Recycling of Industrial Dust

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MSE398A

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Abstract

This article discusses my work, experience, and knowledge gained during my project. During my work, I got the opportunity to do a recycling process on Industrial dust waste that contained many crucial elements that needed to be recycled from both the economic and environmental perspective. The article will mainly discuss the process and results I performed during the characterisation, pretreatment and recycling of the dust waste. It wholesomely involved the hydrometallurgical route and a few heat treatments.

1. Introduction:

In large-scale industrial production, such as steel manufacturing, the production process involves multiple stages that utilise valuable materials. Operations like grinding, crushing, polishing, and palletisation often generate fine particles or dust as a byproduct. Although the wastage per kilogram of material may seem negligible, the cumulative waste becomes significant at large production scales. Therefore, recycling industrial dust through the hydrometallurgical route (It has been seen that the hydrometallurgical route gives more efficiency with less utilisation of energy, capital, and resources than the pyrometallurgical route) is essential from both environmental and economic points of view. This article involves dust from the stainless-steel making Industry.

2. Characterisation of the dust:

During any recycling process, we need to start with the characterisation of the waste that we think of recycling to know the phases, composition and morphology of the elements present in it so that we can accordingly proceed with our recycling process to extract the desired compound/elements either it be base or precious materials.

The following SEM and XRD analyses were conducted:

2.1. **XRD**: As per the given XRD, the major elements present in the form of compounds are K, Cl, Fe, O, and Zn.

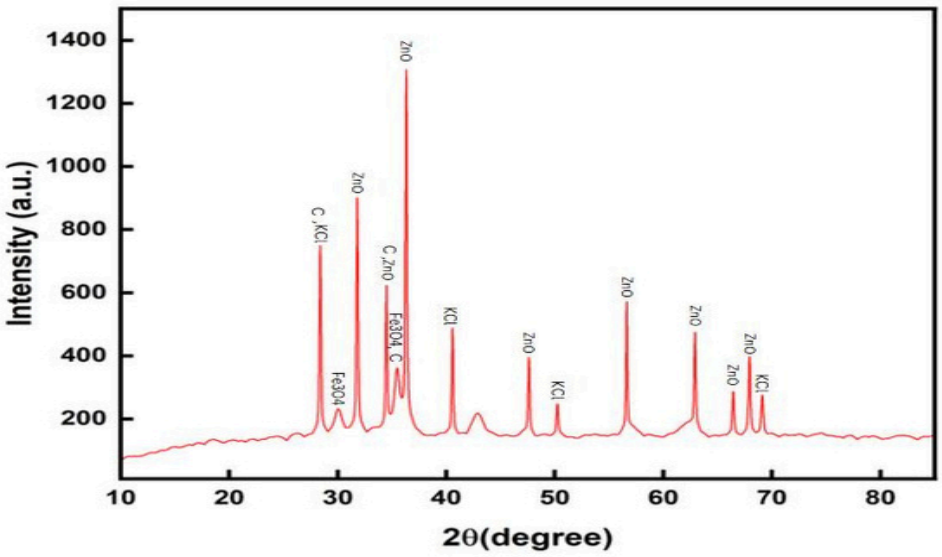
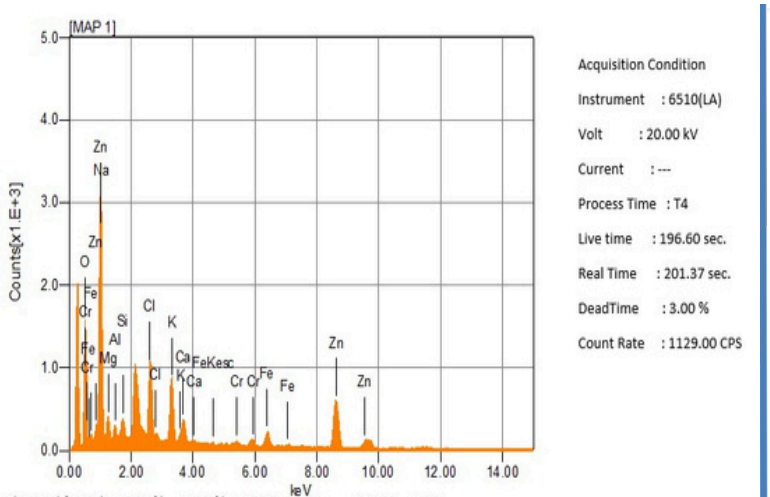
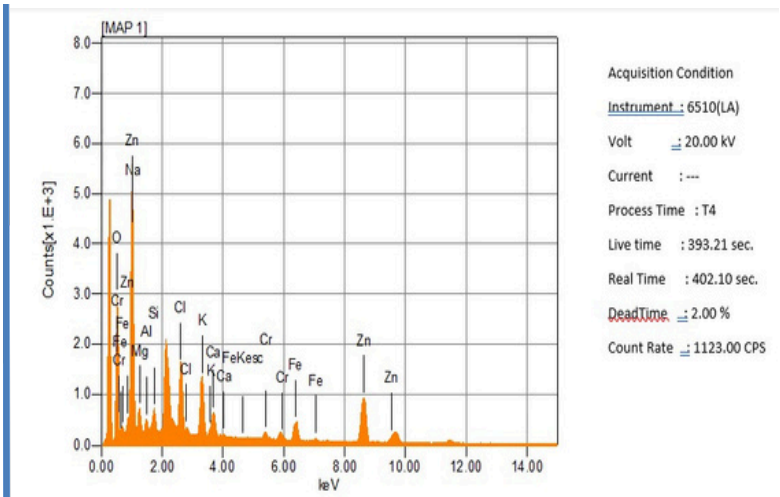


Fig. 1. XRD of the dust

2.2. **SEM**: The SEM analysis was done on the elements as per the data we got from the XRD and estimation from the industry data. As you can see the SEM analysis was done on 2 samples of dust and the result was more or less the same, ensuring the credibility of the data. As seen from the data below, the most abundant metal found is Zn and in small amounts Fe, Na, and K.



Chemical formula	mass%	Atom%	Sigma	Net	K ratio	Line
O*	26.92	48.64	0.09	40146	0.0170583	K
Na*	11.26	14.16	0.19	30588	0.0069221	K
Mg*	3.08	3.66	0.07	9938	0.0013815	K
Al*	1.28	1.37	0.05	5655	0.0007712	K
Si*	1.49	1.53	0.05	7870	0.0012014	K
Cl*	7.27	5.93	0.05	47145	0.0095055	K
K*	7.04	5.20	0.06	42686	0.0100832	K
Ca*	2.31	1.67	0.05	14599	0.0034982	K
Cr*	1.08	0.60	0.05	3800	0.0015428	K
Fe*	4.10	2.12	0.06	11252	0.0061230	K
Zn*	34.18	15.12	0.23	45813	0.0478996	K
Total	100.00	100.00				



Chemical formula	mass%	Atom%	Sigma	Net	K ratio	Line
O*	28.54	50.97	0.07	75360	0.0160100	k
Na*	10.48	13.02	0.14	47686	0.0053956	K
Mg*	3.00	3.52	0.05	16539	0.0011496	K
Al*	1.16	1.23	0.04	8833	0.0006023	K
Si*	1.48	1.50	0.04	13356	0.0010194	K
Cl*	6.51	5.24	0.04	72096	0.0072678	K
K*	6.36	4.65	0.04	66126	0.0078099	K
Ca*	2.49	1.77	0.04	26986	0.0032331	K
Cr*	1.64	0.90	0.04	9934	0.0020163	K
Fe*	5.76	2.95	0.05	26853	0.0073062	K
Zn*	32.58	14.24	0.18	74236	0.0388072	K
Total	100.00	100.00				

Fig. 2. SEM analysed data: (a) Sample 1; (b) Sample 2

3. Leaching:

After the characterisation, it was quite clear that the dust had majorly Zinc (Zn), and some other materials but in tiny quantities such as Fe Cl, Na, Si, K etc. For the extraction, different leaching agents were used which were **HCl**, **HNO3**, and **NaOH**. The
following steps were taken to leach the dust stepwise.

i. 5 gm of dust was added to each of the solutions (HCl, HNO3, and NaOH) of 100ml with 2M concentration.
ii. It was then stirred with a magnetic stirrer at 45o C for 4 hours.
iii. It was then filtered with filter paper to get a filtered solution and residue on the filter paper.
iv. The solution that separated after filtering through paper was precipitated through **Ammonia (NH3)** for HCl and HNO3 and with **dilute HCl** (2-3 drops of **concentrated HCl** were added to about 25ml of water) for NaOH. All the precipitators were about, *14 _ the pH of the filtered solution*, and were added until a good precipitation started showing, at the precipitated stage the pH had become about 7 which is neutral.
v. The material attached to the magnetic stirrer, probably due to the magnetic property was taken out separately.
vi. Then all the samples i.e. the precipitated solution, the residue on the filter paper and the material attached to the magnetic stirrer were dried in the oven for 3 Hours.
vii. Drying in the oven was insufficient for the XRD analysis so calcination was done for 2.5 hours up to 1200oC.
viii. All the samples were then analysed through an XRD pattern to determine the final phases/compounds present.

4. XRD analysis

The following two figures are EBSD imagesofthe samples:

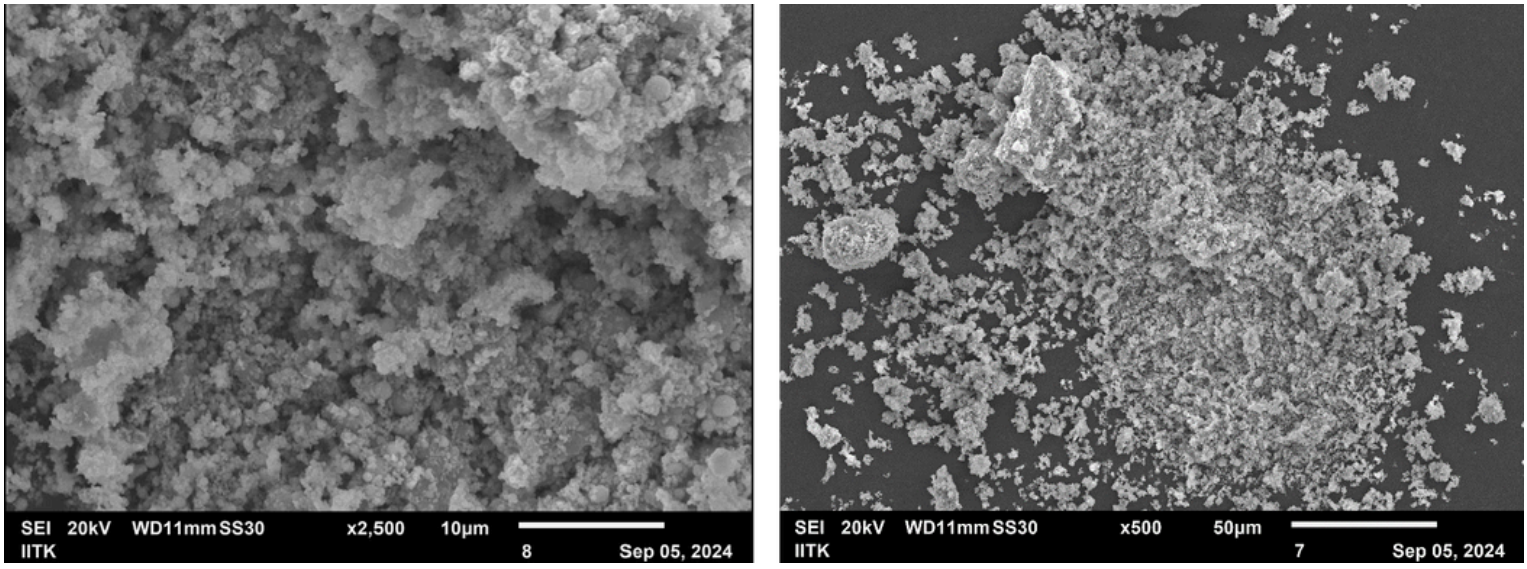


Fig. 3. EBSD Image: (a) X2500; (b) X500

The following are figures of the XRD pattern of samples and some observations:

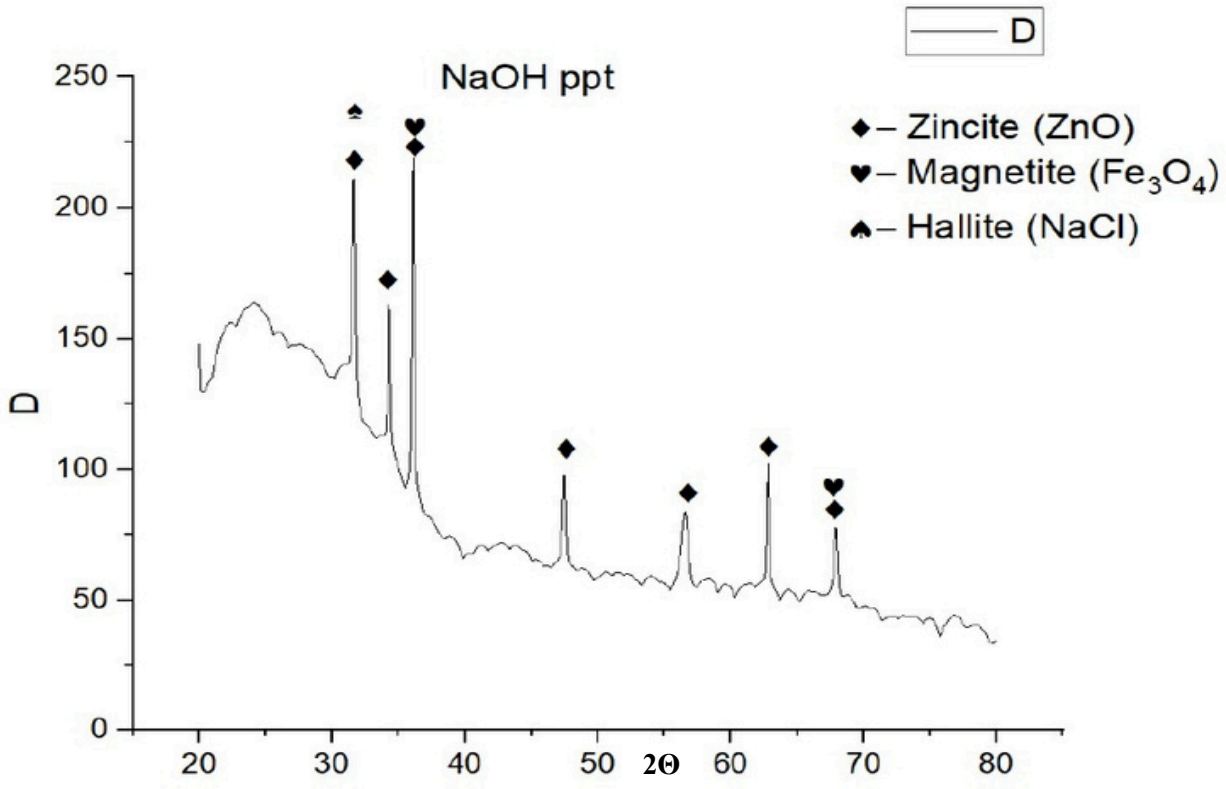


Fig. 4. XRD pattern ofNaOHPrecipitate

- ZnO is present and in fact in good amount as all the peaks matched for ZnO.
- Some amount of Hallite and Magnetite may also be present, as some peaks match them.

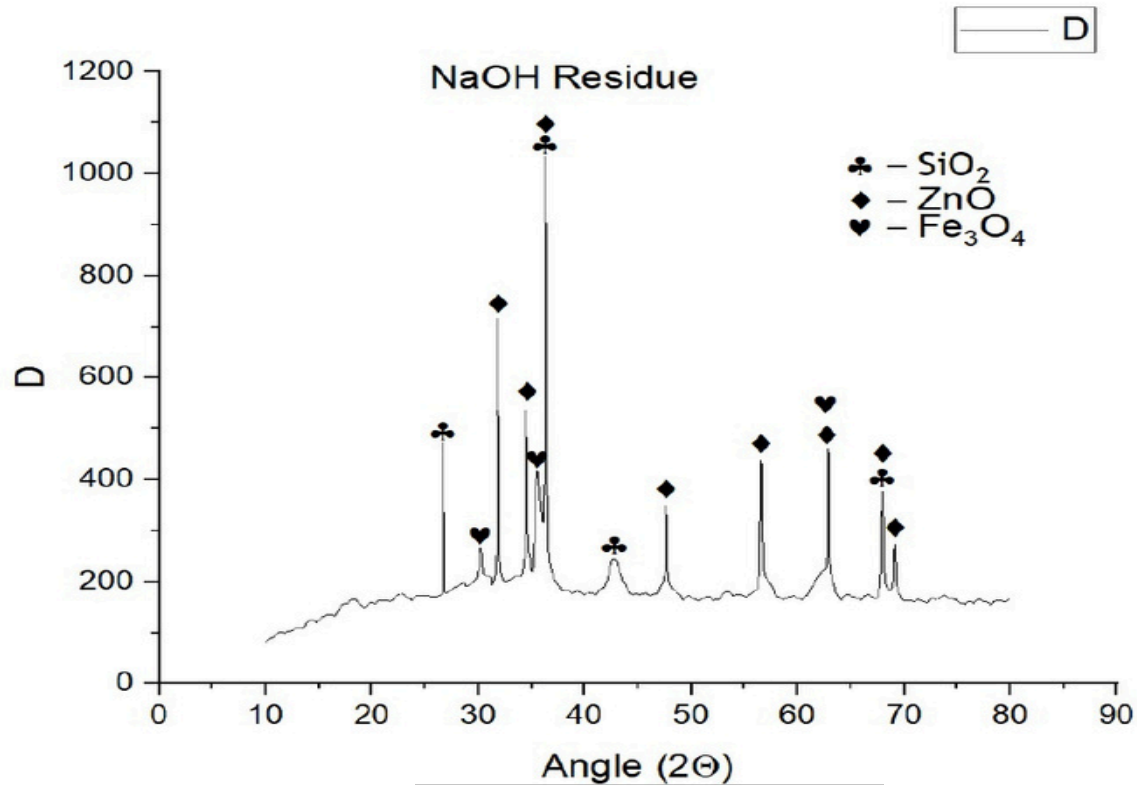


Fig. 5. XRD pattern of NaOH Residue

- Here also ZnO is present, probably in a good amount as maximum peaks match.
- SiO2 is present in low amounts because all picked matched when SiO2 is being considered and obviously, magnetite is also present in some amount.

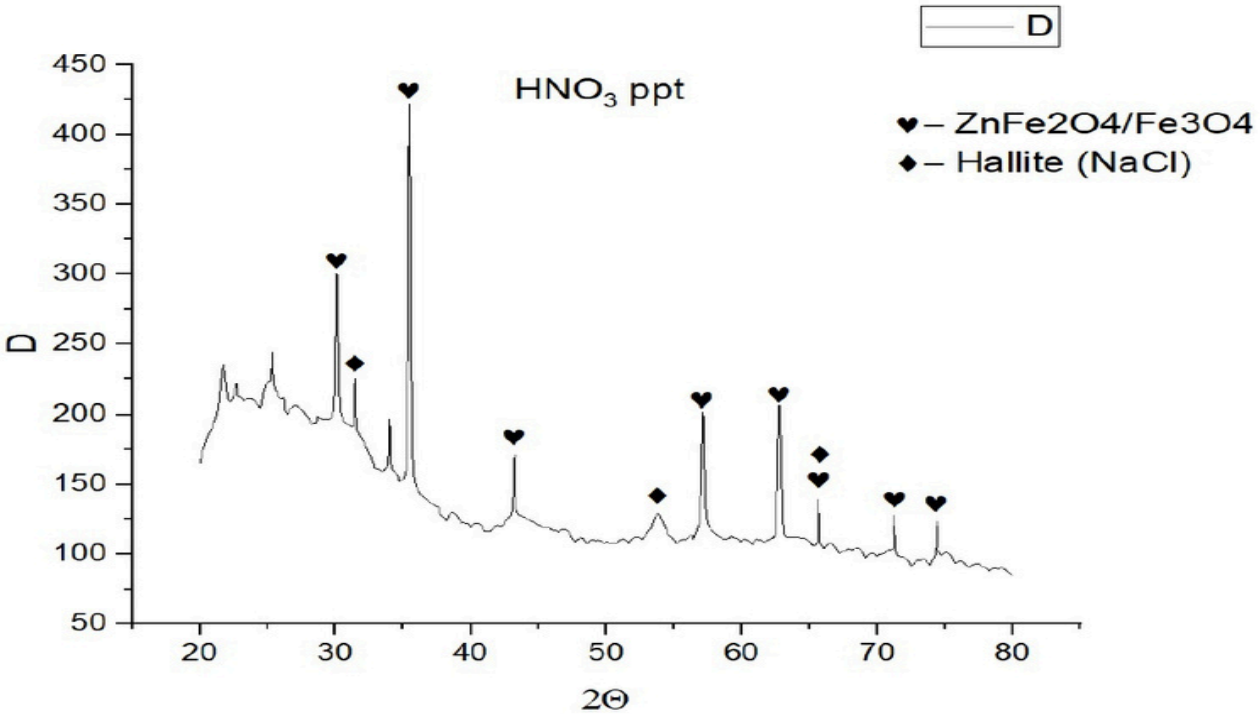


Fig. 6. XRD pattern of HNO3 Precipitate

- Seems ZnFe2O4 or Fe3O4 is present in a good amount as many peaked matches with these.
- Probably a small amount of Hallite is also present as few peaked matched with it and had good scores on the software.

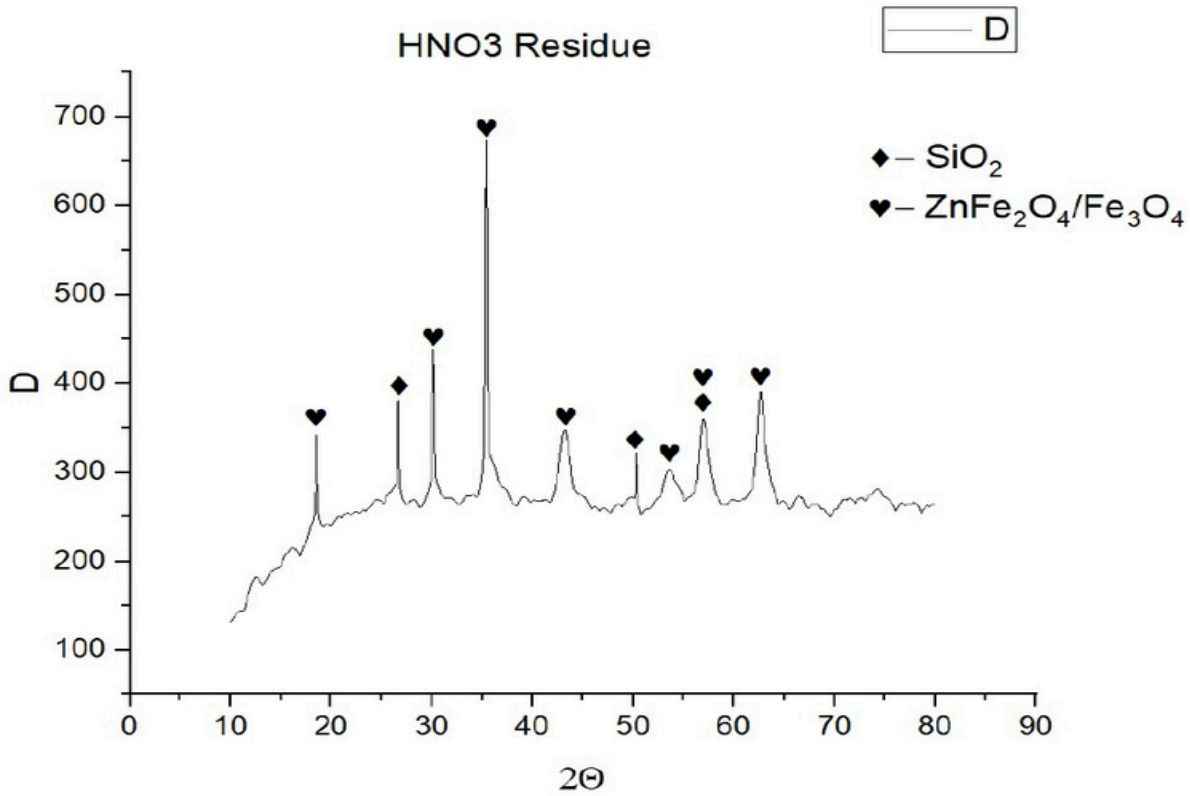


Fig. 7. XRD pattern of HNO3 Residue

- Majorly Franklinites or magnetite is present as major picked matching with it. All peak
- matching when SiO2 is considered, hence definitely in small amounts SiO2 is present as well.

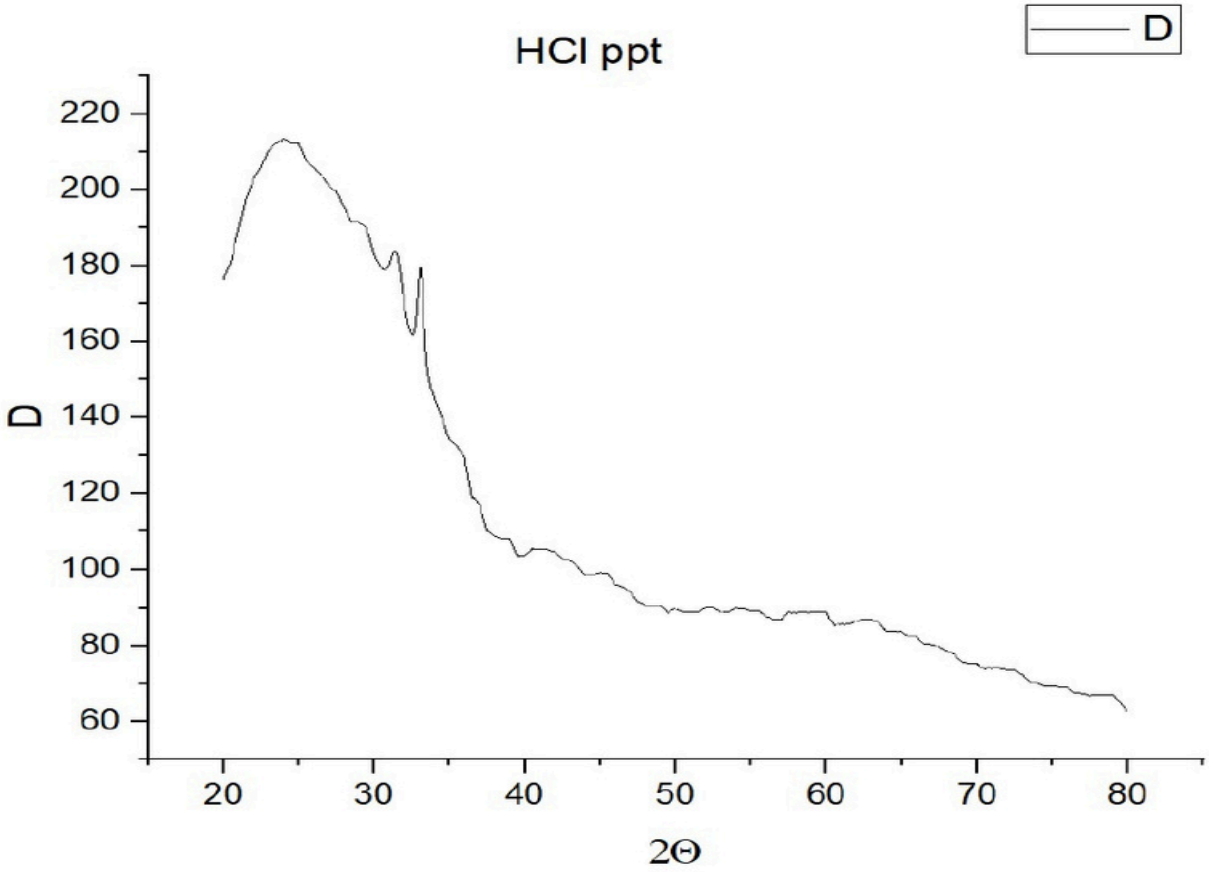


Fig. 8. XRD pattern of HCl Precipitate

- Unfortunately, the XRD of precipitated HCl gave nothing that can be considered.

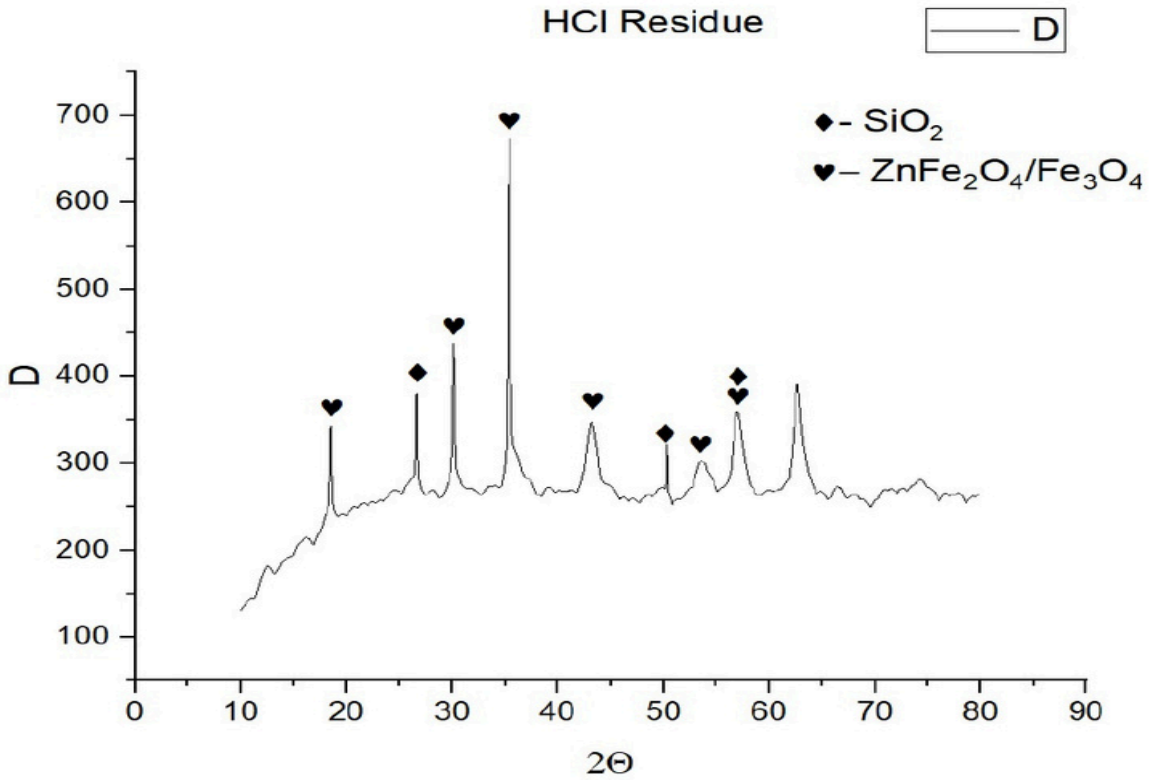


Fig. 9. XRD pattern of HCl Residue

- Same as HNO3 residue i.e. seems majorly Frankelinite or magnetite and in small amounts SiO2.

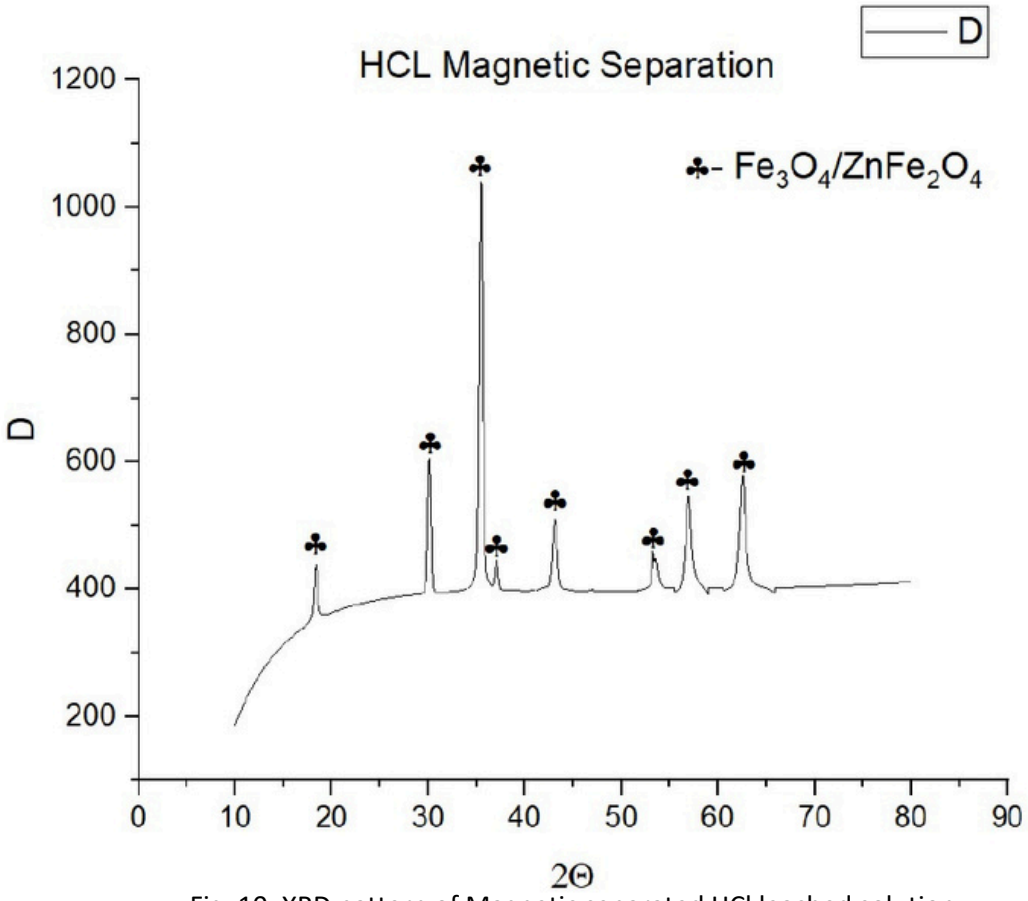


Fig. 10. XRD pattern of Magnetic separated HCl leached solution

- As assumed this solution majorly has only Frankelinite or Magnetite, as all peaks matched with it.

5. Future potential direction/scope:

i. SEM analysis is necessary for each sample to know the composition and morphology of metals so that the best reagent for dust recycling can be decided accordingly. After
ii. identification of the best reagent, need to do calculated titration for the best extraction of our desired metals. In case no reagent suites for recycling the dust, need to figure out
iii. some other reagent, either by experiment or from literature. And lastly, if everything goes in order and correctly, can be scaled up to the industry label and hence can help a lot to
iv. the stainless-steel industry from both economic and environmental points of view.