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A comparative study of wastewater quality analysis in major textile industrial zones of faisalabad for irrigation use

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In the developing countries industrial effluent is often improperly managed and/or disposed directly into public and private drains without treatment. Pakistan being an agricultural country, mostly relies on agro-based industries, Faisalabad is an industrial city featuring clusters of textile industries which have adverse effects on the environment. The present study was conducted to investigate the textile effluent quality levels in the Faisalabad. The effluent samples were collected in triplicate from three major industrial zones after a reconnaissance survey. The analysis of effluent samples showed a wide variation in level of temperature (14.4-36.2 °C), total dissolved solids (2022-3865 mg/L), electrical conductivity (3.0-5.76 dSm^{-1}), salinity (1.5-2.96), pH (7.2-11.3) total hardness (240-503 mg/L), chloride (689-3608 mg/L), nitrate (34.9-223 mg/ L), ammonium (4.5-43 mg/L), and sodium adsorption ratio (14.1-33.4) using standard methods and latest equipment. The measured values of parameters were compared with the Punjab Environmental Quality Standards (PEQS) and Food and Agriculture Organization (FAO) standards for precise assessment of their quality and suitability. It was found that almost all the selected parameters were exceeding the permissible limits from the available standards. Untreated effluent with higher concentration of pollutants makes the situation worse for safer disposal or wastewater irrigation. Based upon the analysis and measured data, it is strongly suggested to treat the effluent up to the standards before disposal to the drains which latter can be used for agriculture safely.
Keywords: Characterization, Industrial zones, textile effluents, wastewater irrigation.

INTRODUCTION

Textile industries share a heavy portion in environmental damage by discharging pollutants, overuse of energy and water. (Lacasse and Baumann, 2004) The textile industry utilizes a large amount of water in various processes and generate effluent accordingly (Paul *et al.*, 2012). It was concluded that the production of large volumes of effluent is one of the major problems of textile industries. These generate millions of litres of untreated wastewater which goes to public drains and ultimately into rivers. This makes the situation worse for human and environmental health (Rizwana *et al.*, 2014). Pakistan's textile industry is one of the major and important industrial sectors in the country. The environmental impact of the textile industry is significant because it uses a large amount of water in various processes and produces highly polluted wastewater (Imtiazuddin *et al.*, 2012). An average-sized textile mill uses about 200 litres of water per kilogram of fabric produced (Holkar *et al.*, 2016).

According to various studies in Pakistan, it was indicated that the water pollution has increased significantly over the past few decades. The level of pollution is higher in the vicinity of the big cities due to large industrial zones. The major reason for water pollution is the disposal of untreated industrial wastes conveying various pollutants into freshwater bodies. The pollutants including persistent toxic, organic chemicals, pesticides, heavy metals when mixed with fresh water can be the reason for waterborne and water washed diseases (Malik *et al.*, 2017). It was estimated that in Pakistan < 1% of wastewater is being treated before disposing to the public drains (Weckenbrock *et al.*, 2011). Faisalabad is branded as the Manchester of Pakistan due to its large industrial sector especially textiles. This city has 512 big industrial units including 328 textile units, 92 chemical units, 92 engineering units, and food processing units, other factories include carpet, hosiery, rugs, publishing, printing, pharmaceuticals, and about 170,000 power loom factories (Khan., 2011). As reported by the environmental protection department, in Faisalabad only seven textile units have wastewater treatment plants (WWTP) out of 328 textile units. Water and Sanitation Agency (WASA) Faisalabad has only one centralized Chokera wastewater treatment plant (WWTP) serving the western side of the city along the Paharang drain. Chokera disposal is of 180 cusec or116 million gallons per day (MGD) capacity. This disposal is discharging combined (mixed industrial and domestic) sewerage water to Pharang drain. Most of the water directly

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discharging into drain and part of it more than 20 MGD is going to treatment ponds. The centralized system showed to be limited in scope and success due to high cost and energy intensiveness (Zhang *et al.*, 2009). According to WASA Faisalabad, the total industrial wastewater generation from the city is around 1,215,000 m^3/day (500 cusecs). Out of this wastewater, a significant portion of wastewater is being used for irrigation without proper treatment.

Wastewater use in agriculture is increasing because of accelerating global water scarcity. It presents risk to public health if not treated well before application. In Pakistan application of wastewater is very common without any regulation and treatment (Ensink and Van der Hoek, 2009). The situation has become worse because no specific guidelines or national standards are available for wastewater irrigation in the country. Only the national and provincial environmental standards are available for municipal and industrial liquid effluents (Sial *et al.*, 2018) and Food and Agriculture Organization (FAO) standards for wastewater irrigation (Pescod, 1992). The overall objective of the present study was to investigate the current situation regarding untreated textile effluent which is the first and necessary step to raise awareness, to start working out for wastewater treatment and integration of wastewater into irrigation.

MATERIALS AND METHODS

Study area: Faisalabad is separated into two zones, eastern side, and the western side. The drainage system comprises Madhuana and Paharang drains and small city municipal channels. Madduana drain receives wastewater from the Eastern side (Khurriawala industrial area) and the Paharang drain receives from the Western side (Punjab small Industrial estate and Industrial estate motorway M-3) (Munir et al., 2003). Based on above-mentioned facts, the following sampling sites were selected. (1) Khurrianawala industrial area, (2) Punjab small industrial estate, and (3) Industrial estate motorway M-3 in city Faisalabad (Figure 1) were selected for the sampling of untreated industrial textile effluent.

Collection of Samples: The samples of textile industrial effluent were collected for consecutive three weeks with triplicates from selected sites from all three zones (Fig. 2, Fig. 3 and Fig. 4).

All the samples were brought to the laboratory for physio-chemical analysis in cold boxes. Temperature and pH of samples were determined on the spot due to the rapid change in composition during transporting to the laboratory. In addition, these parameters were determined again in the laboratory to check the variation.

Physico- chemical Analysis: Standard methods and instruments were used for the analysis of various physio-chemical parameters of the textile effluent. The pH, total dissolved solids, electrical conductivity, salinity, temperature, chloride, nitrate, ammonia was determined using SEBA Hydrometre MPS-16. Sodium was analyzed using flamephotometer. SAR was calculated from the ratio of sodium to calcium and magnesium (Alobaidy *et al.*, 2010). Total hardness was determined by titration method with EDTA, an indicator of eriochrome black tea and some buffer solution (Betz and Noll, 1950; APHA, 2005).

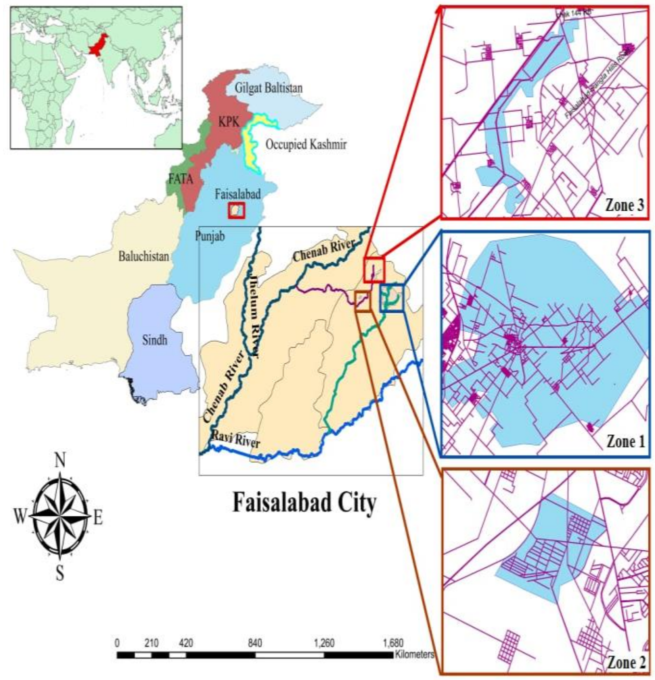

Figure 1. Zone 1 (Khurrianawala Industrial Area), Zone 2 (Punjab Small Industrial Estate), Zone 3 (Industrial Estate Motorway M3) Faisalabad

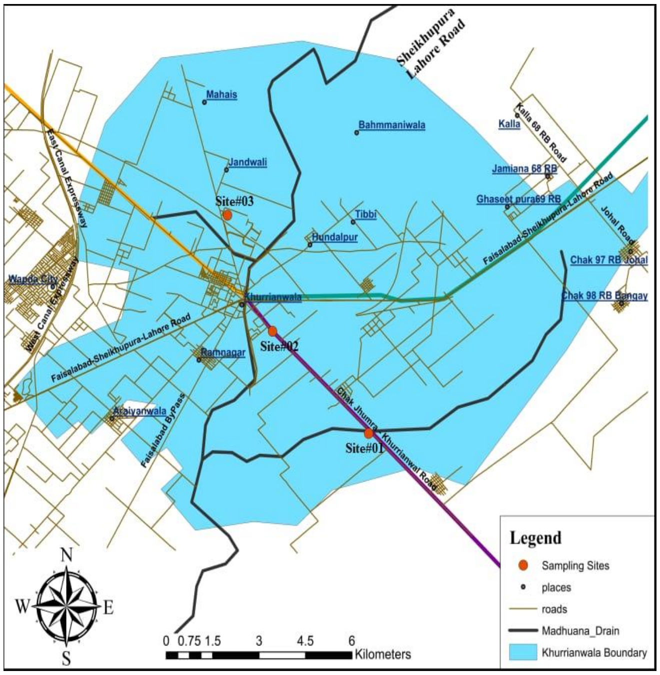

Figure 2. **Map showing sampling sites in Khurrianawala Industrial Area, Faisalabad**

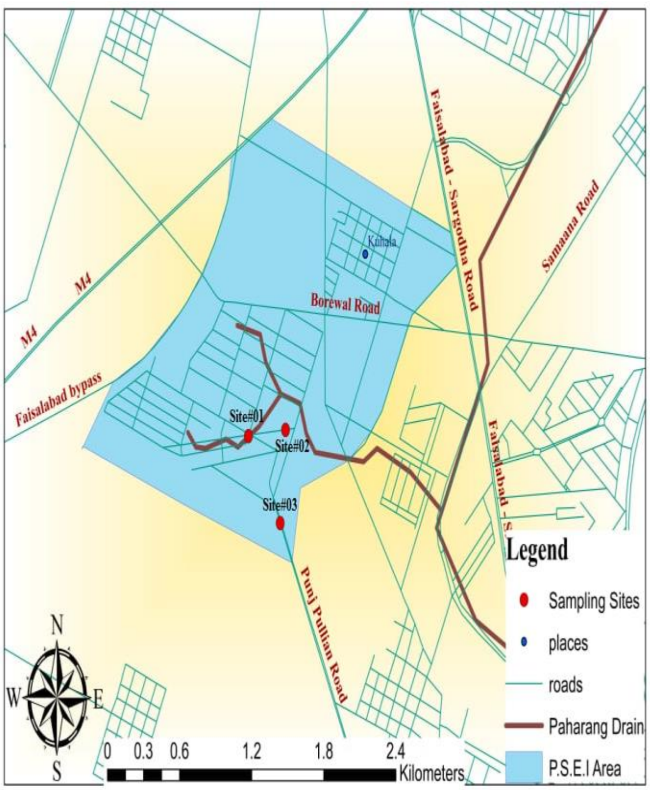

Figure 3. **Map showing sampling sites in Punjab Small Industrial Estate, Faisalabad**

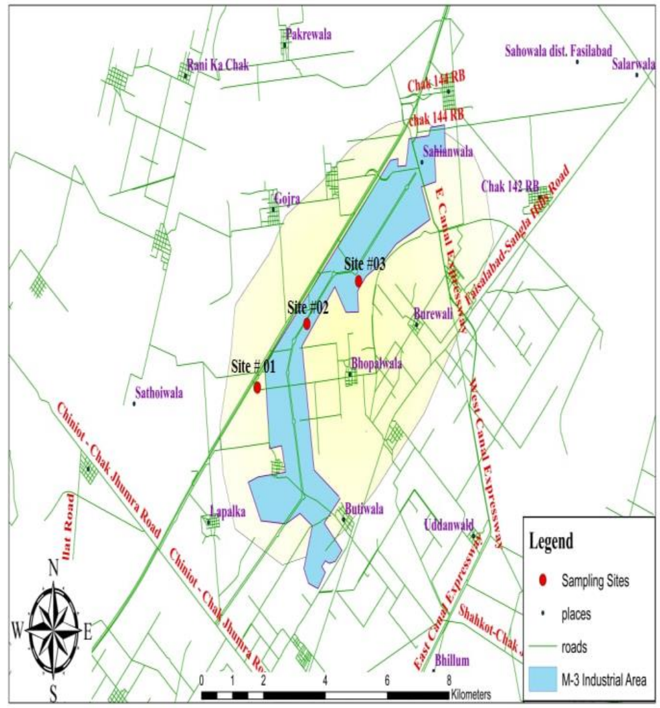

Figure 4. **Map showing sampling sites in Industrial Estate Motorway M3, Faisalabad.**

Table 1. **Recommended limits of wastewater quality for irrigation**

Sr.	Parameter	Unit	PEQS*	FAO**
1	pH	-	6-9	6.5-8
2	TDS	mg/L	< 3500	0-2000
3	EC	dSm^{-1}	-	0-3
4	Salinity	Ratio	-	-
5	Temperature	$^{\circ}C$	$< 3^{\circ}$	-
6	Chloride	mg/L	<1000	-
7	Nitrate	mg/L	5-30	-
8	Ammonium	mg/L	40	0-5
9	Calcium	mg/L	-	0-400
10	Sodium	mg/L	-	0-920
11	Magnesium	mg/L	-	0-60.75
12	Total Hardness	mg/L	-	-
13	SAR	Ratio	-	0-15

*Punjab Environmental Quality Standards; **Food and Agriculture Organization

Statistical Analysis: Analysis was performed in triplicate samples to avoid error and to secure reproducibility of the results. The average of the data was calculated using arithmetic mean. The mean variability of the data was determined by calculating standard error and standard deviation.

RESULTS

After analysis of textile effluent from three major industrial zones and detailed examination of data, results are being reported for regaining useful information. Results are described to quantify and evaluate the concentration of quality parameters of agricultural significance.

Table 2. Physiochemical characteristics of Khurrianawala industrial area (Zone 1) of Faisalabad.

Sr.	Parameter	unit	Range	Mean ± SD*
1	Temperature	˚C	28.7-36.2	32.7 ± 3.75
2	TDS	mg/L	3716-3865	3720 ± 142.5
3	EC	dSm^{-1}	5.34-5.76	5.54 ± 0.20
4	Salinity	Ratio	2.73-2.96	2.84 ± 0.11
5	pH	-	8.7-10	9.2 ± 0.69
6	Total Hardness	mg/L	320-470	408.3 ± 78.4
7	Chloride	mg/L	1850-3608	2629 ± 896
8	Nitrate	mg/L	80.9-146.9	103.2 ± 37.7
9	Ammonium	mg/L	17.8-43	26.4 ± 14.3
10	Calcium	mg/L	10.3-59.2	36.4 ± 24.6
11	Sodium	mg/L	283.6-313.9	296 ± 15.6
12	Magnesium	mg/L	260.7-459.6	371 ± 101
13	SAR	Ratio	19.7-22.4	20.8 ± 1.3

*Standard Deviation

Table 3. Physiochemical characteristics of Punjab small industrial estate (Zone 2) Faisalabad.

Sr.	Parameter	Unit	Range	Mean ± SD*
1	Temperature(°C)	°C	31.1-33.6	33.3 ± 2.1
2	TDS (mg/L)	mg/L	2567-3407	3004 ± 421
3	EC	dSm^{-1}	3.83-5.08	4.48 ± 0.62
4	Salinity	Ratio	1.92-2.57	2.26 ± 0.3
5	pH	-	8.3-11.3	9.8 ± 1.5
6	Total Hardness	mg/L	420-503	451 ± 45
7	Chloride	mg/L	1640-3380	2284 ± 954
8	Nitrate	mg/L	110-223	152 ± 57
9	Ammonium	mg/L	12-42	19.3 ± 20.5
10	Calcium	mg/L	44.6-265	105 ± 139
11	Sodium	mg/L	250-290	272 ± 20
12	Magnesium	mg/L	155-455	345 ± 165
13	SAR	Ratio	15.8-20.0	18.2 ± 2.1

*Standard Deviation

Table 4. Physiochemical characteristics of industrial estate motorway M3 (Zone 3) of Faisalabad.

Sr.	Parameter	Unit	Range	Mean ± SD*
1	Temperature (°C)	°C	14.4-15.1	15 ± 0.54
2	TDS (mg/L)	mg/L	2022-3451	2840 ± 736
3	EC	dSm^{-1}	3.0-5.1	4.2 ± 1.1
4	Salinity	Ratio	1.5-2.6	2.1 ± 0.58
5	pH	-	7.2-7.7	7.5 ± 0.3
6	Total Hardness	mg/L	240-480	380 ± 124
7	Chloride	mg/L	689-1626	1122 ± 472
8	Nitrate	mg/L	34.9-76.7	48.9 ± 24
9	Ammonium	mg/L	4.5-7.3	5.7 ± 1.4
10	Calcium	mg/L	30.1-38.2	34.2 ± 4
11	Sodium	mg/L	204-518	324 ± 169
12	Magnesium	mg/L	209-441	345 ± 121
13	SAR	Ratio	14.1-33.4	23.4 ± 9.6

*Standard Deviation

The temperature of the raw industrial textile effluent was determined on site at the time of sampling from each sampling point in all three zones. The temperature range in zone 1 was 28.7 to 36.2 ˚C with a mean value of 32.7 ˚C ± 3.75 (Table 2). Similarly, in zone 2 the temperature range was 33.1 ˚C to 33.6 ˚C with a mean value of 33.3 ± 2.1 (Table 3). Zone 3 showed a temperature range of 14.4 ˚C -15.1 ˚C giving a mean value of 15 ± 0.54 (Table 4). The mean values of temperature were in the order of zone 2 > zone 1 > zone 3 (Fig. 5).

Total dissolved solids (TDS) were found to be varied from 3716 to 3865 mg/L with a mean of 3720 ± 142.5 in zone 1 (Table 2). The samples from zone 2 showed a variation of 2567 to 3407 mg/L with a mean of 3004 ± 421 (Table 3). In zone 3 the TDS range was 2022 to 3451 mg/L with a mean 2840 ± 736 (Table 4). The TDS values determined was in the order of zone 1 > zone 2 > zone 3 (Fig. 6).

Electrical Conductivity in zone 1 was found to be 5.34 dSm^{-1} to 5.76 dSm^{-1}giving mean value of 5.54 ± 0.2 (Table 2), The minimum to a maximum range of EC in zone 2 was 3.83 dSm-1to 5.08 $dSm^{-1}$with a mean value of 4.48 ± 0.62 (Table 3). In zone 3 the range was 3 $dSm^{-1}$to 5.1 $dSm^{-1}$with a mean of 4.2 ± 1.1. (Table 4). The EC values determined was in order of zone 1 > zone 2 > zone 3 (Fig. 7).

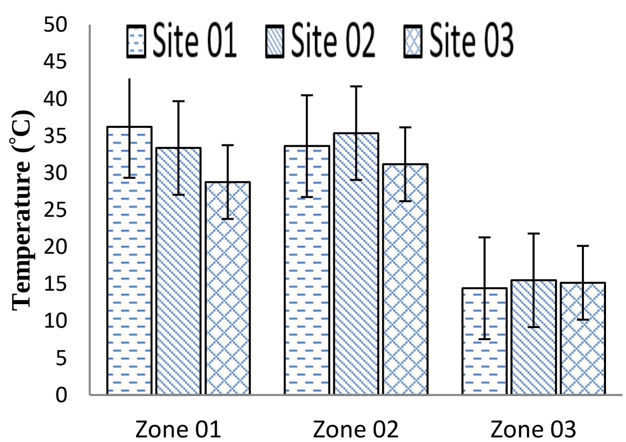

Figure 5. Variation of temperature among zones

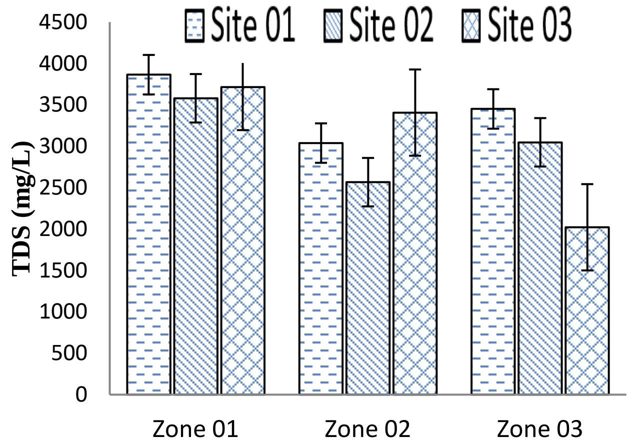

Figure 6. Total dissolved solids range in all zones

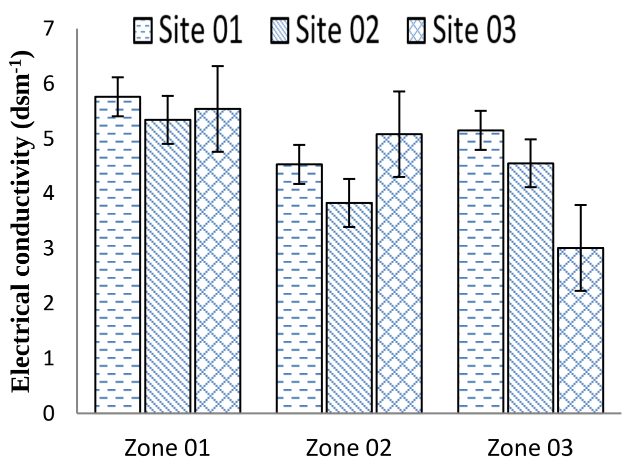

Figure 7. Range of EC across all zones

The value of salinity in zone 1 ranged from 2.73 to 2.96 with a mean value of 2.84 ± 0.11 (Table 2). The salinity in zone 2 showed variation from 1.92 to 2.57and has a mean value of 2.26 ± 0.32 (Table 3). In zone 3 the minimum to maximum salinity was 1.5 to 2.6 with a mean of 2.1 ± 0.58 (Table 4). The data shows mean value of zone 2 > zone 3 > zone 1 (Fig. 8).

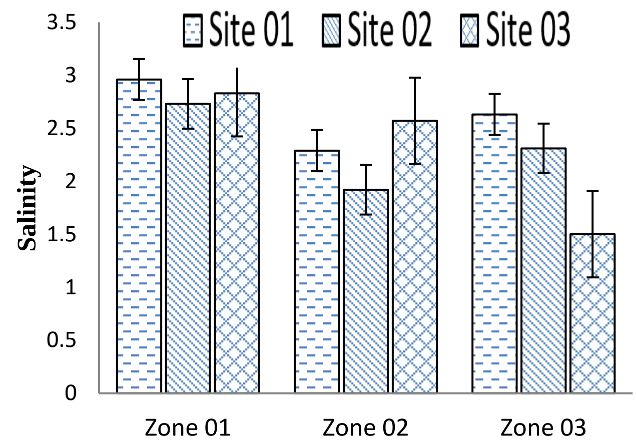

Figure 8. Range of salinity across all zones

In textile industrial effluent, pH is a very important factor (Kahlown *et al.*, 2006a). The range of pH in zone 1 was found to be 8.7 to 10.0 with a mean value of 9.2 ± 0.69 (Table 2), Similarly, the range of pH in zone 2 was 8.3 to 11.3 with a mean value of 9.8 ± 1.5 (Table 3). The pH range in zone 3 was 7.2 to 7.7 with a mean value of 7.5 ± 0.3 (Table 4). The mean values of pH show alkaline nature in zone 1 and zone 2 except in zone 3 which is relatively less alkaline and close to a neutral value of 7.5 (Fig. 9).

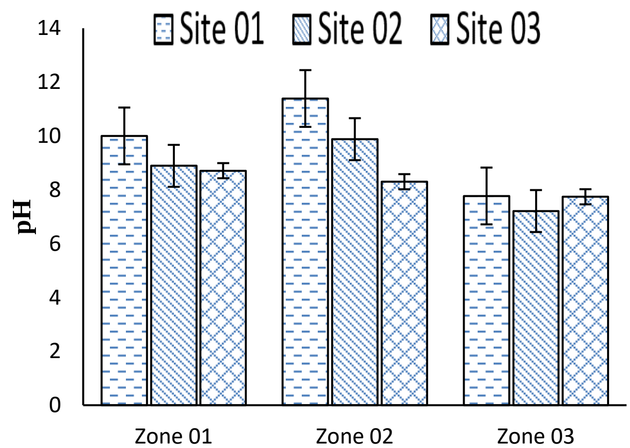

Figure 9. pH values across all zones

The samples collected from zone 1 showed total hardness ranging from 320 mg/L to 470 mg/L with a mean value of 408 ± 78.4 (Table 2). Similarly, in zone 2 the range of total hardness was 420 mg/L to 503 mg/L with a mean of 451 ± 45 (Table 3). Zone 3 showed the minimum to a maximum value of 240 mg/L to 480 mg/L with a mean of 380 ± 124 (Table 4). Among the zones, the order for mean values of total hardness is zone 2 > zone 1 > zone 3 (Fig. 10).

The chloride concentration present in zone 1 ranged from 1850 mg/L to 3608 mg/L with mean value of 2629 ± 896 (Table 2). Zone 2 showed a minimum to a maximum range of

1640 mg/L to 3380 mg/L with a mean value of 2284 ± 954 (Table 3). The chloride concentration in Zone 3 ranged from 689 mg/L to 1626 mg/L with a mean value of 1122 ± 472 (Table 4). The acceptable limit of chloride is1000 mg/L (Table 1). The concentration of chloride in effluent was in the order of zone 1 > zone 2 > zone 3 (Fig. 11).

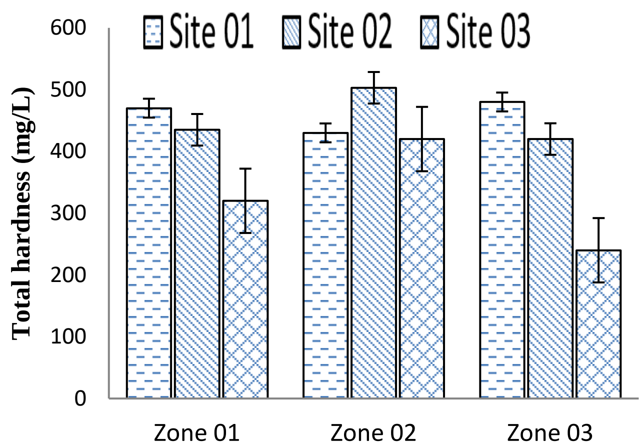

Figure 10. Total hardness in all three zones

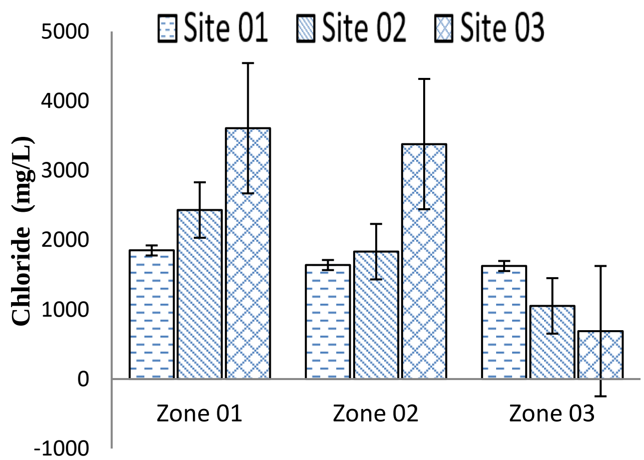

Figure 11. Chloride concentration in all three zones

The nitrate content in textile industrial effluent in zone 1 was 80.9 mg/L to 146.9 mg/L with a mean of 103.2 ± 37.7 (Table 2). Similarly, zone 2 showed variation from 110 mg/L to 223 mg/L with a mean of 152 ± 57 (Table 3). In zone 3 minimum to a maximum ranged from 34.9 to 76.7 mg L^{-1} giving a mean of 48.9 ± 24 (Table 4).

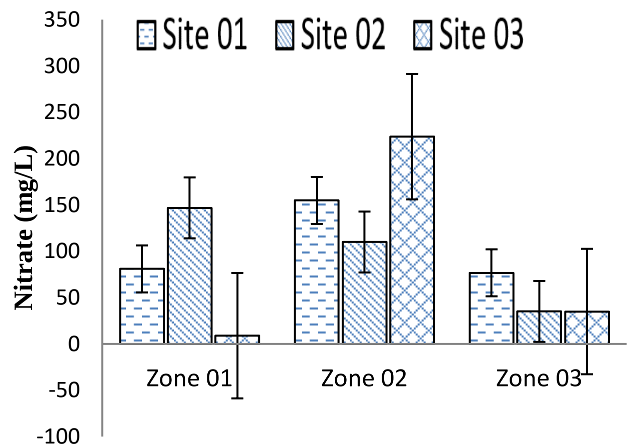

Figure 12. Nitrate variation in all three zones

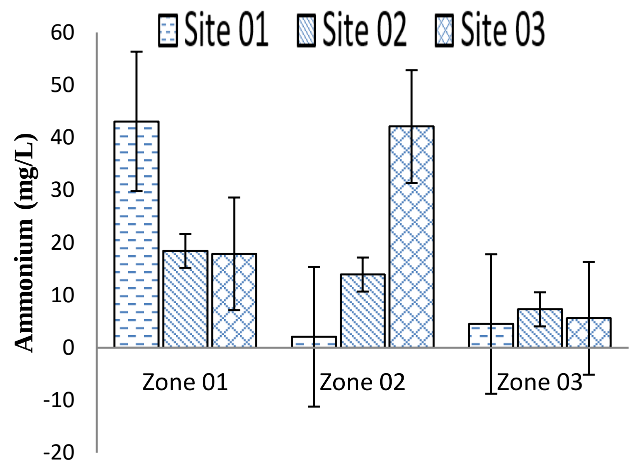

Figure 13. Ammonium ranges in zones

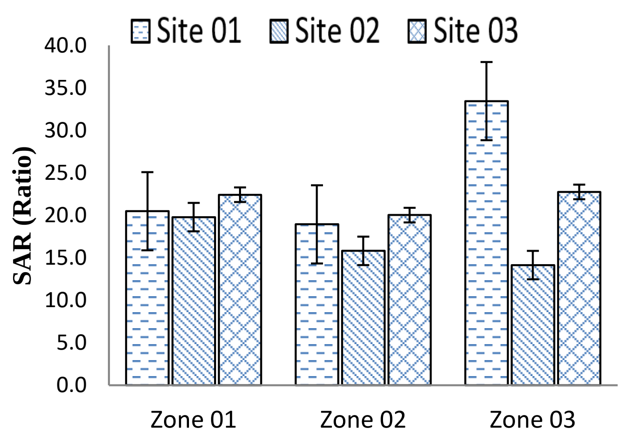

Figure 14. SAR values across all zones

The value of ammonium in zone 1 was found to be between 17.8 mg L^{-1} to 43 mg L^{-1} with a mean of 26.4 ± 14.3 (Table 2). The zone 2 had ammonium range from 12 mg L^{-1} to 42 mg L^{-1} with a mean of 19.3 ± 20.5 (Table 3). In zone 3 the values were 4.5 mg L^{-1} to 7.3 mg L^{-1} with mean 5.7 ± 1.4 (Table 4).

Among zones, the mean value of ammonium in effluent was in the order of zone 1 > zone 2 > zone 3 (Fig. 13).

The sodium adsorption ratio in zone 1 showed variation from 19.7 to 22.4 with a mean of 20.8 ± 1.3 (Table 2). In zone 2 SAR ranged from 15.8 to 20 with a mean of 18.2 ± 2.1 (Table 3). Zone 3 had variation in SAR values from 14.1 to 33.4 with a mean of 23.4 ± 9.6 (Table 4). According to FAO SAR ≤ 15 (Table 1) but as (Figure 14) shows, mean SAR in all zones were higher with zone 3 > zone 1 > zone 2.

DISCUSSION

Monitoring, analysing and assessing characteristics of effluent from textile industry, it is very important to develop strategies for wastewater treatment plant, wastewater reuse for irrigation and protection of environment. Most of the effluent samples from all three major industrial textile zones were not under maximum allowable concentrations given by PEQS and FAO (Table 1). The temperature of water directly influences the water properties and biological activities**.** According to the PEQS, the effluent temperature should be ≤ 3˚C, TDS < 3500 mg/L and FAO < 2000 mg/L (Table 1). The minerals dissolved in water include carbonate, bicarbonate, chloride, phosphate, sulphate, sodium, nitrate, calcium, magnesium, etc (Kahlown *et al.*, 2006b). EC is directly proportional to the number of salts dissolved in water. It is also affected by the temperature as higher the temperature higher the EC. Only 1-degree Celsius increase in water temperature can increase EC by 2-3 %. The reference temperature for EC is 25 ˚C (Dey and Islam, 2015). Salinity and conductivity are inter-relate with each other. The high salinity of the water is toxic to plants (Fipps, 2003). The reason behind the alkaline nature of effluent is the use of caustic and various detergents of alkaline nature in the textile Industry (Imtiazuddin *et al.*, 2012). The permissible limit for pH is 6 to 9 by PEQS and 6.5 to 8 by FAO (Table 1). The values of total hardness are higher than the permissible limit of 250 mg/L and this hardness is due to the presence of calcium and magnesium ions (Ali *et al*., 2006). The values of chloride in textile wastewater streams are due to the softening process in the industry where sodium chloride is used as softeners. Chlorides are also used in the wet processing of textiles (Hussain *et al.*, 2004; Paul *et al.*, 2012). The presence of chloride also shows water hardness because it breaks down from calcium chloride ($CaCl_2$). The high concentration of chlorides in irrigation water makes it toxic (Allen *et al.*, 2005). The major source of nitrate content in the effluent is due to its usage in various process operations. It is used in dyes as a functional group. The data show mean nitrate concentration in zone 2 > zone 1 > zone 3 (Figure 12). When nitrates amount exceeds their limits then it is very harmful to young infants or young livestock. Excessive nitrate can result in the restriction of oxygen transport in the bloodstream (Fernandez-Nava *et al.*, 2010). Ammonium ions in water or unionized ammonia (NH_4^+) are commonly non-toxic and behave like predominates when pH is low. As the pH increases, the toxicity due to ammonium ions also increases (Van Dongen *et al.*, 2001). All zones showing higher values of SAR except zone 2 which is slightly lower than the acceptable range.

Conclusion: The present study concluded that textile industrial effluent is unfit for agriculture use unless properly treated before application. All quality parameters are beyond the permissible limits of standards which could result in major health problems for the people using water from the drains at the study sites. The results of the study can help raise awareness of the government on the issues of un-treated wastewater irrigation. In addition, the farmers should be given awareness about the potential hazards of this practicing irrigation with wastewater.

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Author Contributions: SNK planned, conducted experiment, and analysed data, AN helped in finalizing research theme and objectives, HR guided experimentation and reviewed article, ZA helped in writing results and discussion.

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