

Keywords: Contaminants, Effluent, Freshwater, Heavy metals, Irrigation water, Peri-urban areas

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INTRODUCTION

Freshwater scarcity is a major issue worldwide, which is due to rapid urbanization and anthropogenic activities. In developing countries, due to the non-existence of industrial and environmental standards, the dumping of waste such as pharmaceuticals, industrial and sewage into rivers, streams, and lagoons has become a threat to ecological life which unfortunately causes long term health effects such as gene mutation, lung cancer, and kidney diseases, etc. (1). Water is polluted due to non-conservative materials, conservative pollutants, and accumulation of heavy metals by different sources like pharmaceutical industries, chemical industries, metal fishing and plating operations. Some of the sources of trace metal pollution in rivers and oceans include thermal power plants (2, 3).

Heavy metals' accumulation in the surroundings is deleterious for living organisms as they are non-biodegradable and intensive through the food chain, which causes numerous known health effects such as gastrointestinal and respiratory diseases (4-6), nausea, vomiting, and several diseases (7). Toxic metals are accumulated in the aquatic environment from plastic manufacturing, fertilizers, and metallurgy processing. This wastewater causes a big threat to the ecosystem and causes environmental pollution. Heavy metals when combined with organic matter in the presence of bacteria yield monomethyl mercury and dimethyl cadmium, which are highly toxic compounds (8). Due to the non-availability of fresh water in the peri-urban areas, wastewater is commonly used to irrigate vegetable crops and orchards. Sewage water is mostly used by farmers as it increases the nutrient concentration, but the drawbacks are completely ignored by them, which leads to heavy metal accumulation in the soil, causing contamination and spoiling fruit quality. Contaminants of emerging concerns (CECs) such as pharmaceutical effluents are introduced into the agroecosystem through reclaimed wastewater irrigation. However, the effects of reclaimed wastewater irrigated crops have not caught the attention of the population. Therefore, they are being sold and consumed (9). However, recent studies show that 65% of all the irrigated core plants rely on treated wastewater flow, which causes serious health issues to the patrons (10). The mechanism of bio-chemo-physical properties of the molecule and in-planta processes such as uptake, translocation, accumulation, and transformation, influenced the fate of the pharmaceuticals in the water-soil-plant continuum (11). Numerous studies have shown the consequences of heavy metals in the streams which otherwise would have endured as conventional. This leads to the identification of wastewater treatment plants (WWT) as a substantial source of these compounds for the environment (12). The innovation in modern technology improved the analytical capabilities, which manifested the wide range of pharmaceuticals in the environment. Wastewater has long-term effects on the ecological health of human beings, such as acute and chronic effects (13), behavioral changes (14), and reproductive damage (15). Current studies indicate that pharmaceuticals have also affected aquatic life. The high level of concentration of pharmaceuticals in freshwater causes hormonal changes in fish, which can be a life-altering phenomenon (16). Assessment of risk associated with pharmaceutical effluents in irrigating fruit plants can be studied by checking water quality parameters and formulating a hypothesis on how the chemical composition of fruits has been affected by pharmaceutical effluents (17). Most of the pharmaceutical industries' effluents contain heavy metals (18), solids, organic compounds, and solvents which play a vital role in identifying potential ecological effects. The biological oxygen demand (BOD) (19), chemical oxygen demand (COD) (20), suspended solid (SS) and pH of the pharmaceutical effluent also contribute to checking the quality attributes of the irrigation water (21).

Accumulation of heavy metals in the soil and their effects on the quality attributes of fruits have not been widely studied. However, recent advancements in green chemistry and sustainability have shifted the attention of scientists to studying every aspect of the irrigation source, as improving water quality is beneficial for the environment. Re-use of water for irrigation purposes follows the green chemistry principle, but what if it is affecting the consumers on the other side. Therefore, in the current study, we compared the heavy metal accumulation in the mango, banana, and mulberry cultivars under different pharmaceutical irrigation water. The water quality index of the pharmaceutical effluent samples along with statistical analysis is being studied. The physiochemical attributes and heavy metals' accumulation in water, soil, and fruit samples were studied. Recently, heavy metal contamination in wastewater-irrigated soil and fruits has been studied by scientists from China, India, and other countries. A few papers have been reported, covering the aspect of vegetable crops. This research article is based on the heavy metal contamination in different fruits observed in Sahiwal, Pakistan, along with the wastewater-irrigated soil. Comparison with the determined hazardous elements with standard values gives us a clear idea of the contamination.

MATERIAL AND METHOD

Heavy metal concentration in pharmaceutical water and soil

To determine the concentration of heavy metals in pharmaceutical water, samples from each irrigation source were collected and filtered in the laboratory. Samples of effluent from different locations in Sahiwal at different depths were collected, i.e. Sample A from upper surface discharge wastewater into the drain, a) upper surface, b) 0-5 cm, c) 5-10 cm labeled as ES-1, ES-2, and ES-3, respectively. Sample B, 1 km away from the sample A location and collected from three depths: a) Upper surface, b) 0-5 cm, c) 5-10 cm labeled as ES-4, ES-5, and ES-6, respectively. Sample C, 2 km away from sample B location and collected from three depths: a) upper surface, b) 0-5 cm, c) 5-10 cm labeled as ES-7, ES-8, and ES-9, respectively. Samples of soil from 3 different depths i.e. 0–15 cm were obtained from the same orchards irrigated with water from these irrigation sources. A fruit sample was taken from the nearby orchards irrigated with pharmaceutical effluent. The collected samples were washed, dried, crushed, sieved, and labeled.

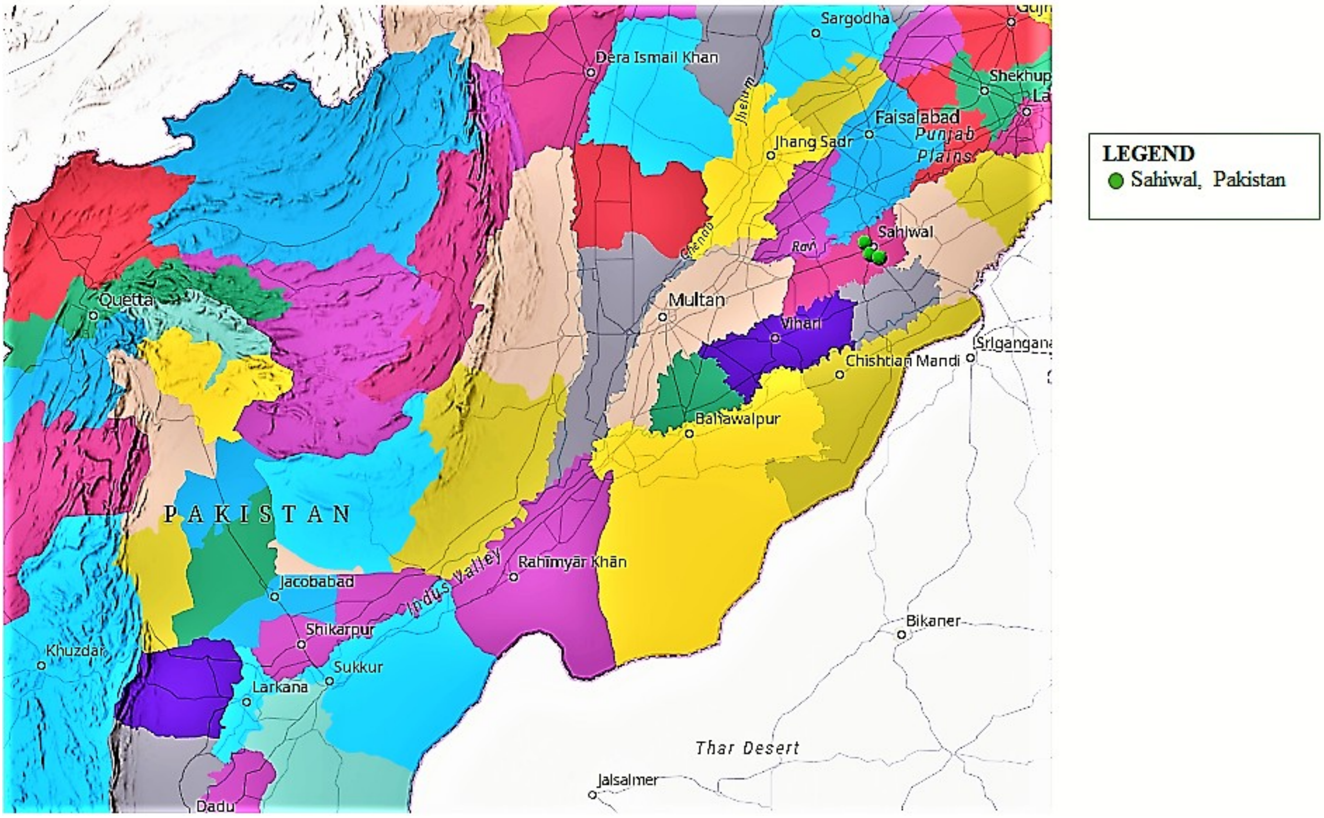

Figure 1: Location of different irrigation water samples collected from Sahiwal near and the natural regions of Pakistan. Source: DIVA GIS 7.5.0 (2015).

Preparation of soil samples

The soil sample was prepared by drying it as it is available from three different sites. The most convenient state is to perform chemical tests on dry soil, so microwave drying was done to remove excess moisture in the soil. Due to the presence of concretions and rocks, crushing of sample into fine powder was done, which was afterwards designated for mechanical analysis with a wooden rolling pin. Samples were sieved by using a set of sieves that have progressively smaller openings, and the grain size was ≤ 0.075 mm. The prepared soil sample was soaked in DPTA solution and then shaken for 3 hours on an orbital shaker. After removing them from the shaker, the flasks were rested for 2-3 minutes and then filtered using the standard method. The sample was saved in the test tube for heavy metal content analysis and labeled as SOR-1, SOR-2, and SOR-3.

Preparation of fruit samples

The samples of mango, banana, and mulberry were collected from the nearby orchard where the irrigation source was the pharmaceutical effluent. The fruit samples were washed to remove any contamination and, after careful sorting of fruits, they were subjected to hot water treatment in cotton bags at 60˚C for 4 minutes, then removed and cooled at 25˚C. Then it was dried in a desiccator at 60˚C for 3 hours. After that, it was crushed into a fine paste and the sample was digested with 30% hydrogen peroxide (H_2O_2) and 50% nitric acid solution (22).

The labeled fruit samples were filtered and diluted with 20 mL of distilled water and saved in a test tube for heavy metal detection by atomic absorption spectrophotometer (Buck model 210VGP HACH). Fresh juice from fruit samples was extracted and filtered twice to remove any excess pulp. The sample was labeled and saved for further chemical analysis (23).

Fruit weight and shelf life

The fruit weights of mango, banana, and mulberry cultivars were noted by a digital weighing balance. Shelf life is regarded as the period during which fruits can be marketed after ripening. It is called shelf life.

Metal Analyses by Atomic absorption spectrophotometer

Before running the samples, calibration curves for each sample were prepared using de-ionized water in the range of 0-100 mg/L. The blank was also prepared, which was free of CECs. The calibration curves were plotted by using absorbance vs concentration and the linearity of the curves was demonstrated by the coefficient of determination (R^2), which ranged from (0.91-to 0.99) with a mean value of 0.95. The operating conditions for the analysis of heavy metals by AAS are given in table 1.

Physiochemical parameters Analyses

Physiochemical parameters such as pH, total suspended solids (TSS), dissolved oxygen, biochemical oxygen demand (BOD), chemical oxygen demand (COD), electrical conductivity, the concentration of ions (Na^+, K^+, Ca^{2+}, CO_3^{2-} /HCO_3^-, Cl^-, Mg^{2+} and SO_4^{2-}, residual sodium carbonate (RSC), and metal ion concentration were checked in the pharmaceutical effluent samples following standard procedures and methods. The pH was determined using a potentiometer. Total dissolved solids in the effluent sample were measured using TDS meter. The dissolved oxygen concentration in the unit (mg/L) was measured by DO meter (Jenway970/HACH Method 8215 & 8043 resp). Biochemical oxygen demand was measured using (BOD) monometer. Chemical oxygen demand was measured using potassium dichromate in 50% sulphuric acid solution and COD meter (Lovi bond RD 125/HACH Method 8000). The sodium ion concentration was analyzed by flame photometer and metal ion concentration by using titration and Schott instrument.

Statistical Analysis

Using IBM SPSS 21, the mean and standard deviation of the heavy metals in the effluent samples, soil samples and fruits were calculated. All calculated results were then subjected to one-way ANOVA with 0.05 probability levels.

RESULTS AND DISCUSSION

Measurement of physicochemical parameters of the effluent sample

All physicochemical parameters, such as TSS, titratable acidity, chemical oxygen demand, TDS, shelf life, biological oxygen demand, ascorbic acid, mineral content, and heavy metal concentration were significantly affected by the irrigation of pharmaceutical effluent. The physiochemical parameters were analyzed separately for each effluent sample, and then the water quality index was calculated. All effluent samples were assessed for these physicochemical parameters (Table 2-4). The pH ranged from 7.8 to 8.8, BOD ranged from 128-142 mg/L, and COD ranged from 279-292 mg/L in the three samples collected from the initial point as listed in table 2. The pH ranged from 8.1-9.1, BOD ranged from 161 to 168 mg/L, and COD ranged from 260 to 276 mg/L in the three samples collected from the initial point as listed in table 3. The pH ranged from 8.3-9.2, BOD ranged from 291-95 mg/L, and COD ranged from 151-169 mg/L in the three samples collected from the initial point as listed in table 4. Irrigation of wastewater improves the biochemical attributes such as flavonoids, antioxidants, and total phenolic of the crops. Literature reported findings concluded that total suspended solids in fruits increased when irrigated with wastewater than with well water (24). Fruit weight and shelf life remain unaffected by the irrigation water.

Among the cultivars, mango resulted in the maximum fruit weight (350.1 g), while the minimum fruit weight was attained in mango (562.5 g). The rate of chemical and biological processes is dependent on the temperature. The optimal temperature for fruits depends on the survival life and good growth of fruits, whereas others prefer warmer water. If the temperature of the water becomes higher than the allowed range of NEQs and WHO for a longer period, then this irrigation water becomes harmful to soil and fruits that are growing by the irrigation of these effluents. Temperature directly affects the concentration of oxygen in the water. By increasing the temperature of effluents, the concentration of oxygen decreases. pH directly affects the concentration of oxygen in the water. By increasing the pH of effluents, the concentration of oxygen decreases. These effluents, which have a high pH from the range of MAC are not good for the growth of fruits and vegetables.

Table 1: Operating conditions for the analysis of heavy metals using AAS.

Element	Cd	Cr	Cu	Pb
Wavelength (nm)	288.8	357.9	324.8	283.3
Burner height (mm)	9	7	7	9
Lamp current (mA)	12	12	8	10
Acetylene flow rate (L/min)	2	1.8	2	1.8
Air flow rate	15	17	17	15

Table 2: Results of pharmaceutical effluents analysis from the initial point.

Sr No.	Parameters	[1]Mean±SD	[2]Mean±SD	[3]Mean±SD	[4]NEQS	[5]WHO
1	Temperature (^0C)	34±1.44	35 ± 1.42	33±1.45	37	40
2	pH	7.8±0.34	8.2 ± 0.34	8.8±0.34	8.4	6-9
3	DO (mg/L)	0.7±0.04	0.8±0.03	0.6±0.02	NA	5-9
4	COD (mg/L)	279±13.4	281±12.6	292±14.1	150	150
5	BOD (mg/L)	128±5.68	137±5.28	142±5.27	80	50
6	TDS (mg/L)	3140±114.8	3210±114.9	3302±115.2	3500	2000
7	TSS (mg/L)	641±24	560±23	595±23	200	150
8	Na^+ (mg/L)	3.92±0.14	4.75±0.15	5.42±0.12	9	9
9	K^+ (mg/L)	0.41±0.24	0.49±0.22	0.62±0.31	9	9
10	Ca^{2+} (mg/L)	0.93±0.31	0.81±0.32	0.46±0.33	9	9
11	CO_3^{2-} (mg/L)	6.9±0.29	7.2±0.31	7.3±0.26	9	9
12	HCO_3^- (mg/L)	0.41±0.32	0.39±0.22	0.49±0.38	8.5	8.5
13	Cl^- (mg/L)	21.69±0.48	22.42±0.41	22.93±0.39	10	10
14	Mg^{2+}(mg/L)	2.42±0.21	2.39±0.28	3.10±0.30	3	9
15	SO_4^{2-} (mg/L)	560±18.02	662±17.09	570±17.95	500	500
16	SAR (mg/L)	4.36±0.19	4.21±0.22	3.92±0.23	-	<6
17	RSC (mg/L)	1.92±1.01	1.31±1.22	1.62±1.08	-	<40

[1]Mean±SD= Mean ± SD (standard deviation) from the upper surface of the water (ES-1).
[2]Mean±SD= Mean ± SD (standard deviation) from the center surface of the water (ES-2).
[3]Mean±SD= Mean ± SD (standard deviation) from the bottom surface of the water (ES-3).
[4]NEQS= National Environmental Quality Standards.
[5]WHO= World Health Organization

Table 3: Results of pharmaceutical effluents analysis from the initial point to 500 (meters) away.

Sr No.	Parameters	[1]Mean±SD	[2]Mean±SD	[3]Mean±SD	[4]NEQS	[5]WHO
1	Temperature (^0C)	38±1.41	37±1.41	39±1.42	37	40
2	pH	8.1±0.32	8.4±0.32	9.1±0.31	8.4	6-9
3	DO (mg/L)	0.7±0.01	0.9±0.09	0.6±0.07	NA	5-9
4	COD (mg/L)	276±13.2	242±12.3	260±14.	150	150
5	BOD (mg/L)	161±5.64	157±5.21	168±5.21	80	50
6	TDS (mg/L)	2960±114.7	3161±114.1	3202±115.2	3500	2000
7	TSS (mg/L)	494±22	520±21	563±22	200	150
8	Na^+ (mg/L)	4.93±0.11	4.41±0.11	5.21±0.17	9	9
9	K^+ (mg/L)	0.92±0.22	1.21±0.23	1.31±0.32	9	9
10	Ca^{2+} (mg/L)	0.88±0.36	0.99±0.36	0.93±0.35	9	9
11	CO_3^{2-} (mg/L)	6.4±0.21	6.9±0.33	7.1±0.22	9	9
12	HCO_3^- (mg/L)	0.41±0.33	0.32±0.23	0.64±0.35	8.5	8.5
13	Cl^- (mg/L)	22.72±0.42	22.31±0.45	21.92±0.31	10	10
14	Mg^{2+}(mg/L)	2.92±0.22	3.21±0.21	3.42±0.34	3	9

15	SO_4^{2-} (mg/L)	602±18.01	590±17.00	660±17.96	500	500
16	SAR (mg/L)	4.92±0.13	4.12±0.28	3.99±0.21	-	<6
17	RSC (mg/L)	2.01±1.07	2.12±1.27	1.99±1.03	-	<40

[1]Mean±SD = Mean±SD (standard deviation) from the upper surface of the water (ES-4).
[2]Mean±SD= Mean±SD (standard deviation) from the center surface of the water (ES-5).
[3]Mean±SD= Mean±SD (standard deviation) from the bottom surface of the water (ES-6).
[4]NEQS= National Environmental Quality Standards.
[5]WHO= World Health Organization.

Table 4: Results of effluents analysis from the initial point to 1000 meters.

Sr No.	Parameters	[1]Mean±SD	[2]Mean±SD	[3]Mean±SD	[4]NEQS	[5]WHO
1	Temperature (°C)	39±1.41	38±1.32	41±1.46	37	40
2	pH	8.3±0.37	9.2±0.34	8.3±0.39	8.4	6-9
3	DO (mg/L)	0.8±0.01	0.5±0.04	0.2±0.04	NA	5-9
4	COD (mg/L)	291±13.9	263±12.5	295±14.4	150	150
5	BOD (mg/L)	169±5.62	182±5.22	151±5.21	80	50
6	TDS (mg/L)	3466±114.1	3342 ±114.2	3240 ±115.5	3500	2000
7	TSS (mg/L)	602±22	660±24	720±24	200	150
8	Na^+ (mg/L)	4.66±0.12	4.84±0.12	4.66±0.11	9	9
9	K^+ (mg/L)	1.10±0.22	2.0±0.21	1.01±0.34	9	9
10	Ca^{2+} (mg/L)	0.72±0.33	0.32±0.32	0.91±0.33	9	9
11	CO_3^{2-} (mg/L)	7.6±0.22	6.1±0.34	7.1±0.22	9	9
12	HCO^{3-} (mg/L)	0.42±0.31	1.0±0.27	0.39±0.37	8.5	8.5
13	Cl^- (mg/L)	22.93±0.38	22.42±0.31	21.90±0.29	10	10
14	Mg^{2+}(mg/L)	3.21±0.28	3.22±0.24	3.93±0.39	3	9
15	SO_4^{2-} (mg/L)	593±18.12	522±17.	595±17.92	500	500
16	SAR (mg/L)	3.98±0.19	4.21±1.2.	4.21±0.23	-	<6
17	RSC (mg/L)	1.91±1.01	1.81±0.013	1.21±1.04	-	<40

[1]Mean±SD= Mean±SD (standard deviation) from the upper surface of the water (ES-7).
[2]Mean±SD= Mean±SD (standard deviation) from the canter surface of the water (ES-8).
[3]Mean±SD= Mean±SD (standard deviation) from the bottom surface of the water (ES-9).
[4]NEQS= National Environmental Quality Standards.
[5]WHO= World Health Organization.

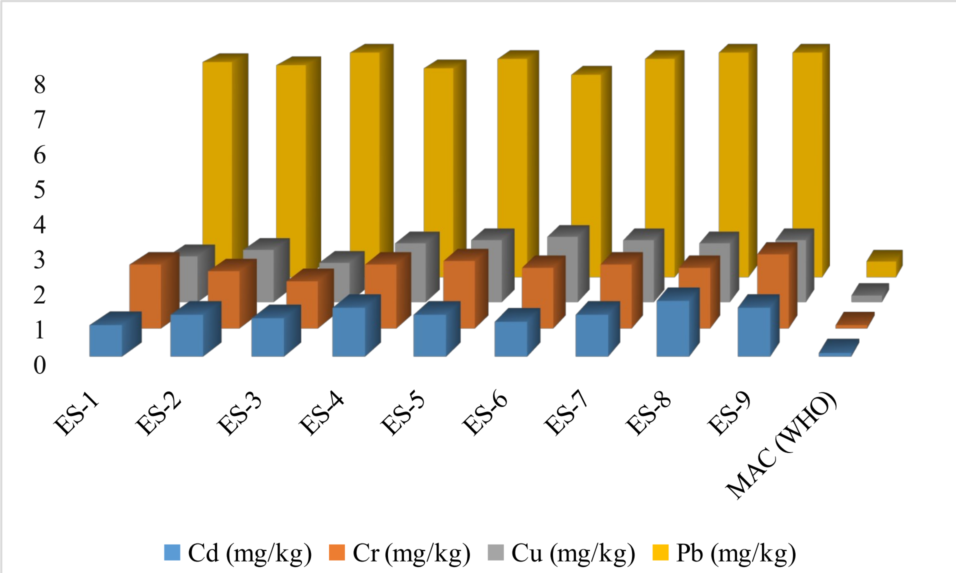

Figure 2: Heavy metal concentration (mg/Kg) in the effluent samples collected from nine sites of Sahiwal and comparison with WHO values.

Water Quality Index of irrigated water

The water quality index is not linked to a single parameter. The physiochemical analysis, as shown in tables 2-4, helps us to study the water quality parameters one by one. However, the water quality index gives us a combined quality index of all parameters. The irrigation water quality index (WQI) of all effluent samples ranged from 63.5- to 63.57 which according to WHO can be used for irrigation purposes as it is non-drinkable water. Thus, the irrigation water quality index (IWQI) is used to assess the quality of irrigation water. The application of this method is carried out based on the criteria specified in FAO 29. Regional characteristics were also investigated in this study. The advantage of IWQI is that it generalizes different quality parameters.

Table 4: Water standards and WQI calculations of effluent sample 1(ES-1 to ES-3), sample 2 (ES-4 to ES-6), and sample 3 (ES-6 to ES-9).

Sr. no	Parameters	Wn = K/Sn (Sample 1)	Wq_n = Wn* qn [b]	W_n = K/Sn (Sample 2)	Wqn = Wn * qn	Wn = K/Sn (Sample 3)	Wqn = Wn * qn
1	pH	0.093875459	8.579347	0.093952	8.626309431	0.093951761	8.626309431
2	DO (mg/L)	0.090514486	0.737525	0.090507	0.737463332	0.090506863	0.737463332
3	COD (mg/L)	0.005430869	0.938937	0.00543	0.938857864	0.005430412	0.938857864
4	BOD (mg/L)	0.016292607	5.278805	0.016291	5.278360279	0.016291235	5.278360279
5	TDS [a] (mg/L)	0.00081463	0.25316	0.000815	0.253138646	0.000814562	0.253138646
6	TSS (mg/L)	0.005430869	1.903218	0.00543	1.90305765	0.005430412	1.90305765
7	Na^+ (mg/L)	0.090514486	4.877725	0.090507	4.87731431	0.090506863	4.87731431
8	K^+ (mg/L)	0.090514486	1.153222	0.090507	1.153124483	0.090506863	1.153124483
9	Ca^{2+} (mg/L)	0.090514486	0.938669	0.090507	0.938589695	0.090506863	0.938589695
10	CO_3^{2-} (mg/L)	0.090514486	6.838872	0.090507	6.838296353	0.090506863	6.838296353
11	HCO_3^- (mg/L)	0.095838867	0.514899	0.095831	0.514855653	0.095830797	0.514855653

12	Cl^- (mg/L)	0.081463037	18.17983	0.081456	18.17830353	0.081456177	18.17830353
13	Mg^{2+}(mg/L)	0.090514486	3.201531	0.090507	3.201261283	0.090506863	3.201261283
14	SO_4^{2-} (mg/L)	0.001629261	0.201159	0.001629	0.201142453	0.001629124	0.201142453
15	SAR (mg/L)	0.135771728	9.828365	0.13576	9.827536927	0.135760295	9.827536927
16	RSC (mg/L)	0.020365759	0.103865	0.020364	0.103856626	0.020364044	0.103856626
	Total	ΣWn = 1	ΣWqn = 63.52913284	ΣWn= 1	ΣWqn= 63.57147	ΣWn= 1	ΣWqn = 63.57146852

[a] *total dissolved solid* [b] *quality rating values*

Values for quality rating were calculated by using the formula:

$$q_{\mathrm{ni}}=\left[\frac{\left(V_{actual}-V_{ideal}\right)}{\left(V_{standard}-V_{ideal}\right)}\right]\times 100$$

V_{actual} = value of parameter of sample
V_{ideal} = value of parameter ideally
$V_{standard}$ = value of parameter as standard

Water quality index WQI (Sample 1) = $\frac{\Sigma W_n qn}{\Sigma W}$

= 63.5291 / 1
= 63.5291

WQI (Sample 2) = $\frac{\Sigma W_n qn}{\Sigma W}$

= 63.57147/ 1
= 63.57147

WQI (Sample 2) = $\frac{\Sigma W_n qn}{\Sigma W}$

= 64.50654/ 1
= 64.50654

Heavy metals in soil layers and fruits

The soil sample taken from the areas which were irrigated with pharmaceutical water was investigated and found to have varying concentrations of heavy metal content (Cu, Cd, Cr, and Pb), which is shown in table 6. The results showed noticeable differences in the concentration of each sample, which was later analyzed by comparing them with the neutral soil sample as a reference and found to have the higher heavy metal concentration due to the variant pH values and the concentration of organic matter. We employed statistical analysis to check for significant differences in the values of the different samples. Table 5 indicated the statistical analysis of soil samples from different sites, which showed that the data for SOR-1 and SOR-3 is highly skewed. The present study indicates that the pharmaceutical irrigated soil has a higher concentration of cadmium (mg/kg) when compared with the WHO value, which is shown in Fig. 2. However, the present study results are compared with those of Anjum *et.al.,* who analyzed the different areas of Sahiwal, and noted that nickel accumulation in soil was non-significant. Heavy metal accumulation varied significantly between soil layers. The copper concentration was found to be highest in the 1st soil layer, labeled as SOR-1. As we predicted, the concentration of heavy metals in soil should gradually decrease from the top layer to the bottom layer irrigated with pharmaceutical wastewater. However, the scenario was a bit different and the copper content significantly increased down the layer. The main reason behind this is that the heavy metals sometimes leach from the top layer of the soil to the bottom resulting in increased concentration of copper and also variable conditions such as pH of the soil, contaminants, and composition of the soil. Cd, Cr, and Pb. Zinc was not detected in the soil sample. Therefore, it has not been discussed in these sections. The purpose of studying soil irrigated with pharmaceutical wastewater is to see the effect of heavy metals' accumulation in the soil on the fruit.

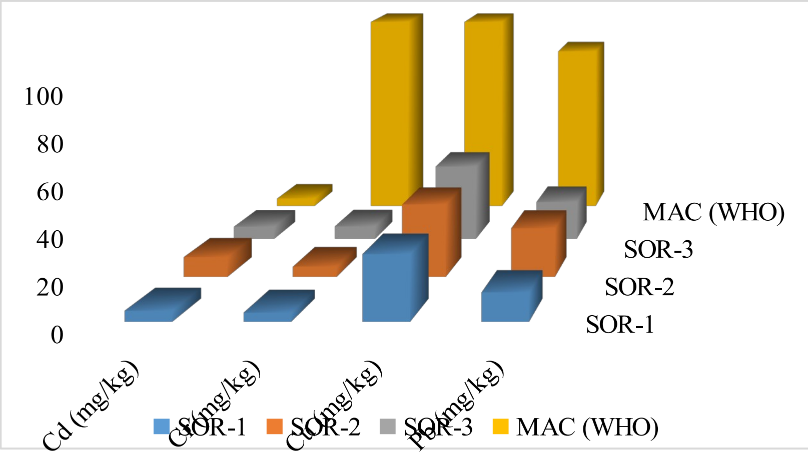

Figure 3: Heavy metal contents (mg/kg) in soil layers irrigated with pharmaceutical effluent.

Table 5: Statistical analysis of metal content mg/kg in the soil; standard deviation, variance, skewness, and kurtosis.

Descriptive Statistics	N	Range	Mean		Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
SOR-1*	4	25	12.58	5.813	11.626	135.163	1.404	1.014	1.480	2.619
SOR-2**	4	29	17.63	6.601	13.202	174.283	.480	1.014	-2.393	2.619
SOR-3***	4	30	16.80	7.153	14.305	204.633	1.166	1.014	.297	2.619
Valid N (list wise)	4									

*SOR-1 = Soil Samples from the upper surface, which is irrigated by pharmaceutical effluents.
**SOR-2 =Soil Sample from the upper surface at 5 cm depth, which was irrigated by pharmaceutical effluents.
***SOR-3 =Soil Sample from the upper surface 10 cm depth, which is irrigated by pharmaceutical effluents

Table 6: Detection of heavy metals (Cu, Pb, Cr and Cd) in various sources of irrigation water and its effects on heavy metal accumulation on soils and fruits.

Effluent sample	Cd	Cr	Cu	Pb
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
ES-1	0.9	1.9	1.4	6.8
ES-2	1.2	1.7	1.6	6.7
ES-3	1.1	1.4	1.2	7.1
ES-4	1.4	1.9	1.8	6.6

ES-5	1.2	2	1.9	6.9
ES-6	1	1.8	2	6.4
ES-7	1.2	1.9	1.9	6.9
ES-8	1.6	1.8	1.8	7.1
ES-9	1.4	2.2	1.9	7.1
SOR-1	4.8	3.9	29	12.6
SOR-2	9.2	4.8	33.8	22.7
SOR-3	6.1	6.2	36.4	18.5
Banana	0	1.203	0	0.231
Mango	0.005	0.891	0.005	0.189
Mulberry	0.002	0.769	0.002	1.248

Table 7: ANOVA analysis of effluents, soil, and fruits.

	Sum of Squares	df	Mean Square	F
Between Groups	965.167	36	26.810	3.983
Within Groups	154.833	23	6.732	
Total	1120.00	59		

The value of F obtained (F= 3.98) experimentally is higher than the theoretical value, so the null hypothesis prediction is dismissed, which means that the value of F is a statistically significant value, and therefore, the null hypothesis is rejected, which means there is a difference between the average value of the soil, fruits, and effluent sample group.

CONCLUSION

Pharmaceutical irrigation water affects the quality attributes of mango, banana, and mulberry. Farmers are attracted to sewage water irrigation as it increases organic matter, but in comparison to canal water, it contaminates the soil, leaves, and fruits with heavy metals. The physiochemical attributes and water quality index show that irrigation water is safe, but still, the risk of contamination can be reduced by educating the farmers to use canal water or treated sewage water by using efficient and low-cost adsorbents. The current study gives an overview of how heavy metals accumulate in the fruit through irrigation water, which has an adverse effect on the living standards of human health. This research article is based on the hazardous element contamination in different fruits observed in Sahiwal, Pakistan, along with the wastewater-irrigated soil. Literature articles focused on either effluent or fruit samples, but this article targeted the heavy metal accumulation in wastewater, soil, and irrigated orchards. Bioaccumulation variables, physicochemical factors, possible dangers, and enrichment factors were evaluated by comparing them to the identified hazardous materials.

CONFLICT OF INTEREST

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

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