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Simultaneous Removal Of Arsenite And Fluoride From Groundwater Applying Electrochemical Coagulation Using Fe And Al Electrode Combinations- Sludge Characterization

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Abstract: Sludge is a residual semi-solid bi-product after treatment of water or wastewater by many ways. Management and disposal of water treatment sludge observed as a problem by municipalities and industries. This study investigates the characteristics of sludge using electrochemical treatment (ECT) for optimum operating conditions of 16 V cell voltage, 4 electrodes; As_0(III) 1.6 mg/L; F^-_0 12 mg/L, electrolysis time (ET) 45 min for Fe_1-Fe_2-Fe_3-Fe_4 (FFFF) and Fe_1-Fe_2-Al_3-Fe_4 (FFAF) electrode combinations for simultaneous removal of arsenite and fluoride from groundwaters. ECC sludge was subjected to proximate analysis and other physico-chemical characteristics such as SEM, EDAX, XRD, TCLP and Calorific value. The TCLP test showed that ECC sludge is non- toxic in nature for various reuse options. Based on the characterization of ECC sludge it is concluded that, ECT is a single solo novel treatment technology which is efficient in target pollutant/contaminant removal, quantity of sludge generation and its management is easy and the sludge generated can be effectively reutilized as a secondary material in various process.

Keywords: ECC sludge, proximate analysis, physico-chemical characteristics, TCLP.

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I. INTRODUCTION

Sludge is considered as a toxic waste is semi-solid residue generated after water/wastewater treatment applying different options. The composition of sludge depends on the pollution load and nature of the raw water/ wastewater and type of treatment used. In India, water treatment plant sludge is discharged directly into nearby water bodies or dumped in landfills after the dewatering process[1]. Though a simple inexpensive method of final disposal, it is not a best option because of the possibility of water contamination and soil by the chemicals used during treatment. The discharging of sludge into water body leads to accumulative rise of aluminum in water, aquatic organisms, and human bodies. Few researchers have reported aluminum's contributory influence to the occurrence of Alzheimer's disease, memory retardation in children called dementia and common effects of heavy metals accumulation[2]**.** Realizing such consequences and adverse environmental impacts, it is likely that stringent regulations pertaining to sludge would be implemented soon. Therefore, development of sustainable sludge management strategies meeting stringent environmental norms is a challenging task for environmental engineers and scientist. This grave situation initiated our interest in exploring reuse options for ECT discarded wastes/residuals.

II. LITERATURE SURVEY

Previous literature report many approaches such as adsorption, chemical coagulation, membrane filtration, electro dialysis, oxidation, biological methods etc., applied for removal of arsenic and fluoride from contaminated waters[3,4,5,6]**.** These technologies suffer from various disadvantages; for instance adsorption process is pH dependent and requires a pre-treatment step, more treatment time (hydraulic retention time - HRT), and pollutant removal efficiency reduces after each regeneration cycle and more sludge generation[7]**.** In addition disposal of the sludge produced after treatment require proper management. Several studies have been performed to manage the sludge produced by drinking water treatment plants (WTP). Reuse of sludge has been studied in different sectors especially of use in the field of construction. The potential of reusing sludge from water softening treatment unit for production of construction materials as gypsum and cement is reported[8]. Disposal problems of arsenic sludge generated during arsenic removal from drinking water is also discussed[9]. A study[10] showed that water treatment plant sludge ash be used in brick manufacturing. Mineralogical composition of the "water treatment sludge" is close to that of clay and shale is reported[11]. This fact encourages the use of water treatment sludge in brick manufacture. Another report, a cost-effective technology for arsenic soil remediation using water treatment residual particularly (Al and Fe-based) its effects and capability in reducing the human risk from arsenic[12] is reported. Sludge from the water treatment plants can be reused in bricks manufacturing[13]**.** [14]studied the possibility of replacement of ordinary water as a component of concrete by water sludge in concrete manufacturing. [15] proposed the use of a mixture consisting of sludge (85%) and sand (silicon dioxide) 15% in pottery manufacturing. [16] suggested use of sludge from Water treatment plants (WTP) as coagulant aid in flocculation to improve sedimentation and sludge improves the removal of suspended solids and phosphate. [17] proposed to reuse sludge as coagulant aid in WTP to improve water quality and reduce the coagulant consumption.

Lacunaes in conventional treatment methods lead to electro chemical coagulation processes for its novelty of high removal efficiency, easy to operate, cost effectiveness and possibility of complete automation process[18,19,20,21] . The main advantage of adopting ECC treatment is production of less quantity of sludge. This technology consists of generating metallic oxides and hydroxides that serve as adsorbents and complexing agents by anodic oxidation of anodes[22]. Co-existence of arsenic and fluoride in natural water has raised severe health issues in many countries worldwide in recent years[23]**.** Co-exposure to these pollutants lead to both endemic fluorosis and arsenicosis[24]**.**

Batch Electrochemical coagulation (BECC) studies were carried out by the same authors for different aluminum and iron electrode arrangements for simultaneous removal of arsenic and fluoride from groundwater. Of the many experiments with different Al-Fe electrode combinations Fe_1-Fe_2-Fe_3-Fe_4 (FFFF) and Fe_1-Fe_2-Al_3-Fe_4 (FFAF) electrode combination proved to be the optimal one for both arsenic and flouride, removal simultaneously, electrode dissolution, sludge generation, energy consumption and operating cost. Objectives in this work were set to investigate the properties of dewatered ECC sludge for said optimum operating conditions viz., 16 V cell voltage, 4 electrodes; As_0(III) 1.6 mg/L; F^-_0 12 mg/L, ET 45 min for Fe_1-Fe_2-Fe_3-Fe_4 and Fe_1-Fe_2-Al_3-$Fe_{4.}$. The intent was to find a suitable reuse option and to solve the sludge disposal problem. To obtain intricate forensic information, the ECC sludge were subjected to detailed analyses using SEM, EDAX, XRD, TCLP and Bomb Calorimeter tests to ascertain the characteristics. Each of the analysis are described in the following sub-sections.

III. MATERIALS AND METHODS

3.1 Sludge Sample Preparation: The sludge obtained at optimum ECC operating conditions viz., 16 V cell voltage, 4 electrodes; As_0(III) 1.6 mg/L; F^-_0 12 mg/L, ET 45 min for Fe_1-Fe_2-Fe_3-Fe_4 and Fe_1-Fe_2-Al_3-Fe_4 electrode combinations were subject to detailed characterization. The decanted slurry sludge was collected from ECC bath and dried in a hot air oven at 105 - 110°C to remove moisture from it. After complete drying, weight of the sludge was noted. The dried sludge had several lumps/cakes of solids in it. These lumps/cakes were finely ground to powder form to obtain homogeneous samples, stored in air tight plastic containers and were kept ready for analysis using XRD, SEM, EDAX, TCLP and calorific value (CV). Also proximate analysis was carried out for the same samples to determine moisture content, volatile matter, ash content and fixed carbon. Dried ECC generated sludge prepared for characterization is shown in Fig. 1.

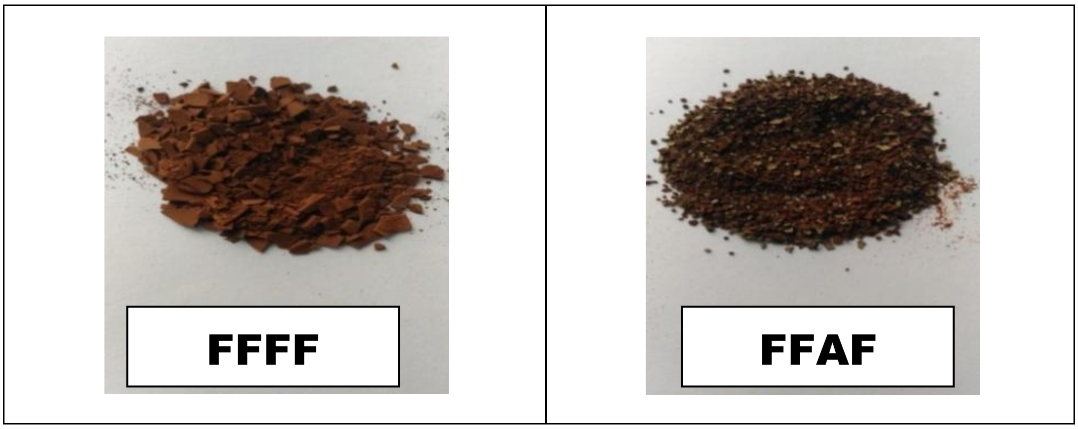

Fig: 1 Dried ECC sludge prepared for sludge characterization

3.2 Proximate analysis (PA): It determines moisture content, %, volatile matter, %, ash content,% and fixed carbon, % in the sludge. The following procedures explain the analysis adopted.

3.2.1 Moisture content (MC): Approximately 1g of finely powdered air dried ECC sludge sample is kept in the crucible and weighed as W_1 g. This crucible with sample is now placed in a hot air oven with temperature maintained at 105-110°C for 1 hour. The crucible is taken out, cooled and weighed as W_2 g. The weight loss is recorded as moisture in % using the formula shown in equation (1.1).

$$\boldsymbol{Moisture\ content}, \% = \frac{W_2 - W_1}{\boldsymbol{Weight\ of\ sludge\ sample\ taken}} \times 100 \qquad \textbf{(1.1)}$$

The dried sludge in the crucible is further used to determine the volatile matter/solids.

3.2.2 Volatile matter (VM): The dry sludge sample after finding the MC (W_2) is then covered with a lid and kept in a muffle furnace for heating at 925 $\pm$ 20°C for 7 min. After this time lapse, the crucible is taken out of the muffle furnace, air cooled and then kept in a desiccator and weighed as W_3 g. The weight loss is noted as VM in %, using the formula given in equation (1.2).

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$$\boldsymbol{Volatile\ matter}, [\%] = \frac{W_2 - W_3}{\boldsymbol{Weight\ of\ sludge\ sample\ taken}} \times 100 \qquad \textbf{(1.2)}$$

The residues remaining in the crucible after finding VM is further subject to determination of the ash content.

3.2.3 Ash content (AC): The residue remaining after finding the VM as (W_3) is again heated without lid at 700 $\pm$ 50°C for 30 min in a muffle furnace. The crucible is then taken out, air cooled, desiccated and weighed as (W_4) g. The heating, cooling and weighing processes is repeated until a constant weight of the residue is obtained. The residue is noted as AC in % using the equation (1.3).

$$\boldsymbol{Ash\ Content}, \% = \frac{W_3 - W_4}{\boldsymbol{Weight\ of\ sludge\ sample\ taken}} \times 100 \qquad \textbf{(1.3)}$$

3.2.4 Fixed carbon (FC): Determination of FC does not have any procedure/protocol to follow; it is simply obtained using a deduction procedure as shown in equation (1.4).

$$\boldsymbol{FC = 100 -}\ \%\ [\boldsymbol{MC + V\ M + A\ C}] \qquad \textbf{(1.4)}$$

3.3 Physico - chemical characterization of ECC sludge

3.3.1 Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Spectroscopy (EDAX): SEM examination of ECC sludge particles provides information on structure, morphology and texture of iron and aluminum and other materials. Elemental information in ECC sludge is obtained using EDAX. For the SEM analysis, a small representative ground sludge sample was pasted on to a copper stuffed tub using a double stick tape. The sample so prepared was observed under Alkali Flame Ionization Detector (AFID) scanning attachment for JOEL 100 TIIX transmission electron microscopes (Japan make). Samples were analysed using a probe current with primary electrons hitting the sludge sample at 20 KV at 50X magnification. EDAX is an intergrated part of SEM energy dispersion calibrated with a standard Cobalt sample before analysis.

3.3.2 Powder X-ray diffraction: The mineralogical composition of As(III) and F^-containing iron hydroxide sludge ($Fe(OH)_2$/$Fe(OH)_3$) and aluminum hydroxide sludge $Al(OH)_3$ was determined using an X-ray diffractometer (Miniflex II). Dried sludge samples were pressed into the sample holder and XRD patterns were obtained at ambient temperature using Cu Kα *(Cu/30KV/15mA)* radiation as a source and Kβ as a filter and a 2θ scan rate of 5°/min operated at a tube current of 15mA. The goniometer speed and the chart speed were maintained at 1°/min, and 1cm/min respectively. The scanning angle 2θ was at 0-60° with 0.020 degree sampling width. The intensity peaks mark the values of 2θ, by applying the Bragg's law. Identification of compounds was carried out using the International centre for Diffraction Data (ICDD) software library.

3.3.3 Toxicity Characteristic Leaching Procedure (TCLP): Extraction of Solid Waste by Acid Digestion Process: TCLP is a solid sample extraction procedure for chemical analysis employed as an analytical approach to stimulate leaching through landfills. Arsenic concentration as per Resource Conservation and Recovery Act (RCRA) if > 5.0 mg/L becomes hazardous. In our work, acid digestion method was adopted to determine various constituents in Fe_1-Fe_2-Fe_3-Fe_4 and Fe_1-Fe_2-Al_3-Fe_4 sludges at optimum operating conditions. The

TCLP procedure begins by weighing accurately 1 g sample in a 250 mL beaker. 30 mL concentrated Hydrochloric acid (HCl) and 10 ml concentrated nitric acid (HNO_3) are added into the beaker and a placed over a hot plate. The sample is digested till it completely dissolves. The solution is cooled and filtered through Whatman filter paper No.1 and diluted to 250 mL standard flask using distilled water. The digested sample solution is tested in Inductively Coupled Plasma Optical Emission spectrometer (ICPOES) for 12 parameters. The calculation is carried out using the equation. 1.5.

$$Parameter\ concentration,\ \frac{mg}{kg} = \frac{concentration\ ,\frac{mg}{L} \times Dilution\ \ factor}{Amount\ \ of\ sample\ \ taken\ ,\ \ g} \quad \textbf{(1.5)}$$

3.3.4 Calorific value (CV) of ECC sludge: A bomb calorimeter measures the quantity of heat generated when a material is burnt in a sealed chamber called Bomb in an atmosphere comprising pure O_2 gas. A known weight of sample as a pellet is taken in the crucible. The crucible is kept hanging in the bomb. The bomb is closed and filled with oxygen at a pressure of 25 kg/cm^3. The bomb is then placed in the water jacket. The electrical terminals are connected to the bomb-firing unit, connected to the power supply and the stirrer is set on. After 10 min, the bomb is fired and the initial temperature is noted. The rise in temperature is noted down continuously till it reaches to maximum temperature. The calorific value (CV) is determined using the equation. 1.6.

$$H, Cal/Kg = \frac{WT}{M} \quad \textbf{(1.6)}$$

where, H is heat of combustion of sludge, calorie/kg ;W is water equivalent of calorimeter assembly in calories/ °C; T is the rise in temperature in °C, and M is the mass of the sample burnt in g; The CV of ECC sludge for both Fe_1-Fe_2-Fe_3-Fe_4 and Fe_1-Fe_2-Al_3-Fe_4 electrode combinations.

IV. RESULTS AND DISCUSSION

ECC sludge of both FFFF and FFAF electrode combination was subjected to proximate analysis[25] and various physico-chemical characterization to determine its characteristics before further use and disposal.

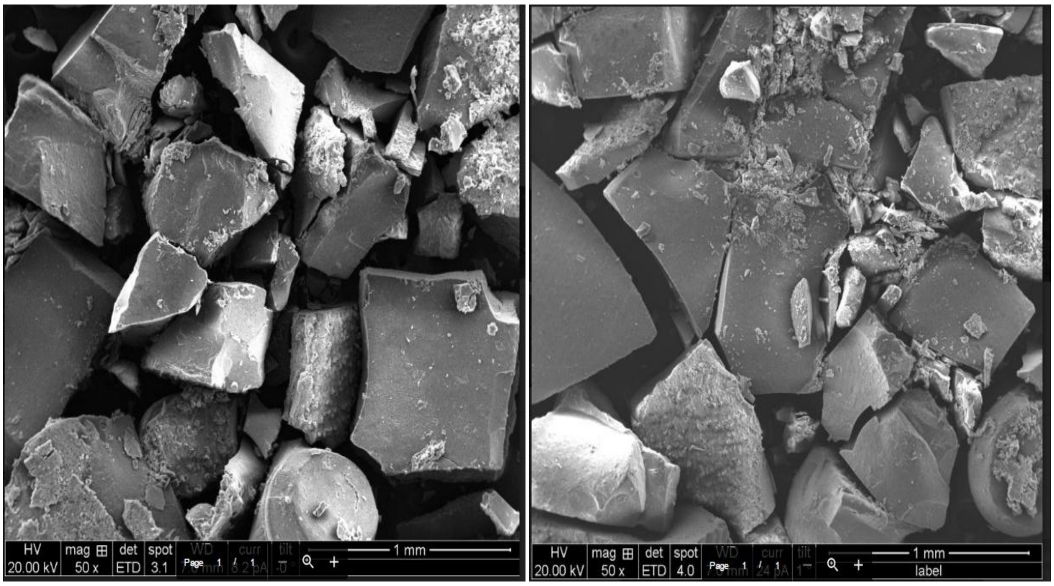
4.1 Proximate analysis: ECC sludge for the said combination was analysed for moisture content, volatile matter, ash content and fixed carbon as per the standard procedure and the results are presented in Table 1.

Table 1: Proximate analysis of ECC sludge

Sl. No.	Proximate analysis of ECC dry sludge	Unit	FFFF	FFAF	FFFF	FFAF	Indian Coal
1.	Moisture Content (MC)	%	**0.27**	**0.31**	**8.11**	**12.62**	9 - 11
2.	Volatile Matter (VM)	%	**15.11**	**26.11**	**3.66**	**3.15**	18 - 25
3.	Ash Content (AC)	%	**82.72**	**72.65**	**1.88**	**1.01**	25 - 37
4.	Fixed Carbon (FC)	%	**1.90**	**0.93**	**86.35**	**83.22**	27 - 48

Proximate analysis provides valuable information for assessing the quality of ECC sludge comparing with that of coal. It was observed that, lower the moisture better is the quality of coal. Higher VM content in coal is not desirable, because high volatile matter containing coal burns with a long flame, high smoke and has a low CV and do not cake well. Good quality coal gives low AC. A higher percentage of FC is desirable because it gives a higher calorific value. In the present work, FFFF and FFAF generated ECC sludge was subjected to proximate analysis and compared with Indian Coal. FFAF moisture content is more than that of Indian coal and FFFF is less than that of Indian coal. VM for both FFFF and FFAF is well within the Indian Coal standards. FC percentage of FFFF and FFAF is near double to that of Indian coal indicating that ECC sludge with high CV is much better than Indian coal. A similar sludge characterization study is reported by [26] for ECC sludge of black liquor and comparing with Indian coal.

4.2 Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray (EDAX): The ECC sludge sample subject to SEM analysis confirm the nature of the sludge. SEM analysis of sludge was carried out with primary electrons hitting the sample at an energy level of 20KV and at 50 X magnification. The analysis revealed morphology of the sludge showing amorphous nature because of the presence of hydroxide compounds and hence shallow peaks and diffuse peaks were observed in the XRD spectrum.

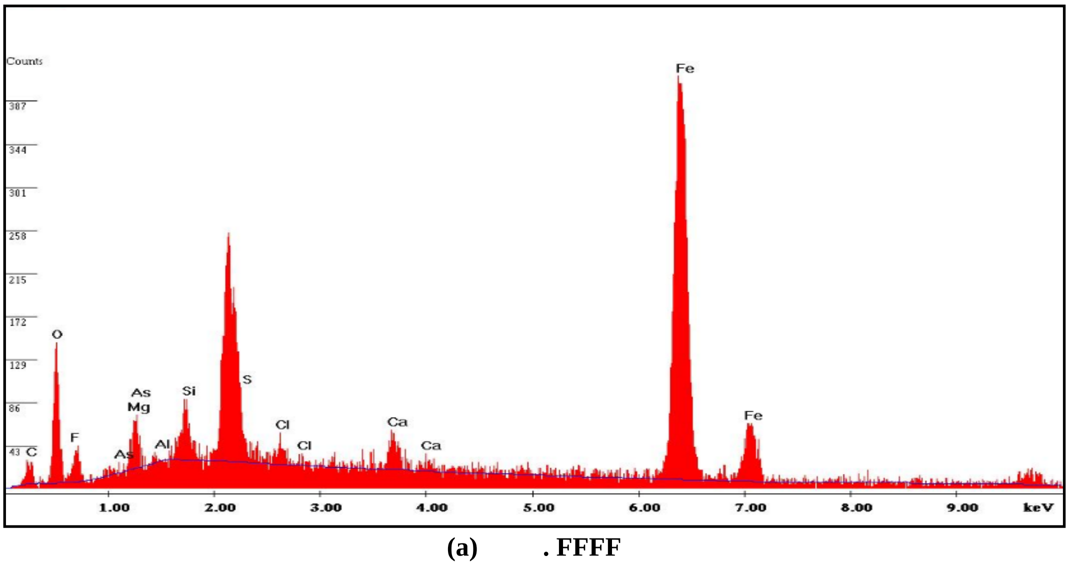


(a). FFFF **(b). FFAF**

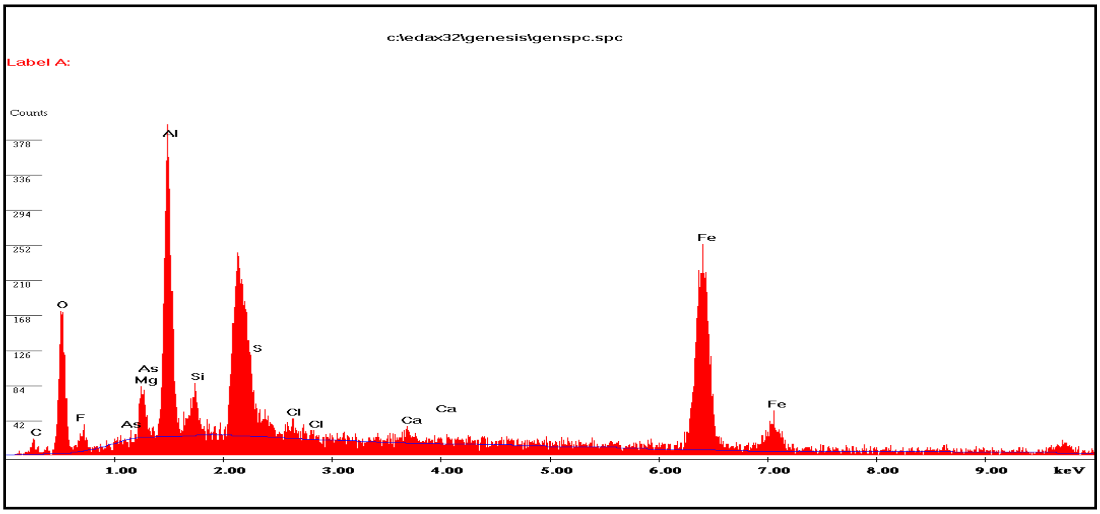
Fig: 2 SEM images of the dry sludge obtained after ECC for electrode arrangement (a) FFFF and (b) FFAF

Operating conditions: Cell voltage 16 V; no. of electrodes 4; As_0 (III): 1.6 mg/L; F^-_0 : 12 mg/L; ET: 45 min

It may be from the Fig. 2(a) and (b) that the sludge generated in the ECC process using FFFF and FFAF electrode combinations were dark brown in color for FFFF (iron) and light brown for the latter. The lighter color might be because of the whitish $Al(OH)_3$ interspaces filled with brown colored iron hydroxide by adsorption. The interaction between iron hydroxides and aluminum hydroxide is high favoring the adsorption process during ECC. ECC sludge obtained for the elemental information of FFFF and FFAF electrode combinations at optimal operating conditions were obtained from EDAX analysis.



(a) . FFFF



(b) . FFAF

Fig: 3 EDAX spectrum of ECC dry sludge for electrode combination (a) FFFF and (b) FFAF
Operating conditions: Cell voltage 16 V; no. of electrodes 4; As_0 (III): 1.6 mg/L; F^-_0 : 12 mg/L; ET: 45 min

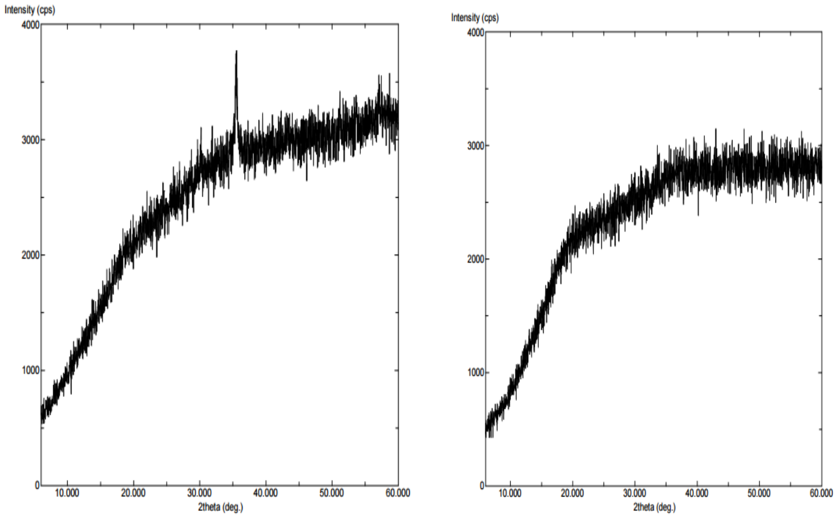
In Fig. 3(a) and (b) the peaks show that ECC sludge consists of aluminum (Al), fluoride (F^-), magnesium (Mg), iron (Fe), sulphur (S), chloride (Cl), calcium (Ca), arsenic (As), oxygen (O), carbon (C) and silicates (Si). The EDAX analysis of the sludge shows the weight (%) of elements present in it as shown in Table 2.

Table 2: Elemental composition of the ECC sludge

Element	**Weight (%)**	
	FFFF	**FFAF**
C	3.64	3.21
O	7.69	8.20
F	0.87	0.96
Mg	2.51	2.0
Al	13.77	14.10
Si	2.13	2.06
S	1.81	1.32
Cl	0.73	0.40
Ca	0.94	1.12
Fe	52.86	53.53
As	13.05	13.09
Total	**100 %**	**100 %**

Thus, the elemental analysis by EDAX carried out for FFFF and FFAF confirmed the target contaminant removal showing 0.87% fluoride and 13.05% arsenic for FFFF and 0.96% fluoride and 13.09% arsenic for FFAF. The presence of other elements such as Ca, Fe, Al, Mg, S, Si, C, F and Mg indicate successful entrapment of other pollutants/ contaminants present in the water during the ECC treatment process as a result of adsorption on the sludge matrix by M^+. The presence of other elements is from adsorption of the conducting electrolye, chemicals used, alloying and scrap impurities present in the anode and cathode[27]. By comparison of EDAX curves with the work carried out by [28]using aluminum and iron electrodes in a single cell for As removal, the sludge is seen to be amorphous with poor crystalline phases for aluminum hydroxide/oxyhydroxides (bayerite $Al(OH)_3$, diaspore, Fe_3O_4, iron oxyhydroxides (lepidocrocite (FeO(OH), magnetite (Fe_3O_4) and iron oxide. Similar findings were reported by [29] in line with our observations. One research reports that the ECC byproduct comprising of iron hydroxide and aluminum hydroxide can further be used as a hybrid adsorbents for removal of arsenic from drinking water[30].

4.3 Powder X-ray Diffraction: XRD analysis showed broad band peaks with noise due to interference of irregular reflection of the reflected monochromatic light beam throughout the prescribed 2Θ range during the analysis. The XRD scans were recorded from 0 to 60 degree 2Θ with 0.02 degree sample width and with 1 count. The experiments



(a) FFFF **(b) FFAF**

Fig 4: XRD images of the ECC dry sludge obtained after ECC for electrode arrangement (a) FFFF and (b) FFAF

Operating conditions: Cell voltage 16 V; no. of electrodes 4; As_0 (III): 1.6 mg/L; F^-_0 : 12 mg/L; ET: 45 min

were run at 30 KV and 15 mA power.

Fig 4 shows a diffractogram of the sludge obtained for FFFF and FFAF respectively. From the Fig. 4(a), it may be observed that, the spectrum of analysed byproduct showed broad and diffuse peaks upto 35 degree but at same angle a small sharp peak was noticed. On comparing with the previous research results obtained by [31], the XRD spectrum of iron sludge showed the presence of iron hydroxide oxide and lepidocrocite at 35 degree. Thus, from the XRD spectrum of FFFF, the presence of Iron hydroxide oxide and lepidocrocite showing amorphous nature was confirmed. As per the research by[32] at 35 degree, aluminum fluoride hydroxide was present in the mechanism of fluoride removal during ECC.

From Fig.4(b), the spectrum showed broad, diffuse peaks along with broad humps which confirmed characteristic phases of amorphous nature. The peaks of FFAF were compared with the XRD pattern of ECC sludge of orange dye (II) using Al electrode carried out by [33] thus the presence of Boehmite AlO(OH), bayerite $Al(OH)_3$ and Diaspore Al(OH) were identified. Thus, from the XRD spectrum, it was concluded that the sludge obtained from both the electrode arrangements were amorphous and the chemical speciation of this amorphous phase was ascribed to the presence of aluminum hydroxides, aluminum oxyhydroxides, iron hydroxides and lepidricrocite. Hernandez et al., 2009 also reported that when combined Fe and Al electrodes where used in a single electrochemical cell for As(III) removal, the sludge seems to be amorphous/poorly crystalline phases for aluminum hydroxide/ oxyhydroxides (bayerite $Al(OH)_3$), diaspore (AlO(OH) and iron oxyhydroxides (lepidricrocite (FeO(OH)), magnetite (Fe_3O_4) and iron oxide (FeO). The present analyses, reveals the phase nature of the ECC byproduct obtained for both the electrode combination FFFF and FFAF at optimum operating condition because of its irregular reflection from the samples that appeared in the form of noise confirmed the amorphous nature of the ECC by-products.

3.4 Toxicity Characteristic Leaching Procedure (TCLP): Extraction of Solid Waste by Acid Digestion Process

The TCLP was developed by the USEPA (1992) to simulate leaching of metals and organic compounds from solids under severe temperature and pressure conditions from landfills. TCLP tests were carried out on the ECC sludge for the said electrode combinations. Table 3 shows metal concentrations in the ECC sludge for both FFAF and FFFF electrode combination and TCLP regulatory limits and heavy metal concentrations in the sludge in mg/L.

Table 3: TCLP characterization for FFFF and FFAF electrode combinations

Sl. No.	Characteristics	Unit	Schedule II Class A of Hazardous Waste and other waste (Management & Transboundary Movement) Rules 2016	FFAF	FFFF
1.	Arsenic as As	mg/L	5.0	3.29	3.14
2.	Iron as Fe	mg/L	---	1237.9	1863.3
3.	Aluminum as Al	mg/L	---	298.86	1.19
4.	Copper as Cu	mg/L	25.0	0.541	0.892
5.	Zinc as Zn	mg/L	250.0	10.29	2.10
6.	Manganese as Mn	mg/L	10.0	2.33	2.92
7.	Lead as Pb	mg/L	5.0	0.031	0.21
8.	Cadmium as Cd	mg/L	1.0	0.024	0.30
9.	Nickel as Ni	mg/L	20.0	0.052	0.116
10.	Chromium as Cr	mg/L	5.0	0.507	0.183
11.	Barium as Br	mg/L	100.0	0.047	0.031
12.	Silver as Ag	mg/L	5.0	bdl*	bdl*
13.	Fluoride as F^-	mg/L	180.0	0.906	0.950

Note: bdl*: below detection level

Very low concentrations of metals were detected compared to the regulatory limits of the metals with values at acceptable levels. The results obtained are in agreement with the findings of the Florida Department of Environmental Protection which states that water treatment sludge do not contain pollutants that may pose threat to humans or to the environment[33]. By comparing the characteristics of ECC sludge for FFFF and FFAF with the Schedule II Class A of Hazardous waste and other waste (Management and Transboundary Movement) Rules 2016, all the parameter values were well within the limits with conclusions drawn that the ECC sludge treating arsenite and fluoride is non-hazardous.

3.5 Calorific Value of arsenic and fluoride laden ECC sludge

Calorific value (CV) of ECC sludge obtained after batch experiments with FFFF and FFAF were determined using a Bomb caloriemeter giving values of 212.9 Kcal/Kg and 230.23 Kcal/Kg respectively.

3.6 ECC Sludge Utilization Option

ECC sludge being non- hazardous its utilization of ECC sludge in a scientific and secured manner play a key role in environmental management. In this regard, Mahesh et al., 2006 discussed ECC generated sludge management by utilization in making fuel briquettes which can be fired in the boilers to recover its energy value. Also the utilization of bottom ash after combustion may be blended with organic manure for use in agriculture/horticulture fields. [35] reported that the bottom ash obtained after its combustion can be blended with cementitious materials for use in construction purpose inline with the same [36] has also discussed the same. [37] investigated using arsenic contaminated sludge in making ornamental bricks recommending a proportion of sludge in ornamental bricks at 4 % by weight to produce good quality ornamental bricks.

V. CONCLUSION

Arsenic and fluoride contaminated groundwater was effectively treated using the electrochemical coagulation process using Al and Fe electrodes at optimal operating electrode combinations at the optimum operating condition i.e. 16 V cell voltage, 4 electrodes; As_0(III) 1.6 mg/L; F^-_0 12 mg/L, ET 45 min for Fe_1-Fe_2-Fe_3-Fe_4 (FFFF) and Fe_1-Fe_2-Al_3-Fe_4(FFAF). This electrode combinations were more efficient in removal of both arsenite and fluoride simultaneously within 45 min of ET. The ECC sludge was subjected to proximate analysis and other physico-chemical characteristics such as SEM, EDAX, XRD, Calorific value and TCLP test ensured that the ECC sludge is non- toxic and same can be further reused for brick manufacturing, pottery manufacturing and cement brick blocks etc., This research work showed that the ECC sludge management and disposal can be made eco-friendly.

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