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Assessment of the impact of industrial effluents on surface water quality near Balotra, Rajasthan, India

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Abstract

The study was conducted to assess the impact of Industrial effluents on the surface water quality near Balotra Rajasthan. Water samples were collected from upstream, midstream and downstream at Khariya wala nala which further meets with River Luni near Balotra. Water samples were analysed for pH, electric conductivity, total dissolved salts, total suspended solids, calcium, chloride, total hardness, total alkalinity, chemical oxygen demand and heavy metals like Copper, Cadmium, Iron, Nickel, Zinc, Cobalt, Manganese and Lead. The results show that concentration of different parameters in water increases after receiving the effluents. It was found that water was contaminated with high concentration of TDS, EC, COD, TSS, Chloride, total hardness and total alkalinity. Heavy metals were well within the range; however concentration of lead was much higher constituting an alarming situation for the ecological health of surface water bodies. The study finds that the water body is heavily polluted at mid and downstream and water is not suitable for irrigation as well as for domestic use. Since the water body lies in an arid region with very low chance of fresh water addition, continuous disposal of industrial effluents may result in severe contamination and continuous degradation of water quality.

Keywords: *Industrial effluents; surface water bodies; water quality, CETPs, HRTS*

Introduction

Despite its significance, water is perhaps the most ill managed resource in the world. Deterioration of ground and surface water quality owing to industrial and urban waste is now a well-recognized fact. At present, only about 10 percent of waste water produced is being treated while the rest is released as it is into various bodies (CAG, 2011). About three-fourth of the fresh water used by household and industrial sector, gets back as sewage and industrial effluents, ending up in rivers and streams or ground water and deteriorating the water quality (CAG, 2011). Rivers and streams are the most common receivers of industrial effluents. India's 14 major, 55 minor and several hundred small rivers receive millions of litres of sewage, industrial and agricultural wastes (CAG, 2011). The rapid population growth along the rivers, urbanisation and industrialisation have stressed the rivers, leading to water pollution and environmental and health degradation (Jamal and Ajmal, 2020a; Jamal and Ajmal, 2020b; Ganaie et al. 2020). The contaminated water is being used by people living in the surrounding areas for drinking, bathing, washing clothes as well as for irrigation purposes, unaware of the harms it could cause. Deteriorated water quality poses adverse impact on the ecosystem as well as health of the people using it.

The study was conducted in Balotra- a well-known hub of the textile, dying and printing industries. There are about 400 industrial units in Balotra alone while there are 214 and 111 industrial units in the adjacent Bithuja and Jasole villages (which are developed along with Balotra industrial areas) respectively, making it a total of 725 industrial units in the area. Major environmental threats from these industries are liquid effluents that comprise heavy metals and other harmful materials. Effluents from these industries, either untreated or partially treated, are discharged into river Luni and other surface bodies of the region. Acidic effluents from industrial units have percolated far below the surface and have contaminated the ground water in the villages like Asada, Astora, Tapra, Dakha and Khed etc (Meghwal and Parihar, 2017; Mathrani, 2019). People living in Balotra are affected due to contamination of surface water bodies as well as ground water. The polluted water has ruined various crops like jowar, wheat, millet, vegetables and fodders which were cultivated previously in the region (Mishra and Soni, 2016). Since surface and ground water quality is deteriorating and crops are getting destroyed due to polluted water, local organizations have approached the high court which issued order for stopping all units from dumping of waste water into the river. About 700 units were closed rendering some 34000-45000 people (Mishra and Soni, 2016) unemployed. However, after a year, industries resumed working discharging their effluents in the river (Meghwal and Parihar, 2017).

A few studies have focussed the impact of the release of industrial effluents into the river (Mishra, 2012; Mishra and soni, 2016; Meghwal and Parihar, 2017). However, there is scanty attention paid to the functioning of CETPs (Common Effluent Treatment Plants) in the region. At present, there is one CETP in Balotra, which treats industrial effluents generated from the industries in the region. After treatment in the CETP, treated and partially treated water is sent to solar evaporation ponds (SEP), also known as HRTS (High Rate Transpiration System) sites from where it is supposed to be evaporated into the atmosphere. CETP Balotra, currently has two SEPs, one situated near river Luni while the other located near the village Khed. The Analysis report by NGT of treated waste water at CETP Balotra has claimed that important parameters like fixed dissolved solids, total dissolved solids, chemical oxygen demand, biological oxygen demand, chloride and sulphate are much beyond the CETP inland surface water standards (Status report, 2018). This treated waste water is stored in solar evaporation ponds or HRTS where it is polluting the surrounding land and water bodies through leakage from the pond walls and transportation pipes. National Green Tribunal (NGT) in its report insisted on the need to study the impact of HRTS on surface water and ground water quality in the region. Keeping all these aspects in the mind, an attempt has been made to estimate the impact of HRTS sites on surface water quality. In the present study, one such HRTS located near Khed village is identified and its impact on adjacent water body locally known as *Khariyawala nala* is studied (Fig 1). This is first of its kind that examines the impact of HRTS on surface water in the region. During the field visit, leakage of partially treated water from the HRTS to surrounding land and *khariyawala nala* has been observed (plate 1 and 2). *Khariyawala nala* is a seasonal stream which flows in the region and joins river Luni in the downstream. Since, *khariyawala nala* meets river Luni, it also carries pollutants into the river. Besides, water from *khariyawala nala* is used for agriculture as well as for different domestic purposes.

Materials and Methods

Study Area

Balotra Town (25.83° N, 72.23° E) is located in the arid Barmer district of Rajasthan and is about 91 km away from Jodhpur (Figure 1). It is an important industrial hub and well-known for hand block printing and textile industries. It is also famous for colouring and printing of yarn and polyester clothes (Mishra, 2012). At present about 800 clothing units are running in Balotra, Bithuja and Jasole (Bithuja and Jasole are adjacent to Balotra) out of which 400 Industrial units are in Balotra alone. There are some unregistered factories too, which release their effluents into the drains and Luni River (Mishra and Soni, 2016).

Hydrogeology - Balotra region is a part of Great Indian Thar Desert and desert sands

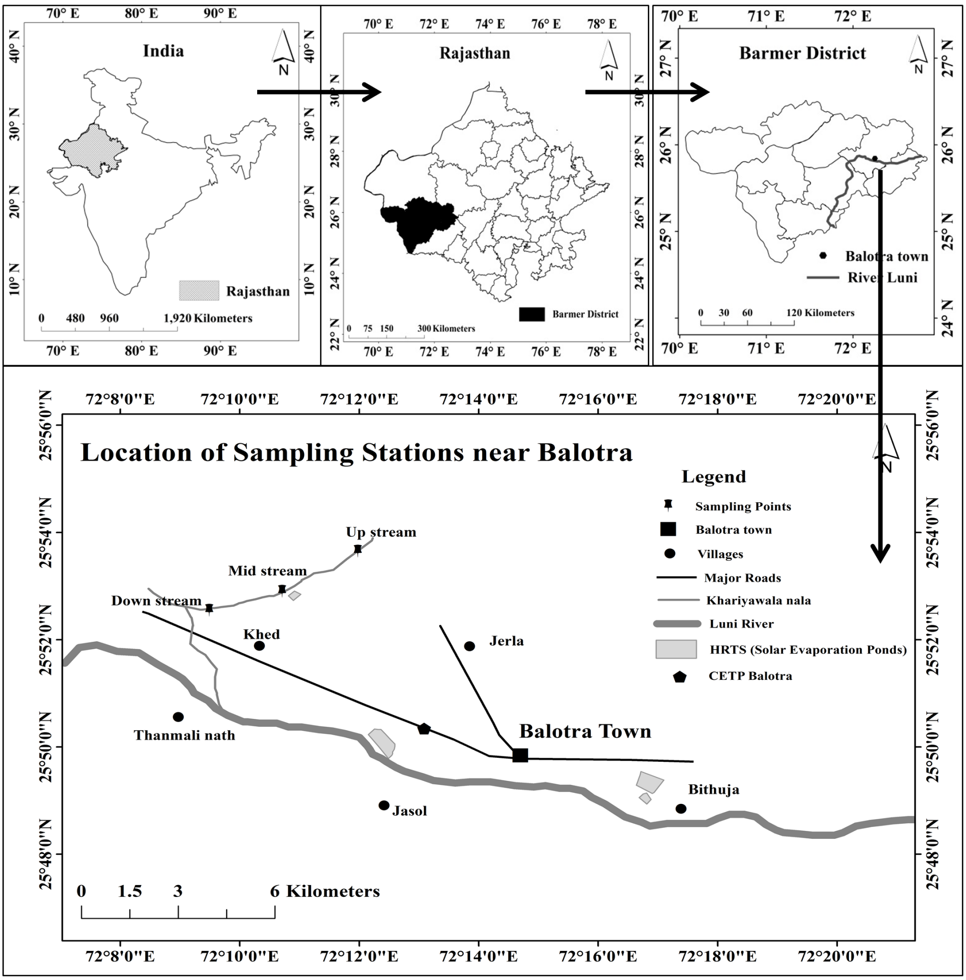

Fig. 1: Location of the study area in Rajasthan, India.

and sand dunes are prevalent in the region. Windblown sand covers surface area which is further followed by rocks of Malani groups like rhyolite and granites. The Malani Igneous Suites of rocks are most extensively exposed and are oldest in the area. They consist of volcanic rocks rhyolites and plutonic rocks like granites and associated intrusive rocks like basic dykes of aplites and quartz veins. Unconsolidated formations in the Balotra include quaternary alluvium which is most extensive and forms potential aquifers. The pre- monsoon water level in Balotra is 22.05 meter below ground level and the post monsoon water level in Balotra is minimum 4.10 meter below ground level and maximum 38.07 meter below ground level. The exploration drilling data indicate that the alluvium is composed of heterogeneous sequence of sand, silt, clay and *kankar* with occasional tongues and lenses of gravel and cobbles. The thickness of alluvium varies generally from 40 to 100 m (CGWB, 2013). This is important as the soil of the area permits high percolation rate of the treated effluent disposed on land, leading to possibility of ground water pollution.

Climate- May and June are hottest months with approximate mean-maximum and minimum daily temperatures of 42°C to 50°C and to 27°C to 33°C respectively. Average annual rainfall is less than 200 mm from June to September months accounting for about 88 percent annual rainfall in Balotra. Since Balotra lies in an arid region, nature of rainfall is quite erratic, reducing chances of freshwater mixing in the region leading to deterioration of water quality due to mixing of waste water

Sampling

Water samples were collected from three different points of the Khariyawala nala- upstream, midstream and downstream. Upstream sample was taken near the over bridge, bhatiyo ki dhani road; midstreams near the HRTS site while downstream sample was taken near over bridge, Jogmaya Temple road (Figure 1). Samples were collected in one litre plastic bottles to analyse pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), total suspended solids (TSS), Chloride (Cl), Calcium (Ca), Chemical oxygen demand (COD), total hardness as $CaCO_3$, total alkalinity as $CaCO_3$ and heavy metals such as copper (Cu), cadmium (Cd), iron (Fe), lead (Pb) and zinc (Zn), Nickel(Ni), Manganese (Mn) and Cobalt (Co). From each point, samples were taken, approximately 25 cm below the surface. Each bottle, containing samples were labelled separately with adequate information. The samples were analysed at *Ramky Enviro Engineers Limited, Rajasthan Waste Management Project, TSDF, Udaipur.* All the parameters were determined following the protocol of APHA (2000) viz. APHA 4500H + B (pH), APHA 2510 B (EC), APHA 2540 C (TDS), APHA 2540 D (TSS), APHA 4500 Cl- C (Chloride), APHA 2340 c (Total Hardness), APHA 3500 Ca B (Ca), APHA 2320 B (Total Alkalinity), APHA 5220 B (COD) and APHA 311 B, AAS (Zn, Pb, Cu, Cd, Fe, Ni, Mn and Co).

Results and Discussion

Physicochemical and heavy metal analysis of CETP outlets

There are 3 CETPs under action, one each at Balotra, Bithuja and Jasole. The industrial effluents generated from industries in Balotra are sent to CETP at Balotra for treatment. On an average, CETP Balotra receives monthly inlet effluent from 7.81 to 9.45 MLD (million litres per day). However, the CETP has a capacity of 20 MLD of wastewater with tertiary treatment. The waste water from different industries of the region is being treated at CETP. Treatment scheme of CETP constitute primary treatment i.e. equalization tank, flash mixing, clariflocculation, secondary treatment, comprising Sequential Batch Reactor and treated water collection tank and tertiary filters comprising Pressure sand Filters and activated Carbon filters. CETPs are mainly responsible for physicochemical treatment followed by aerobic biological treatment. After treatment in the plant, treated, partially treated wastewater and residue sludge are transported in closed HDPE (High-density polyethylene) pipelines to Solar Evaporation ponds (SEP) also known as HRTS sites. CETP Balotra, currently has two SEPs, one situated near river Luni while the other is located near the village Khed. As per the status report of CETPs and HRTS as demanded by National Green Tribunal (NGT) in 2018 and 2019, CETPs at Balotra, Bithuja and Jasole cannot treat the total effluent generated from the catchment region. There is no evaporation pond or plantation/ agriculture for the treated effluents, and the SEPs that receive partially treated effluents are not lined properly. It has been found that seepage is taking place from HRTS sites and as a result agricultural lands and surrounding water bodies are getting contaminated (Field Survey, 2019; plate 1 and 2). The six month report of treated wastewater of CETP from May 2018 to Dec 2018 has been shown in table 1. It has been found that values of biological oxygen demand (BOD), Chloride, total dissolved solids (TDS) and sulphate were higher in all the samples while value of chemical oxygen demand (COD) was higher than standard limit in the samples taken in May only. A perusal of the table 1 reveals that though the value of TSS was measured for one month only; in that one sample too, it was beyond the standard limit. BOD directly affects the amount of dissolved oxygen in rivers and streams. The greater the BOD, higher is the depletion of oxygen in the stream adversely affecting higher form of aquatic life. High levels of BOD and COD indicate a heavily polluted water body making it less suitable for aquatic life. Higher levels of total dissolved solids often harm aquatic species. The TDS changes the mineral content of the water, which is important for survival of many animals. Chlorides can contaminate fresh water streams and lakes. Fish and aquatic communities cannot survive in high levels of chlorides. Sulphate can have a temporary laxative impact on human and livestock if they consume it. High level of total suspended solids increases water temperatures and decrease dissolved oxygen which is harmful for aquatic life. Since outlet water from CETPs has been seen flowing on the surrounding land and water bodies, it can harm the plant and animals of both land and water. Other parameters like pH, Temperature, Ammonical Nitrogen and heavy metals were within limit (Status Report, 2018 & 2019).

Physicochemical analysis of surface water samples

To assess the impact of effluent leakages from HRTS sites on the water quality of surrounding *khariyawala nala*, different parameters of the water were examined. Concentration of parameters obtained from three points (upstream, midstream and downstream) of the water body, has been shown in table 2 and 3. Trend of the parameters moving from upstream to downstream has been shown in figure 2 and 3. pH value of sampling points ranged from 8.26 to 8.45 with a mean value

Table 1: Analysis report of outlet of CETP Balotra from May 2018 to Dec 2018

Date	Ammonical Nitrogen N	BOD	Cd	COD	Chloride Cl	Cu	Fixed Dissolved Solids	Fluride F	Fe	Pb	Ni	Oil & Grease	pH	Phosphate	Sulphate	Zn	Cr	TSS
Outlet Standard	50	20	0.05	250	1000	3	2100	2	3.0	0.1	3	10	6-9	5	1000	5	2	100
3/12/18	0.4	30	0.0422	246	7571	0.418	N/A	1.16	0.413	0.026	0.044	10	8.2	0.3	1490			
1/11/18	1	26	NT	185	8200	0.123	19810	1.14	0.244	NT	0.22	1	8.49	1	1436			
11/10/18	2.2	38	NT	239	8260	0.29	21040	1.11	NT	NT	NT	1	7.69	1	2509			
6/9/18	0.8	46	NT	241	8220	0.111	20268	1.2	NT	NT	0.085	1	8	0.5	1736			
3/7/18	1	36	NT	230	7240	0.094	19460	1.3	0.913	0.05	0.195	1	8.02	0.3	2109			
19/6/18	1	33	0.002	201	7040	0.084	19204	1.35	0.061	NT	NT	1	8.21	0.2	1936			
7/5/18	1.6	74	NT	459	7800	0.109	17428	1.19	0.828	NT	0.09	3	8.47	0.5	1236	.029	.017	136

Source: Status Report on CETPs, STPs and Industrial Pollution in Jojari River (Jodhpur to Balotra, Rajasthan (2018)

All Concentrations are expressed in (mg/L)

NT- Non Traceable

Table 2: Physicochemical parameters of Khariya wala nala

Parameter	Sampling Stations			Mean	Standard Deviation
	Upstream	Midstream	Downstream		
pH	8.26	8.45	8.36	8.357	0.095
Conductivity (µs/cm)	5591	25456	36540	22529	15680.741
TDS (mg/L)	2900	25400	22300	16866	12194.398
TSS (mg/L)	306.12	450	312.5	356.207	81.290
Chloride (mg/L)	1034.67	1502	249.92	928.863	632.710
Total Hardness as CaCO3 (mg/L)	390	540	1200	710.000	430.929
Ca (mg/L)	52.1	54.5	148.29	84.963	54.856
Total Alkalinity as CaCO3 (mg/L)	900	480	1100	826.667	316.439
COD (mg/L)	203.28	175.23	1376	584.837	685.311

Source: Samples collected from khariya wala nala, parameters analysed by Ramky Enviro Engineers Limited, Rajasthan Waste Management Project, TSDF, Udaipur

of 8.35. It suggested that water was alkaline. pH values were within range of inland surface water bodies which is suitable to support water life. Electrical conductivity (EC) which is the ability of water to pass an electric content depends upon the salt content in the water as dissolved salts and other inorganic materials. EC ranges from 5591 in upstream to 36540 in downstream with a mean value of 22529 while total dissolved salts ranged from 2900 mg/l upstream to 25400 midstream with a mean value of 16866. Values of electrical conductivity and total dissolved solids were higher in midstream and downstream. The increase in the amount of dissolved solids moving downstream is due to deposition of solids along the stream course. The increasing solid content in the stream can also slow down the stream's velocity resulting in further rapid deposition of solids (Fakayode, 2005). The higher values of electrical conductivity and total dissolved solids suggest that a greater amount of solids was added in water due to leakage of water from Solar Evaporation Ponds/HRTS. Previous studies have also found that the amount of dissolved solids in the water bodies is added due to dumping of solid waste and industrial effluents (Chowdhury, 1994; Irshad et al., 2011). The relationship between EC and TDS has been shown in the figure indicating an increase in EC with increase in TDS (Fig. 4). Higher amount of salts in the water is not suitable for aquatic species and their biodiversity tends to fall with growing salt content (Derry et al., 2003).

Value of COD (chemical oxygen demand) in the sampling stations ranges from 175-1376 with a mean value of 584. Value of COD was the highest downstream, much higher than the standard for water bodies. The study revealed a significant positive relationship between COD and EC where the level of COD increases with increasing EC (Fig. 7). Therefore it could be said that with increasing amount of salts in water, amount of oxygen used by inorganic substances for oxidization (COD) increases and consequently amount of dissolved oxygen in the water decreases. Total suspended solids in the sampled stations

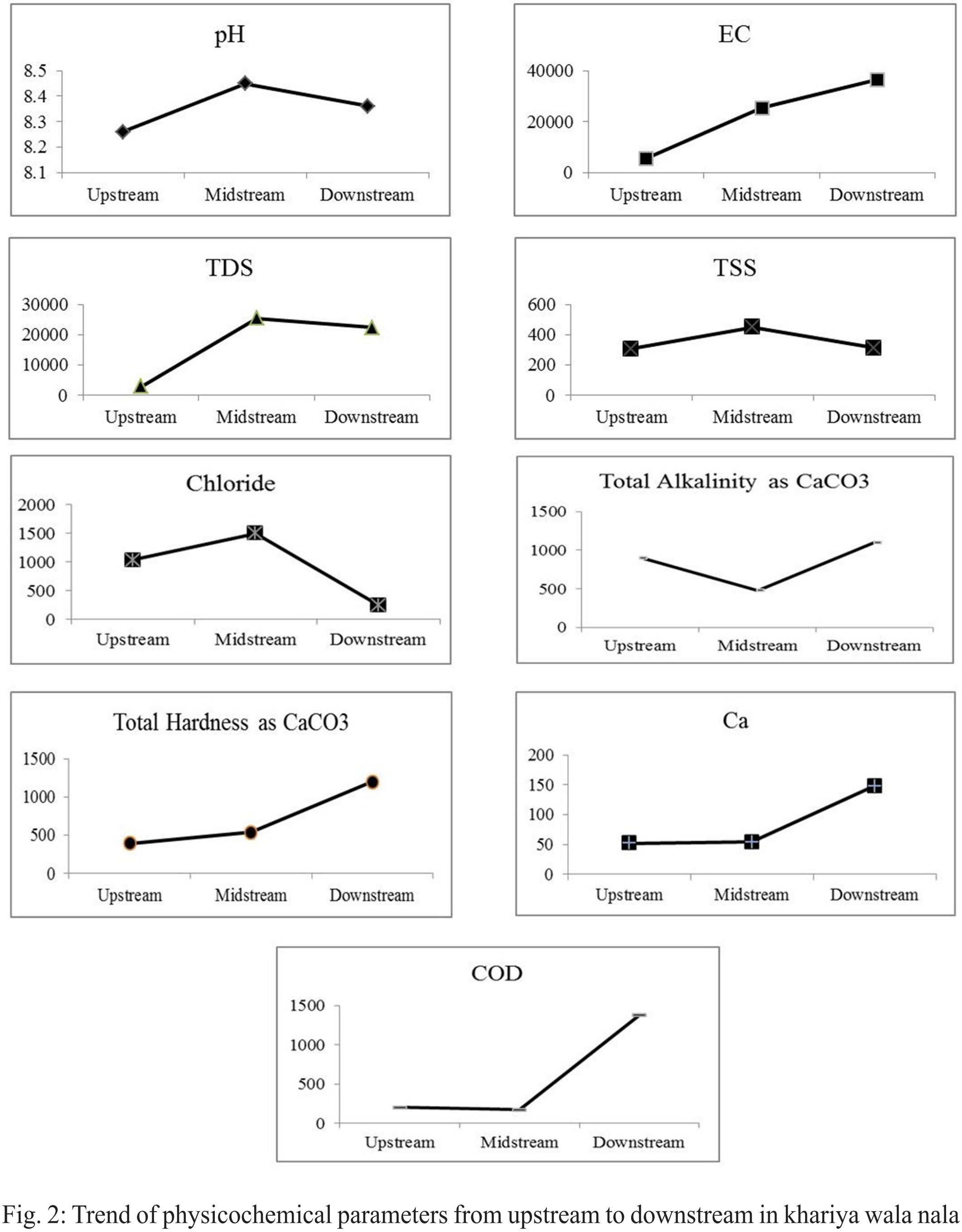

Fig. 2: Trend of physicochemical parameters from upstream to downstream in khariya wala nala

Note- All Concentrations are expressed in (mg/L) except EC (µs/cm)

Source: Samples collected from khariyawala nala, parameters analysed by Ramky Enviro Engineers Limited, Rajasthan Waste Management Project, TSDF, Udaipur (2019).

Table 3: Analysis of heavy metals in khariya wala nala

Parameter (mg/L)	Sampling Stations			Mean	Standard Deviation
	Upstream	Midstream	Downstream		
Zn	0.06	0.22	0.13	0.13	0.080
Pb	0.21	0.15	0.53	0.29	0.204
Cu	0.03	0.03	0.06	0.04	0.017
Cd	0.01	0.01	0.01	0.01	0.000
Fe	0.31	0.32	0.62	0.41	0.176
Ni	0.06	0.09	0.35	0.16	0.159
Mn	0.16	0.06	0.25	0.15	0.095
Co	0.03	0.02	0.17	0.07	0.084

Source: Samples collected from khariya wala nala, parameters analysed by Ramky Enviro Engineers Limited, Rajasthan Waste Management Project, TSDF, Udaipur

ranges from 306 to 450 with mean value of 356. Concentration of suspended solids was unacceptably high at midstream- i.e. beyond the permissible limit at all the stations. The high levels of suspended solids at midstream could be attributed to mixing of industrial effluents in the river body.

Suspended solids are also responsible for transportation of toxic pollutants as they absorb toxic metals and carry them elsewhere in the river or lake systems. Concentration of chloride in the water ranges from 249 to 1502 with a mean value of 710. Chloride is beyond the permissible limit (EPA, 2018) for all the stations. The level at midstream was higher than upstream due to mixing of industrial effluents. Value of alkalinity in the sampling stations ranges from 480-900 with an average of 826 while the corresponding total hardness value ranges from 390-1200 with mean value of 710. Both total hardness and alkalinity were recorded to be the highest in downstream. However lowest value of alkalinity was found at midstream while lowest value of hardness was at upstream. The phenomenon suggested that Ca ion is not the only source of both hardness and alkalinity. The relationship between Ca and hardness is very strong and it was found that hardness increases with increasing Ca though the relation is not strong in the case of Ca and alkalinity (Fig 7). This suggests that presence of other basic salts like sodium and potassium other than calcium and magnesium could be prevalent in the river. The relatively greater amount of alkalinity recorded downstream could be attributed to high levels of COD after receiving effluents from the industries.

Heavy metal analysis of surface water samples

Sources of the heavy metal in the environment could be both natural as well as anthropogenic. Heavy metals enter into environment by weathering of rocks, mining, soil erosion, industrial discharge, urban runoff as well as sewage effluents. Problem of heavy metal contamination is more severe in developing countries due to upsurge of industrial complexes with negligible implementation of environmental and pollution control

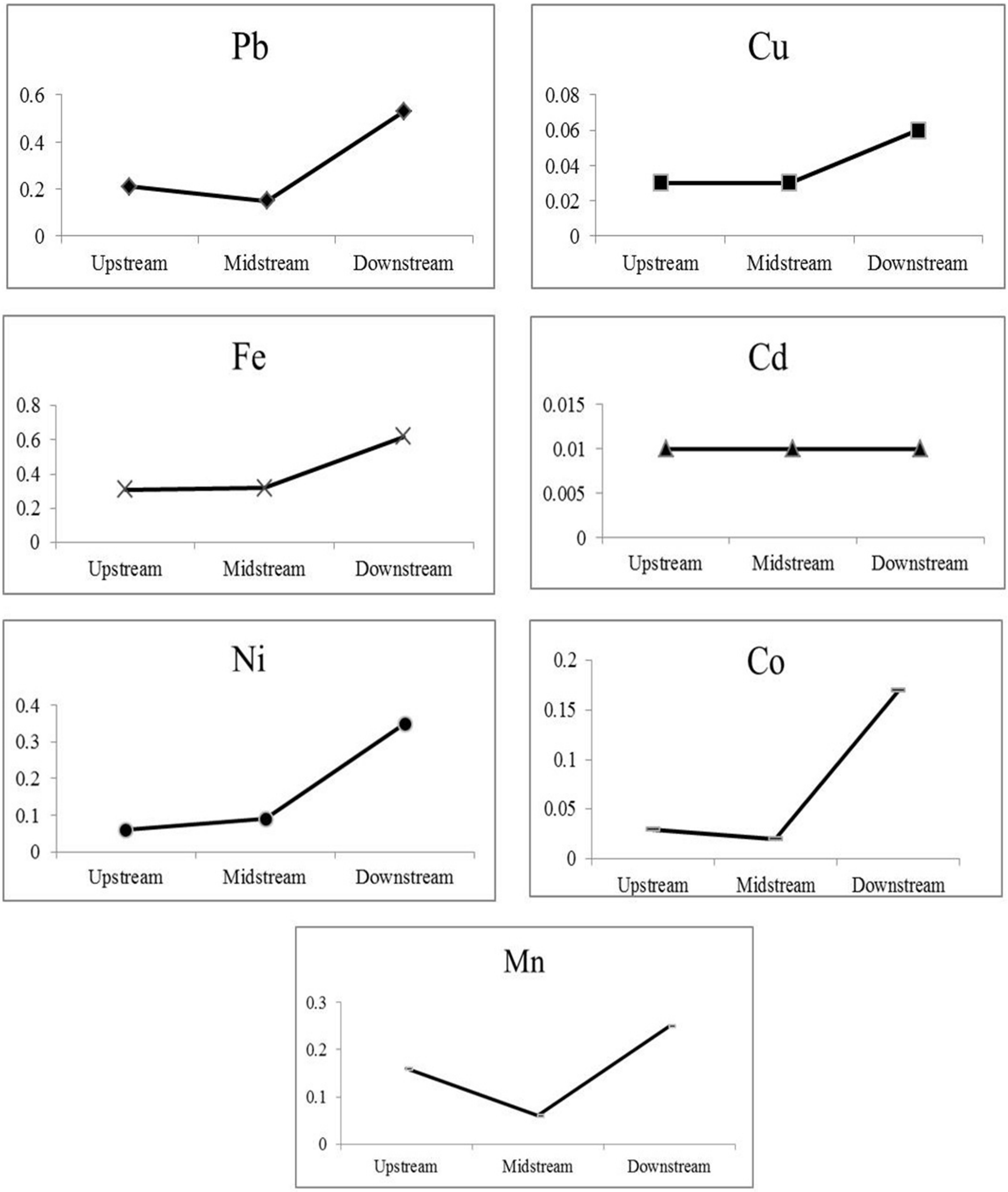

Fig. 3: Trend of heavy metals from upstream to downstream in khariya wala nala

Note- All Concentrations are expressed in (mg/L).

Source: Samples collected from khariyawala nala, parameters analysed by Ramky Enviro Engineers Limited, Rajasthan Waste Management Project, TSDF, Udaipur (2019).

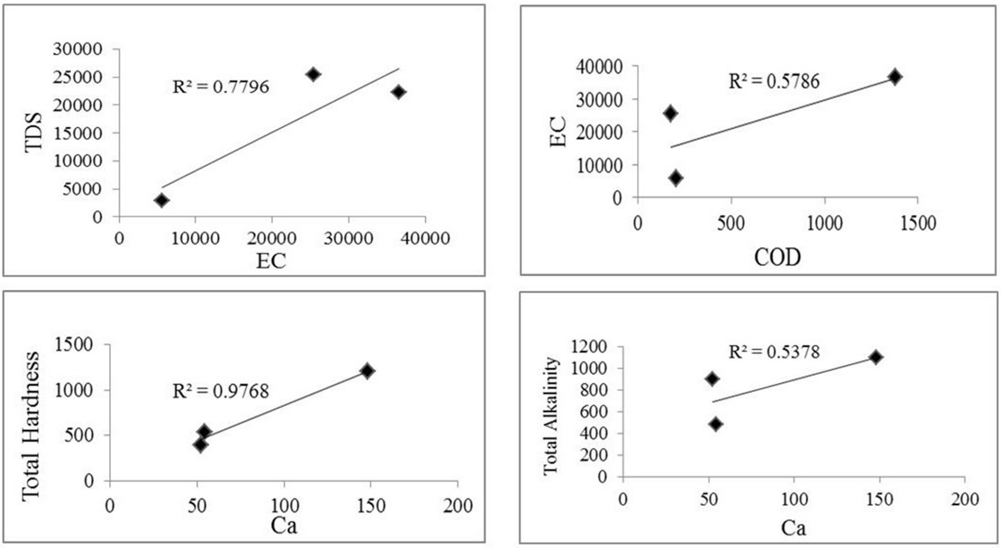

Fig. 4: Relationship between different parameters of water

Source: Samples collected from khariyawala nala, parameters analysed by Ramky Enviro Engineers Limited, Rajasthan Waste Management Project, TSDF, Udaipur (2019)

strategies (Matta et al. 2014; Matta et al. 2015; Arora, 2014). For the analysis of heavy metals in water body, concentration of Pb, Zn, Cu, Fe, Cr, Ni, Mn and Co was analysed (Table 3 and figure 6). The concentration of Zn ranges from 0.06 to 0.22 with a mean value of 0.13, Cu ranges from 0.03 to 0.06 with mean of 0.04 and concentration of Cd was found 0.01 mg/l at all the stations. It has been found that all the metals were within standard limit. However concentration of Pb was found higher with a range of 0.15 to 0.53 and mean value of 0.29 which was more than the standard limit for surface bodies at all the stations. Exposure to lead has adverse impacts on human health. Since water of the stream is used for bathing as well as for irrigation purposes, chances of human exposure are high which can be detrimental to human health. Mean values of other metals were 0.41, 0.16, 0.25, 0.07 for FE, Ni, Mn and Co respectively, which were within the prescribed limits. However an increasing trend in heavy metals has been observed, moving from upstream to downstream (Fig. 6) contributed by the mixing of industrial effluents. Similar result has also been found by Sudhakar et.al in their study of metal pollution due to release of industrial effluents in Godavari River (Sudhakar et.al., 1991). Studies have revealed that industrial and municipal waste water discharge is the main sources of metals in rivers (Jain et.al, 2005; Suthar et.al, 2009).

Conclusion

The study reveals that the outlet of the CETP, Balotra rarely meets the standard limit of surface water bodies and there are some important parameters that hugely exceed permissible limit and do not meet the CETP inland surface water standards. These parameters include BOD, Chloride, dissolved solids, sulphate, COD and TSS.

The wastewater after leakage from solar evaporation ponds mixes with adjacent rivers and streams. Analysis of the sampled water from *Khariyawala nala*, flowing parallel to HRTS site, shows that water at the upstream was neutral with low Chemical Oxygen Demand and other parameters. Although the proportion of all the parameters were not satisfactory even upstream, water quality was comparatively better than the water mid and downstream, after receiving industrial effluents. Heavy metals were within the permissible range except Pb which was beyond the permissible limit at all the points. It has been found that mixing of effluents in the water has adverse impact on water quality and therefore the water is not good for irrigation or for domestic purposes like bathing and washing clothes. Since the study area lies in an arid region, nature of rainfall is quite erratic, reducing chances of freshwater mixing in the region resulting in deteriorating water quality. In such a situation, proper functioning of CETPs is necessary and treated and partially treated waste should be disposed properly. Treated water should be reused in textile industries so that there will be lesser pressure on ground water and problem of disposal of treated wastewater could be minimized. Regular monitoring of seepage from solar evaporation ponds should be done and treatment units must be held accountable for discharging partially treated waste water into the water bodies.

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Plate 1- Leakage of partially treated waste water from HRTS walls

Source: Field survey. 2019

Plate 2- Mixing of partially treated waste water into khariya wala nala