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The effects of marble industries effluents on water quality in Swat, Northern Pakistan

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Abstract

The quality of water is being deteriorating due to rapid increase in industrialization in recent times. The marble industry is the leading waste generating industry causing pollution of both surface and groundwater sources. The current study was conducted to analyze the effects of the marble industry effluents on the groundwater parameters in District Swat, Pakistan. All the 30 groundwater samples were collected in different locations in the study area. Among these, 11 groundwater samples were collected from non-industrial zones (Bahrain and Madyan territory of District Swat) as control sample group whereas 19 groundwater samples were collected from industrial zones (Mingora, Kabal, Kanju and Barikot regions of District Swat) as exposed sample group. The groundwater samples were analyzed using different tools for various physico-chemical parameters such as taste, color, odor, temperature, turbidity, hydrogen ion concentration, total suspended solids, total dissolved solids, electrical conductivity, total hardness, total chlorine, chloride, nitrate, nitrite, salinity and alkalinity. Most of the groundwater parameters exceeded the standards set by World Health Organization (WHO). It has been concluded from the current study that marble industry effluents have a negative impact on the quality of groundwater in District Swat. Proper treatment would be needed before using such contaminated water for different useful purposes.

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Introduction

The current study was carried out to assess groundwater quality of the area (District Swat) and to evaluate the impacts of marble industries effluents on the groundwater quality which is being used for various purposes including drinking, cooking etc. The ground water is the sole source for different domestic uses and its pollution by marble industries effluents is of major concern for the local residents.

Safe drinking water is the basic human right and it is important to provide safe drinking water for the protection of people's health (Ahmed *et al.,* 2013). The Earth covers about three-quarters of water on which all life depends (Nasrullah *et al.,* 2006). Oceans cover about 97% of Earth surface water which is not suitable for drinking and only 3% of water on the Earth surface is fresh water (glaciers and ice caps comprise 2.97%) and the remaining small portion (0.3%) is accessible as surface and groundwater for the utilization of humans (Miller, 2007).

Groundwater is a major source used for drinking and irrigation purposes (Edmunds, 2003). Statistical data suggest that more than half of the world's population rely on groundwater for their survival (Mohrir *et al.,* 2002). In Pakistan, about 70% of the people depend on groundwater for their domestic use (Malik *et al.,* 2010). Analysis of groundwater quality has become important as it is used in public water supply, irrigation, industrial applications and power generation etc (Ahmed *et al.,* 2008). Groundwater is the major source mainly used for drinking and other domestic purposes. Humans largely depend on groundwater resources for their survival (Edmunds, 2003; Mohrir *et al.,* 2002). However, these water sources are continuously being deteriorating due to rapid increase in industrialization. Marble industries are the important waste generating units causing pollution of both surface and groundwater sources in District Swat.

Marble industries produce a bulk of waste materials. About 70% of this valuable mineral resource is lost during mining, its processing and in polishing procedures. These wastes are in different forms like rock fragments, effluents and dust particles. These are discarded either in nearby pasturelands, roads, riverbeds and agricultural fields or landfills. Thus it is creating a wide range of environmental pollution especially of water bodies affecting aquatic life (Akbulut *et al.,* 2003).

Marble is the most famous aesthetic rock, used in large number and also easily accessible in nature (Sarkar *et al.,* 2006). Deposits of marble in Pakistan are found in several districts of Khyber Pakhtunkhwa (KP) province such as Swabi, Mardan, Swat, Buner, Nowshera, Bajaur Agency and Mohmand Agency, Chaghi (Balochistan), Kashmir valley (Azad Jammu and Kashmir) and Northwestern Mountains (Manan *et al.,* 2007). In Pakistan, above 297 billion tons of estimated marble reserves and granite reserves are present. These marble and granite reserves occur in about 100 different colors and varieties in this country (PFS, 2010).

District Swat is a beautiful valley, rich in natural resources and fertile area located in the Khyber Pakhtunkhwa province of Pakistan. Groundwater sampling in the present study was conducted from various locations of District Swat (Fig. 1). In Swat valley the drinking water is usually obtained from different groundwater sources like tube wells, hand pumps dug wells as well as from spring. In these sources the quality of water could not be well protected and can be dominantly polluted by anthropogenic and geogenic sources (Shah *et al.,* 2010).

Materials and methods

Study area

The study area lies in District Swat having mainly a mountainous terrain situated in the Hindukush Himalaya range of Khyber Pakhtunkhwa province in Northern Pakistan. It lies at 34° 30′ 00″ to 35° 50′ 00″North latitude and 72° 05′ 00″ to 72° 50′ 00″ East longitude.

It is bordered by district Chitral in the North, while the districts of Lower and Upper Dir lies in the West, District Malakand and District Buner lies in the south, District Shangla lies in the east, Gilgit-Baltistan province in the North-east (Bacha *et al.*, 2018). The elevation varies from about 600 meters in the south to above 6000 meters in the North. District Swat covers an area of 5337 square Kilometers having a population of 125,76,02 persons (1.26 million)in 1998 (Qasim *et al.*, 2013; Quraishi *et al.*, 2015). During the last 19 years, the population of district swat have grown tremendously and almost doubled now to 230,95,70 persons (2.31 million) in 2017. The population's average annual growth rate in district swat is an overwhelming 3.24 % during the inter census period of 1998 to 2017 (Government of Pakistan, 2017; Khan *et al.*, 2017).

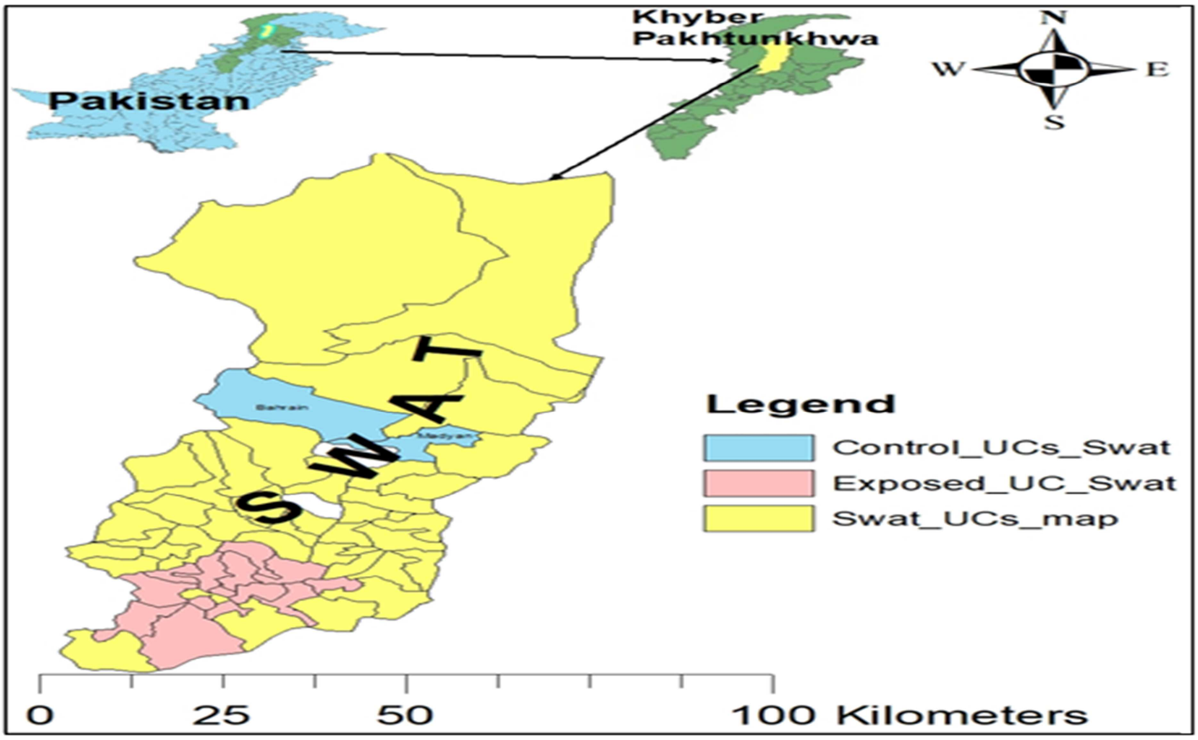

Fig. 1. Map of district swat showing the location of Union Councils (areas) selected as control (Bahrain and Madyan areas located in upstream areas of river Swat) having no Industries (Shown by blue color) and Exposed Union Councils (areas)is having Industries (shown by pink color here and located in the downstream of river swat).

District Swat is categorized in three different ecological zones. These are Lower Swat, Middle Swat and Upper Swat. Lower Swat is having hot, humid summer season while the winter season is cold having frost but rare snow. Middle Swat has warm, humid summer seasonwhilethe winter season is having frost and infrequent snow.

On the other hand, Upper Swat has a temperate climate. Upper Swat has moderate summer season while the winter season is tremendously cold having heavy frost and also heavy snow (Nafees *et al.,* 2009).

The district Swat is entirely drained by the River Swat which is the main river running from the Northern uplands to the southern lowlands in the Swat district (Ahmad *et al.,* 2015).

Sampling and pretreatment

A total of 30 groundwater samples were collected during the months of June and July, 2015 from various water sources such as springs, tube wells, bore wells, dug wells and hand pumps in the study area. Among these, 11 groundwater samples were collected from the non-industrial zones of District

Swat i.e. Bahrain and Madyan territory (control sample group) whereas 19 groundwater samples were collected from the vicinity of marble industry i.e. Mingora city of District Swat (exposed sample group) shown by Fig. 2 and Fig. 3.

Water samples were collected in clean polyethene bottles (1L) and the bottles were sealed, labeled and kept cooled before analysis. Coordinates (position) and elevation from the sea of all groundwater samples were identified on the spot using Global Positioning System (GPS) device.

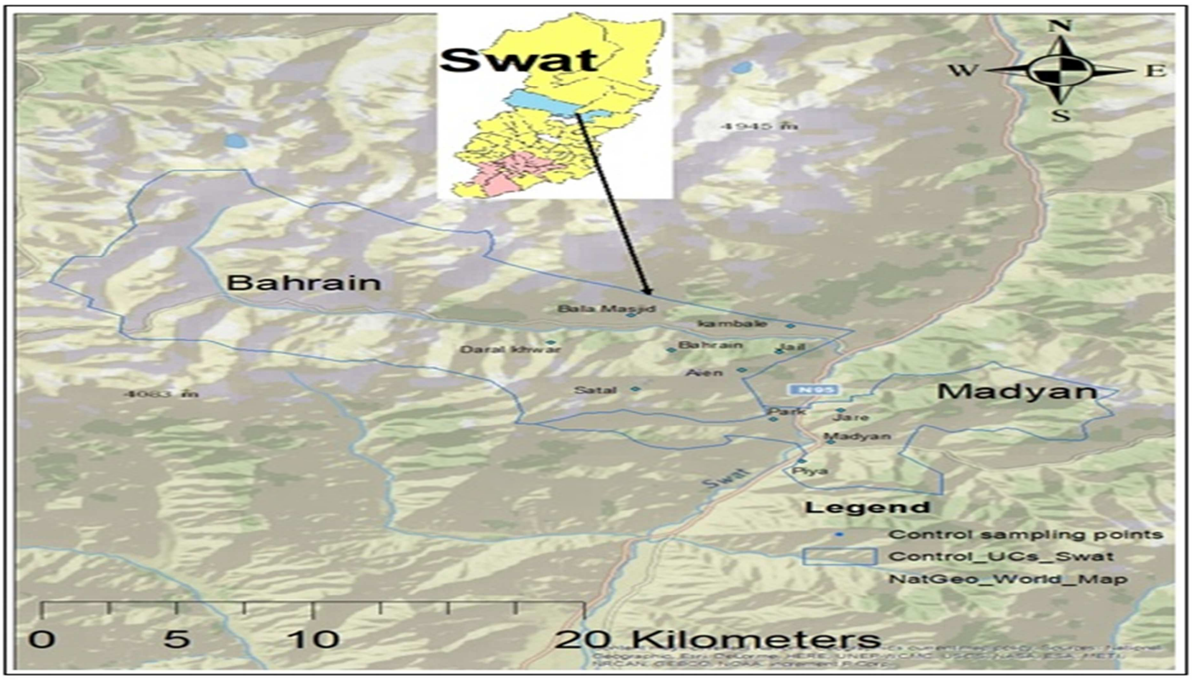

Fig. 2. Showing location of Bahrain and Madyan areas located upstream of river swat and no industries are present in this region. Control samples were collected from these areas in district Swat.

Analytical procedure

Analysis of water quality parameters was carried out at the Department of Environmental and Conservation Sciences in University of Swat. Physical parameters like taste, color and odor of all groundwater samples were determined through visual and organoleptic method.

Temperature was recorded by a portable digital thermometer, turbidity was determined by a portable turbidity meter and total suspended solids (TSS) were determined through standard operating procedure as described earlier (APHA, 1992).

For analysis of chemical parameters such as pH (Hydrogen ion concentration), a portable digital pH meter was used. Electrical conductivity (EC) was measured by EC meter.

Salinity and chloride were determined through gravimetric titration method. Total dissolved solids (TDS) were determined by digital TDS meter. For measurement of total hardness (TH), alkalinity, total chlorine (T.Cl), nitrates (NO_3^-) and nitrites (NO_2^-) a test kit was used (Richards, 1954).

Statistical analysis

The values of the mean and standard deviation (SD) were determined for both of the studied groups (control and exposed samples), and the resulted values of the two groups were compared. Similarly, the p-values of both the sample groups were calculated by computerized software known as Statistical Package for Social Sciences (SPSS) version 19.To find the significance of data a paired t-test was used and p-value of ≤ 0.05 at 95% confidence interval was considered as the significant.

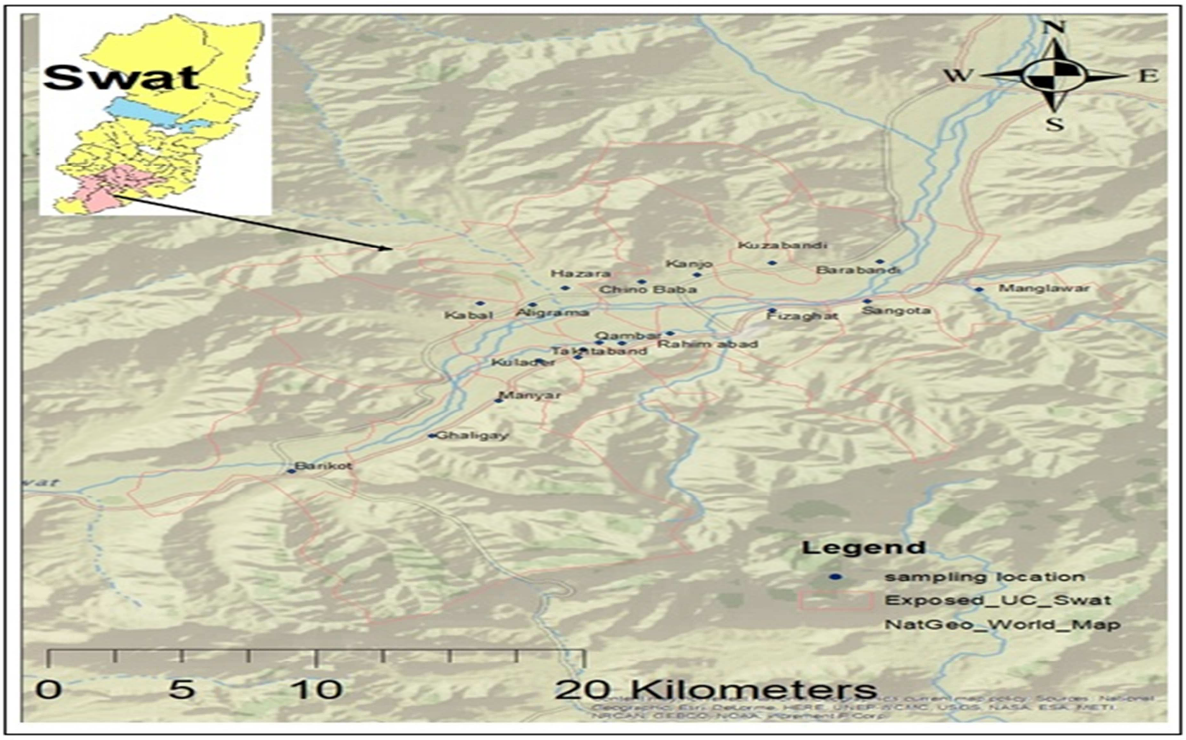

Fig. 3. Showing location of Mingora and the surrounding region located downstream of river swat and industries are present in this region. Exposed water samples were collected from these areas in district Swat.

Results and discussion

The level (mean ± SD values) of most of the chemical parameters tested (EC, salinity, chloride, TDS, TH, alkalinity, T.Cl, NO_3^- and NO_2^-) show a dramatic increase for exposed sample group in comparison to the control sample group. In contrast, the mean ± SD values of pH of exposed sample group were slightly decreased when compared to the control sample group (Table 1).

Taste, color and odor of exposed samples in the current study were largely changed when compared with control samples (Table 1). This study is in controversy with the previous study of Ullah *et al.* (2014) who reported that most groundwater samples analyzed in District Dir (a neighboring district of Swat) were tasteless, colorless and odorless. The conflict between the two studies may be due to different environment, the type of industry involved and biological degradation in water bodies.

The mean value of temperature of groundwater samples in the current study (20.64 °C) was similar to those observed by Ullah *et al.* (2009) in Sialkot District of Punjab (21.85°C).

A slight variation in temperature between the two sites may be due to different climatic conditions and level of pollution of the two regions.

The groundwater samples that have been exposed to industrial pollution had a higher turbidity mean value (12.1NTU) than the control samples (3.45NTU). The mean value of turbidity of groundwater samples studied by Pathak *et al.* (2012) was 13.15 NTU. In both studies turbidity of groundwater has been negatively affected by marble industry effluents. The high level of turbidity in exposed water bodies may be due to the presence of suspended or colloidal particles.

The mean value of TSS in groundwater samples that have been collected from industrial zones was much higher (8.53 mg/L) as compared to control sample group (3.18 mg/L).Similarly, the mean value of TSS in groundwater samples studied by Khan *et al.* (2012) was even higher (16.32 mg/L) than the current innovation.

In both of these findings the level of TSSin most groundwater samples were exceeding the standards set by WHO.

The high values of TSS in water sources may be due to sediments from soil erosion and industrial wastes discharge.

The pH of groundwater samples that have been collected from the vicinity of marble industry was slightly acidic (pH 6.44) while the pH of control samples was slightly basic in nature (pH 7.14). These observations show similarity with the previous findings of Nasrullah *et al.* (2006) who reported a pH of 7.12 for the groundwater sources. These findings suggest that the pH of most groundwater samples was within the permissible limit of WHO.

Table 1. Effect of marble industry effluents on groundwater quality parameters in District Swat.

S. No.	Parameter	Groundwater samples		P-value	WHO limit
		Exposed samples	Control samples		
		Mean ± SD	Mean ± SD		
1	Taste	Marble like	Acceptable	---	Acceptable
2	Color	Milky	Acceptable	---	Acceptable
3	Odor	Bad (Objectionable)	Acceptable	---	Acceptable
4	Temperature (°C)	21.60 ± 1.40	18.98 ± 2.05	0.000*	No guideline set by WHO
5	Turbidity (NTU)	12.10 ± 2.76	3.45 ± 1.03	0.009*	< 5 NTU
6	TSS (mg/L)	8.53 ± 2.32	3.18 ± 1.10	0.001*	5 mg/L
7	pH	6.44 ± 1.19	7.14 ± 0.47	0.074	6.5 – 8.5
8	TDS (mg/L)	443.80 ± 122.49	159.36 ± 62.17	0.005*	500 mg/L
9	EC (µS/cm)	566.11 ± 202.75	290.39 ± 68.88	0.000*	400 µS/cm
10	TH (mg/L)	337.89 ± 66.59	225.14 ± 38.33	0.011*	300 mg/L
11	T.Cl (mg/L)	7.58 ± 2.20	2.77 ± 1.47	0.091	5mg/L
12	Cl^- (mg/L)	148.91 ± 48.32	61.07 ± 30.62	0.242	200 mg/L
13	NO_3^- (mg/L)	52.05 ± 7.55	16.04 ± 5.68	0.000*	50 mg/L
14	NO_2^- (mg/L)	4.25 ± 1.07	1.97 ± 0.67	0.000*	3 mg/L
15	Salinity (mg/L)	190.62 ± 45.64	175.72 ± 44.91	0.393	500 mg/L
16	Alkalinity (mg/L)	223.75 ± 24.82	183.78 ± 34.17	0.001*	200 mg/L

The values for mean and standard deviation (±SD) were calculated for several physical and chemical parameters of groundwater samples and comparison was made between the two groups. Paired t-test was used for finding the significance of data and a p-value of ≤0.05 at 95% confidence interval was considered as significant (indicated by asteric*).

The mean amount of TDS in groundwater samples that have been exposed to marble industrial wastes was much higher (443 mg/L) in comparison to control sample group (159.36mg/L). This study is in consistency with the previous findings of Hussain *et al.* (2014) who observed an amount of 312.53 mg/L in the groundwater samples contaminated by marble industry waste products. Both of these findings are in agreement that most groundwater samples could be negatively affected by marble industry effluents.

The mean value of EC in groundwater samples collected from the vicinity of marble industry was much higher (566.11µS/cm) in comparison to control sample group(290.39 µS/cm). This study is in consistency with the previous findings (592.10 µS/cm) of Aghazadeh *et al.* (2010) as EC of exposed samples were negatively affected by marble industry effluents. EC in water bodies may be due to large concentration of ionic constituents that increases corrosive nature of water.

The groundwater samples that have been exposed to marble industrial wastes had a higher TH mean value (337.89 mg/L) as compared to control sample group (225.14 mg/L).

This is similar with the findings (317.12 mg/L) of Sarala *et al.* (2012)as only in exposed samples TH was negatively affected by marble industry effluents. Hardness of water may be due to the presence of calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions. Poor lathering with soap and deterioration of the quality of clothes are some of the characteristics of hard water.

The mean value of T.Cl in groundwater samples collected from the vicinity of marble industry was much higher (7.58 mg/L) in comparison to control sample group (2.77 mg/L). The current study is in agreement with the previous findings (24.31 mg/L) of Ackah *et al.* (2011) as T.Cl in most groundwater samples was negatively affected by marble industry effluents.

The mean amount of Cl^- in groundwater samples that have been exposed to marble industrial pollution was higher (148.91 mg/L) than the control sample group (61.07 mg/L). There is no contradiction between the current and the previous findings (103.11 mg/L) of Hussain *et al.* (2014)asCl^- in most groundwater samples was within the permissible limit of WHO.

The groundwater samples collected from the vicinity of marble industries had a higher NO_3^- mean value (52.05 mg/L) than the control sample group (16.04 mg/L). There is a disagreement between the current and the previous findings (14.32 mg/L) of Khattak *et al.* (2012) as only exposed samples in the present study were negatively affected by marble industry effluents. The disagreement may be due to different environmental conditions, the type of industry involved, runoff from fertilizer use in variant amount and leaking from septic tanks.

The mean value of NO_2^- in groundwater samples that have been exposed to marble industrial pollution was slightly higher (4.25 mg/L) in comparison to control sample group (1.97 mg/L).

The current study is in consistency with the previous findings (2.51 mg/L) of Sarala *et al.* (2012) as groundwater samples were partially affected by marble industry effluents. NO_2^- may be added to water sources from the use of fertilizers and erosion of natural deposits.

The groundwater samples collected from the vicinity of marble industry had slightly higher mean value of salinity (190.62 mg/L) than the control sample group (175.72 mg/L).There is no contradiction between the current and the previous findings (108.45 mg/L) of Ullah *et al.* (2009) as salinity of groundwater samples was within the permissible limit of WHO.

The mean value of alkalinity in groundwater samples that have been exposed to marble industrial wastes had slightly higher (223.75 mg/L) in comparison to control sample group (183.78 mg/L). This study is in agreement with the previous findings (230.65mg/L) of Hussain *et al.* (2014) as alkalinity in most groundwater samples were negatively affected by marble industry effluents. Alkalinity of water may be due to carbon-based mineral molecules suspended in water such as $CaCO_3$ etc.

Conclusion

It has been concluded from this study that the effluents ooze out from marble industry could adversely affect the quality of groundwater sources that are particularly more adjacent to marble industry discharge units. This industrial discharge results in the degradation of water quality which causes health hazards and death of human beings, livestock and death of aquatic lives, affect crop growth and their quantity and quality. The lack of treatment facilities, financial resources and misconception of environmental laws and policies do further aggravate the problem. So, it is recommended that proper procedures should be adopted to prevent the flow of contaminated water discharges from different industries into water sources to protect human health and its environment.

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