

# Synthesis of Zirconia in Cement (Zir-Cem) and Study of Adsorption of EDTA on Zir-Cem



Ajay Kumar Mishra, B S Panigrahi

**Abstract:** The important problem to address in nuclear industries involves mitigation of the radioactive and corrosion products of nuclear reactor components. Even though physical and chemical methods lend a helping hand in solving this problem, the dominant method is by carrying out chemical cleaning. But this process results in the metal ions in complex state, not viable for treatment. To render the metal ions in the free state advanced oxidation process using oxidizing agents like ozone, Hydrogen peroxide, electro flotation, supercritical oxidation etc can be resorted. The decontaminating agents used are picolinic acid, EDTA, ascorbic acid, NTA etc. EDTA complex the metal ions but generate secondary waste with them. In our work, treatment of generated decontaminated waste using EDTA as decontaminant has been dealt with. From the literature, we understand that attempts have been made to degrade ethylene diamine tetraacetic acid using Fenton's reagent in the presence of light [1]. This will facilitate the release of free radioactive ions for further treatment. In addition to chemical oxidation of EDTA, photochemical oxidation in presence of Zirconia and titania which generates electrons and positive ions for further oxidation has been reported [2]. In this paper, we have made an attempt to absorb the EDTA on zirconia loaded on white cement, study the adsorption characteristics which is the first step for photodegradation using UV light. Zirconium oxide was synthesized by the sol-gel method using Zirconium isopropoxide to water ratio 1:2 which resulted in powder by this process. This Powder was characterized for physical and chemical parameters before immobilizing with cement for adsorption. The system containing cement bonded to Zirconia (Zir-Cem) was subjected to removal of EDTA by adsorption. Since the zirconia powder as generated was found to have a high surface area compared to heat-treated (470°C and 720°C resulting in monoclinic and tetragonal crystalline forms) the as prepared zirconia was found to be the best candidate for efficient adsorption.

**Keywords:** Sol-gel, ZrO<sub>2</sub>, Surface Area, and Adsorption.

## I. INTRODUCTION

We know corrosion products and impurities are transported into the nuclear steam generator by feed water during the operation of the Pressurized Water Reactor. Since the accumulation of these deposits will hinder power production it is imperative to resort to the chemical cleaning process.

For the removal of contamination from the nuclear components, dilute amino carboxylic acids, oxidising reducing agents to remove oxide layer [3] have been applied. Photochemical oxidation of EDTA complexed with radioactive ions is the preferred method for freeing the metals rendering it amenable for treatment. This method involves adsorption of the complexant as the initial step which has been envisaged, carried out and presented in this paper. Ethylenediaminetetraacetic acid is not easily biodegradable, scarcely degradable by chlorine and hardly retained by activated carbon filters [4-5]. In the present study, adsorption of EDTA on zirconia prepared by sol-gel technique has been reported. Metal ion-EDTA complex gets adsorbed on Zirconia, Our study is confined to the first step of oxidation of EDTA by photochemically which adsorption of EDTA on Zir-Cem. We have confined our studies to adsorption of EDTA only. Since the strength of radioactive metal ion is so less (ppt level), we have taken into consideration the only adsorption of EDTA a. So the process includes adsorption of EDTA containing radioactive ions in small concentrations. The second step involves photochemical oxidation of EDTA alone resulting in free radioactive ions for further treatment. After adsorption of complexant and its photochemical oxidation resulting effluent containing radioactive ions in the Free State can be subjected to treatment and fixed in cement. [6] Also, zirconia can be regenerated for further usages for the adsorption of EDTA on the zirconia which can be photochemically oxidized. Zirconium oxide as formed results in high surface area. Hence it can be used for the adsorption of complexants such as EDTA. The application of Zirconia was chosen for this purpose since it aids in the adsorption of complexant due to its characteristics viz. its chemical stability, non-toxicity, low cost, and reusability. The EDTA which is used as a complexant for the removal of fission products can be oxidized photochemically using zirconia bonded to white cement (Zir-Cem) as an adsorbent. [6] The first step in the photochemical oxidation involves adsorption of EDTA on Zir-Cem and subsequent photochemical oxidation. [7] Since plenty of literature is available on photochemical oxidation, we have given importance to optimization of maximum adsorption of EDTA on zirconia only. In this connection, a study on the preparation of zirconia by sol-gel method, anchoring of zirconia on white cement, characterization of the resulting product with respect to TG/DTA, XRD, SEM, FTIR, BET surface area were studied [8]. Also, the condition for maximum adsorption of EDTA on the above product was optimized. Zirconium oxide as formed results in a high surface area. The amount of adsorption and recovery of EDTA was carried out using UV-Visible spectrophotometer.

Manuscript received on 19 August 2022 | Revised Manuscript received on 05 September 2022 | Manuscript Accepted on 15 October 2022 | Manuscript published on 30 October 2022.

\*Correspondence Author(s)

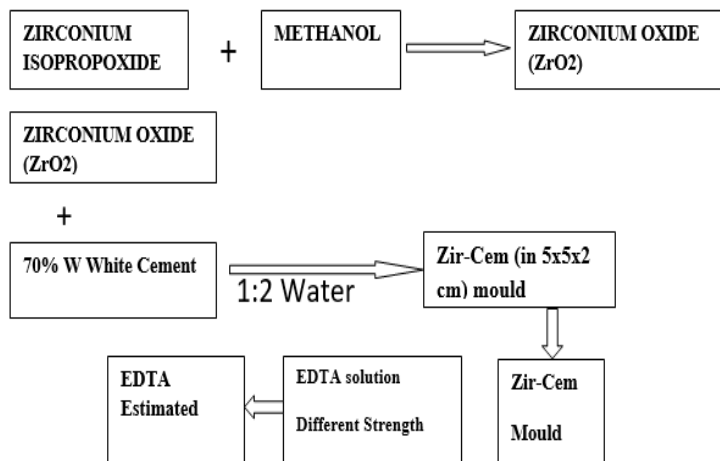
Ajay Kumar Mishra\*, Centralized Waste Management Facility, Department of Atomic Energy, Bhabha Atomic Research Centre Facilities, Kalpakkam (Tamil Nadu), India. E-mail: [aju612@gmail.com](mailto:aju612@gmail.com)

B. S. Panigrahi, Indira Gandhi Center for Atomic Research, Kalpakkam (Tamil Nadu), India.

©The Authors. Published by Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP). This is an open access article under the CC-BY-NC-ND license: <http://creativecommons.org/licenses/by-nc-nd/4.0/>

# Synthesis of Zirconia in Cement (Zir-Cem) and Study of Adsorption of EDTA on Zir-Cem

## Block diagram for Zirconia in Cement (Zir-Cem) and Adsorption of EDTA on Zir-Cem



## II. MATERIALS AND METHODS

### 1.1. Chemicals

Zirconium isopropoxide (ZIP) procured from sigma Aldrich was used as a Zirconium oxide precursor. Methanol was used as a solvent for the synthesis of ZrO<sub>2</sub> precursor, distilled water was used for hydrolysis and formation of Zirconia, white plaster cement procured from M/s Navakar chemicals, Chennai was used for attaching Zirconium oxide powder. For characterization of zirconia, we have used XRD of make PAN analytical, the Netherlands for elucidating the crystallinity, which is a prerequisite for functioning as an adsorbing medium. FTIR study was carried out for elucidation of the types of bonds with the adsorbent and to ensure the bonding of EDTA with zirconia. To study morphology, the surface area of zirconia, which is required for effective adsorption of EDTA surface area meter, was used. The anchoring of EDTA by adsorption over zirconia for further photochemical oxidation is a necessary condition. In this connection, it is to be emphasized that in photochemical oxidation, the first step involves adsorption of EDTA over zirconia bonded to cement(Zir-Cem). Zirconium oxide powder in white gel form was characterized by TG/DTA (D2100, Thermo analyzer, Delaware, USA) for its thermal stability behavior. Surface area analyzer (EI, Quanta 200, was used for finding out the surface area since it plays a major role in the adsorption.

## III. EXPERIMENTAL

### 2.1. Synthesis of zirconium oxide powder via sol-gel method

Zirconium oxide powder was synthesized (ratio of water to ZIP= 2) via sol-gel method using RB flask & refluxed at 70°C. Hydrolysis of the ZIP was carried out by water to produce the Zirconium oxide powder. The white suspension was filtered and dried at 200°C for 1 hour and calcined to 470 °C and 720°C for 1 hour.

### 2.2. Preparation of Zirconium oxide powder anchored on white cement (Zir-Cem)

The white plaster cement was used for immobilizing Zirconium oxide because it has good workability, improved adhesion, very fine structure, easy availability, and cheap in cost. 30 gm Zirconium oxide powder was mixed with 70gm

of white cement to obtain 30 w/w percentage of Zirconium oxide powder. Zirconium oxide powder and cement were mixed homogeneously with water as a binder and poured in the Aluminum mold of 5 x 5 x 2cm and placed in drier for drying process. The FTIR study was carried out to find out the extent of bonding of zirconia with cement and extent of adsorption of EDTA on the anchored zirconia with cement. Then adsorption of EDTA was carried out using the above mold. Parameters like Effect of initial concentration of EDTA, Study of adsorption isotherm, Kinetic study of adsorption of EDTA were carried out to get insight into the adsorption of EDTA using a cement bonded Zirconium oxide powder adsorbent (Zir-CEM). Figure 4d shows FTIR of EDTA bonded to Zir-Cem at room temperature and heated to 470°C and 720°C respectively.

### 2.3 Characterization of zirconium oxide powder anchored on white cement (Zir-Cem)

The surface area of Zir -Cem as prepared and heat treated to 470 oC and 720 oC were carried out using nitrogen adsorption method.

Table 1 Surface area as function of temperature

S. No.	Temperature (°C)	Surface area(m <sup>2</sup> /gm)
1	As prepared (27)	200
2	470	150
3	720	40

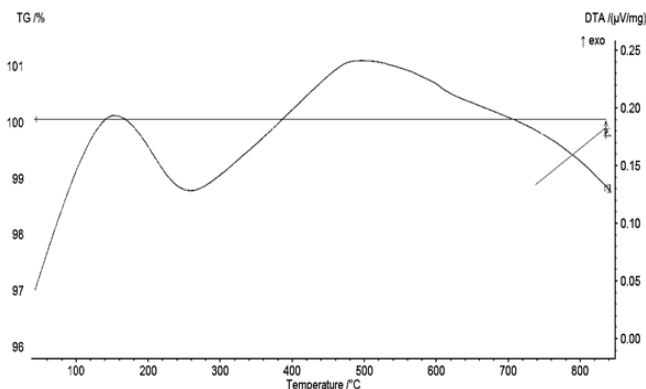


Figure 1. TG/DTA of Zir-Cem as prepared



Fig.2 shows XRD of Zirconia, Zirconia included with cement (Zir-Cem) and Zir-Cem with EDTA

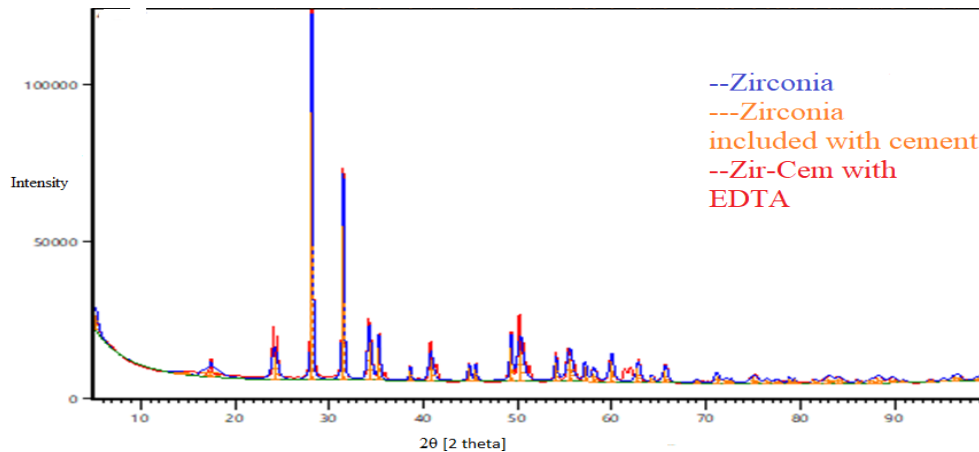


Fig. 2 XRD of Zirconia as prepared and heated to 470°C

Fig 3a, shows FTIR of as prepared zirconia at room temperature heated 470 °C and 720 °C. Figures 3b, 3c show FTIR of as prepared zirconia included to cement at room temperature heated 470 °C and 720 °C. and figure 3d show FTIR of EDTA bonded to Zir-Cem at room temperature Zir-Cem heated 470 °C and heated to 720 °C.

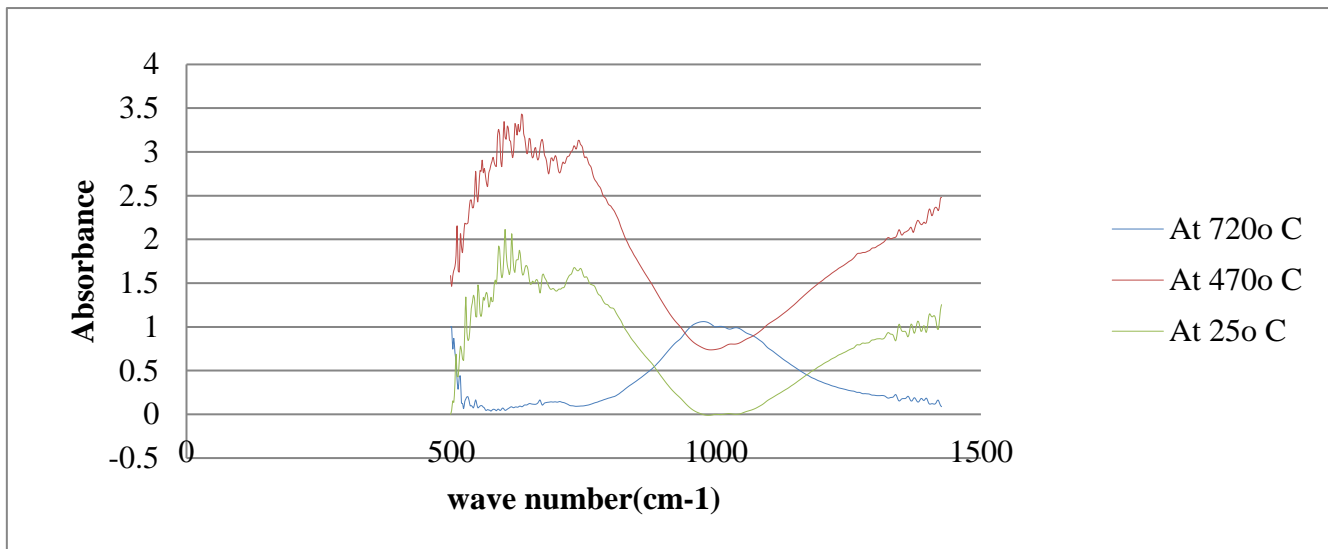


Fig. 3a: FTIR of Zirconia at different temperature

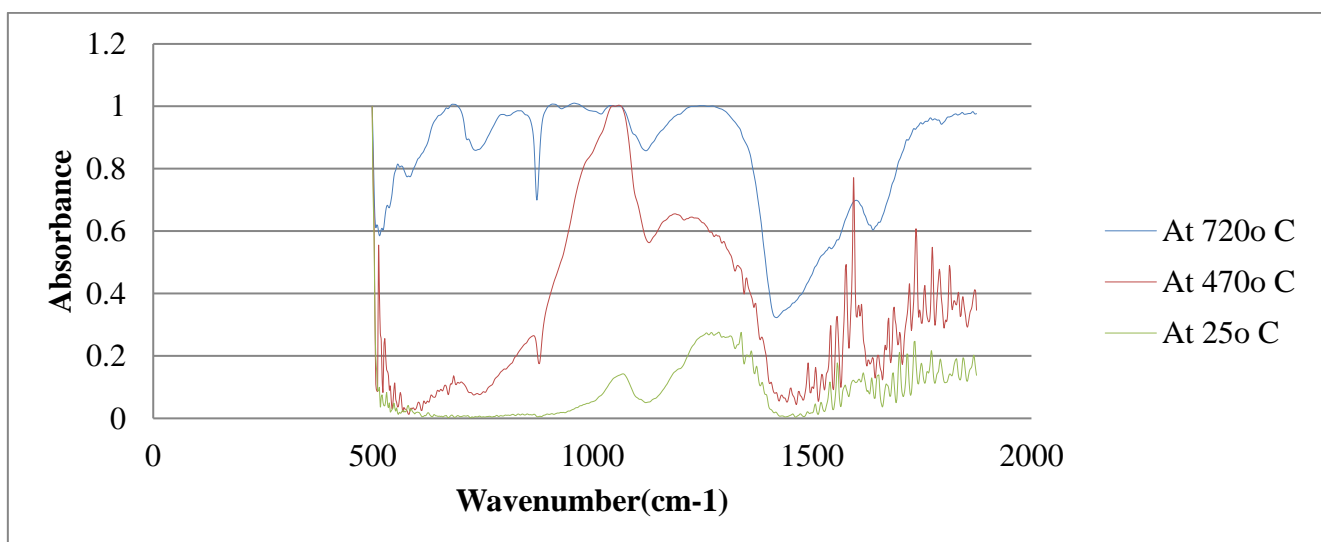


Fig. 3b: FTIR of Zirconia bonded with cement (Zir-Cem) at different temperature

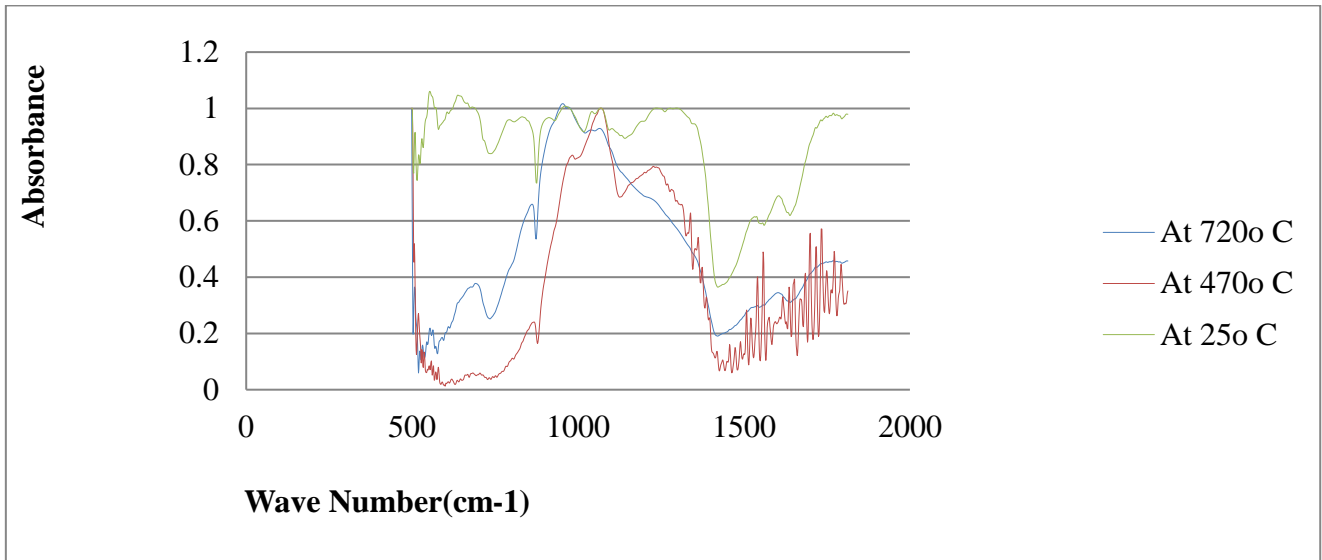


Fig. 3c. FTIR of Zirconia bonded with cement (Zir-Cem) with EDTA at different temperature

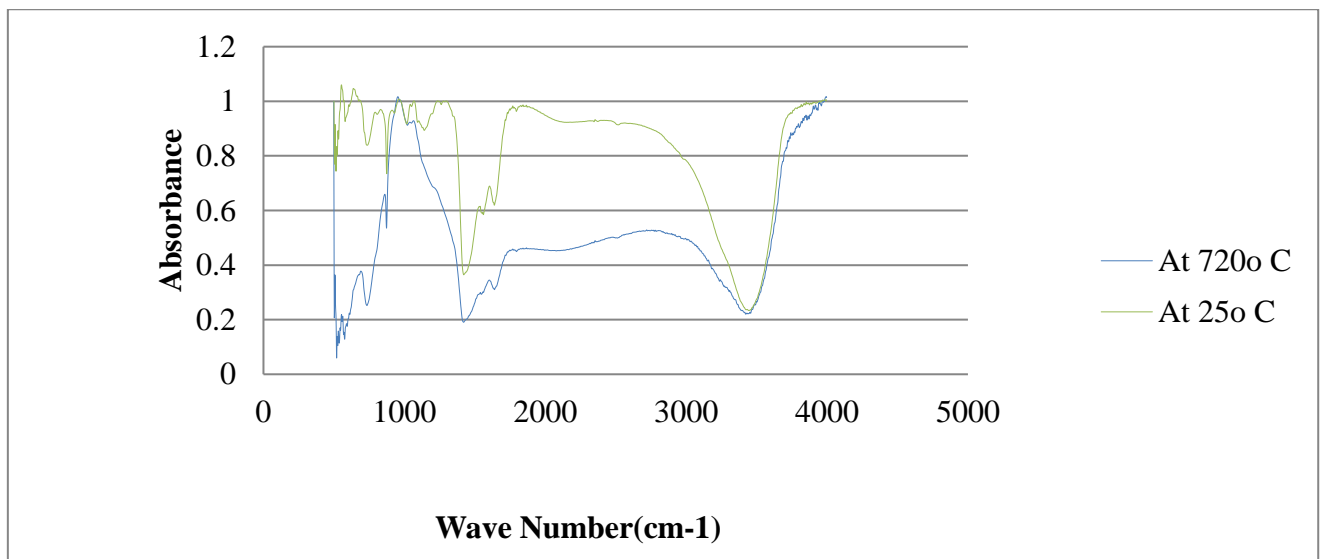


Fig. 3d. FTIR of Zirconia bonded with cement (Zir-Cem) with EDTA at 25°C to 720°C temperature

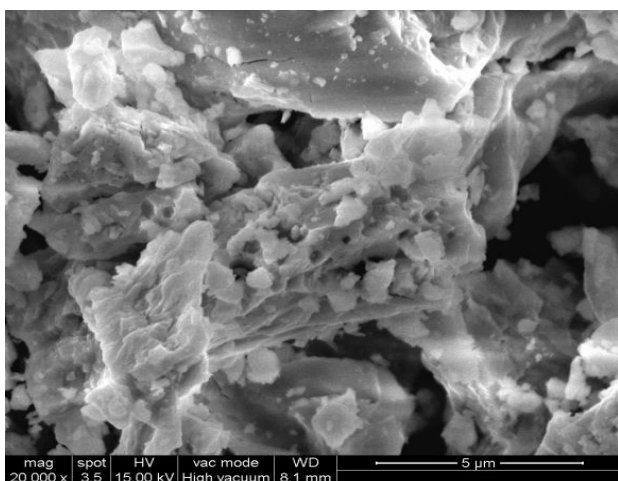


Fig. 4a, SEM of Zir-Cem as prepared

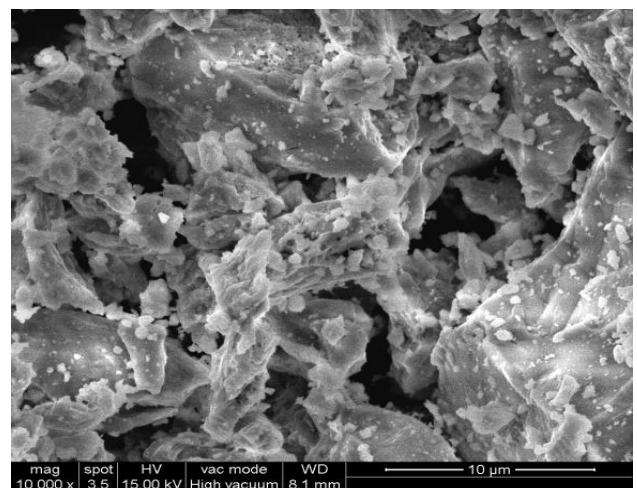


Fig. 4b SEM of Zir-Cem as heated 470°C

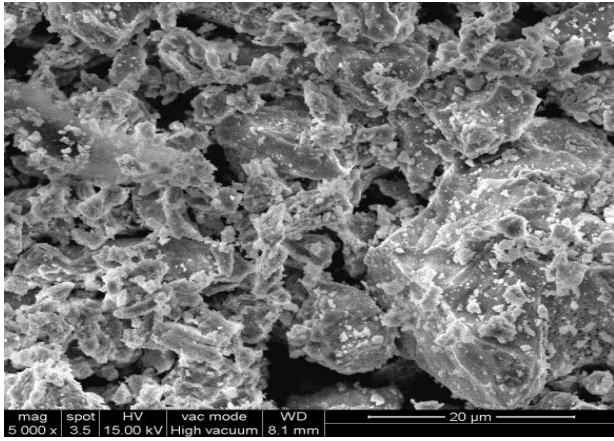


Fig. 4c SEM of zirconia as prepared and heated to 470°C.

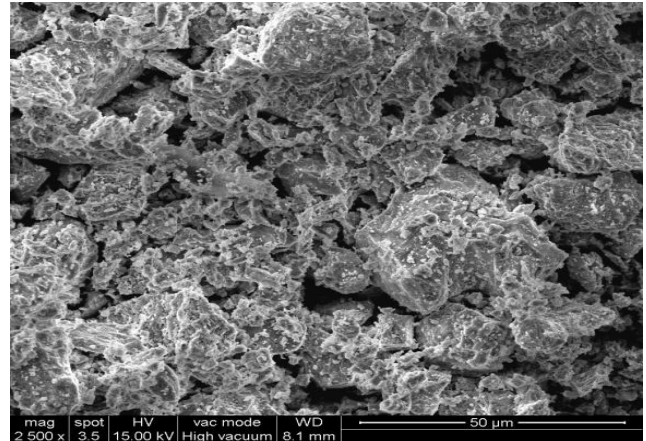


Fig. 4d. SEM of Zir-Cem as heated 720°C

**2.4. Effect of pH on the adsorption of EDTA:** Since adsorption involves electrostatic interaction between negatively charged EDTA with the charged surface of zirconia it is imperative to study the effect of pH on the extent of adsorption. The pH of the medium has a strong influence in imparting a charge to the surface. 1g of cement anchored with zirconia as prepared was taken in 5 different beakers and treated with 100 ml of 200ppm EDTA adjusted to pH 2, 4, 6, and 10. The experiments were repeated with 400 ppm, 600 ppm, 800 ppm and 1000 ppm and stirred for continuously for one hour. Unadsorbed EDTA was estimated and the percentage EDTA adsorbed was plotted as a function of various initial concentrations of EDTA. (fig 5).

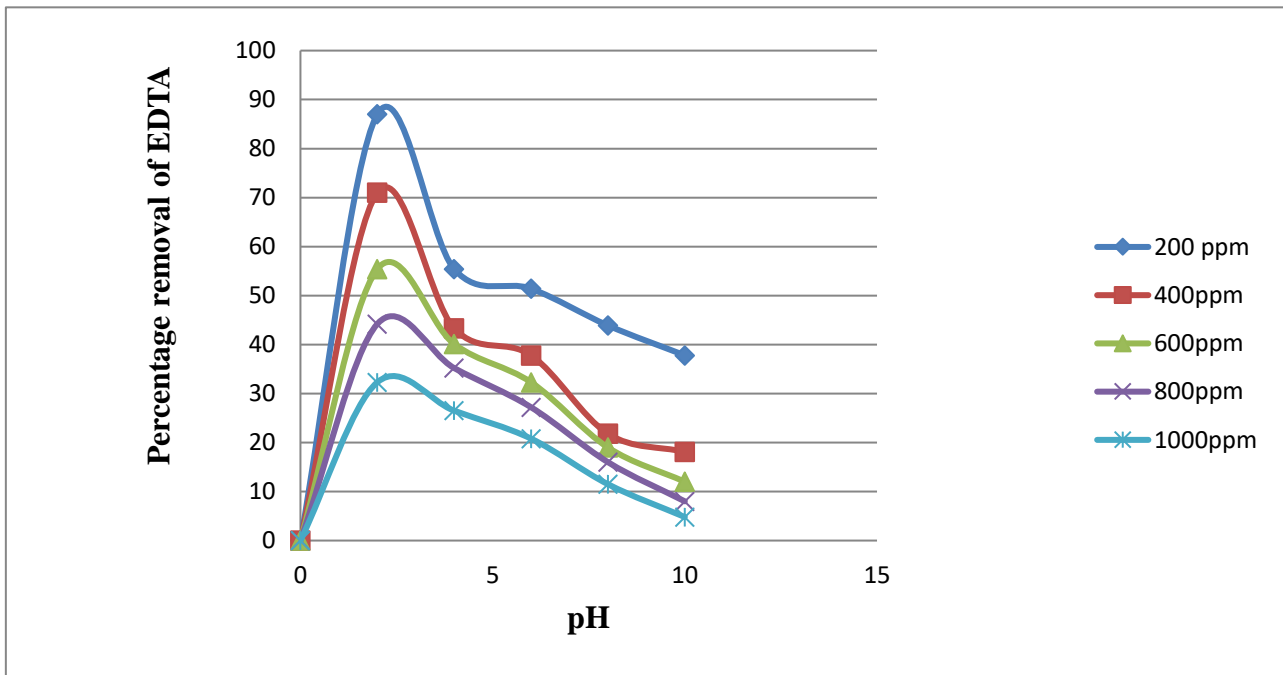


Fig 5: Percentage removal of EDTA as function of pH

**2.5. Estimation of particle charge density of the Zirconia powder (Zir-Cem) anchored to white cement:** Since pH of the medium plays an important role in the adsorption process, it is imperative to study the effect of pH on the adsorption. Also the electrostatic charge on the particle has profound influence in the adsorption. An attempt was made to estimate the particle charge density of Zir-Cem as function of pH.

**2.5.1 Estimation of particle size**

1 g of zirconia anchored to white cement (Zir-Cem) was taken in five different beakers, pH of water in contact with the Zir-Cem adjusted to 1.2, 2.8, 4.1, 8.8, and 11.6 using pH meter. It was stirred and the Particle size of Zir-Cem powder was estimated using a particle sizer. Figure 6 shows the particle size of the powder as the function of pH

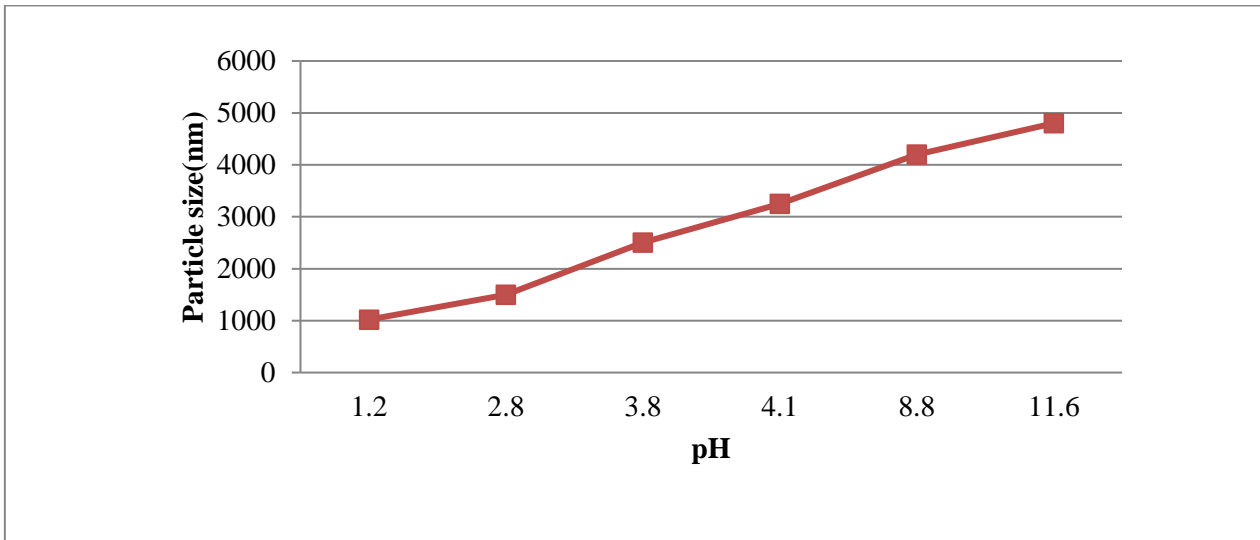


Fig. 6: Particle size as function of pH

**2.7 Estimation of zeta potential of the Zir-Cem powder.** 1 gm of zirconia anchored to white cement (Zir-Cem) was taken five in different beakers. pH of water in contact with the zirconia powder was adjusted to 1.2, 2.8, 4.1, 8.8 and 11.6 using pH meter. It was stirred. Zeta potential was estimated in each case. The table shows the Zeta potential of (Zir-Cem) powder as a function of pH

Table 2 shows Zeta potential of Zir-Cem at different pH

S.N.	pH	Zeta potential(mV)
1	1.2	10.2
2	2.8	6.3
3	4.1	1.89
4	8.8	-9.8
5	11.6	-15.01

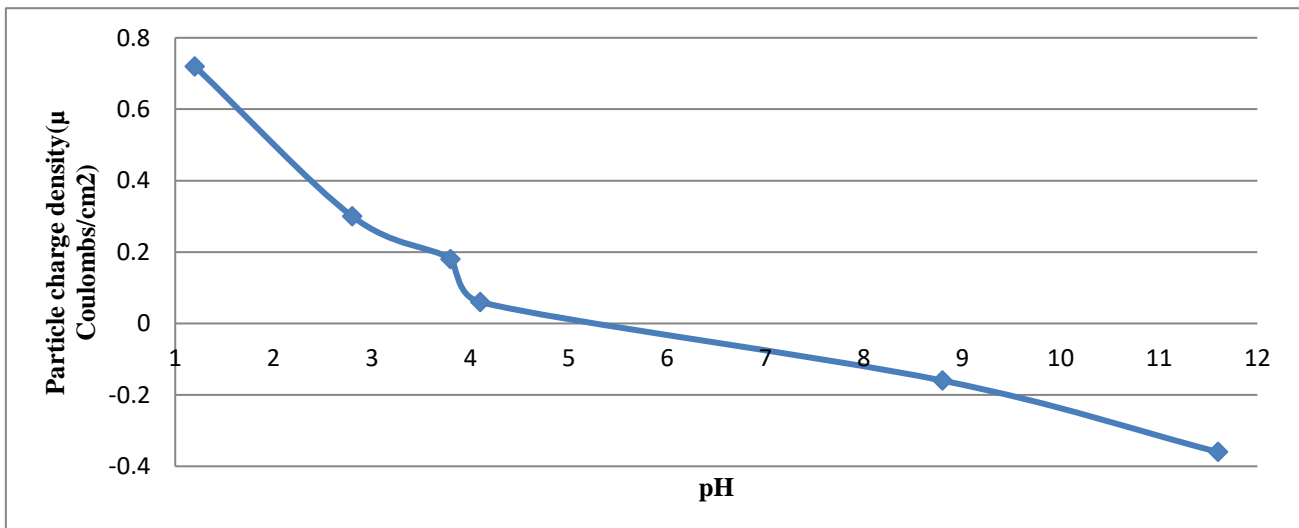
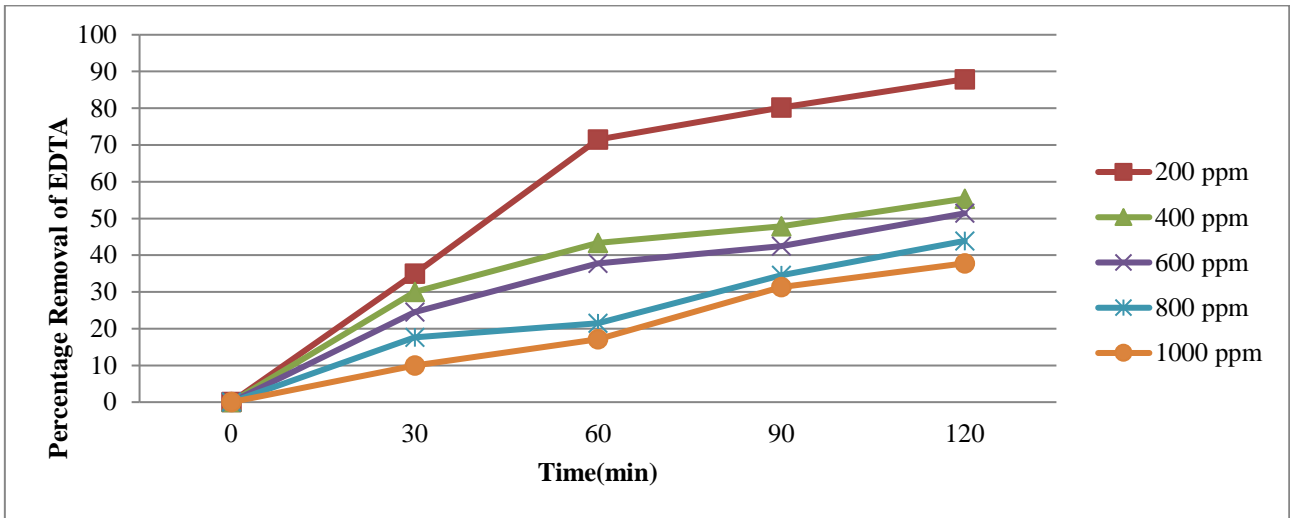


Fig. 7. Shows particle charge density of Zir-Cem powder as function of pH.

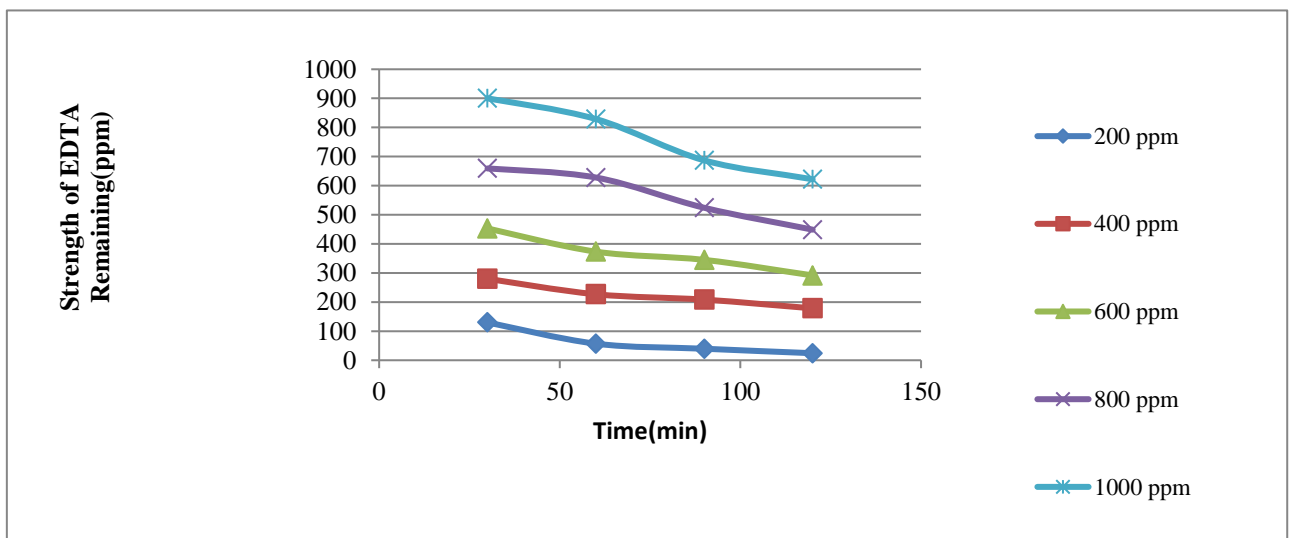
**2.8 Effect of initial concentration of EDTA**

Since the initial strength of EDTA is a vital parameter to estimate the efficacy of adsorption of EDTA on Zir-Cement bonded to white cement (Zir-Cem), experiments were carried out to study the rate of removal of EDTA by Zir-Cem. 1 g of zirconia bonded to white cement was taken in five different beakers and treated with EDTA solutions of strength 200,400,600,800 and 1000 ppm. Sampling was done at 30 minutes intervals. The un adsorbed EDTA was estimated and the percentage removal of EDTA was plotted as a function of time. (Figure 8)



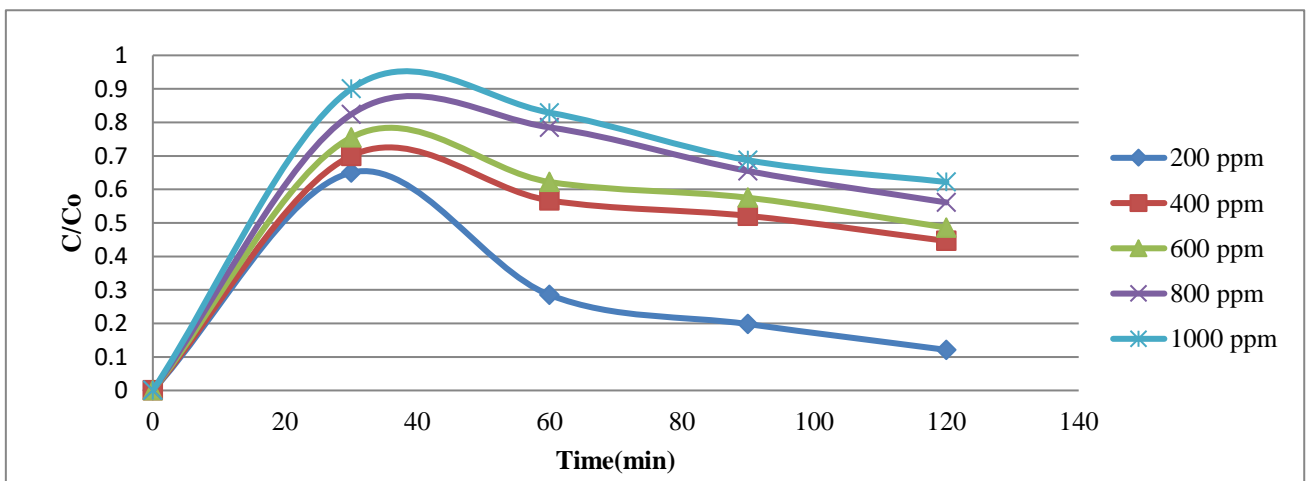
**Fig.8 Percentage Removal of EDTA as function of time using 1g of Zirconia loaded on cement (Zir-Cem)**

The strength of remaining EDTA was plotted as function of time (Figure 9).



**Fig9. Strength of EDTA remaining as function of time on 1gm Zirconia loaded on cement (Zir-Cem)**

Figure 10 shows the plot of  $C/C_0$  as function of time where C and  $C_0$  represent remaining and initial strength of EDTA. Fig 11 shows  $\ln C/C_0$  as function of time.



**Fig10 Strength of EDTA remaining(C) to initial strength (Co) as function of time on 1gm Zirconia loaded on cement**

Figure 11: shows plot of  $\ln C/C_0$  as function of time on 1gm of Zirconia loaded on cement at different strength of EDTA



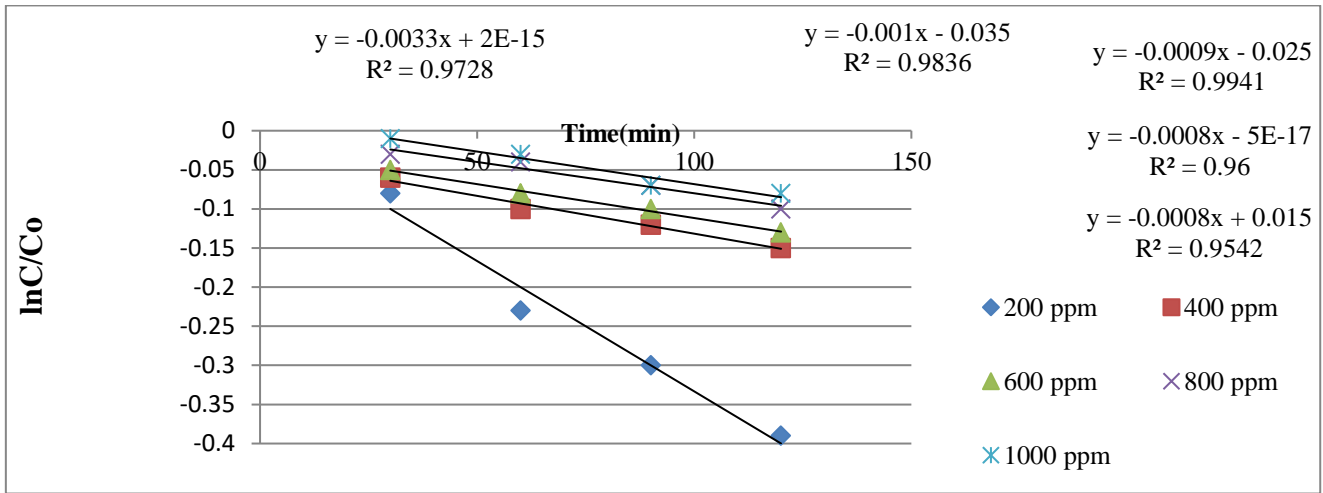


Fig. 11  $\ln C/C_0$  as function of time on 1gm of Zirconia loaded on cement at different strength of EDTA

**2.8 Removal EDTA as a function of wt of Zir-Cem:** In order to study the effect of zirconium oxide anchored on cement as adsorbent for the removal of EDTA experiments were carried out using different weights of the adsorbent (1,2,3,4, and 5g) and different strength of EDTA (200ppm,400ppm,800ppm and 1000ppm). Figure 12 shows percentage Removal EDTA as a function of wt of Zir-Cem

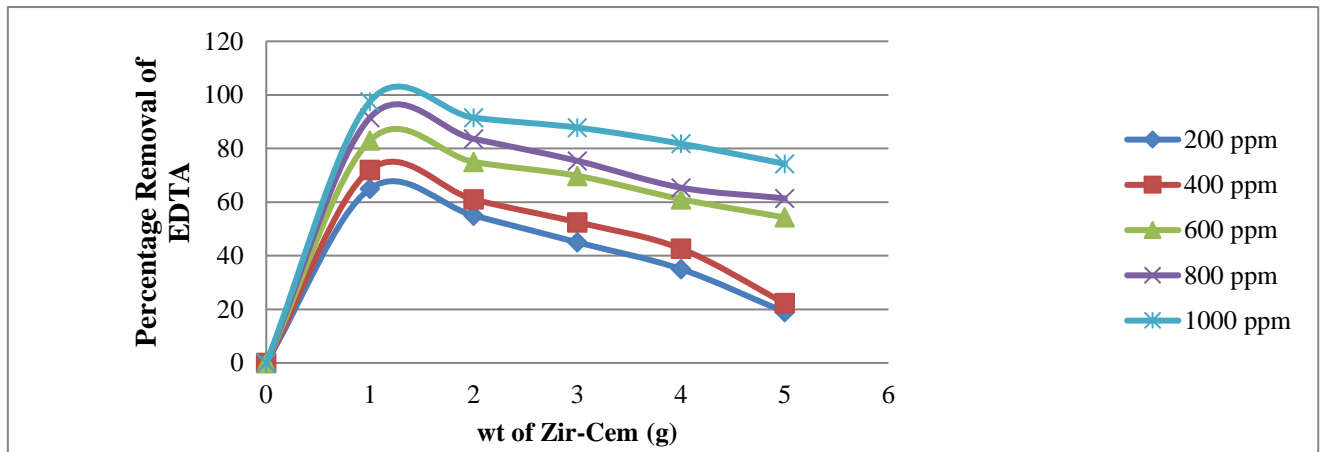


Fig. 12: Percentage Removal EDTA as a function of wt of Zir-Cem

**2.9. Adsorption isotherms of EDTA on Zir-Cem:** Since temperature plays an important role in the adsorption phenomena it is imperative to study the adsorption of EDTA on Zir-Cem bonded to white cement. 1 g of zirconia bonded to white cement was treated with EDTA solutions of strength 200-1000 ppm thermostated at 40°C, 50°C, 70°C, and 90°C with stirring. Sampling was done after one hour. The amount of EDTA adsorbed per g of adsorbent as a function of the equilibrium strength of EDTA was plotted for each temperature. Figure 13a to 13d shows Adsorption isotherm of EDTA on  $ZrO_2$  at 40°C, 50°C, 70°C and 90°C

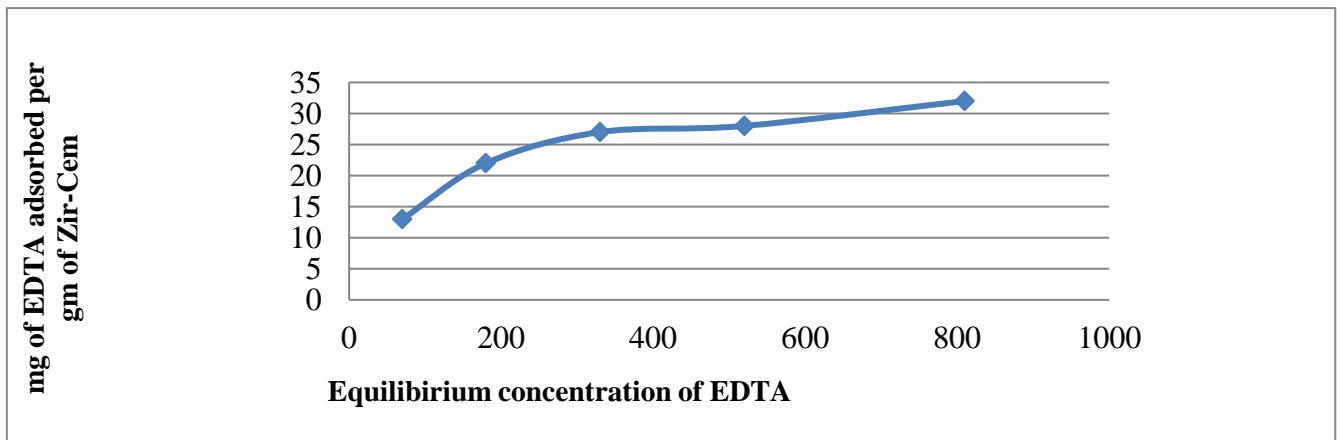


Fig 13a: Adsorption isotherm of EDTA on Zir-Cem at 40°C



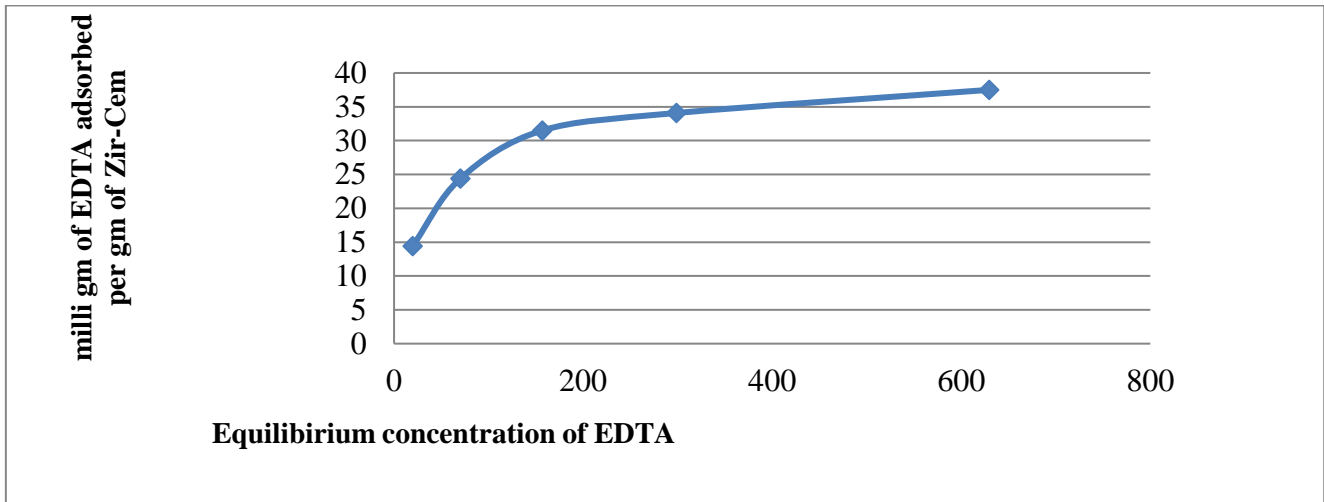


Fig. 13b: Adsorption isotherm of EDTA on Zir-Cem at 50°C

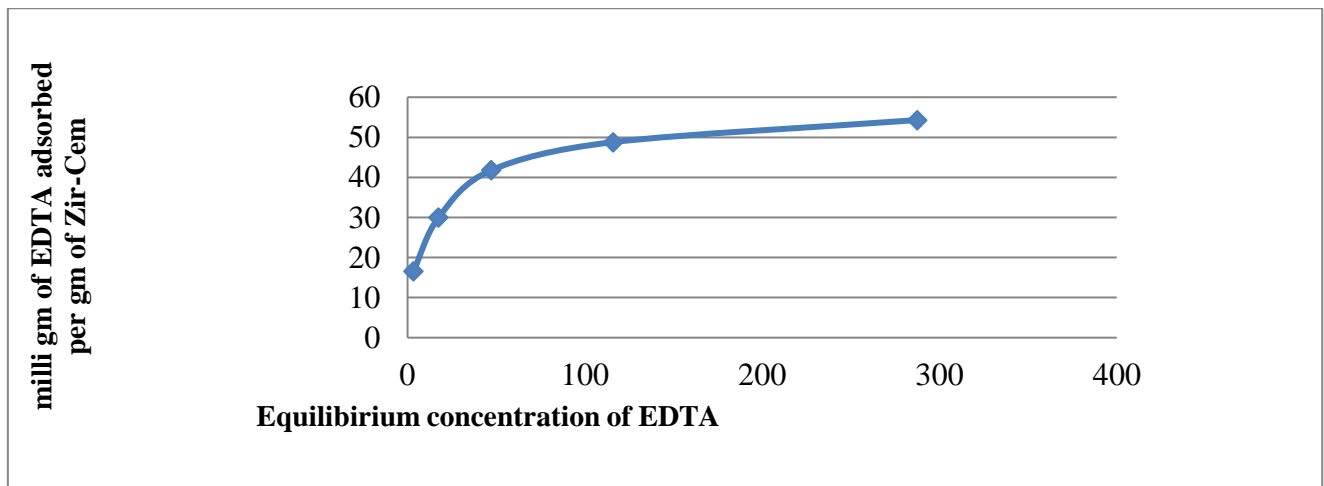


Fig. 13c: Adsorption isotherm of EDTA on Zir-Cem at 70°C

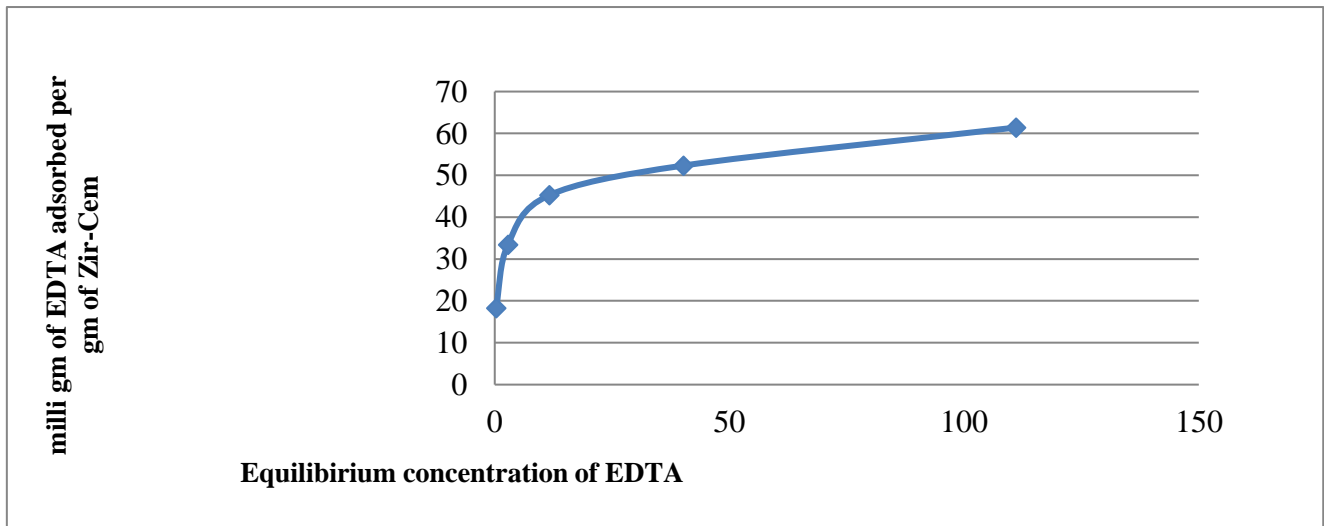


Fig. 13d: Adsorption isotherm of EDTA on Zir-Cem at 90°C

#### IV. RESULTS AND DISCUSSION

##### 3.1 Zirconium oxide powder bonded to cement (Zir-Cem) characterization:

From table 1 we find that the surface area of the Zir-Cem particles is 200, 150, 40 m<sup>2</sup>/gm at temperatures 27°C, 470°C, 720°C. Hence we infer that surface area decreases with the temperature. Because of heat treatment, the particles come closer fused to form bigger particles resulting in less surface

area at a higher temperature. Therefore it is understood that the Zir-Cem as formed without heat treatment is a suitable candidate for adsorption at room temperature. Particle size measurement shows that powder has a particle size in the range of 1020 to 4800 nm with a mean particle size of 2878nm.

Figure 1 shows the TG/DTA curve of Zir-Cem oxide powder. weight loss occurs at a temp below 150°C due to evaporation of volatile species of water & methanol. Subsequent wt loss due to removal of inorganic compounds occurs at 300°C. Fig.2b shows the XRD pattern of Zir-Cem powder The crystallization transition from amorphous to monoclinic phase occurs at 420°C and tetragonal at 720°C. The powder shows the highest peak at 28 degrees in 2θ showing that powder is pure of monoclinic crystal structure having higher crystallinity at 470°C.

FTIR of Zir-Cem shows a pattern similar to what Hung-en-et-al and wang et al reported. Hung-en-et-al reported  $ZrO_2$  sub microspheres with Zr-O stretching mode at a wave number of about 568  $cm^{-1}$ . Wang-et-al. also observed a strong adsorption band of Zr-O-Zr in the range of 400-850 $cm^{-1}$ . the FTIR Zir-Cem bonded with EDTA shows Shift Zr-O frequency by 10  $cm^{-1}$  indicating bonding of EDTA with Zir-Cem by adsorption.

From the SEM images, we find that Zir-Cem powder has spherical shape particles having a smaller particle size in conformity with the nitrogen adsorption technique.

### 3.2 Effect of pH

Since pH of the medium plays a strong role in the adsorption of EDTA, the study on the effect of pH on the adsorption of EDTA was carried out. From the fig5 we find that adsorption of EDTA increases from pH 1 to 2 and afterwards decrease with pH. This may be due to a more positive charge imparted on the surface Zir-Cem at low pH for the adsorption of negatively charged EDTA. Figure 5 shows the Percentage removal of EDTA was found to be 37.5-87, 71-18.1, 55.4-12, 44.2- 8, and 32.2 - 4.8 percentage in the pH range 2-10 for initial concentrations of EDTA in the range 200-1000 ppm.

### 3.3 Effect of the initial concentration of EDTA solution degradation

From fig 6 we find that the adsorption of EDTA is more at the lower concentration of EDTA due to the larger availability of active sites on the surface of Zir-Cem. The adsorption is less at a higher concentration of EDTA. From fig 6 we find that percentage removal of EDTA of strength 200, 400, 600, 800, 1000 ppm was found to be 88 to 38 and percentage degradation of EDTA was found to be 32 percent to 88 percentages.

Figure 7 shows the Strength of EDTA remaining after adsorption on Zir-Cem loaded on cement

### 3.4 Studies on the Kinetics of adsorption.

Figure 8 shows the percentage removal of EDTA as a function of pH. Figure 8 Shows the Percentage removal of EDTA was found to be 35-87.9, 30-55.4, 24.5-51.4, 17.6-43.9, and 30 - 37.8 percentage for the duration of 30-120 min for initial concentrations of EDTA in the range 200-1000 ppm. Figure 9 shows the strength of EDTA remaining as a function of time for various initial concentration of EDTA was found to be 130-24.2, 280-178.4, 453-291.6, 659.2- 448.8, and 900-622ppm for the duration of 30-120 min for initial concentrations of EDTA in the range 200-1000 ppm. Figs 10 and 11 show  $C/C_0$  and  $\ln C/C_0$  as a function of time at various initial strength of EDTA (where

$C_0$  and C refer to initial and strength at any intent of time). Figure 10 shows the strength of EDTA remaining(C) to initial strength( $C_0$ ) as a function of time on 1gm Zirconia loaded on cement found to be 0.65-0.121, 0.7-0.446, 0.755-0.486, 0.824 – 0.561, and 0.9-0.622  $C/C_0$  for the duration of 30-120 min for initial concentrations of EDTA in the range 200-1000 ppm.

Figure 11 shows the strength of EDTA remaining(C) to initial strength( $C_0$ ) as a function of time on 1gm Zirconia loaded on cement found to be -0.08 to -0.39, -0.05 to -0.15, -0.05 to -0.13, -0.03 to - 0.1 and -0.01 to -0.08  $\ln C/C_0$  for the duration of 30-120 min for initial concentrations of EDTA in the range 200-1000 ppm. We find a linear trend in the graph of  $\ln C/C_0$  against time, which shows the first-order nature of adsorption.

### 3.5 Effect of the weight of adsorbent:

Figure 12 shows the Percentage removal of EDTA as a function of wt of Zirconium oxide is found to be 65 - 19.1, 72 - 22.3, 83 – 54.3, 91.5 – 61.4, and 97.5 – 74.3 using 1,2,3,4,5 g of the adsorbent for initial concentrations of EDTA in the range 200-1000 ppm. Hence percentage adsorption increases with increased wt of adsorbent, because of the availability of the more active site and more surface area.

### 3.6 Adsorption isotherms of adsorption of EDTA:

Figs 13a to 13d show milli gm of EDTA adsorbed per gm of adsorbent as a function of equilibrium strength of EDTA. The adsorption studies of EDTA at 40, 50, 70 and 90°C show features of Langmuir nature of adsorption evidencing physical adsorption. It enables desorption and so recovery of EDTA. But since our study needs the release of radioactive ion from EDTA for further treatment the physisorbed EDTA complex can be subjected to degradation using the photochemical method. Researchers in the photochemical degradation of organics have found that adsorption is the first step in photodegradation.

### 3.7 Estimation of particle charge density of the Zir-Cem

The study on the estimation of particle charge density on the surface of Zir-Cem helps in the understanding of the adsorption phenomenon. This was done by estimation of particle size and zeta potential of the particles as a function of pH. The particle size of Zir-Cem as prepared was found to be 1000 to 5000nm in the pH 1-11. Zeta potential was found to decrease from pH 1 to 4.1 on the positive side and in the alkaline range further increase on the negative side. Using particle size and zeta potential, particle charge density was estimated.

The particle charge density of particle equilibrated in aqueous solution of specified pH was estimated with measured zeta potential( $\psi$ ), the particle diameter(d), dielectric constant( $\epsilon$ ), of the medium(78.5 for water,) and X(where  $1/X$  is the effective thickness of double layer surrounding the particle. Using the equation

$$\sigma = \frac{\psi \epsilon \left(1 + \frac{x_d}{2}\right)}{2\pi d} \quad (1)$$

X was calculated using equation

$$X = \left(\frac{\sum 4\pi C_i z_i^2 e^2 N}{\epsilon_T \times 1000 K_B}\right)^{1/2} \quad (2)$$

Where  $\epsilon$  is the dielectric constant of the medium (78.5 for water),  $C_i$  is the concentration in moles/lit. Of the  $i^{\text{th}}$  species,  $K_b$  is the Boltzmann constant ( $1.38 \times 10^{-16}$  erg/deg),  $N$  is the Avogadro number ( $6.022 \times 10^{23}$ ),  $e$  is the electronic charge ( $4.8 \times 10^{-10}$  e.s.unit).

The particle charge density is found to be 0.7 to -0.4 microcol/cm<sup>2</sup> in the pH range 1-11. Showing zero charge at pH around 5. Since EDTA is negatively charged, positive charge on the particle at lower pH of the medium helps in better adsorption.

## V. CONCLUSION

We have investigated the synthesis of Zirconium oxide powder for adsorption via the sol-gel method using Zirconium isopropoxide as a Precursor. The Zirconia was synthesized and immobilized in cement powder and characterized physiochemically.

It was found that the adhesion of ZrO<sub>2</sub> powder with cement was quite a good paving way for adsorption and amenable for further photochemical degradation of EDTA.

## REFERENCES

1. Chitra S, Sandhya C, Sasidhar P, Lal KB and Amalraj RV .Ind. J Env. Pro 1991,11(9),689-692.
2. H Seshadri et al Photocatalytic degradation of liquid waste containing EDTA Distelation vol 232 issue1-3 2006 p139-144 [CrossRef]
3. Rufus AL, Sathyaseelan V, Velumurgan S, Narasihman S V ; 2004 IAEA Vol(43)1, P47-53 [CrossRef]
4. Hinck ML, Ferguson J, Puhaakka J, Wat. Sci. Tech 1997,35(2-3),25-31. [CrossRef]
5. Brauch HJ, Schullerer S, V. Vom Wasser 1987,69,155-164.
6. Rosikova K, John J, Danacikovas-Popelova E, Sebesta F, Hooper EW. In Proceedings of 4th institute for International Cooperative Environmental Research, Florida State University, Tallahassee FL.1998, 379-385.
7. L. Wang, Young chun, Zhou ,and Junjin Zhang, American Society, 2017, 31, 9
8. Oing-He Zhang, Yu-Oi Feng and Shi-Lu-Da, The Japan Society For Analytical Chemistry 1999 Vol.15 P 767-772 [CrossRef]

## AUTHOR PROFILE



**Ajay Kumar Mishra**, born in Uttar Pradesh, India completed his Master in Science (Chemistry) from Annamalai University in 2008 and Ph.D. from University of Madras in 2021. At present he is a working at Bhabha Atomic Research Centre Facility, Kalpakkam (Tamil Nadu), India. His field of interest is environmental, development of new materials, characterization, application of various processes in nuclear and chemical industries and Water chemistry

mail: [aju612@gmail.com](mailto:aju612@gmail.com)



**Bhabani Shankar Panigrahi**, born in Odisha, India completed his Master in Science (Chemistry) from Berhampur University in 1983 and Ph.D. from University of Madras in 2001. At present he is a retired scientific officer from Indira Gandhi Centre for Atomic Research, Kalpakkam (Tamil Nadu), India. His field of interest is lanthanide luminescence, Thermo luminescence and power plant water chemistry.