

Study of Leaching Behavior of Wastes Generated Due to Iron Ore Mining in India and Liberia

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Abstract

Iron is the fourth most abundant mineral in the earth's crust, and it is the most needed raw material in the manufacturing of steel. The demand for steel for construction, manufacturing of machines, pipelines, electrical appliances, military equipment, etc. is ever increasing leading to the increased demand for iron ore. However, exploitation of iron ore is associated with several undesirable impacts on the environment. The mining method for extraction of iron ore is usually opencast, or open pit method since most of it occurs close to the surface of the earth. Moreover, iron ore deposits mostly occur in forest areas and hilly terrain. Thus, it has the potential to cause degradation of surface and ground water, flora, and fauna, aesthetic view of the natural landscapes, as well as the ambient air quality within the mining area and surrounding environs. The contamination of water quality is mainly due to surface runoff and leachates that are generated from the overburden and tailings produced during mining and successive processing activities. Since most mines use overburden to backfill mined out areas, ground water adulteration may also result from leaching activities. In the present study, the leaching behavior of the solid wastes from two iron ore mines, one in India (Asia) and another in Liberia (West Africa) was investigated. The leaching behaviors of overburdens, tailings, and blue-dusts samples have been established using two types of leaching solutions. Results from indexing and leaching tests carried out revealed high levels of Fe, Hg, As, Cu, Ni, Mn, Zn, Se, NO₃, Residual Chlorine, Fluoride, Phenol, etc. at most sampling locations. The leaching behaviors were found to be variable to locations, parameters, and types of leaching solution, as this could damage the environment significantly with harmful contaminants if protective measures are not taken. The overall findings on a comparative scale showed that both mining districts are polluted due to iron ore mining, but the Liberian mining district is the most polluted, which calls for proper scientific management of the solid wastes generated from mining activities.

Keywords: Leaching, Iron Ore Mining, Pollution, Overburden, Tailings, Liberia, India, Water Quality Index.

1.0 Introduction

Iron ore has been mined for the past three thousand years from vast reserves in chemical and classic rocks viz. sedimentary, igneous and metamorphic (Morris, 2012). Mining denotes excavation of minerals of economic significance from the earth crust and associated activities such as drilling, blasting, hauling, beneficiation - elimination of associated gangues to improve the ore's quality, etc. Iron is the fourth most profuse mineral in the earth crust. India ranked 5th in the position amongst nations with world highest iron ore reserves, after Australia, Brazil, Russia, and China. Haematite and magnetite are the most important types of iron ore found in India. Iron ores formed are predominantly banded iron formation (BIF). The major host of iron ore in India State-wise is Jharkhand, Odisha, Chhattisgarh, Karnataka, and Goa (Gleekia and Sahu, 2016).

Liberia is a West African Nation with major iron ore reserves. During the late 1970s and early 1980s, Liberia and India accounted for 6% of world export of Iron ore (Yachir, 1988; Gleekia and Sahu, 2016). Iron ore mines generate a large volume of wastes – overburdens, tailings, etc., that contain a sizable amount of harmful trace elements viz. Pb, Cu, Se, Mn, Cr, Hg, As, Ni, Cd, Zn, Al, Ba, etc., that are injurious to health even at low concentration. These metals may get leached when these wastes come in contact with acid mine runoff, thus degrading water bodies within the mining district (s) and surrounding environs. The extent of the leachates to be released in water bodies is reliant upon the chemical constituents of the mine's wastes and the topography of the terrain (Nordstrom and Alpers, 1999; Akcil and Koldas, 2006; Wong, 1981; Gleekia and Sahu, 2016). Iron ore mining can affect relatively smaller areas but can have an immense topical aesthetic impact on the environment.

Discharge of metals from mining sites occurs mainly through acid mine drainage (AMD), erosion and surface runoff from overburden dumps and Tailing Pond (Salomons, 1995).

Asia is regarded as the world leading producer and consumer of iron, whereas Africa, Oceania Latin America, etc. are amongst regions with the world highest iron cycle (Wang et al., 2007). Open cast mining method, by which iron ore is normally extracted promotes to massive erosion, the formation of sinkholes, loss of species (flora and fauna), degradation of surface and ground water bodies quality, as a result of excavation and beneficiation activities (Monjezi et al. 2009). Thus, to maintain environmental safety, all mine water of metal mines must be collected and stored in tailing pond (Lottermoser 2012; Rankin, 2011). Water contamination due to mining is repeatedly being considered as a burden amongst investors globally (Ground, 2010). The impacts of these contaminants on aquatic animals are prolonged mortality, health or conceptive concerns, and a decline in the abundance of species (Boyd, 2000). Iron ore mining can contribute toxic and non-toxic constituents to surface water. The potential sources of toxic pollutants derived from iron ore mining are tailings pond, open pits, tailings, stockpiles of ore and sub-ore, dumps of waste rocks, mill tailings resulting from mining, the concentration of metal ores and cleaning. The discharge of these impurities in surface water is exaggerated when exposure to terrestrial rain. The ultimate expulsion of surface runoff engendered from terrestrial rain is one of the mechanisms that give rise to the release pollutants into surface waters. Moreover, the discharges of pollutants into surface waters may as well result indirectly through the ground water with a hydrological linking to surface water.

AMD is one of the most serious environmental effects as far as metal extraction is concerned. It ensues when sulfide bearing ore (s), such as pyrite is exposed to oxygen or water, a process which generates sulfuric acid. This process is often accelerated by microbes that feed on acid. The acidic water may leach heavy metals that are present in OBs and tailings and consequently contaminates the surface and ground water bodies in the mining districts. The major sources of acidic fluids (effluents) generation in iron ore mines are waste rock stock piles, exposed mine waste, the mine openings, and the mine pit walls.

1.2 Study Area

The Koira-Joda Mining Area was selected for the study in India. The study zone can be found at latitude 21° 52' 48" and 21° 53' 58" N and longitude 85° 08' 37" and 85° 17' 22."

E. Figure 1. The China Union Iron Ore Mine (CUIOM) of Liberia was selected for the study in Liberia. CUIOM lies within latitude 10° 22' 11" and 10° 13' 38" N and longitude 6° 48' 0" and 6° 48' 0" E, Figure 2.

In the present study, two major iron ore mining areas of the world are considered The Koira-Joda Mining Area (KJMA) situated in Keonjhar and Sundargarh districts of Odisha State, India; and China Union Iron Ore Mine (CUIOM) located in Bong and Margibi Counties, Liberia, West Africa. KJMA contains over 73 mines out of which 23 mines were active during the study period. These mines predominantly extract Iron and manganese ores. The ores mined this region serve as major source of raw materials for steel plants operational within and out of Odisha State.



Fig. 1: View of iron ore deposit in KJMA, India.

Sections from left to right: (a) Barsua (inscribed polygon dictates active mining areas), (b) Taldith (middle-green), and (c) Kalta (end-white section).

Mining activities at CUIOM licensed area started in the 1960s by the Bong Mining Company (BMC). Prior mining operations at the licensed area had significant adverse impact on the environment due to the absence of suitable environmental regulations and mining laws at the time. As evidence, the Mineral and Mining Law of

Liberia adopted in the year 2000. Thus, it is worthy to note that CUIOM licensed area was previously polluted to some extent before it began operation. Previous mining activities at the licensed area left behind eight abandoned mine pits which occupy an area of 151 ha. These abandoned mine pits often get flooded by terrestrial rain water and discharge toxic effluents into adjoining surface and ground water bodies (China Union EIA, 2013).



Fig. 2: View of China Union Iron Ore Mine (CUIOM), Liberia.

2.0 Leachability Behaviour of Solid Waste

The leaching behaviour of solid wastes sampled from both mining areas was assessed under two separate conditions as discussed below:

i. Under the first condition, double distilled water (DW) was used as the leaching fluid. The pH of the samples was first determined with the help a Micro pH Meter before leaching. The ratio of solid to liquid used to leach samples was 1:10 (25 g of solid sample to 250 ml of DW) respectively. The samples were then leached for 18 hours, after which the samples were filtered using 0.45 micron filters (fisher brand). After filtering, all 6 samples was acidified below pH 2 and refrigerated at temperature 4 °C, and analysed the next day with the help of ICP-MS LSX-213 at the Department of Geology and Geophysics, India Institute of Technology Kharagpur (IIT Kharagpur).

ii. The second condition of leaching was carried out using Toxicity Characteristics Leaching Procedure (TCLP) of US EPA, method 1311 (6010B-Lead). TCLP normally consist of four basic steps viz. (i) sample preparation, (ii) samples leaching, (iii) preparation of Leachate for analysis and (iv) leachate analysis. The pH of the samples was first determined with the help a Micro pH Meter before leaching. For this procedure, 2 types of leaching fluid were prepared and coded as extraction fluid1 and extraction fluid 2, depending on the pH of individual sample. The pH of extraction fluid1 after preparation was 4.83, and was used to leach samples with pH <5, while extraction fluid 2 of pH 2.877 was used to leach samples with pH >5. With respect to pH conditions, extraction fluid one was used to leach CUIOM OB only, since the pH was found to be 3.3, see Table 1.

The ratio of solid to liquid (leaching fluid) used for leaching each sample was 1:10, as in condition one, i.e., 25 g of solid sample to 250 ml of extraction fluid, with the help of analytical balance and graduated cylinder. The sample and fluid together were mixed in a conical flask of 250 ml capacity and placed in orbital shaking incubator at room temperature and allowed to agitate for 18 hours at 30-40 rpm respectively. The pH details of all analytical samples and leaching fluid are presented in Table 1 and leachate analysis results are presented in Table 2.

Table 1: pH of OB and Tailings before and after Leaching.

SI No.	Sample Code	pH Before Leaching	pH After Leaching	Extraction Fluid
1	OB_dw	3.3 at 30.1 °C	3.0 at 30 °C	Distilled water
2	OB_aa	3.3 at 30.1 °C	1.9 at 30 °C	1
3	TL_dw	8.6 at 30.2 °C	6.2 at 30.1 °C	Distilled water

4	TL_aa	8.6 at 30.2 °C	4.3 at 30.1 °C	2
5	OB3E_dw	6.7 at 24.5 °C	4.8 at 24 °C	Distilled water
6	OB3E_aa	6.7 at 24.5 °C	3.5 at 24 °C	2
7	OB8_DW	6.3 at 24.6 °C	4.3 at 24.2°C	Distilled water
8	OB8_aa	6.3 at 24.6 °C	3.3 at 24.2°C	2
9	TI_dw	7.3 at 24.6 °C	5.4 at 24.4°C	Distilled water
10	TI_aa	7.3 at 24.6 °C	4.1 at 24.4°C	2
11	BD_dw	7.2 at 24.4 °C	5.1 at 4.4°C	Distilled water
12	BD_aa	7.2 at 24.4 °C	4.3 at 24.4°C	2
<i>Extraction Fluid 1: was used for leaching of samples with pH < 5; Extraction Fluid 2: was used for leaching of samples with pH > 5.</i>				

Table 2: ICP-MS analytical results for the two types of leachate generated.

Sample Code	Na (mg/L)	Mg (mg/L)	Al (mg/L)	K (mg/L)	Ca (mg/L)	Mn (mg/L)	Zn (mg/L)	As (mg/L)	Cd (mg/L)
OB_dw	1.17	35.11	7.29	5.94	5.91	9.12	0.3855	0.0006	0.0035
OB_aa	84.04	23.89	0.97	20.04	3.2	8.55	0.2139	0.0013	0.0023
TL_dw	0.337	0.328	0.396	5.58	1.71	0.0042	0.0177	0.0006	0.00001
TL_aa	0.515	5.65	1.269	22.41	23.01	0.862	0.1457	0.0087	0.00007
OB3E_dw	0.148	0.021	0.002	0.077	0.07	0.006	0.0071	0.00003	0.00001
OB3E_aa	0.203	0.362	7.79	0.133	0.82	0.192	0.1025	0.0001	0.00009
OB8_dw	0.294	0.016	0.0039	0.121	0.064	0.005	0.0157	0.00003	0.00001
OB8_aa	0.248	0.148	7.38	0.192	0.44	0.28	0.0824	0.0002	0.00006
TI_dw	0.24	0.41	0.0049	0.268	0.426	0.0018	0.0113	0.00003	0.00001
TI_aa	0.476	1.182	8.833	0.284	1.213	0.472	0.1504	0.0001	0.0027
BD_dw	0.342	0.031	0.007	0.14	0.13	0.030	0.0174	0.00003	0.00002
BD_aa	0.24	0.046	11.48	0.076	0.26	3.39	0.0880	BDL	0.00001

Continued

Sample Code	Fe (mg/L)	Co (mg/L)	Ni (mg/L)	Cu (mg/L)	Hg (mg/L)	Pb (mg/L)	Ba (mg/L)	Cr (mg/L)
OB_dw	1.66	0.2633	1.0164	0.0131	BDL	0.00030	0.0681	0.0031
OB_aa	0.97	0.2108	0.7813	0.0201	0.00019	0.00418	0.1280	0.017
TL_dw	0.19	0.0003	0.0017	0.0019	0.00012	0.00039	0.0237	0.002
TL_aa	23.69	0.0523	0.0366	0.0154	BDL	0.00195	0.6440	0.032
OB3E_dw	0.013	0.0006	0.0006	0.0003	0.00015	0.00014	0.0013	0.0008
OB3E_aa	0.087	0.0032	0.0048	0.0070	0.00012	0.01102	0.0667	0.012
OB8_dw	0.017	0.0007	0.0008	0.0007	0.00016	0.00021	0.0053	0.001
OB8_aa	0.061	0.0035	0.0037	0.0116	0.00012	0.01102	0.0491	0.015
TI_dw	0.022	0.00006	0.0011	0.0009	0.00011	0.00011	0.0026	0.0021
TI_aa	0.9705	0.0054	0.0063	0.0175	0.00024	0.05107	0.0543	0.019
BD_dw	0.0206	0.00007	0.0007	0.0027	0.000078	0.00035	0.0022	0.001
BD_aa	0.3265	0.0024	0.0009	0.0034	BDL	0.18617	0.0067	0.011

TI=Tailings (India); TL= Tailings (Liberia); OB=Overburden (Liberia); OB3E=Overburden #3 East (India); OB8=Overburden #8 (India); BD= Blue Dust - powdery iron ore (India).

dw-1st condition of leaching, double distilled water;

Aa-2nd condition of leaching, acetic acid glacial (NaOH) as per US EPA, method 1311 (6010B-Lead), TCLP.

3.0 Water Quality Index (WQI)

The overall water quality index for all sampling points at CUIOM and KJMA was determined (Brown, 1972; Sahoo, 2014; Gleekia and Sahu, 2016). The procedures used to develop the WQI are delineated below:

- The water quality parameters of interest were recognized and were run by the suitability for their recommended consumption as a part of a water body.
- Careful approximations of parameters were determined by the created conditions for each parameter in Microsoft Excel and were contrasted, and the subjective rating was done using dimensionless sub-list of values ranging from zero to one for each parameter.
- The measuring variables or heuristics were characterized for every parameter and were considered while building a general WQI.
- The algorithm for computation and formulation of WQI was chosen with the available information and presumptions.

3.1 Rating Scale of WQI

A required rating-scale (X_r) was suitably prepared in range from minimum to maximum concentration of selected parameters. The range of rating for each parameter began at 0 and ended at 100. This was again sub-divided into 5 separate ranges. $X_r = 0$; suggests that the water is most desirable for consumption. $X_r = 25$, $X_r = 50$ and $X_r = 75$, suggest that the water is slightly, moderately, and extremely polluted. Likewise, $X_r = 100$ dictates the water quality parameter exceeds the relevant permissible limit of the required standard value, which means the water is severely polluted.

The ranges of water quality parameters in drinking water are indicated by its allowance limits as per IS10500 (2012), Indian Drinking Water Quality Standard. The water quality rating Q_i for the i th water quality parameters is acquired from the equation:

$$Q_i = 100 \left(\frac{V_i}{S_i} \right) \quad (3.1)$$

Where:

Q_i = water quality rating for the i th water quality parameters

V_i = estimation of the i th water quality parameter at a given sampling station,

S_i = standard permissible limit value of i th water quality parameter.

This condition guarantees that $Q_i = 0$, when a pollutant is absent in the water, while $Q_i = 100$ if the concentration of the i th parameter is equivalent to its permissible values in drinking water. Thus, the higher the value of Q_i , the more polluted is the water with the i th pollutant. The water quality evaluations for the potential of hydrogen (pH) and Dissolved Oxygen (DO) require exceptional care and consideration (Sahoo, 2014). The safe range of pH for drinking water is 7.0 to 8.5. Therefore, water quality rating for pH can be calculated as:

$$Q_{pH} = 100 \left[\frac{V_{pH} - 7}{8.5 - 7.0} \right] \quad (3.2)$$

Where:

V_{pH} = estimated value for pH ~7, it denotes the numerical contrast amongst V_{pH} and 7.0 ignoring arithmetical sign. Note: $Q_{pH} = 0$ for samples with pH = 7.0.

The quality assessments of other water quality parameters were assumed like that of water quality rating of pH above (4.2). The more harmful a given water quality parameter is, the lesser is its permissible limit value for drinking water. Thus, the "weights" for parameters of different water quality examined thought to be conversely relative to the guidelines prescribed by Indian Council of Medical Research (ICMR) for comparison of water quality parameters (Sahoo, 2014) as given in the below equation 4.3:

$$W_i = \frac{K}{S_i} \quad (3.3)$$

Where:

W_i = unit weight for the i th water quality parameter ($i = 1, 2, 3, \dots, n$), K is the constant of proportionality which is determined from the condition of the water being examined. For straightforwardness, $K = 1$. The estimations of k were computed as given in equation 4.4 below:

$$W_i = \frac{K}{\sum_{i=1}^n \left(\frac{1}{S_i} \right)} \quad (3.4)$$

So, the aggregate of unit weight of nth water quality parameters can be given as:

$$\sum_{i=1}^n W_i = 1 \quad (3.5)$$

The weightage of all the components were computed by applying the above condition (equation 4.5). The standard unit weights of water quality components allocated by ICMR and Central Public Health Environmental Engineering Organization (CPHEEO) of India (Sahoo, 2014). To compute the WQI, the sub index (SI)_i corresponding to the ith water quality parameter is calculated as the result of the quality rating Q_i and the unit weight W_i of the ith parameter as given below:

$$(SI)_i = Q_i * W_i \quad (3.6)$$

The overall water quality index (WQI) of Koira-Joda Mining Area (KJMA), India, and China Union Iron Ore Mine (CUIOM), Liberia, was computed by accumulating these sub-indices (SI) directly. In this manner, WQI can be calculated as:

$$WQI = [\sum_{i=1}^n Q_i W_i / \sum_{i=1}^n W_i] = \sum_{i=1}^n Q_i W_i \quad (3.7)$$

Where:

$$\sum_{i=1}^n W_i = 1 \quad (3.8)$$

The results of overall water quality index for CUIOM Liberia, and KJMA, India are presented in tables 3 & 4 respectively.

Table 3: WQI of Koira-Joda Mining Area, India

Sampling Station	Overall WQI	Rating (WQI)	Grading (WQI)
B-1	88.45	Very Poor	D
B-2	62.88	Poor	C
B-3	71.85	Poor	C
B-4	78.57	Very Poor	D
B-5	35.06	Good	B
B-6	83.03	Very Poor	D
B-7	23.30	Excellent	A
B-8	88.88	Very Poor	D
K-1	53.05	Poor	C
K-2	77.28	Very Poor	D
K-3	21.42	Excellent	A
K-4	69.24	Poor	C
K-5	81.56	Very Poor	D
K-6	73.47	Poor	C
K-7	34.30	Good	B
K-8	61.96	Poor	C
K-9	63.72	Poor	C
K-10	73.12	Poor	C

Table 4: WQI of China Union Iron Ore Mine, Liberia

Sampling Station	Overall (WQI)	Rating (WQI)	Grading (WQI)
S1	86.80	Very Poor	D
S2	65.36	Poor	C
S3	86.94	Very Poor	D
S4	37.32	Good	B
G1	8.12	Excellent	A
G2	8.47	Excellent	A

4.0 Results and Discussion

4.1 Leaching Test

The primary reason for conducting leaching test on OBs, tailings, and blue-dust samples was to investigate their long term behavior when exposed to water, which could be slightly acidic (rain water) or highly acidic (AMD) depending on the geo-mining conditions of the terrain. From the two types of leaching method applied, (Table 1), the results obtained revealed dissimilar leaching behavior with respect to samples leached. The photographic views of the OB dumps and tailings storage facilities of CUIOM and KJMA from which samples were collected have been presented in Figure 3a and b.



Fig. 3a: CUIOM Overburden Dump (left) and Tailings Storage Facility (right).



Fig. 3b: CUIOM Overburden Dump (left) and Tailings Storage Facility (right).

4.1.1 China Union Iron Ore Mines (CUIOM), Liberia

The leaching results for CUIOM samples showed diverse leaching behaviour with respect to the leaching fluid used and sample type. The study OB leaching behaviour shows, Zn, Mg, and Fe to be more leachable in double distilled water than acidic fluid. The concentration of Hg was below detectable limit (Figure 4a, b, & c). The leaching result of OB with acidic fluid revealed an elevated concentration of Cr, Pb, Hg, Ba, Na, and K (Figure 4b, c, and d).

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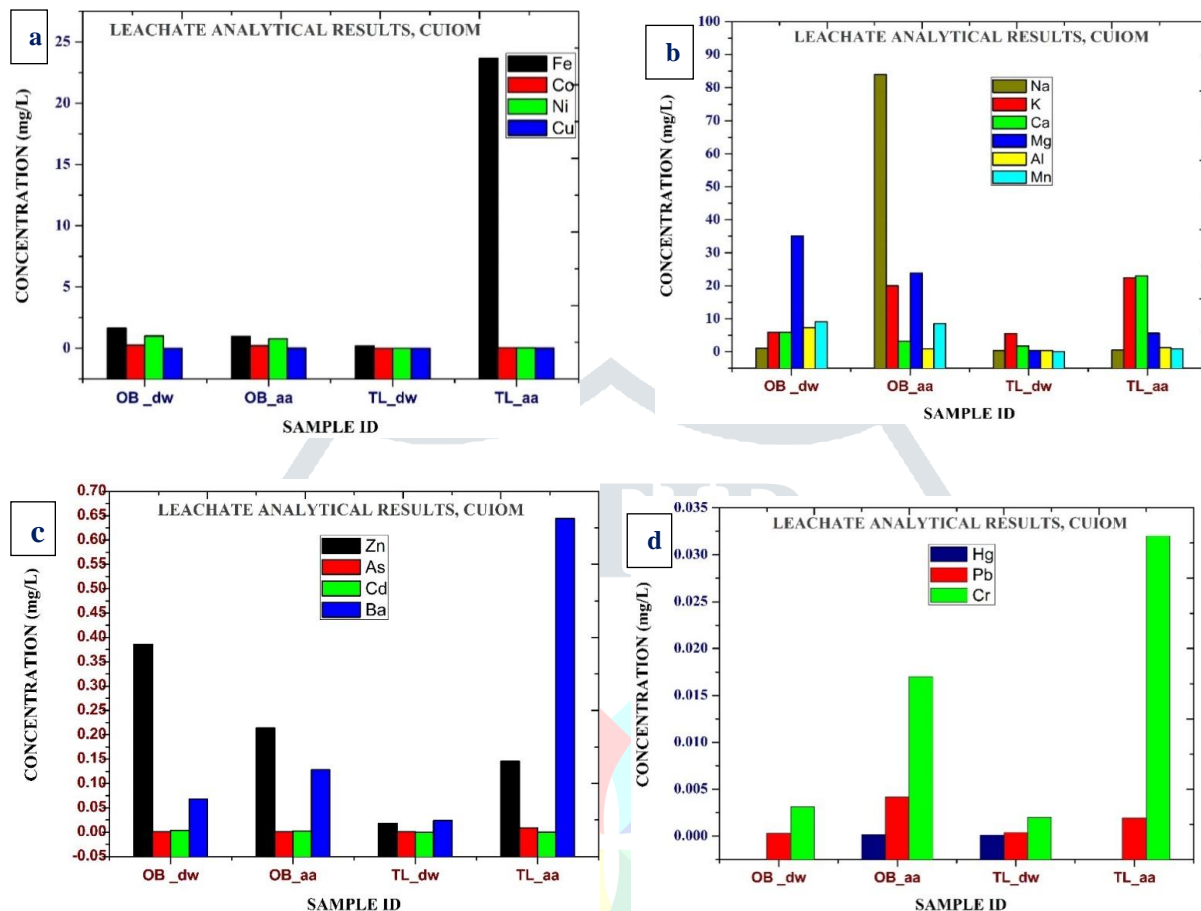


Fig. 4: Leaching behaviour of trace elements in CUIOM OB and tailings.

The acidic leaching fluids were very efficient in leaching of trace elements from both samples of OB and Tailings, except Hg, for tailings analyzed. Hg was leached significantly from the tailings samples of CUIOM by double distilled water leaching fluids. However, Hg concentration in acidic leachate from OB during analysis was null – below detectable limit (BDL).

On the contrary, Hg was leached significantly from OB by double distilled water leaching fluids but was poorly leached by DDW leaching fluids from tailings samples analyzed.

The reason for the variability can be directly linked to pH, as the pH of OB was 3.3 (very acidic), while the pH of tailings was 8.6 (Table 1). Comparatively, acidic leachates from tailings of CUIOM contained a higher concentration of heavy metals, cations, and anions than the non-acidic leachate of double distilled water, except for Hg. The value for Hg was below detectable limit in acidic leachate, but analytical results from distilled water leachate revealed a significant amount of Hg (Figure 2d).

4.1.2 Koira-Joda Mining Area (KJMA), India

eachates analyzed from all four samples gathered from KJMA showed better result as acidic leachates displayed much higher levels of trace elements in OB and tailings except for blue-dust that performed differently with respect to parameters analyzed (Fig. 5b). The concentration of Hg and As in the acidic leachate of blue-dust (BD_aa), were below detectable limits. For the same sample, Hg value was below detectable limit (BDL), in the distilled water leachate, but detectable in significant amount in the acidic leachate.

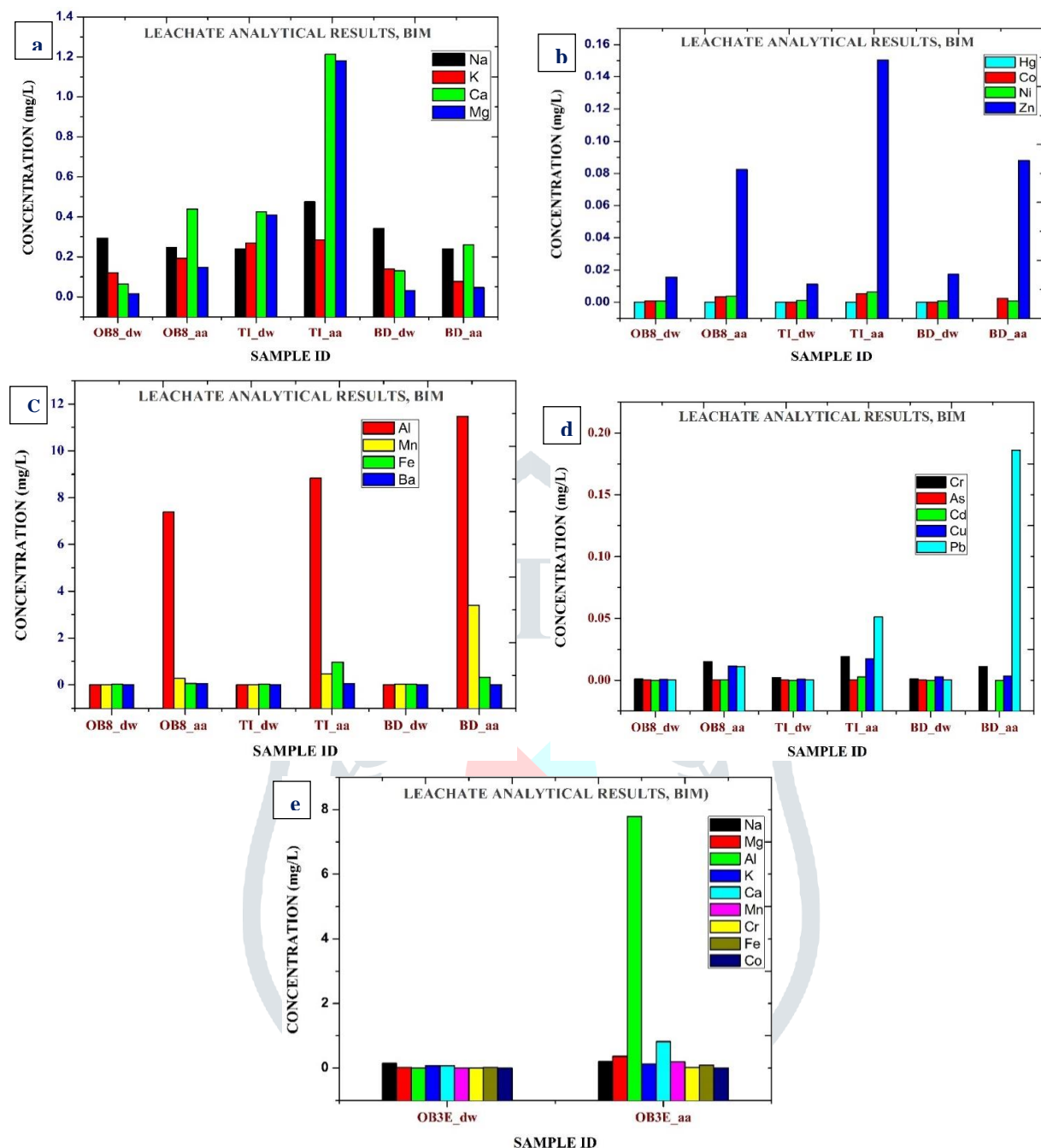


Fig. 5: Leaching behaviour of trace elements in KJMA OB, blue-dust and tailings.

As stated above, in CUIOM tailings generated leachate, Hg value was below the detection limit for acidic leachate and significantly detectable in double distilled water leachate. Thus, it is worthy to note that Hg of CUIOM OB is susceptible to leaching significantly in acidic medium, while the tailings of CUIOM is liable to leaching in the non-acidic medium. In the KJMA samples analyzed, Hg values were below detectable limit in acidic leachates of blue-dust and OB3E. The OB3E leachate of double distilled water did not reveal Hg as well.

4.2 Water Quality Index

Water quality of both mining areas can be classified into five intervals relying upon WQI estimations of the parameters analyzed as Excellent, good, poor, very poor, and unsuitable for consumption (Sahoo, 2014; Brown, 1971, Gleekia and Sahu, 2016). The corresponding intervals of classification are 0 – 25 (Excellent Quality), 26 – 50 (Good Quality), 51– 75 (Poor Quality), 76 – 100 (Very Poor Quality), and greater than 100 (Unsuitable). The water quality index studies indicated that the overall water quality of KJMA was excellent (B7 and K3), Good (B5, K7), poor (B2, B3, K1, K4 & K6), and very poor (B1, B4, B6, B8, K2, & K5). In similarly manner, the overall water quality of CUIOM was excellent (G1 and G2), Good (S4), poor (S2), and very poor (S1 and S3). The sampling stations selected for indexing indicated in parentheses adjacent the quality found from the analysis.

5.0 Conclusion

The leaching test result revealed that OBs and Tailings of KJMA are more susceptible to leaching by acidic solutions while Blue-Dust leaching mechanism was found to vary. A parameter such as Hg could not be leached in acidic medium but was leached significantly in the non-acidic medium. OB and Tailings from CUIOM showed complex leaching behavior. The trace elements found in OB were most leachable in acidic medium but Hg was leachable in the non-acidic medium. It is important to realize that, pH plays a vital role in leaching of metal in a mining environment. The leaching test revealed that not all trace elements get leached in acidic medium at all pH condition, but the issue is a lot of harmful metals get leached in higher concentrations as pH gets lower and lower in the acidic range of the pH Scale. And consequently, these metals may precipitate in a basic medium as pH increases above 7. The OB of CUIOM, Liberia is a major source of pollution generation in the mining area. Since the pH of OB is already in range of 3.3 (highly acidic), the introduction of terrestrial rain may give rise to acidic surface runoff generation and may further prompt the dissolution of harmful heavy metals such as Hg, Pb, Ba, Cr, Zn, Mg, Cd, Al, Ni, etc., as indicated by the leaching test results (Figure 2 and 3).

Findings from the water quality index studies clearly indicates that iron ore mining and subsequent processing activities have degraded the water quality in the mining regions. Hence, overburdens and tailings from both iron ore mining environments of Liberia and India contain numeral trace elements of complex behaviors, but OB of CUIOM is highly contaminated due to in low pH (3.3). Further studies are required to investigate the factors contributing to such low pH of CUIOM OB.

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