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Pollution loads generated by the steel industry and their impact on the environment. Case of the arcelor mittal steel complex - Algeria

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Abstract

The steel industry uses large quantities of water, notably for cooling operations at different stages of steelmaking and discharges huge amounts of residual water. The present study focuses on the assessment of Pollution loads produced by effluents of the Arcelor Mittal –Algeria steel complex. Pollution quantification is carried out through major physicochemical parameters BOD_5 (biochemical oxygen demand of 5 days), COD (chemical oxygen demand), TSS (total suspended solids) and certain heavy metals (Zinc, Iron, Chromium, Copper and Nickel) at the main drains downstream of the complex by the Meboudja Wadi. Pollution loads produced by these industrial effluents exhibit high COD (>600 T /y), TSS (>900 T /y), chlorides and certain heavy metals such as iron (> 7, 5 T/y) loads, as well as nickel to a lesser extent. They are discharged to the wadi Meboudja, then to the receiving environment, (the Seybouse oued). They pose a severe threat to receiving environment and to ecosystem integrity.

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Introduction

The protection of water resources and water quality control are two necessary conditions for sustainable development and the preservation of the environment and ecosystems.

The history of industrial development has been associated with water. Water is mainly used in heavy industry to supply the cooling system (Hantz, 2005). Water is also involved in the steel industry for its mechanical action, particularly in descaling, granulation and water spraying operations during the rolling stages. The make-up water consumption of a steel site equipped with a recycling system represents 3 to 6m^3 per tonne of steel processed (Strebel, 2004).

In response to the worrying state of water quality, the World Bank (1996) intervened to finance a study in the region under consideration to control pollution in the steel mill. Many recommendations were addressed to the authorities, but this did not prevent the persistence of pollution cases. The Seybouse River, considered one of the most important rivers in northeastern Algeria, still suffers from various types of pollution, including industrial pollution (Chaffai and Mourdi, 2011; Mourdi *et al.*, 2014; Sayad *et al.*, 2014).

Population growth and industrial development, particularly in the metallurgical sector in the Annaba region, are facing a spatially heterogeneous distribution of industries, on the one hand, and particularly lack an efficient wastewater drainage system, on the other. The procedure adopted consists of carrying out a series of physico-chemical water analyses at seven sampling points in major installations: blast furnaces, steel mills, rolling mills, reinforcing bar units and seamless and spiral tube workshops.

The industrial vocation of the region has often been the subject of many alarming reports from different parties involved denouncing the passivity of certain industries for better management of the different local ecosystems and the environment in general (Bougherira *et al.*, 2014; Chaffai *et al.*, 2016; Sedrati *et al.*, 2016; Sayad *et al.*, 2017; Mourdi *et al.*, 2018). Therefor the main objective of this study is to quantify the state of pollution generated by the intense activity of the El Hadjar complex steel mill and its impact on the environment.

Materials and methods

Consumption and destination of water

As for metallurgical industries, steel industry, uses huge quantities of water, the annual volumes of which provided by ADE (Algérienne Des Eaux) for meeting the needs of the complex are given in the following table, with a daily volume of raw water ranging between 15000 and 30000m^3/day, coming from the El Chafia dam (Table 1); this latter evolve into industrial water, demineralized water, soft water as well as drinking water. This consumption varies from one unit to another, the biggest consumer of which are the blast furnaces with a mean of 3500m^3/day, then come the steel plants, the rolling mills and the SPU (sinter production unit), with less volumes.

Table 1. Annual water consumption of the steel complex (source, ADE Annaba, 2014).

Year	2007	2008	2009	2010	2011	2012	2013
Consumption (m^3/y) 10^3	14283	4745	8192	11639	9237	9384	6045

Additionally, its use is intended to the main circuits of the plant, namely cooling circuits (air coolers), gas washing circuits, filters washing circuits, rinsing water, boiler-feed water as well as sanitary water. Apart from evaporation and recycling of a part of water, a large part of this latter (70%) is returned; it is pretreated and discharged by gravitational force to the Meboudja wadi (Fig. 1) through 09 drains.

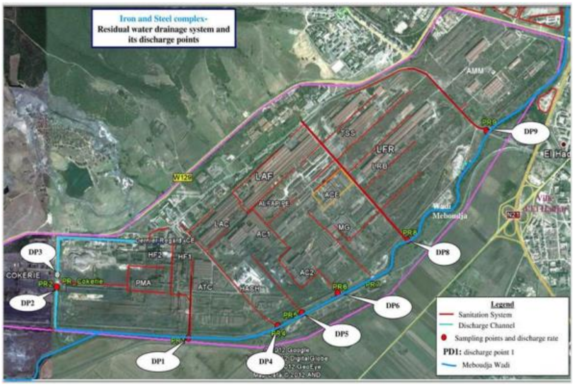

Fig. 1. Geographical location and residual water drainage system of the steel complex.

Study area

The Arcelor Mittal Algeria steel complex constitutes the most important industrial pole of the Seybouse wadi catchment. It stretches over more than 800 hectares, employs 6000 persons and includes the set of the steel processes from the preparation of the ore to the production of sheet and long products, wire and reinforcing bar. The Algerian state and Arcelor Mittal Algeria company have signed a partnership agreement by virtue of which the Algerian state holds 51% share in the company and Arcelor Mittal 49%, with the launching of an investment plan for a value of 763 million dollars for the steel complex and mines, thereby aiming to realise a production of 2, 2 Million tons by the year 2020. The site includes 12 distinct industrial units generating liquid effluents, with the characteristics provided in Table 2.

Table 2. Identification of the steel complex industrial units (MATE, 2012).

Unit	Activity	Pollution type	Origins of major pollution effluents
LFR	wire rod rolling mill	Tox Bio IRW (1)	Cooling water, washing water
LAC	Hot rolling mill (coil production)	Tox Bio IRW	Blast furnaces gas washing, cooling water
STEEL PLANT 1 (SP1)	Slabs production	Tox Bio IRW	Cooling circuit water, filters washing water
STEEL PLANT 2 (SP2)	Billets production	Tox Bio IRW	
PMA 1 and 2	Sinter production	Tox Bio IRW	Cooling circuit water, blast furnaces gas washing, concentration purge water, Slag granulation water
BLAST FURNACES	Liquid cast iron production	Tox Bio IRW	
Electric arc furnace (EAF)	Billets and ingots production	Tox Bio IRW	Filters washing water
LRB	Reinforcing bar rolling mill	Tox Bio IRW	Cooling water, oils, neutralisation water
TSS	Seamless pipes fabrication	Tox non Bio IRW (2)	Cooling circuit water, lubricating water
ALFAPIPE	Spiral steel pipes Fabrication	ERI non Bio Tox	Cooling water, test water
LAF	Cold rolling mill : Sheet production	Tox non Bio IRW	Cooling water, oils, neutralization water, chromium passivation (trivalent)
COX	Oxygen, nitrogen and argon production	Tox Bio IRW	Cooling circuit water, filters washing water
WATER PLANT	Industrial water production	Tox Bio IRW	Treatment products discharges, filters washing water, purge water
COKE PLANT (3)	Coke production	Tox non Bio IRW	Gas treatment discharges

(1) - Tox non Bio IRW: Toxic non-biodegradable industrial residual water.

(2) - Tox Bio IRW: Toxic biodegradable industrial residual water.

(3) - Stopped unit.

Analyses and measurements

Sites and sampling frequency

The Arcelor Mittal complex is equipped with industrial effluents drainage system, the treatment of which is made downstream of each unit through decanting basins fitted with deoiling systems and sand filters. Collected and pretreated residual water is conveyed towards 09 drains (06 circular, 02 ovoid and one buried channel), then discharged to the Meboudja wadi (Table 3).

Sampling was carried out during the month of August and September in 2012 and 2013 (Four sampling campaigns) at outlets of the major drains of the complex, by means of 24- flask sampler « CIGMA wastewater autonomous sampler ».

Samples were collected in polypropylene bottles, initially cleaned and rinsed with distilled water and were kept in an isothermal suitcase at 4°C and carried to the laboratory « Eurl Laboratoire Fethallah de Contrôle de la Qualité » (Rodier *et al.*, 2009).

In situ measurements (Temperature, PH, dissolved oxygen and conductivity) were performed with the help of HQD – HACH multiparameter for the dosage of physicochemical parameters (biological oxygen demand, chemical oxygen demand, suspended solids and chlorides). Heavy metals (iron, copper, zinc, chromium and nickel) were measured according to the reference methods presented in Table 3.

Table 3. Dosage methods of physicochemical elements and heavy metals.

Parameters	Method/Reference
BOD_5	Afnor dilution method: NF EN 1899-1
COD	Photometric method: (HI 83099- HI 83200)
TSS	AFNOR filtration method: NF EN 872
Chlorides	Afnor titrimetry method: NF iso 9297
Heavy metals (Fe, Cu, Zn, Cr, Ni)	Lightwave UV-visible spectrophotometer 2 (190nm-100nm)

Effluents Discharge rate measurement

The discharge rates of the complex were determined continuously by height/speed (Mainstream IV) Doppler flowmeter. The Height is determined by means of Doppler piezoresistive level sensor and speed by Doppler speed sensor. An ultrasound beam is emitted by an immersed probe, according to the pipe axis. These waves are reflected by all particles suspended in water; they are analysed in order to determine the average speed of water (S = f(H)) and Q = V * S). Data processing was made by means of Winfluid software. The discharge rate was measured by a mean error estimated at ± 1%. The discharge measurements were realised during six to seven days at seven drains in parallel with sampling, aiming at really quantifying pollution at the wadi by computing pollution loads. (Louati, 2015; MATE, 2016).

Table 4. Properties of residual water drainage system of Arcelor Mittal Complex.

Outfall	Discharge points	Units discharges	Effluents nature
Drain 1	DP 1	- Blast furnace 1(HF1) - Construction workshops (CW)	Cooling circuit water, blast furnaces gas washing, concentration purge water
Drain 2	DP2	- Sinter production (PMA) and blast furnace (HF2)	Cooling circuit water, blast furnaces gas washing, concentration purge water, slag granulation water, Ores leaching water
Drain 3	DP 3	- Off-site	Storm water.
Drain 4	DP 4	-LAC	Blast furnaces gas washing, cooling water
Drain 5	DP 5	- Lime plant	Cleaning water and washing water
Drain 6	DP 6	- LAF- - AFAPIPE - Steel plant 1 (SP1) - Steel plant 2 (SP2)	-Cooling water, oils, neutralisation water, chromium passivation (trivalent) -Test water and lubricants -Rinsing water (pickling, galvanization and tinplating)
Drain 7	DP 7	No discharge	-
Drain 8	DP 8	- TSS, - LFR - LRB - ACE	Cooling water, oils, neutralisation water Filters washing water Coolant pipe, quenching, oven and engine Hydrosid residual water
Drain 9	DP 9	- VW (Vehicles workshops) - Water plant	Decarbonisation sludges discharge Filters washing water Sanitary water and leaching water

Calculation of daily Pollution loads

From the findings obtained in (mg/l) and in parallel with discharges at the drains as a function of time (24 hours), the average values of Pollution loads were calculated according to the following formula (Kapepula *et al.*, 2015; MATE, 2016; Richards, 1998):

Load (Kg/d) = Q discharge ×Ci

Ci : parameter concentration in mg/l

Q discharge: daily discharge flow rate in m^3/d

The Fig. 1 presents all of the industrial units of the steel complex and their drainage system joining the wadi Meboudja via the 09 discharge points.

Results and discussion

Measured discharge rates

The measured discharge rates in seven drains by Mainstream IV vary from one drain to another. The drain number n°9 exhibits a daily maximum discharge rate of the order of 4972, 8m^3/d, the maximum daily mean discharge rate is recorded at the inlet of the drain n°6 with 4300, 8m^3/d. These irregularities are due to discharge specificity at each production workshop (Table 5).

Physicochemical analyses

The findings of the physicochemical analyses of residual water were performed at the discharge points of the Arcelor Mittal Steel Complex, except the drain 7 (dry and abandoned) and the discharge 3, which receives water from outside of the complex.

Table 5. Discharge rates recorded by Mainstream IV at outlet of different drains.

Discharge point	DP 1	DP 2	DP 4	DP 5	DP 6	DP 8	DP 9
Q max (m^3/d)	2872,80	3177,60	2116,8	1579,2	4956	469,1	4972,8
Q Med (m^3/d)	2054,40	2145,60	962,4	919,2	4300,8	259,8	2116,8
Q max (m^3/s)	0,80	0,88	0,588	0,439	1,377	1.04	1,381
Q Med (m^3/s)	0,57	0,60	0,267	0,255	1,195	0.70	0,588

The values of in situ measured parameters pH, conductivity, dissolved oxygen and temperature vary from one drain to another according to the nature and rhythm of activity and to the pretreatment system available at each unit. The temperature values are slightly greater than regimental limits (30°C) at two drains. For the other discharges, they meet the regulatory limits due to cooling systems at each unit. Besides, the values of dissolved oxygen are good (>1mg/l), except one single value, that of point 9 (0,9mg/l); this is explained by the high discharge rates conveyed by the drains. Conversely, the point 9 can be explained by the effluent containing sanitary water (organic pollution). In contrast, the pH values (hydrogen potential) show fluctuations ranging from 7,1 to 8,9, except the discharge point 5, whose pH is basic (11,5) due to the effluent of the lime production unit and to neutralization of LFR discharge by lime (Table 6).

Table 6. Values of in situ parameters.

Parameters	Min	Max	Medium	Standard deviation
T °C	21,00	36,00	29,85	3,36
pH	5,45	11,55	7,73	1,47
O_2 mg/l	0,28	9,35	7,26	2,92
EC (µs/cm)	354,00	3240,00	737,00	674,97

Apart from the discharge 5 (Table 7), the average values of electrical conductivity are lower than the limits of an industrial discharge. Moreover, the conductivity value at the point 5 is slightly high, and this is explained by neutralization effluent of LFR discharge by lime (discharge of metallic salts).

Table 7. Average values of in situ parameters per discharge point.

Discharge point	pH	T °C	O_2 mg/l	EC (µs/cm)
DP1	8,6	28	7,76	869
DP2	8,87	31	7,09	687
DP4	7,56	28,6	7,5	387
DP5	11,5	32	7,3	2610
DP6	7,1	31	6,8	453
DP8	8,9	29,7	8,8	358
DP9	7,6	27	0,9	750

The findings of physicochemical parameters presented in the form of Pollution loads reveal very high pollution loads, particularly for suspended solids TSS (> 28000Kg /d) higher than the limits of industrial discharge (<15kg/d), with a maximum concentration of 542mg/l (Table 8); this is explained by the nature of activity, notably the discharges of blast furnaces and PMA (scale, rust, gas washing), as well as leaching water (Boeglin, 1999; Fouad, 2014; Franck Chevalier Conseil, 2009; Hantz, 2005 ; Journal Officiel de la République Algérienne, 2006).

Table 8. Concentrations of physicochemical parameters.

Parameters	Min	Max	Medium	Standard deviation
BOD_5 (mg/l)	4,00	140,00	29,00	32,35
COD (mg/l)	7,00	316,00	70,00	82,63
TSS (mg/l)	3,41	542,00	56,50	169,01
Chlorides (mg/l)	41,80	410,50	97,50	96,20

In addition, the values of chemical oxygen demand indicate very high Pollution loads COD (> 2000Kg /d), higher than the limits of discharge to environment (<100kg/d), with a maximum concentration of 316mg/l, so a potential chemical pollution, which is explained by the presence of mineral salts, biodegradable or non-biodegradable organic matter, such as oils, greases and lubricants (Boeglin, 1999; Fouad, 2014; Franck Chevalier Conseil, 2009; Hantz, 2005; Journal Officiel de la République Algérienne, 2006). BOD_5 (833Kg/d) load is relatively loaded and it is notably presented at the discharge point 9; it is explained by sanitary water and exceeds the limits of discharge to natural environment: <30kg/d (Boeglin, 1999).

For this purpose, the findings of the analyses show that the discharged effluents are slightly loaded with biodegradable pollution, the average COD/ BOD_5 ratio values of which are comprised between 2, 4 and 2, 8. We equally see that the discharged effluents are fairly loaded with chlorides (> 2600Kg/d); they originate from the regeneration of ion exchange resins for the operations of demineralization and purification of water used at demineralization and softening stations (concentrate discharge). In the annual scale, Pollution loads are very high, of which 650 tons of COD, 900 tons of TSS, 260 tons of BOD_5, 550 tons of Chlorides are discharged to the Meboudja wadi, (Table 9).

Table 9. Pollution loads of physicochemical parameters generated inKg/d by the Arcelor Mittal Steel Complex.

Discharge point (DP)	Volume (m^3/d)	BOD5	COD	TSS	Chlorides
DP 1	2379	91	220	269	111
DP 2	2704	79	200	643	605
DP 4	1320	18	33	6	110
DP 5	1147	44	122	475	405
DP 6	4389	186	460	183	394
DP 8	8151	144	291	125	705
DP 9	2801	272	698	1154	337
Total		833	2023	2855	2667

The whole daily Pollution loads calculated from the analyses results for the major physicochemical parameters are illustrated in the following graphs (Fig. 2).

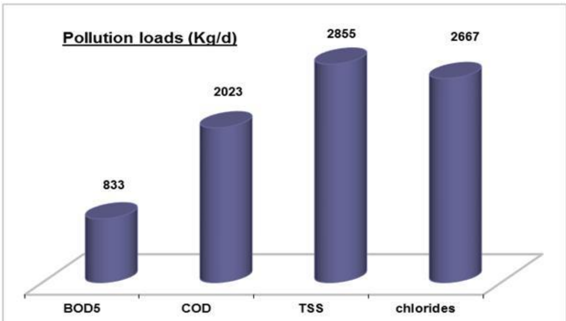

Fig. 2. Pollution loads in conventional physicochemical elements generated by The Arcelor Mittal Complex.

For heavy metals, the findings of the analyses and of calculated loads reveal very high loads of certain metals, namely iron and nickel to a lesser degree. Iron load is of 24Kg/day (7.6tons/y), with maximum values recorded at the discharge 6, whose concentration maximum value is of 8,1mg/l (Table 10); this is explained by metallic salts due to iron oxidation at the cold rolling mill, as well as relatively high values at the discharge 2, due to discharges of ores leaching coming from sinter production unit-PMA; its presence in the discharge 5 can be explained by leaching water and metallic salts.

Table 10. Concentrations of heavy metals.

Parameters	Min	Max	Medium	Standard deviation
Iron (mg/l)	0,00	8,10	0,28	1,85
Zinc (mg/l)	0,00	0,22	0,00	0,04
Copper (mg/l)	0,00	0,70	0,03	0,24
Chromium (mg/l)	0,00	0,09	0,01	0,03
Nickel (mg/l)	0,00	0,28	0,09	0,08

Furthermore, we also note high values for nickel, with a load of 2.5Kg /d (800Kg/y); it always originates from the LAF (surface treatment discharge according to Table 11), therefore, the values of these two metals are greater than limited values of discharge to natural environment (Franck Chevalier Conseil, 2009; Journal Officiel de la République Algérienne, 2006).

Table 11. Pollution loads of heavy metals generated by the Arcelor Mittal - Steel Complex.

Discharge point (DP)	Iron (kg/d)	Zinc (kg/d)	Copper (kg/d)	Chromium (kg/d)	Nickel (kg/d)
DP 1	0,73	0,00	0,19	0,00	0,29
DP 2	4,47	0,44	0,53	0,04	0,19
DP 4	0,08	0,06	0,05	0,03	0,08
DP 5	5,16	0,00	0,42	0,11	0,36
DP 6	11,17	0,00	0,20	0,05	0,63
DP 8	1,24	0,41	0,18	0,11	0,35
PR 9	1,82	0,00	0,08	0,14	0,67
Total	24,67	0,91	1,64	0,49	2,56

For the values of other parameters, (Zinc, Copper and Chromium III), they are relatively low and don't exceed the limited values of an industrial discharge to natural environment (Fig. 3).

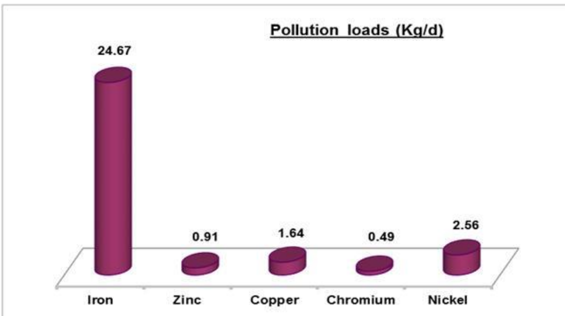

Fig. 3. Pollution loads with heavy metals generated - Arcelor Mittal-Algeria Complex.

Generally, heavy metals are micropollutants susceptible to pose hazards to aquatic environment, humans and nature, even when they are discharged in small quantities, because of their bioaccumulation potential and their variable solubility (Mikuel, 2001).

To summarise, analytical findings and, on the set of parameters, Pollution loads generated by the steel complex are greater than the regulatory limits of discharge to natural environment, whose residual water is marked by toxic and poorly biodegradable pollution. The whole daily Pollution loads heavy metals are illustrated in the following graphs:

Conclusion

Based on collected data, field surveys and findings of balances and measurement, which were realised during the period (2012-2013), computed pollution loads reveal very high values for physicochemical parameters, in particular COD, TSS, BOD_5 and chlorides, with a low degree of biodigradability, whose COD/BOD_5 ratio ranges between 2,4 and 2,8. In terms of toxicity, the findings of balances also reveal high values for heavy metals, iron and nickel, which exceed the limited values required in natural environment. To summarise, analytical findings and, on the whole parameters, the Pollution loads produced by the Arcelor Mittal-Algeria steel plant are higher than regulatory limits of discharge to natural environment, residual water effluent of which is marked by toxic and poorly biodegradable pollution. Consequently, and in order to improve the quality of this water and to remove this pollution, an industrial water treatment plant grouping all outfalls of the complex is highly recommended.

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