Occurrence and Enhanced Removal of Heavy Metals in Industrial Wastewater Treatment Plant Using Coagulation-Flocculation Process

Zied Marzougui, Mohamed Damak, Boubaker Elleuch, and Abdelhamid Elaissari

Keywords
Enhanced removal • Heavy metals • Wastewater treatment • Coagulation-flocculation

1 Introduction

Heavy metal pollutants in aquatic environments cause a severe threat to public health and ecological systems (Wang et al. 2010; Ambashta and Sillanpää 2010). Cadmium, zinc, copper, nickel, lead, mercury and chromium are often detected in industrial wastewaters, which originate from metal plating, mining activities, tanneries, surface treatment processes, paint manufacture, and photographic industries (Beljaj et al. 2014), etc. The presence of metals in industrial wastewater is one of the main causes of water and soil pollution. Accumulation of these elements in wastewater depends on a number of local factors such as the industry type. Therefore, WTP company was considered as a pattern in this study. It was mainly renowned as a brass-producing company (Sinks, bathroom fixtures, fittings for water and sanitation gas …). The effluents are rich with heavy metals derived from brass lingo trained by zinc copper nickel and lead, besides the use of chromium in the treatment of metallic pieces (Fu and Wang 2011; Semerjian and Ayoub 2003). However, the company has a local wastewater treatment plant to reduce inorganic and organic pollutants before its discharge. In this study, monthly samples taken from wastewater entering the studied company WTP were analyzed in 2016 to determine effluent characteristics. The objective was to review the potential of coagulation process for the treatment of industrial effluents, especially the removal of heavy metals from aqueous environments.

Z. Marzougui (✉) · A. Elaissari
University of Lyon, University Claude Bernard Lyon 1, CNRS, LAGEP UMR 5007, 43 boulevard du 11 November 1918, F-69622, Villeurbanne, France
e-mail: marzougui_zied@hotmail.com

M. Damak
Department of Chemistry, Faculty of Sciences, Applied Chemistry and Environment Research Unit, Boulevard de l'Environnement, 5000 Monastir, Tunisia

Z. Marzougui · B. Elleuch
Laboratory of Environmental Engineering and Ecotechnology GEET, National School Engineer of Sfax, University of Sfax, 3052 Sfax, Tunisia

2 Materials and Methods

Monthly samples taken from wastewater entering the studied company WTP were analyzed to determine effluent characteristics. Water samples were analyzed for heavy metals using automatic absorption spectrometry (ICE 3000 Series). the samples were dried in oven at 105 °C for 24 h. Sub-samples were subsequently digested with 5 mL concentrated HNO_3 at 160 °C till colorless solution was obtained. After cooling, the suspensions were filtered and filtrate was adjusted to 50 mL with double deionised water. Additionally, the chemical oxygen demand (COD) and the biological oxygen demand (BOD_5) were determined with the reactor digestion using a HACH DR 2010 analyzer and the manometric method with a respirometer (BSB-controlled Model OxiTop WTW) respectively. According to AFNOR, pH was measured using pH meter (INOLAB WTW Model 720). SS measured by vacuum filtration of the samples, according to JIS K 0102.14.1.

3 Results and Discussion

The study of the coagulation-flocculation system performance included the evaluation of the treated waters quality in comparison to the Tunisian water quality standards for emission into the sewerage system (Table 1). The average

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Table 1 Physico-chemical characteristics of WTP effluent

Parameters	Tunisian standards ONAS	Unit	01/2016	02/2016	03/2016	04/2016	05/2016	06/2016	07/2016	08/2016	10/2016	12/2016
DBO_5	400	mg O_2/l	4	11	21	2	40	15	33	9	36	12
DCO	1000	mg O_2/l	63	36	150	85	48	42	30	47	115	220
SS	400	mg/l	6.2	2.6	113	3.2	48	4	2.2	8.8	6.2	9.8
pH	$6.5 \leq pH \leq 9$	/	7.3	8	8.25	8.2	8.4	7.95	8.1	8.5	8.5	8.35
Cr^{6+}	0.5	mg/l	**1.09**	0.029	0.416	0.06	0.2	0.06	0.006	0.82	**3.18**	**1.08**
Cr^{3+}	2	mg/l	0.05	0.03	0.49	0.25	2.55	0.04	0.016	0.038	0.295	0.026
Cl^-	700	mg/l	**1077**	**1084**	**1083**	**1064**	**1116**	**1227**	**1086**	**1036**	**958**	**870**
Ni^{2+}	2	mg/l	**5.42**	**3.44**	1.07	**3.51**	0.33	**4.7**	0.962	0.2	**2.28**	1.606
Pb^{2+}	1	mg/l	0.2	**5**	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Cu^{2+}	1	mg/l	0.05	**5**	0.05	0.05	0.005	0.05	0.05	0.05	0.05	0.05
Fe^{2+}	5	mg/l	0.1	0.134	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Zn^{2+}	5	mg/l	0.138	0.118	0.055	0.05	0.05	0.13	0.05	0.067	0.05	0.05
Oil and grease	30	mg/l	**4**	**12.5**	**12**	0	0.1	0	**2.2**	0	**248.3**	5

Table 2 Treatment WTP with $Al_2(SO_4)_3.18H_2O$

Removal ratio (%)	Pb	Cr	Zn	Cu	Ni
pH 8.5; dose 0.03 g/1	100	97.53	96.59	98.73	49.12
pH 8.5; dose 0.08 g/1	100	96.96	95.34	99.16	54.39
pH 8.5; dose 0.13 g/1	100	97.77	95.99	100.00	52.88
pH 6.5; dose 0.03 g/1	100	90.78	91.45	97.30	38.08
pH 6.5; dose 0.08 g/1	100	93.54	94.79	97.99	41.14
pH 6.5; dose 0.13 g/1	99.85	90.24	89.94	94.25	42.93
pH 4.5; dose 0.03 g/1	98.72	82.08	81.56	90.62	34.18
pH 4.5; dose 0.08 g/1	98.26	90.50	84.56	97.32	42.06
pH 4.5; dose 0.13 g/1	93.26	88.54	88.20	95.38	39.99

values obtained in the effluent for pH, COD, BOD_5, SS, were in agreement with the limits of the Tunisian recommendations. However, some of the compounds, the effluent residual loads were above the values required by standards. The high amounts of Cl^- and Ni^{2+} outflow can be partially explained by their relatively elevated concentrations in the raw influent. In spite of the advantages cited in the literature, there are inherent limitations to the effectiveness of the flocculation process for industrial wastewater treatment. In some cases, it may not be possible to achieve the desired outflow concentration due to the high natural background levels of the concerned contaminants.

The Jar tests conducted to optimize the pH (between 4.5 and 8.5) yielded data on heavy metals removal efficiencies with effect of coagulant dose (varying between 0.03 g/L and 0.13 g/L). The results, presented in Table 2; Fig. 1, show that Aluminum sulfate increased the removal ratio of heavy metals, except for the nickel ion. In fact, a low Ni removal ratio (between 34 and 41%), was achieved within a pH range of 4.5 and 6.5 and a coagulant dose of 0.03–0.08 g/L. The optimum coagulant dose on the nickel removal was 0.1 g/L and at pH of 6.6 efficiency. However, the results of treatment with Ferrous sulphate, presented in Table 3; Fig. 2, show that the removal ratio of heavy metals was lower than the

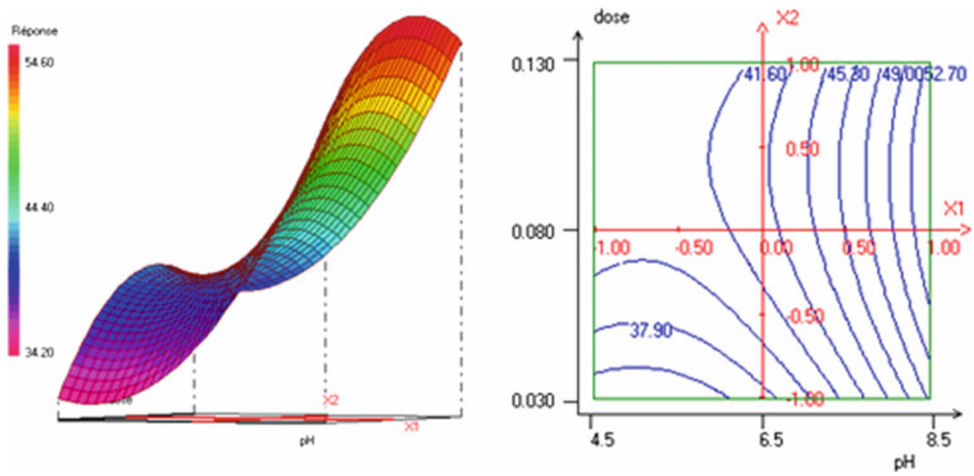

Fig. 1 Effect of pH and coagulant dose on the Ni removal by $Al_2(SO_4)_3.18H_2O$

Table 3 Treatement WTP with $FeSO_4.7H_2O$

Removal ratio (%)	Pb	Cr	Zn	Cu	Ni
pH 4.5; dose 0.03 g/l	20.78	43.65	12.12	20.21	2.51
pH 4.5; dose 0.08 g/l	25.99	44.33	15.06	23.57	2.31
pH 4.5; dose 0.13 g/l	32.40	46.79	19.61	27.77	5.77
pH 6.5; dose 0.03 g/l	74.41	78.94	89.86	88.77	67.02
pH 6.5; dose 0.08 g/l	68.89	75.75	88.43	88.54	69.71
pH 6.5; dose 0.13 g/l	71.53	76.50	86.59	88.08	67.18
pH 4.5; dose 0.03 g/l	57.82	52.39	49.45	49.38	65.61
pH 4.5; dose 0.08 g/l	52.76	53.61	52.80	53.07	48.36
pH 4.5; dose 0.13 g/l	41.64	45.96	35.60	33.96	37.68

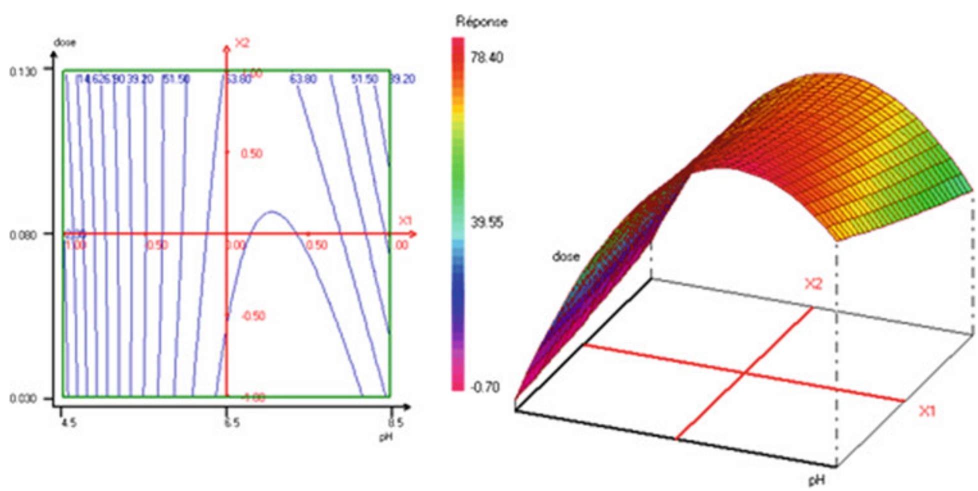

Fig. 2 Effect of pH and coagulant does on the Ni removal by $FeSO_4.7H_2O$

one treated with Aluminum sulfate. The optimum coagulant dose on the nickel removal was 0.03 g/L and at pH of 6.6. The removal ratio was 78%.

4 Conclusion

The study showed that some of the WTP compounds were present at trace levels, their contents in the treatment plant influent were shown to be quite variable. The WTP plant was obviously effective in the removal of heavy metals from industrial wastewater. The studied metal concentrations, except for Ni(II), were reduced to their specific permissible limits set for wastewater in Tunisia. That is why additional proper treatment based on scientific approaches should be considered. Adsorption by zeolite (Yousef et al. 2011) can be used as an adjunct to coagulation-flocculation for Cl^- removal.

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