Journal of Environmental Protection, 2016, 7, 72-81
Published Online January 2016 in SciRes. http://www.scirp.org/journal/jep
http://dx.doi.org/10.4236/jep.2016.71007

Contamination of Industrial Waste Water in Central India

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Received 7 December 2015; accepted 8 January 2016; published 11 January 2016

Abstract

The most of iron, cement, paper and plastic related industries are running in Raipur area of the country. They use a large amount of water by discharging effluents into the streams and rivers by polluting nearby water resources. In this work, the physico-chemical characteristics of discharged waste water of 34 industries (*i.e.* iron, steel, power, paper and polymer) are described. The waste water is found to be acidic in nature with high contents of F^- and other ions.

Keywords

Waste Water Quality, Acidity, Fluoride, Metals

1. Introduction

Industrial wastewater is one of the important contaminating sources in pollution of the water environment. Industries that use large amounts of water for the processings have the potential to pollute waterways through the discharge of their wastes into streams, rivers and nearby water sources. They include organic materials, pathogens, metals, salts, ammonia, pesticides, pharmaceuticals, endocrine disruptors, etc., and cause adverse impacts in the surrounding water resources [1]-[15].

The most of iron and cement industries of the country is running in the Raipur area, central India due to huge availability of the raw materials. At least 600 sponge iron and 20 cement industries are running by roasting minerals and coal by adding effluents into the environments. In addition, other industries such as paper and polymer industries also emit effluents into the environments. In this work, the quality of waste water released by iron, cement, paper and plastic industries of Raipur city, central India is described.

How to cite this paper: Yadav, A., Rajhans, K.P., Ramteke, S., Sahu, B.L., Patel, K.S. and Blazhev, B. (2016) Contamination of Industrial Waste Water in Central India. *Journal of Environmental Protection*, **7**, 72-81.
http://dx.doi.org/10.4236/jep.2016.71007

2. Materials and Methods

2.1. Study Area

Raipur is mainly an industrial city, being the largest steel market of India. It is a capital of Chhattisgarh state with population of 2.0 million. The city has steel, coal, power, cement and rice milling industries. At least 500 medium and large sizes industries in two industrial sectors: Siltara and Urla of Raipur city are in operation. The remaining industries are running in the Bhilai, Jamul and Durg areas. The one of the Asia biggest steel plant, Bhilai Steel Plant (BSP) with capacity of 4.8 MT iron/Yr is running with subsequent dumping of the industrial effluents over area ≈12 km^2. The BSP includes 67 coke ovens, 3 sintering plants, 7 blast furnaces, 2 steel melting shops, rolling mills, rail and structural mills, merchant mills, wire rods mills and plate mills. In this work, the quality of waste water released by 34 industries are described.

2.2. Sample Collection

The industrial waste water samples were collected from different 34 industries during February 2012 by using established methodology, as shown in **Figure 1** [16]. For the BSP, the water is supplied from Tandula reservoir through ≈60 km long canal into the water supply pond (WSP). There is an ore washing pond (OWP) nearby the WSP. The wastes have been dumping in the surrounding area, dumping pond (DP). The area of DP, OWP and WSP are being ≈12, 7 and 5 km^2, respectively. Six composite samples (S1-6) were collected from various sketches of the DP of the BSP. Sample no. S7 and S8 were collected from the OWP and WSP, respectively. Sample no. S9 was collected from source point (SP) of the BSP sludge waste.

The cleaned polyethylene bottle (1 L) was used for the sample collection. It was ringed thrice with the same water prior to the sampling, and filled up to the mouth. The physical parameters *i.e.* temperature (T), pH, electrical conductivity (EC), dissolved oxygen (DO) and reduction potential (RP) were measured at the spot. The collected water samples were dispatched to the laboratory by cooling them into the freezer at −4˚C.

2.3. Analysis

The water samples were filtered with glass micro filter of pore size, 2 µm. The total dissolved solid (TDS) value of the sample was determined by evaporation method [16]. The total hardness (TH) value was analyzed by the titration methods [17]. The fluoride content of the water was analyzed by the ion selective method using Metrohm-781 ion meter using the total ionic strength adjustment buffer (TISAB). The contents of other ions were quantified by the Dionex ion chromatography-1100. The metal contents were analyzed by Varian Liberty AX Sequential ICP-AES and Varian AA280FS Atomic Absorption spectrophotometer. Other elements *i.e.* Cd, Pb, As, Hg and Se were analyzed by using the Varian SpectrAA 220Z and equipped with the VGA-77.

The weighed arithmetic method was used for evaluation of the water quality index (WQI) of the water by using five parameters *i.e.* pH, DO, EC, TDS and NO_3^- values with the help of following expression [18] [19].

$$\text{WQI} = \sum q_n W_n \Big/ \sum W_n$$

where:

$$q_n = 100\left(V_n - V_{io}\right) \Big/ \left(S_n - V_{io}\right)$$

q_n = Quality rating of the nth water quality parameter

V_n = Estimated value of the nth parameter of a given water

S_n = Standard permissible value of the nth parameter

V_{io} = Ideal value of the nth parameter of pure water (*i.e.* 0 for all other parameters) except pH and dissolved oxygen (7.0 and 14.6 mg/L, respectively)

W_n = Unit weight for the nth parameter

3. Results and Discussion

3.1. Physical Characteristics

The physical characteristics of the waste water are summarized in **Table 1**. The pH value of all waste waters (n = 34) was ranged from 1.2 - 6.9 with mean value of 5.9 ± 0.6. All waters were found to be acidic in nature due to

Table 1. Physical characteristics of industrial waste water.

S. No.	Industry	Location	T, ˚C	pH	DO, mg/L	RP, mV	EC, µS/cm	TDS, mg/L	TH, mg/L
1	Iron	Raipur	20	4.8	7	112	3770	8978	380
2	Iron	Raipur	23	2.2	6.9	424	11,550	6066	340
3	Iron	Raipur	24	2.4	7	186	5620	7035	750
4	Iron	Raipur	23	6.9	6.3	87	1448	5064	350
5	Iron	Raipur	21	2.9	6.9	427	8790	6214	330
6	Iron	Raipur	25	5.4	5.4	62	5760	6750	810
7	Iron	Raipur	23	6.3	6.9	137	16,860	22,913	820
8	Iron	Raipur	24	6.3	7.4	114	1050	4870	430
9	Iron	Raipur	27	6.5	6.3	93	1667	6110	410
10	Iron	Raipur	23	6.6	6.8	138	1250	5553	720
11	Iron	Raipur	23	4.9	7.2	238	4390	4915	390
12	Iron	Raipur	25	6.4	6.7	402	14,390	4234	760
13	Iron	Raipur	23	6.7	7.5	68	1741	4075	350
14	Iron	Durg	24	6.8	6.6	154	2420	5102	1170
15	Iron	Durg	27	6.5	5.1	94	1784	4823	470
16	Iron	Durg	23	6.9	5.2	59	1815	5641	380
17	Iron	Durg	26	6.8	6.2	132	2350	4636	1130
18	Iron	Durg	28	6.9	6.8	182	1667	5612	300
19	Iron	Durg	26	6.8	6.4	140	1555	5141	210
20	Iron	Durg	27	6.7	5.2	57	1915	3240	440
21	Iron	Bhilai	29	6.9	4.9	44	1433	4901	370
22	Iron	Bhilai	30	1.2	6.1	456	3425	5308	460
23	Iron	Bhilai	28	6.6	5.3	184	2460	5048	390
24	Iron	Bhilai	29	6.9	6.9	187	1274	4690	410
25	Iron	Jamul	28	6.5	6.7	163	1803	2894	410
26	Iron	Jamul	25	6.7	6.4	160	4210	3947	140
27	Iron	Jamul	23	6.8	6.6	186	1187	3351	570
28	Iron	Jamul	28	6.6	5.8	148	2280	3901	340
29	Cement	Bhilai	24	6.7	6.6	153	1720	3286	300
30	Cement	Jamul	28	6.9	6.5	196	1563	3166	520
31	Paper	Raipur	26	2.3	6.2	647	10,250	10,638	370
32	Polymer	Raipur	26	6.9	6.8	87	1181	2953	370
33	Polymer	Raipur	28	6.8	6.7	97	3070	6309	720
34	Polymer	Raipur	22	5.8	6.4	28	3740	6441	850

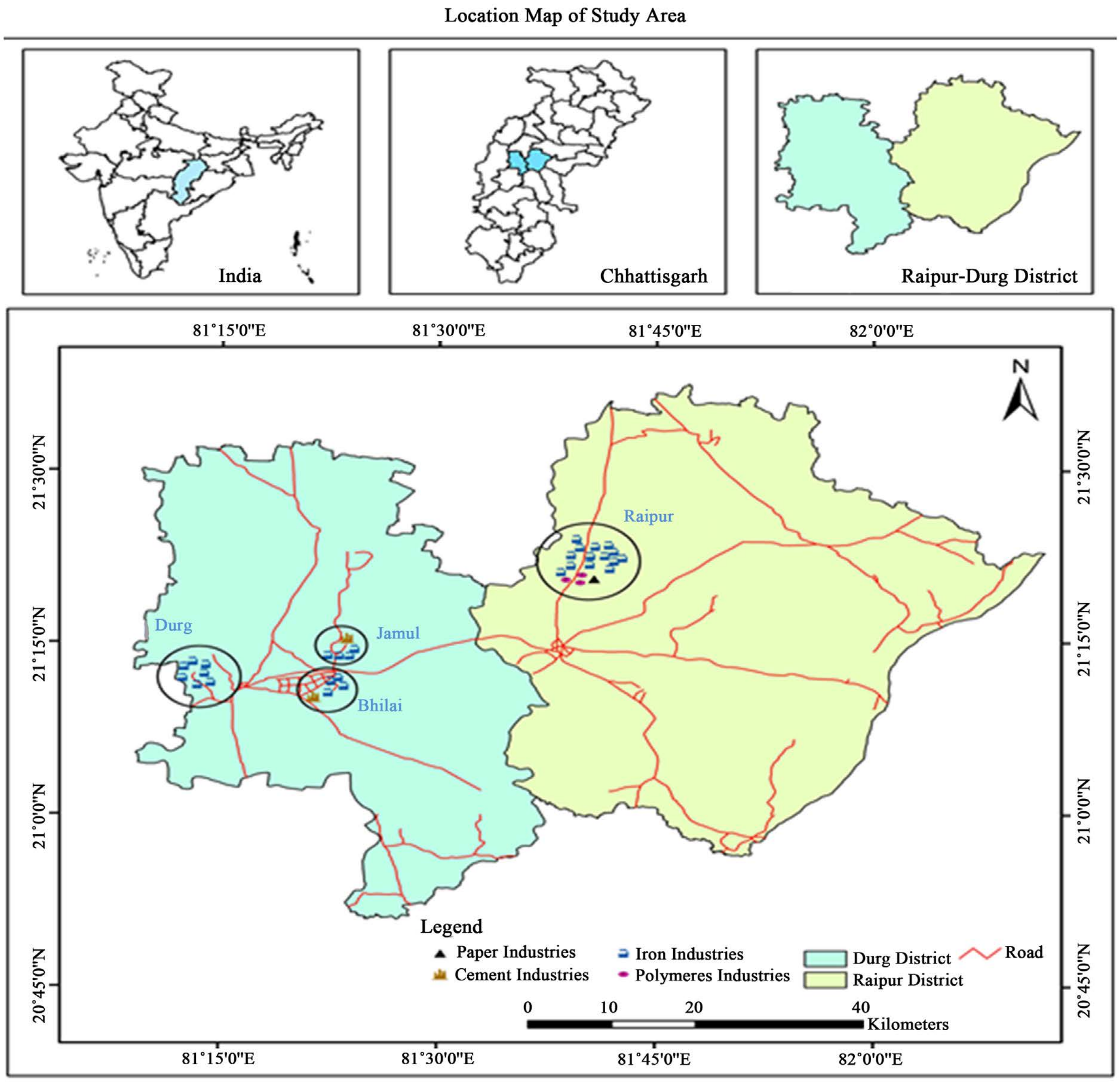

Figure 1. Representation of sampling locations of industrial waste water the study area, CG, India.

presence of acids *i.e.* HNO_3 at excessive levels. The value of T, EC, RP, DO, TDS and TH was ranged from 20˚C - 30˚C, 1050 - 16,860 µS/cm, 28 - 647 mV, 4.9 - 7.5 mg/L, 2894 - 22,913 mg/L and 140 - 1170 mg/L with mean value of 25˚C ± 1˚C, 3864 ± 1327 µS/cm, 178 ± 46 mV, 6.4 ± 0.2 mg/L, 5700 ± 1159 mg/L and 505 ± 82 mg/L, respectively. The value of EC, TDS and TH was found to be far above the recommended value 300 µS/cm, 500 mg/L and 300 mg/L, respectively [18] [19]. The reducing capacity of some waste waters was found too low, may be due high dissolved organic carbon (DOC) and HNO_3.

3.2. Chemical Characteristics

The chemical characteristics of the waste water is shown in **Table 2**. The concentration of F^-, Cl^-, NO_3^-, SO_4^{2-}, Na^+, K^+, Mg^{2+} and Ca^{2+} was ranged from 1.7 - 9.9, 11 - 169, 290 - 1310, 28 - 647, 30 – 10,250, 11 – 10,638, 24 - 850 and 22 - 230 mg/L with mean value of 3.6 ± 0.7, 89 ± 13, 825 ± 99, 162 ± 33, 827 ± 690, 827 ± 785, 103 ± 64 and 126 ± 19 mg/L, respectively. Two ions *i.e.* Na^+ and K^+ were found at excessive levels due to mineralization in water from the ores and coal. The concentration of F^-, NO_3^-, Mg^{2+} and Ca^{2+} was found to be higher than

Table 2. Chemical characteristics of industrial waste water, mg/L.

S. No.	F^-	Cl^-	NO_3^-	SO_4^{2-}	Na^+	K^+	Mg^{2+}	Ca^{2+}
1	2.2	64	1098	177	1110	47	27	106
2	2.7	124	1120	173	159	80	24	95
3	1.9	99	1310	213	104	70	54	210
4	2.1	128	908	139	99	85	25	98
5	2.1	82	1250	171	140	60	24	92
6	5.3	131	1100	162	130	165	58	227
7	2.3	53	568	233	5500	70	59	230
8	2.4	43	980	112	106	33	31	120
9	3.7	96	1120	122	148	156	30	115
10	2.6	89	980	162	92	48	52	202
11	2.5	99	876	116	160	50	28	109
12	1.8	92	416	117	152	194	55	213
13	7.4	53	760	143	30	78	25	98
14	8.2	60	1021	172	60	56	28	90
15	5.6	46	1042	125	36	12	37	110
16	5.4	11	1218	115	34	24	64	182
17	4.6	112	844	162	38	16	46	136
18	9.9	56	1163	165	49	18	48	136
19	2.7	74	1023	188	39	42	36	102
20	1.7	63	528	119	59	23	38	118
21	6.4	81	911	103	72	49	54	164
22	2.7	28	1042	181	39	24	55	184
23	2.6	28	911	123	160	43	50	162
24	5.7	91	815	216	98	15	32	102
25	2.3	98	387	120	34	11	43	154
26	3.7	84	707	134	33	65	32	98
27	2.2	98	467	194	39	22	36	124
28	2.3	98	520	197	150	42	33	101
29	3.6	117	290	86	194	43	27	105
30	2.1	125	314	222	800	123	52	202
31	2.6	123	360	647	10,250	10,638	370	26
32	2.6	169	680	87	1181	2953	370	26
33	2.8	168	670	97	3070	6309	720	28
34	2.2	158	640	28	3740	6441	850	22

recommended value of 1.5, 45, 30 and 75 mg/L, respectively [18] [19]. They were occurred in following increasing order: $F^- << Cl^- < Mg^{2+} < Ca^{2+} < SO_4^{2-} < NO_3^- \approx Na^+ \approx K^+$.

3.3. Concentration of Metals in Sludge Water

The contamination of heavy metals was determined in the SP, DP, OWP and WSP of the BSP, **Table 3**. The concentration of As, Se, Fe, Cr, Mn, Ni, Cu, Zn, Cd, Pb and Hg was ranged from 0.6 - 7.8, 0.06 - 0.21, 0.7 - 5.0, 0.31 - 0.62, 0.4 - 1.0, 0.03 - 0.12, 0.7 - 1.5, 0.1 – 2.70, 0.06 - 0.25, 0.3 - 1.2 and 0.03 - 0.12 mg/L with mean value of 2.9 ± 1.4, 0.13 ± 0.03, 3.2 ± 1.1, 0.47 ± 0.07, 0.64 ± 0.15, 0.08 ± 0.02, 1.1 ± 0.2, 0.63 ± 0.56, 0.20 ± 0.04, 0.71 ± 0.21 and 0.07 ± 0.02 mg/L, respectively. Among heavy metals, the highest concentration of as was observed in the sludge water, **Figure 2**.

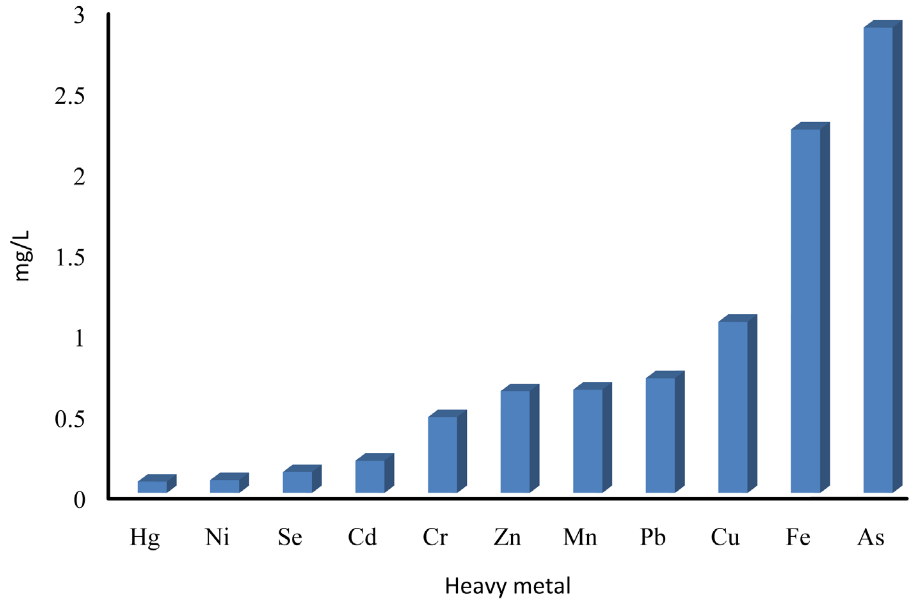

Figure 2. Distribution of heavy metals in the BSP waste water.

Table 3. Concentration of chemical species in sludge waste water of Bhilai steel plant, mg/L.

Species	S1	S2	S3	S4	S5	S6	S7	S8	S9
As	4.3	2.4	3.1	2.5	0.6	7.8	3.1	1.2	0.9
Se	0.18	0.15	0.15	0.09	0.12	0.21	0.06	0.09	0.09
Fe	1.60	3.57	1.13	1.30	4.62	1.47	0.74	0.54	0.82
Cr	0.43	0.53	0.59	0.50	0.50	0.62	0.37	0.34	0.31
Mn	0.65	0.97	1.01	0.53	0.48	0.76	0.44	0.40	0.50
Ni	0.12	0.09	0.09	0.06	0.09	0.09	0.03	0.06	0.06
Cu	1.12	0.90	0.84	0.99	1.40	1.49	1.18	0.65	0.96
Zn	0.12	0.31	0.09	1.24	2.70	0.50	0.09	0.47	0.12
Cd	0.25	0.22	0.19	0.22	0.19	0.16	0.22	0.06	0.25
Pb	0.50	0.25	1.09	0.74	0.40	1.18	0.90	0.47	0.84
Hg	0.12	0.06	0.06	0.09	0.09	0.06	0.06	0.03	0.09

3.4. Spatial Variations

The lowest pH value of the paper waste was found, may be due to acid treatment of the pulp, **Figure 3**. The lower RP values were marked in the case of iron, cement and polymer wastes, may be due to excessive loading of the oxidizing wastes. However, the comparable values of DO and TH were seen in the all wastes, **Figure 3**. Remarkably higher concentration of Na^{+}, K^{+}, Mg^{2+} and SO_4^{2-} was detected in the paper effluents, **Figure 4**. Fluoride was released in the roasting of iron, cement, paper and polymer materials, and its elevated concentration was observed in the iron effluents, may be due to contamination of the minerals and coal with fluorites, **Figure 4**.

The spatial variation of heavy metals at point source of waste effluent (S7), dumping lake (S1-6), washing tank (S8) and water supply Tank (S9) is presented in **Figure 5**. The higher concentration of the most of the metals was observed in the waste waters (S7 and S1-6).

3.5. Water Quality Assessment

The water was found to be acidic and hard in nature. The WQI value was ranged from 168 - 2153 with a mean value of 574 ± 177. The concentration of As, Se, Cr, Mn, Fe, Ni, Cd, Pb and Hg was found to be higher than recommended value of 0.01, 0.01, 0.05, 0.5, 0.3, 0.02, 0.003, 0.01 and 0.001 mg/L, respectively [18] [19]. The industrial waste water was seemed to be unsuitable for drinking purposes for animals, aquatics and birds.

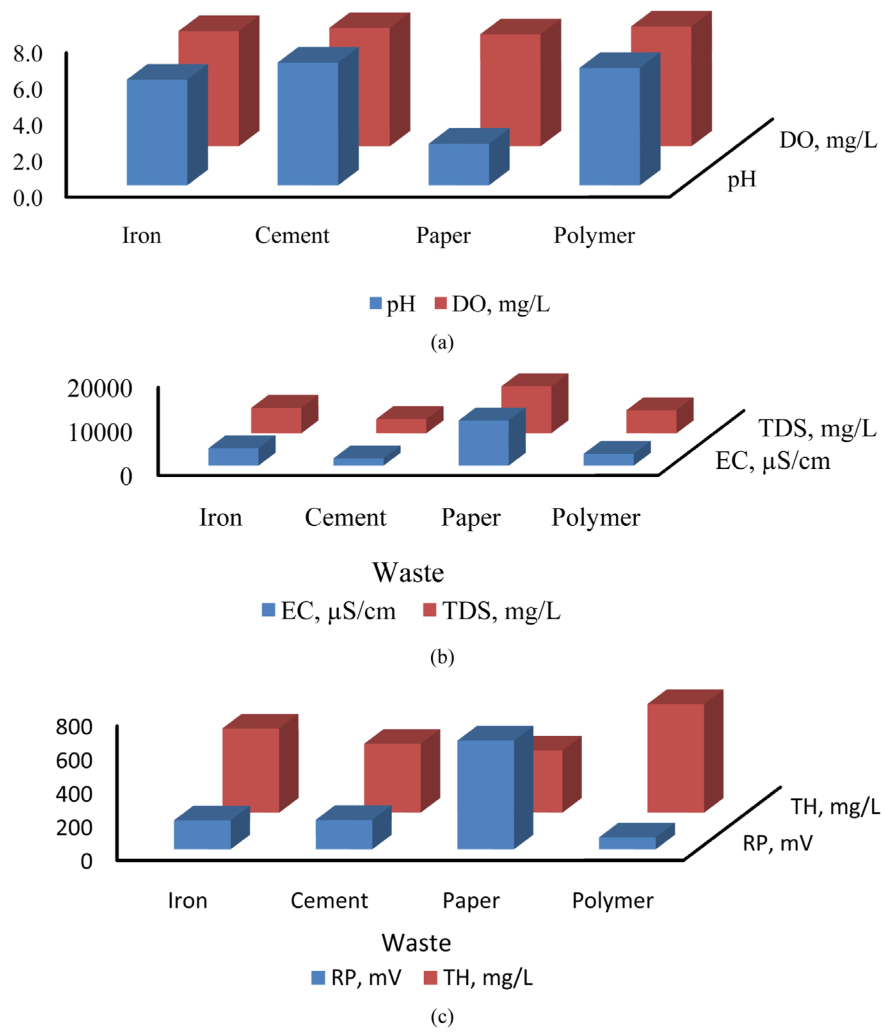

Figure 3. Variation of physical parameters in various industrial waste.

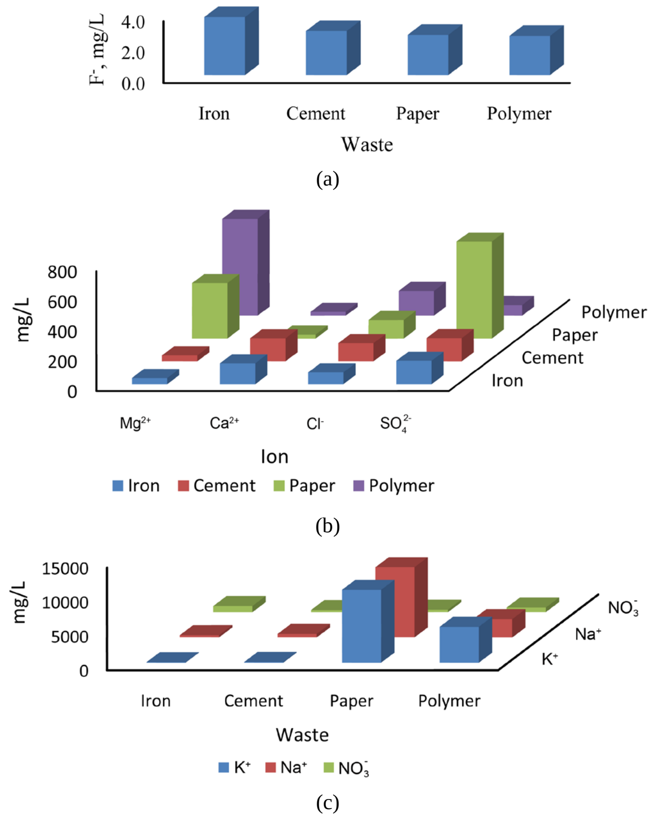

Figure 4. Variation of chemical parameters in various industrial waste.

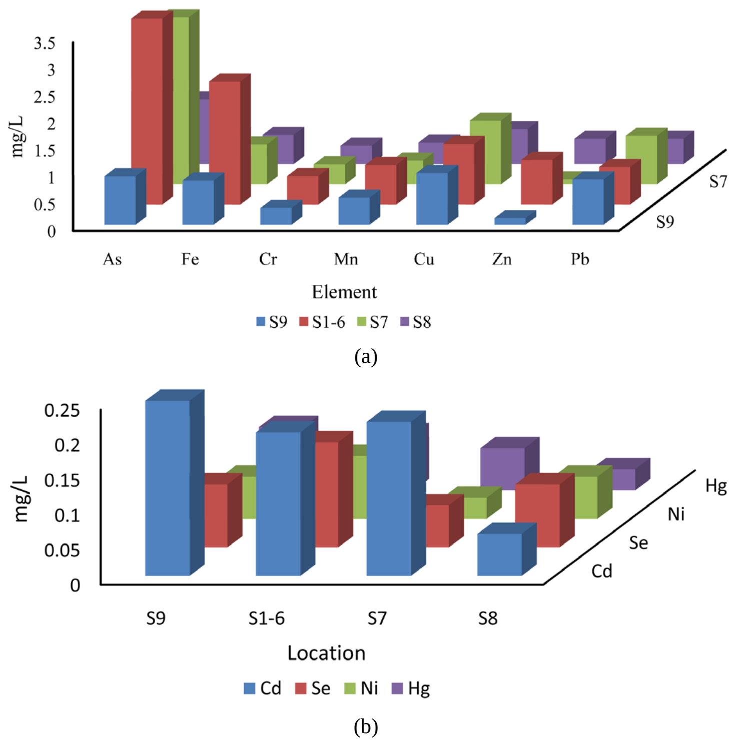

Figure 5. Variation of heavy metals in BSP waste water (S1-6 and S7), washing water (S8) and lake water (S9).

4. Conclusion

All types of industrial wastes *i.e.* iron, cement, paper and polymer were observed to be acidic in nature with remarkable high EC and TDS values. Some wastes showed too low RP values, and might be due to excessive loading of the oxidizing agents. They were found to be highly enriched with elements *i.e.* F^-, Na^+ and K^+. The iron sludge wastes were contaminated with toxic heavy metals beyond permissible limits.

Acknowledgements

We are thankful to our University for providing special equipment grant to the SOS in Environmental Science.

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