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ANSF APPLIED AND NATURAL SCIENCE FOUNDATION

Journal of Applied and Natural Science
13(1):250 - 257 (2021)
Published online: March 8, 2021
ISSN : 0974-9411 (Print), 2231-5209 (Online)
journals.ansfoundation.org

Research Article

Assessment of monthly variation in heavy metal characteristics of Electroplating industrial untreated wastewater at selected sites of Chandigarh

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Article Info
https://doi.org/10.31018/jans.v13i1.2527
Received: January 22, 2021
Revised: March 3, 2021
Accepted: March 7, 2021

How to Cite

Pandey, V. and Rattan, V. K. (2021). Assessment of monthly variation in heavy metal characteristics of Electroplating industrial untreated wastewater at selected sites of Chandigarh. *Journal of Applied and Natural Science*, 13(1): 250 - 257. https://doi.org/10.31018/jans.v13i1.2527

Abstract
With the contest of urbanization and industrial development, electroplating industries have grown rapidly. The different chemicals, metal salts and discharge of large volume of wastewater with inefficient treatment facilities had created the pollution load on water bodies. The present study was carried out to investigate the assessment of the monthly variation of pH and heavy metals (Cr, Ni, Zn, Fe) of electroplating untreated industrial wastewater from the selected study sites viz. SS-1: Atul Industries, SS-2: Suresh Fasteners, SS-3: Bajrang Industrial Company, SS-4: Stylex Industries, SS-5: Karan Industries, SS-6: Avon Industries, SS-7: Geetika Enterprises, SS-8: Atop Fasteners, SS-9: Accufit Fasteners and SS-10: Ashoka Furniture Udyog at industrial area phase I and phase II of Chandigarh. The untreated electroplating wastewater samples were collected from ten study sites (SS-1 to SS-10) and were analyzed following the standard methods for the examination of water and wastewater. The results of the present study revealed that the maximum concentration of heavy metals such as Zn (122.20 mg/l)during the month of August 2019 at the SS-8, Ni (156.37 mg/l) during the month of August 2019 at the SS-4, Cr (467.01 mg/l) during the month of October 2019 at the SS-5 and Fe (13.22 mg/l)during the month of December 2019 at the SS-2. The load of metallic ions discharge from the electroplating industries before any treatment from the selected study sites (SS-1 to SS-10) was found in the following order as Cr>Ni>Zn>Fe. Thus the present study would provide baseline data for the development of treatment strategies for wastewater discharge from electroplating industries and also in minimizing the effects of heavy metal contamination of receiving water bodies.

Keywords: Chemical precipitation, Electroplating, Heavy metal, Hexavalent chromium, Wastewater treatment

INTRODUCTION

Metal pollution is of great concern as these hazardous pollutants are accumulated in living organisms, including plants, animals, microorganisms, human and environment and cause harmful effects due to their non-degradability (Hashem and Abed, 2002, Kanoun-Boule *et al*., 2009). Due to the scarcity of clean water, the availability of freshwater is one of the challenging issues to mankind around the world. The water bodies such as rivers, canals, estuaries are being polluted continuously due to unsystematic discharge of wastewater as well as other anthropogenic activities. Thus the reuse of wastewater has become an absolute necessity (Sivasangari *et al.,* 2016).

Electroplating is one of the several techniques of metal finishing. It is a technique of deposition of a fine layer of one metal on another through the electrolytic process to impart various properties and attributes, such as corrosion protection, enhanced surface hardness, lustre, colour, aesthetics, value addition etc. Electroplating operations form part of largescale manufacturing plants (e.g. automobile, cycle, engineering and numerous other industries) or performed as job-work by small and supplementary units (CPCB, 2008). In India, electroplating industries are mostly characterised by small

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scale units having discrete features like as tiny, family-owned jobber units, practices old and obsolete technologies. The electroplating industries are arranged in unauthorized and unplanned areas with lack of infrastructure. These units are in an area of 10-25 sqm and having unskilled manpower (Upadhyay, 2006). The Electroplating industries use various chemicals and metal salts which creates pollution problems by discharging a large quantity of toxic metallic wastewater. The major pollution in these industries is caused by rinse water, spray losses and solution dumping and leakages (Sivasangari *et al.,* 2016). These industrial processes generate a very huge quantity of wastewater containing heavy metals such as nickel, chromium, zinc and iron that are the elements of major concern. These heavy metals discharged from electroplating units above the standard limits can cause a serious ill effect on the environment and human health (Raju *et al., 2019).* Analytical facilities are not easily accessible to these units, resulting in a lack of control on process parameter and improper documentation of production details. Keeping this in view, the main objective of the present study was to evaluate the monthly variation in pH and heavy metal concentration in untreated wastewater of selected Electroplating industries of Chandigarh.

MATERIALS AND METHODS

Study area

Geographically, the industrial area of Chandigarh is located within latitude 30^0 44' 14N in the north to longitude76^0 47' 14E in the east. It has an average elevation of 321 meters (1053 ft) above mean sea level. The Industrial Area of phase I and II has a vast expanse of about 485.62 hectares with more than 3500 independent industrial units in operation along with a number of electroplating industrial units installed and their treated and untreated or partially treated waste effluents are discharged into the Sukhna Choe (receiving water body) which further mixes with River Ghaggar. The electroplating units are operated in small areas near to 2000 Sq. ft and have their own effluent treatment plant (ETP). Sometimes electroplating industries discharge their effluent without treatment or partially treated wastewater and cause metallic pollution in the receiving water bodies. In view of numerous electroplating industries in this area, the Study sites of ten electroplating industries were selected as Site-1 (SS-1), Site-2 (SS-2), Site-3 (SS-3), Site-4 (SS-4), Site-5 (SS-5), Site-6 (SS-6), Site-7 (SS-7), Site-8 (SS-8), Site-9 (SS-9) and Site-10 (SS-10) (Fig.1). The operational unit description of selected electroplating industries in Chandigarh is shown in Table 1.

Sampling procedure

The three-grab samples of untreated electroplating industrial wastewater post-manufacturing operation and prior to any treatment from each electroplating sites of Chandigarh were collected during each month from July 2019 to September 2020. Due to COVID 19, as an announcement of the country lockdown (April, May, and June) during the year 2020, the sampling of the lockdown period was completed in the month of July, August, and September for the year 2020. All the samples were collected in sufficient quantity (1000 ml) in a non-reactive plastic bottle preserved by adding HNO_3 and brought to the laboratory.

Fig. 1. *Showing location of sampling Sites (SS1 to SS 10) of Electroplating industries in Chandigarh.*

Table 1. Description of operating units of selected Electroplating industries in Chandigarh.

Study sites (SS)	Area (Sq. Ft.)	Type of Electroplating	Name of Electroplating unit	Manufacturing process
SS-1	4100	Zn Plating	Atul Industries	Screw Manufacturing Unit
SS-2	4100	Zn Plating	Suresh Fasteners	Screw Manufacturing Unit
SS-3	2000	Zn Plating	Bajrang Industrial Company	Job Work of Electroplating
SS-4	5500	Ni-Cr Plating	Stylex Industries	Modular Kitchen Items Manufacturing Unit
SS-5	2000	Ni-Cr Plating	Karan Industries	Taps and Screw Manufacturing Unit
SS-6	43560	Ni-Cr Plating	Avon Industries	Cycle Rims Manufacturing Unit
SS-7	2000	Zn Plating	Geetika Enterprises	Screw and Rivets Manufacturing Unit
SS-8	5500	Zn Plating	Atop Fasteners	Tractor Parts Pins Spring Washer Manufacturing Unit
SS-9	2000	Zn Plating	Accufit Fasteners	Job Work of Electroplating
SS-10	5500	Ni-Cr Plating	Ashoka Furniture Udyog	Steel Furniture Manufacturing Unit

Analytical methods

pH of samples was estimated by the digital pH meter (Orion Star pH/ISE Meter). For heavy metal analysis, all the collected samples were digested by nitric acid digestion method as described in APHA (2017). Heavy metals concentration in digested samples was estimated by atomic absorption spectrophotometer (Analytic Jena, Model- Zeenit 700P) by running three replicates of each sample. For the standardization process, the calibration curves were prepared separately for all the metals by running different concentrations of standard solutions prepared from Certified Reference Materials (CRMs). A standard solution was run as a reference throughout the analysis of heavy metals. The observed data of three-monthly samplings subjected to statistical analysis for the mean, standard deviation (SD) and was calculated using MS Excel 2010.

RESULTS AND DISCUSSION

The mean±SD values of pH and various heavy metals of the Electroplating industries during July 2019 to September 2020 are given in Table 2 to 6.

pH Value

Variations in pH of electroplating wastewater were found in the range from 4.4 -5.81 of all study sites (SS-1 to SS-10) and are shown in Table. 2. It was found that the minimum pH of electroplating wastewater was 4.4±0.30 at SS-9 in the month of November 2019 while the maximum pH was 5.81±0.38 at the SS-2 in the month of October 2019.It indicated that the observed values of pH were acidic in nature and were not in the range of discharge standard (6.0- 9.0) given by the MOEF, 2012 in all the study sites of the Electroplating industries of Chandigarh. Lokhande *et al.*(2011) observed the 5.2 to 8.7 pH of the effluents discharged from the Taloja industrial area in Mumbai, India. Adakole and Abolude (2009) reported the pH 1.70-11.80 of the effluents discharged from industrial units involved in metal finishing works at Zaria, Nigeria. pH affects the quality of wastewater, and any value higher or lower than 6.5-8.5 limit could be harmful to the environment as per WHO (2003).

Zinc (Zn)

The maximum value of Zn (122.20±2.38 mg/l) was observed at the SS-8 in the month of August 2019, while the minimum value of Zn (3.89±1.66 mg/l) was recorded at SS-10 in the month of March 2020 (Table 3). As seen in Table 3, the reported values of Zn from all the study sites SS-1 to SS-10 without any treatment was found beyond the discharge limit (5 mg/l) of MOEF, 2012 standard, while during the month of February and March 2020, the concentration of Zn was found below the MOEF, 2012 standard limit (5 mg/l) at the SS-10. Kumar and Thatheyus (2013) reported that the concentration of Zn (739 mg/l) was found exceedingly beyond the permissible limit of discharged standards of effluents from electroplating units at Madurai, India. Singh *et al.*(2016) observed that the concentration of zinc varied from 97 to 731 mg/l across the Haryana region while the concentration of zinc was found 118 mg/l in the Chandigarh region, which was found beyond the acceptable limit of 5 mg/l.

Nickel (Ni)

The maximum concentration of Ni (156.37±9.36) was recorded at the SS-4 in the month of August 2019 however, the minimum concentration of Ni (0.77±0.20) was found the SS-1 in the month of February 2020. As depicted in table 4 all the measured values of Ni were

Table 2. Variation of pH in electroplating industrial effluent at different study sites of Chandigarh during the year 2019-2020 (Values are mean±SD of three replicates of the month).

2019-2020	Study sites (SS)									
Months	**SS-1**	**SS-2**	**SS-3**	**SS-4**	**SS-5**	**SS-6**	**SS-7**	**SS-8**	**SS-9**	**SS-10**
July, 2019	4.89±0.67	5.29±0.35	5.08±0.17	5.24±0.65	5.09±0.15	4.65±0.32	4.90±0.34	5.07±0.24	4.59±0.83	4.56±0.80
August	4.22±1.60	4.54±1.87	5.36±0.25	5.43±0.19	5.02±0.12	5.08±0.19	5.14±0.21	5.16±0.29	5.01±1.07	4.63±0.74
September	5.10±0.26	5.37±0.24	5.46±0.81	5.40±0.31	5.11±0.14	5.02±0.16	5.20±0.28	4.57±0.32	5.06±0.97	4.67±0.44
October	5.29±0.17	5.81±0.38	5.10±0.20	5.53±0.72	4.78±0.18	5.14±0.34	5.38±0.45	4.93±0.24	4.82±1.12	4.95±0.61
November	4.49±1.91	4.49±2.00	4.56±1.88	5.05±0.06	5.36±0.25	4.83±0.55	5.10±0.19	5.03±0.31	4.40±0.30	4.52±0.30
December	4.96±0.61	5.79±0.16	5.77±0.51	5.17±0.30	5.08±0.19	5.10±0.13	4.68±0.36	4.90±0.35	5.22±1.31	4.94±0.31
January, 2020	5.17±0.46	5.18±0.24	5.60±0.63	5.43±0.42	5.50±0.17	4.88±0.26	5.43±0.55	4.53±0.59	5.25±0.54	4.64±0.57
February	5.17±0.29	5.36±0.20	5.87±0.32	5.85±0.19	5.42±0.21	5.25±0.12	5.68±0.46	5.43±0.49	5.08±0.82	5.76±0.51
March	5.11±0.19	5.3±0.19	5.09±0.29	5.35±0.59	5.56±0.41	4.81±0.43	5.08±0.18	5.13±0.25	5.38±0.27	4.13±0.49
July	5.70±0.23	5.53±0.61	5.25±0.27	5.02±0.36	5.21±0.12	4.94±0.10	5.13±0.12	5.32±0.38	5.47±0.29	5.47±0.17
August	5.77±0.68	5.34±0.20	4.96±0.07	5.26±0.18	5.11±0.14	5.43±0.19	5.44±0.27	5.19±0.43	5.50±0.46	5.52±0.26
September	5.78±0.51	4.99±0.48	5.48±0.45	5.56±0.37	4.84±0.28	5.31±0.21	4.50±0.16	5.37±0.75	5.56±0.75	4.53±0.26

Table 3. Characteristics of Zn in electroplating industrial effluent at different study sites of Chandigarh during the year 2019-2020 (Values are mean±SD of three replicates of the month).

2019-2020	Study sites (SS)									
Months	**SS-1**	**SS-2**	**SS-3**	**SS-4**	**SS-5**	**SS-6**	**SS-7**	**SS-8**	**SS-9**	**SS-10**
July, 2019	80.30±15.89	103.76±11.88	72.14±2.11	21.22±5.02	31.01±1.41	42.64±0.58	70.61±8.19	68.20±16.88	65.30±14.97	20.21±7.79
August	67.42±25.05	82.33±37.08	71.26±2.97	20.98±1.80	25.51±0.82	33.69±11.82	71.29±0.84	122.20±2.38	59.89±12.80	17.51±3.13
September	76.87±6.32	82.98±3.81	83.52±5.01	22.31±5.50	23.61±1.14	30.90±1.04	67.82±12.52	62.21±6.05	63.06±12.81	16.30±6.27
October	83.70±8.19	59.91±23.06	75.70±9.25	25.79±6.16	30.33±1.73	32.24±8.57	71.49±5.33	72.65±9.13	49.26±6.65	17.02±2.81
November	68.10±27.36	56.43±28.54	69.02±28.16	25.30±5.16	21.44±0.96	33.26±6.77	76.92±5.02	71.48±13.29	61.78±17.94	13.73±5.10
December	67.36±1.65	54.10±4.94	78.55±14.30	35.02±18.01	17.62±1.10	26.91±2.23	79.11±2.82	77.43±5.69	56.70±27.91	14.35±1.84
January, 2020	66.70±3.90	56.59±13.69	78.98±14.68	34.60±17.39	16.60±1.61	38.33±2.58	66.61±9.81	71.02±16.46	58.67±12.83	10.75±7.61
February	59.77±6.28	69.23±9.88	58.59±1.79	33.82±1.09	24.58±1.14	18.99±1.13	52.37±1.27	81.43±42.78	49.08±5.92	5.92±5.11
March	63.30±6.22	92.1±20.39	75.64±14.31	32.28±17.69	23.09±1.42	19.82±0.44	57.22±3.44	69.25±2.50	51.84±6.12	3.89±1.66
July	53.00±4.41	95.21±5.30	78.70±16.03	48.67±14.44	23.25±2.18	18.03±3.75	46.68±1.92	76.64±1.80	67.87±10.16	13.35±3.82
August	39.14±26.69	72.62±4.45	56.73±2.75	47.37±15.91	38.16±2.65	17.35±2.64	50.70±1.27	78.52±36.91	63.38±13.89	13.85±1.49
September	24.25±27.67	96.67±5.12	51.80±2.59	43.14±12.58	34.38±1.15	16.76±1.00	50.10±1.80	81.57±37.88	58.17±3.68	12.56±1.55

observed higher at the SS-4, SS-5, SS-6 and SS-10 than the discharge limit of MoEF i.e. 3 mg/l, as these sites are the Ni and chromium plating sites as given in table 4. The concentration of Ni was found below the MoEF (3 mg/l) standard limit at the SS-1, SS-2, SS-3, SS-7, SS-8 and SS-9, while the concentration of Ni was found beyond the standard limit in the month of September, October and December at the SS-2. As per results reported by Singh *et al.,* (2016), the concentration of Ni was found from 68 to 291 mg/l in the effluent of electroplating industries of the Haryana region (Faridabad, Gurgaon, Yamunanagar, Karnal, Jagadhri, Panchkula, Panipat, Ambala and Sirsa) and Chandigarh. It was also observed that the minimum value of Ni (68 mg/l) was found in the effluent of electroplating industries of Gurgaon while the maximum value of Ni (291 mg/l) was found in the effluent of electroplating industries of Ambala. Dermentzis (2010) observed that nickel is the one of hazardous heavy metal in electroplating wastewater as only 30-40 % of nickel can be utilized in the product while 60-70% unused Ni is discharged into the water environment as waste effluent. Sanyaolu *et al.* (2013) reported that the concentration of nickel (0.093 mg/l) was beyond the standard limit prescribed by WHO (2003) in the effluent of FMCG products manufacturing industry at Ikorodu, Lagos State, Nigeria.

Chromium (Cr)

The maximum concentration of Cr (467.01±247.13) was recorded at SS-5 in October 2019, while the minimum concentration of Cr (2.34±0.76) was found in the SS-1 in December 2019, which was higher than the discharge limit of MOEF, 2012 (2 mg/l) standard at all the study sites of Chandigarh (Table 5). Singh *et al.* (2016) studied the physicochemical characterization of electroplating industrial effluents and reported the concentration of Cr varies from21.5 to 47 ppm in all the Haryana region (Faridabad, Gurgaon, Yamunanagar, Karnal, Panchkula, Panipat, Ambala, Sirsa and Jagadhri) and Chandigarh. Arora *et al.* (2016) assessed the pollution load at the SIDCUL industrial area and found the concentration of Cr 11.264 mg/l, which was exceeded the permissible limit of BIS (2012).

Iron (Fe)

The maximum concentration of Fe (13.22±4.55 mg/l) was observed at the SS-2 in December 2019, while the minimum concentration of Fe (0.81±0.21) was found at the SS-5 in August 2020. At the study sites SS-1, SS-4 to SS-10, the concentration of Fe was below the discharge limit of MOEF (3 mg/l) standard while the concentration of Fe was beyond the discharge limit of MOEF (3 mg/l) during February, March, July, August and September 2020 at the SS-1 (Table 6). However, at the SS-2 and SS-3, the concentration of Fe was be-

Table4. Characteristics of Ni in electroplating industrial effluentat different study sites of Chandigarh during the year 2019-2020 (Values are mean±SD of three replicates of the month).

2019-2020	Study sites (SS)									
Months	**SS-1**	**SS-2**	**SS-3**	**SS-4**	**SS-5**	**SS-6**	**SS-7**	**SS-8**	**SS-9**	**SS-10**
July, 2019	2.02±1.15	2.40±0.43	2.78±0.29	114.53±16.97	113.82±1.92	55.53±0.78	1.91±0.56	1.52±0.33	1.64±0.83	76.28±12.48
August	1.78±1.12	2.18±0.93	2.04±0.16	156.37±9.36	86.75±1.50	43.81±10.10	1.59±0.13	0.88±0.18	1.35±0.31	89.52±13.05
September	1.41±0.43	3.28±0.28	2.35±0.50	115.39±17.11	96.86±1.71	40.32±1.32	1.95±0.62	1.32±0.47	1.24±0.21	89.70±1.26
October	2.43±1.33	3.60±0.32	1.97±0.74	102.76±3.95	106.69±2.01	46.15±7.57	1.79±0.48	1.37±0.45	1.83±1.04	72.82±20.33
November	1.98±0.93	2.43±1.25	1.91±0.71	117.21±13.75	95.60±3.10	49.03±4.94	2.31±0.20	1.44±0.62	1.89±1.19	87.13±29.28
December	1.19±0.24	3.05±0.56	1.79±0.30	103.28±23.59	111.52±0.95	38.94±2.15	1.30±0.13	1.58±0.52	2.23±1.16	62.11±19.79
January, 2020	1.20±0.14	2.02±0.91	1.24±0.13	104.17±28.22	79.36±2.83	42.19±7.62	1.75±0.49	1.96±0.64	1.44±0.58	51.54±37.66
February	0.77±0.20	1.28±0.41	1.26±0.18	112.90±2.00	99.25±2.06	33.63±10.02	0.77±0.20	1.18±0.34	1.52±0.60	86.46±9.31
March	0.99±0.10	1.05±1.30	1.23±0.82	101.79±23.26	82.51±1.55	33.15±7.00	0.93±0.17	1.18±0.10	2.26±1.19	88.22±32.09
July	1.32±0.08	0.88±0.50	1.69±0.40	61.34±9.39	46.20±1.54	24.02±5.32	1.25±0.07	1.20±0.14	1.10±0.14	56.18±30.53
August	1.21±0.23	1.22±0.08	0.83±0.27	42.96±36.53	60.55±1.94	36.92±3.09	1.24±0.08	1.33±0.33	1.47±0.60	113.30±13.30
September	0.77±0.68	1.27±0.20	1.05±0.06	24.00±39.64	40.52±0.72	38.83±6.63	1.59±0.17	1.24±0.48	1.32±0.23	28.30±26.13

Table 5. Characteristics of Cr in electroplating industrial effluentat different study sites of Chandigarh during the year 2019-2020 (Values are mean±SD of three replicates of the month).

2019-2020	Study sites (SS)									
Months	SS-1	SS-2	SS-3	SS-4	SS-5	SS-6	SS-7	SS-8	SS-9	SS-10
July, 2019	2.97±1.44	74.54±7.30	80.27±1.83	128.49±24.92	255.13±97.23	87.24±1.51	68.06±14.18	61.52±14.51	51.02±8.87	153.31±56.14
August	2.69±1.38	58.82±28.08	84.87±3.60	128.13±1.86	319.85±32.20	68.17±19.92	68.06±12.86	48.03±2.53	49.56±0.86	223.82±36.76
September	2.58±0.43	55.28±3.73	86.53±11.70	126.36±25.19	235.05±59.76	67.48±1.66	69.16±17.14	56.67±20.09	52.97±1.16	171.68±50.38
October	2.82±1.80	51.66±3.83	83.06±15.75	127.42±13.29	467.01±247.13	78.74±7.74	73.23±16.86	51.00±4.89	48.16±3.31	262.17±173.58
November	2.37±1.18	42.48±20.04	73.46±28.25	135.11±17.40	466.58±170.39	76.63±2.00	60.72±20.58	44.34±6.73	56.23±18.08	303.97±212.89
December	2.34±0.76	43.74±4.46	64.20±6.22	264.15±187.45	275.07±31.04	51.69±1.34	54.60±2.23	57.81±5.06	48.45±8.08	444.99±79.45
January, 2020	2.36±1.55	45.22±21.38	57.79±4.62	260.86±230.66	275.43±27.15	64.09±16.39	69.12±17.44	62.06±17.69	54.25±1.43	260.62±41.15
February	45.17±12.85	49.87±7.67	45.74±2.85	142.00±2.79	216.02±76.74	75.33±12.47	39.81±1.72	62.11±14.82	58.67±18.07	271.48±22.86
March	60.10±3.16	68.45±15.25	48.20±24.51	267.84±213.89	191.66±41.74	74.35±2.58	31.63±2.57	50.66±1.62	42.64±4.55	173.74±75.17
July	84.47±6.94	63.26±11.26	64.68±16.81	186.35±119.59	207.23±15.99	84.44±5.75	75.92±3.16	58.31±3.03	57.81±7.53	192.17±66.59
August	86.81±12.73	54.60±5.53	90.33±2.85	161.24±127.45	305.57±146.82	86.07±25.68	71.73±2.79	61.85±14.07	62.68±7.43	174.98±44.03
September	89.95±12.92	57.22±12.15	68.96±19.40	81.21±38.51	380.40±21.12	69.51±27.10	79.50±2.16	63.29±18.61	56.97±14.93	220.75±26.54

Table 6. Characteristics of Fe in electroplating industrial effluent at different study sites of Chandigarh during the year 2019-2020 (Values are mean±SD of three replicates of the month).

2019-2020	Study sites (SS)									
Months	SS-1	SS-2	SS-3	SS-4	SS-5	SS-6	SS-7	SS-8	SS-9	SS-10
July, 2019	1.30±1.03	6.67±1.94	3.22±0.20	2.13±0.50	2.16±0.19	3.81±0.31	1.49±0.27	2.29±0.63	3.95±0.26	1.15±0.20
August	1.21±0.88	6.73±2.64	3.68±0.11	1.09±0.11	1.31±0.30	2.28±1.15	1.41±0.43	1.38±0.15	4.31±0.49	1.03±0.08
September	1.34±0.45	5.92±0.27	3.50±0.78	2.11±0.24	1.06±0.11	2.46±0.11	1.39±0.70	1.76±0.56	4.45±0.51	1.10±0.20
October	1.71±1.04	7.18±1.32	3.98±1.38	1.41±0.40	1.95±0.07	3.02±0.74	1.64±0.58	2.34±0.47	3.30±0.34	1.06±0.25
November	1.62±0.63	6.44±3.31	3.26±1.26	1.74±0.66	1.23±0.13	3.37±0.44	1.36±0.10	1.50±0.57	4.30±1.01	0.93±0.15
December	0.98±0.38	13.22±4.55	4.62±1.38	1.70±0.16	1.13±0.11	1.66±0.54	1.07±0.09	1.98±0.68	3.94±0.66	0.99±0.13
January, 2020	1.16±0.24	10.03±2.50	5.54±1.11	1.60±0.38	0.82±0.30	2.20±1.15	1.22±0.21	1.67±0.52	4.33±0.49	1.01±0.08
February	3.12±1.54	4.33±1.27	11.27±1.19	1.37±0.30	1.74±0.48	1.11±0.13	4.70±0.55	1.62±0.28	4.43±0.41	1.27±0.16
March	4.03±1.30	12.45±3.90	5.47±0.57	1.77±0.18	1.09±0.12	1.33±0.39	1.39±0.12	2.17±0.18	4.58±1.18	1.24±0.25
July	5.48±1.45	8.14±1.71	6.72±3.90	1.89±0.25	1.23±0.12	1.26±0.25	1.26±0.08	2.47±0.15	5.29±1.34	1.40±0.18
August	6.63±1.53	6.25±3.30	5.04±0.18	2.63±1.09	0.81±0.21	2.17±0.24	1.38±0.17	1.50±0.37	4.42±0.69	2.49±0.47
September	8.17±0.24	7.91±1.20	4.34±0.51	3.45±1.40	1.61±0.49	2.04±0.17	2.20±0.14	1.62±0.47	3.74±1.22	1.29±0.19

yond the discharge limit of MOEF, 2012 (3 mg/l). It was observed that the increase in the productivity of primary producers at the lower concentration; however, at the higher concentration might cause oxidative stress, disrupt cell membrane and even DNA damage, ultimately leading to the death of the organism (Linton *et al*., 2007; Sinha *et al*., 2009); Keller *et al*., 2012). Arora *et al*. (2016) studied the pollution load assessment and potential environmental risks of composite industrial effluents discharged from SIIDCUL Integrated Industrial Estate, Haridwar (Uttarakhand) and found that the concentration of heavy metals like Fe (37.38 mg/l), Cr (11.254 mg/l), Cu (4.9 mg/l) and Pb (2.11 mg/l) was beyond the prescribed permissible limits of BIS (2012).

Thus, on the basis of the overall pollution load of the metals viz. Cr, Ni, Zn, Fe in the untreated wastewater of Electroplating Industries, it is very clear that this wastewater has enough pollution potential to badly pollute the receiving water body. Although all of the industries have their own effluent treatment plant but knowingly or unknowingly, sometimes wastewater is discharged without treatment or improper treatment. This may cause a hazardous impact on the aquatic life, environment and human health with reference to heavy metal contamination in receiving water body, i.e. Sukhna Choe, which further mixes into Ghaggar river. As this water is further used for irrigation and in some places it is also used for drinking purpose, it is very important to ensure that wastewater is released, only after proper treatment, from the electroplating industries. Managements of these industries have to work out responsibly to make strategies to find out and remove the deficiencies in the electroplating process as well as the treatment process to ensure the same.

Conclusion

It was concluded from the present study that the electroplating wastewater discharged from the electroplating industries of Chandigarh without any treatment had very poor quality as per the prescribed standard of MOEF (2012). The study revealed that there was a maximum concentration of heavy metals such as Zn (122.20 mg/l) during August 2019 at the SS-8, Ni (156.37 mg/l) during August 2019 at the SS-4, Cr (467.01 mg/l) during October 2019 at the SS-5 and Fe (13.22 mg/l) during December 2019 at the SS-2. The concentration of metallic ions without any treatment were in the order of Cr>Ni>Zn>Fe. The variation in the production process may increase heavy metals concentration in wastewater discharge from the electroplating industries. The improper management of chemical handling may also be the reason for pollution load on the receiving water body by the unskilled workforce in the rinse water, drag-out losses and solution dumping and leakages of chemicals. The present study would help to determine the water quality in terms of heavy metals in electroplating effluent and provide the baseline for further research on the development of treatment strategies for wastewater discharge from electroplating industries and minimizing the effects of heavy metal contamination of receiving water bodies.

Conflict of interest

The authors declare that they have no conflict of interest.

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