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*International Journal of Current Research*
*Vol. 5, Issue, 03, pp. 704-710, March, 2013*

**INTERNATIONAL JOURNAL OF CURRENT RESEARCH**

**ISSN: 0975-833X**

**RESEARCH ARTICLE**

# SEQUESTRATION OF URANIUM (VI) FROM AQUEOUS SOLUTIONS USING BREWERY YEAST (*Saccharomyces cerevisiae*)

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**ARTICLE INFO**

***Article History:***
Received 16th December, 2012
Received in revised form
28th January, 2013
Accepted 11th February, 2013
Published online 19th March, 2013

***Key words:***
Biosorption,
Equilibrium Isotherms,
Kinetics,
FTIR.

**ABSTRACT**

The biosorption mechanisms of Uranium to active chemical groups on the cell wall matrix of the nonliving fungi, *Saccharomyces cerevisiae* were examined by Fourier-transform infrared (FTIR) analysis and scanning electron microscopy (SEM). Based on FTIR study, the biomass was subjected to chemical modification of its amino and carbonyl groups, to examine their roles in the U (VI) removal from the aqueous phase. After investigating biosorption potential of acid and base treated biomass, base treatment was found to enhance the metal removal ability of untreated biomass. Meanwhile, Biosorption conditions were optimized in batch system. The percentage removal was observed at optimum pH of 5, biosorbent dose of 10g/L, initial metal concentration of 100mg/L, contact time of 75 minutes and particle size of 100µm. Sorption isotherms were interpreted in terms of Langmuir, Freundlich and BET models. Equilibrium data fitted well to Langmuir model and Uptake kinetic followed pseudo-second order model. In conclusion, the maximum biosorption potential of non living *S. cerevisiae* can be harnessed by using base treated biomass under optimized set of functional conditions.



## INTRODUCTION

Heavy metals and Radionuclides released from various industrial and mining processes are the major pollutants in marine, ground, industrial and even treated wastewater (Martin *et al*., 2006). These pollutants are of significant environmental concern due to their recalcitrance and consequent persistence due to non-biodegradability and bioaccumulation property. Among all, Uranium is one of the most seriously threatening heavy metal because of its high toxic, chemical and radiological characteristics. As 55% of world production came from underground mines, excessive amounts of uranium have found their ways into the environment through the activities associated with the processing of uranium ore. At a grade of 0.1% uranium, 99.9% of the material is left over (Peter Diehl, 2011). Uranium mining, milling, processing, enriching and disposal all have the potential to contaminate ground water. It has been calculated that civilian industries, as a consequence of their nuclear programs based on enriched uranium, have amassed worldwide 1.2 million tons of useless depleted uranium (NEA-IAEA, 2001). Uranium is a long live radionuclide with suitable radioactive daughter products which can pose a human health and ecological risk. Uranium (VI) is thermodynamically stable in ground waters and interacts strongly with solid phases. U (VI)-particle interaction governs the transport of U (VI) and ultimately the fate and distribution of uranium in the subsurface.

In drinking water the chemical properties of uranium are of greater concern than its radioactivity. The Health Canada guidelines of Canadian drinking water quality have established a maximum acceptable concentration (MAC) of 0.020 mg/l. Ground water is the major source of drinking water in many parts of India. Mining and processing of low grade uranium ore (<0.04% $U_3O_8$), in cluster of mines spreaded in the region and centralized ore processing plant at Jaduguda in east-Singhbhum region of Jharkhand in India, contributes a lot in contamination of nearby ground water. In addition, natural and anthropogenically accelerated Uranium mobilization also occurs in the area with high natural background Uranium concentrations. All uranium mixtures (natural, depleted and enriched) in the region, have found to have chemical effects on living organisms. (Vishnu, 2010). Large amount of uranium can react with tissues and can cause kidney disease, tubular degeneration and necrosis. It is not known to cause cancer but the daughter progeny formed after its decay, have that potential. Threat of heavy metal or radionuclide pollution is slowly becoming a reality all over the world. Thus necessitating the monitoring of exposure level and remedial measures before it is too late. Fortunately, these aspects have received the global attention of scientists in recent years. Multidisciplinary research projects are underway worldwide to remediate heavy metal or radionuclide pollution.

Various techniques developed for their removal are chemical precipitation, ion exchange, flocculation, sand filtration, chemical oxidation and reduction, evaporation, concentration, electrolysis, carbon adsorption, sludge separation, reverse osmosis and membrane separation (Crini, 2006). Conventional methods had significant disadvantages which include incomplete metal removal, high capital cost, high reagent or energy requirements and generation of toxic sludge or other waste products that require disposal (Goksungar *et al*., 2005). These disadvantages, together with need for more economical and effective methods for recovery of metal, have resulted in development of alternative separation technologies. In this endeavor, biosorption, a biological method of environmental control, has emerged as an alternative to conventional effluent treatment methods as it has advantages of low operating cost, effective in dilute solutions, generates minimum secondary waste, completes within short time period and have no toxicity limit for heavy metals (Ahalya *et al*., 2003). Biosorption is the term that describes the removal of heavy metals by passive binding to biomass from aqueous solution. Biosorption is attractive since naturally occurring biomass or spent biomass from various fermentation industries can be effectively utilized (Gupta *et al.*, 2000). These advantages have served as potential incentives for promoting biosorption as viable clean up

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technology for heavy metal pollution. Certain fungi, bacteria, algae and certain abundant seaweed can be used as biosorbent. (Vijayaraghavan *et al.*, 2008, Dhankhar. and Hooda, 2011). Fungal biosorption have been studied extensively because of the availability of large amount of waste fungal biomass from fermentation industries and the amenability of microorganisms to genetic and morphological manipulation. Bisorption potential of fungi like *Rhizopus, Aspergillus, Streptoverticillum, Phanerochaet, penicillium* and *Saccharomyces* have been explored many times (Pakshirajan *et al*., 2010, Wang *et al.*, 2010, Merugu *et al*., 2012, Yan *et al.*, 2012). *Saccharomyces cerevisiae* have found to be the efficient biosorber of heavy metals like Au, Mn, Cu,Co, Pb (Lin *et al*., 2005, Parvathi *et al*., 2007, Mishra *et al.*, 2009). In light of this, present study has been carried out to investigate the chemical characteristics relevant to metallic ion sorption by the fungal biosorbent. The associated functional group in this interaction has been analyzed through FTIR analysis. The biosorption mechanism was also investigated in terms of kinetics and more information was gained by Scanning electron microscopy (SEM). Finally, the biosorption potential of *Saccharomyces cerevisiae* for removal of uranium from aqueous solution have been elucidated by analyzing the *e*xperimental parameters affecting biosorption process such as pH, biosorbent dose, initial metal concentration, contact time and particle size were studied. The equilibrium biosorption data were evaluated by Freundlich, BET and Langmuir Isotherms.

## MATERIAL AND METHODS

### Chemical, reagents and analytical methods

All the chemicals used were of fine analytic grade and the chemicals were supplied by Qualigen Fine Chemicals (Bombay, India). Stock metal solutions of U (VI) were prepared by dissolving appropriate quantities of uranyl acetate salt in double distilled water. The stock solutions were diluted further with deionized distilled water to obtain working solutions of different concentrations. Uranium estimation was carried out by spectrophotometric method by using arsenazo (III) dye according to Khan, 1992.

### Development of Biosorbent

Pure culture of S. *cerevisiae* were obtained from I.A.R.I., New Delhi and were routinely maintained by streaking on rose bengal agar medium and incubated at 25˚C. For mass culturing, *S. cerevisiae* was cultivated in liquid medium using the shake flask method. Spores and mycelium from the spread plate cultures were transferred to 250 ml Erlenmeyer flasks containing 100 ml growth medium. This growth medium had the following composition (g/l): Bactodextrose, 20; Bactopeptone, 10; NaCl, 0.2; $CaCl_2.2H_2O$, 0.1; KCl, 0.1; $K_2HPO_4$, 0.5; $NaHCO_3$, 0.05; $MgSO_4$, 0.25; $Fe(SO_4)_2.7H_2O$, 0.005. The pH of the growth medium was adjusted to 4-5 using 1N HCl before autoclaving. Once inocubated, the flasks were shaken on a rotary shaker at 125 rpm for five days at 22±2˚C. The cultures grew as discrete pellicles. Harvesting of biomass was carried out by filtering the cultured medium in the shake flask through a 150 µm sieve. Once harvested, the biomass was washed with deionized water. Non-viable biomass was obtained from cultured cells by heating at 80ºC in an oven till their weight become constant. The dried samples were ground and sieved through the variant pore sizes as per requirement. The biomass thus obtained is untreated biomass. In order to generate active site and enhanced biosorption, the biomass was treated with 0.1N NaOH for 6 hrs at 30˚C. The treated biomass was collected by centrifugation at 2500*g for 10 minutes. Then the biomass was washed twice with extra pure double distilled water. After washing, the biomass was dried at 60˚C in an aluminium foil till weight of biomass become constant. It was ground and sieved through screen with pore size of 100µm and stored at 60˚C.

### Batch biosorption procedure

All uptake experiments were performed by suspending the biosorbent in 100 ml of metal solution at desirable pH, biosorbent dose, initial metal concentration, contact time and particle size. Sorption contact experiments with metal-bearing solutions were run in duplicate with a blank undergoing the same treatment. *Optimization of pH***:** In order to evaluate the effect of pH on metal uptake, the pH of the solution was adjusted in the range between 1 to 10 viz. 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 before mixing biomass. The pH was adjusted to the required value with 1N HCl and 1N NaOH. Initial concentration of metal ion was 100 mg/L and biosorbent dose was 1g/100 ml at 27˚C. *Optimization of adsorbent dose:* The adsorption experiment was carried out in 100 ml of 100mg/L U (VI) solution, in which the adsorbent dose varied from 0.25 to 2g. After 2 h of adsorption, the concentration of U (VI) in the solutions was analyzed.

*Optimization of Initial metal concentration:* The batches were set at different initial concentrations of U (VI) ions from 25 to 300 mg/L at biomass dose of 1g in 100ml of 100mg/L solution at 27˚C.

*Optimization of contact time:* For optimization of contact time required for the sorptive separation of uranium at biosorbent surface from aqueous solutions (1 g) was equilibrated with test solutions (100 ml at the temperature of 27˚C) containing metal ions at the concentration of 100 mg/L for contact time of 15, 30, 45, 60, 75, 90, 105, 120, 135 and 150 minutes.

*Optimization of particle size:* In order to evaluate the effect of particle size of biosorbent on metal uptake the biosorbent particles of different size viz. 100, 200, 300, 400 and 500 µm were treated with solution having an initial concentration metal ions of 100 mg/L and biosorbent dose of 1gm/100 ml at optimized temperature and pH. The degree of sorption was determined by measuring the concentration of metal ion in the aqueous phase before and after contact with the biomass, and expressed according to Eq. (1) and Eq. (2):

Biosorption capacity (q) = $(C_o-C_f)*V/M$ (1)
Biosorption efficiency (%) = $(C_o-C_f)*100/ C_o$(2)

where,

$C_o$ is the initial concentration of metal ion (mg/L)
$C_f$ is the final concentration of metal ion (mg/L)
M is the mass of biosorbent (g)
V is volume of metal solution (L)

q is Biosorption capacity or metal uptake per unit gram of biosorbent (mg/g)

### FTIR

The FTIR spectrums of the biosorbent were obtained from the sophisticated analytical instrumentation facility, Panjab University (Chandigarh). Infrared spectra of the biosorbents, before and after adsorption, were recorded on a Nicolet model 6000, FTIR spectrometer equipped with a liquid nitrogen cooled detector. The samples for IR examination were prepared in KBr discs. The spectrum was recorded in the range of 4000 $cm^{-1}$ to 400 $cm^{-1}$. The technique was used to elucidate the chemical characteristics relevant to metallic ion sorption by the fungal biosorbents. The participating functional groups revealed through FTIR were chemically modified through base treatment and further insight was obtained by reanalyzing unloaded and loaded biomass after treatment.

## RESULT AND DISCUSSION

### FTIR analysis

The functional groups involved in U (VI) biosorpiton by *S. cerevisiae* biosorbent was elucidated on the basis of FTIR analysis. IR absorbance spectra of *S. cerevisiae* sp. (native) and U (VI) loaded one are given in Figure 1 and Figure 2 respectively. Very strong absorption band around 3200-3400$cm^{-1}$ was observed which may be

due to presence of O-H stretching vibrations and N-H stretching of amines and amides, particularly due to stretching of secondary amide ($RNHCOCH_3$) group of chitin component. Polymeric association which is normally found in hydroxyl compounds also gave rise to absorption band in range of 3200-3400$cm^{-1}$. C-$CH_3$ groups might have caused the appearance of absorption band in range of 2600-2900$cm^{-1}$. The peak centered around 1650$cm^{-1}$, is an indicative of involvement of double bond structures such as C═C or C═O. Strong absorption in carbonyl region can be assigned to C-O stretching of amide bond in poly-N-acetylglucosamine (chitin) and protein peptide bond present in biomass. After absorption of U (VI) significant changes in peaks were observed. Appearance of sharp peak at 1559.2 cm-1 can be attributed to N-H stretching in amine or amide. Shifting of peak from 1405.9 $cm^{-1}$ to 1377.5 $cm^{-1}$ in loaded biomass can be due to shift in bending vibration from $CH_2$ to $CH_3$. FTIR spectra reveals that mainly carbonyl, amino groups and methyl groups present on biomass cell surface were responsible for U (VI) biosorption. The result was concordent with (Mukhopadhyay *et al.*,2006a,b). Pretreatment of biosorbent produced additional binding sites via denaturation of proteins on the cell wall structure as shown in Figure 3 and 4. The changes in the functional groups and the surface properties of fungal biosorbents were confirmed by FTIR spectra before and after pretreatment as shown by change in functional groups.

**SEM**

The Scanning Electron Microscope micrograph of non-living native fungal sample (unloaded biomass) and Uranium treated sample (loaded biomass) are given in Figure 5 and Figure 6 respectively. The difference in the surface morphology of unloaded and loaded biomass can be clearly analyzed by comparing both the figures. Many different pores and irregular particles are present on the corrugated biomass surface of unloaded biomass that makes the surface of biomass rough after metal uptake. SEM analysis gave confirmation of uranium accumulation within *Saccharomyces cerevisiae* biomass.

**Biosorption batch studies**

***Effect of pH:*** pH value of the solution was an important controlling factor in the biosorption process. The results are shown in the Figure 7. Results showed that the maximum bisorption capacity for 100 mg/L initial metal ion concentrations was observed to be 7.89 and 8.35 mg/g respectively for untreated and base treated biosorbent at pH 5.0 and 4.0 respectively. The sorption of metal ions depends on solution pH, which influences electrostatic binding of ions to corresponding functional groups. *S. cerevisiae* contains abundant chitin–chitosan units and reasonable amount of protein and amino acids like hystidine,

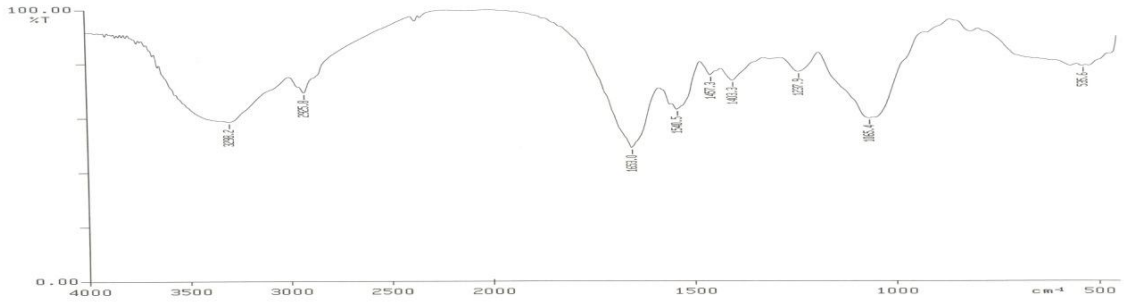


**Figure 1. FTIR of unloaded *S. cerevisiae* (untreated) biomass**

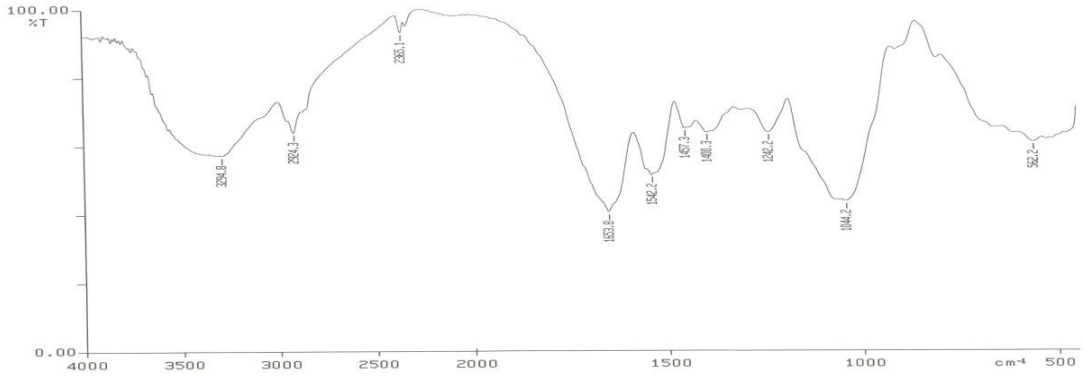


**Figure 2. FTIR of U (VI) loaded *S. cerevisiae* (untreated) biomass**

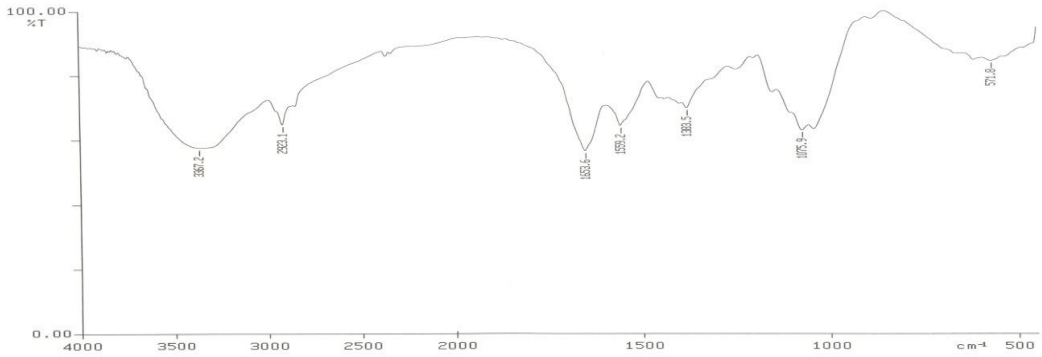


**Figure 3. FTIR of U (VI) unloaded *S. cerevisiae* (Base treated) biomas**

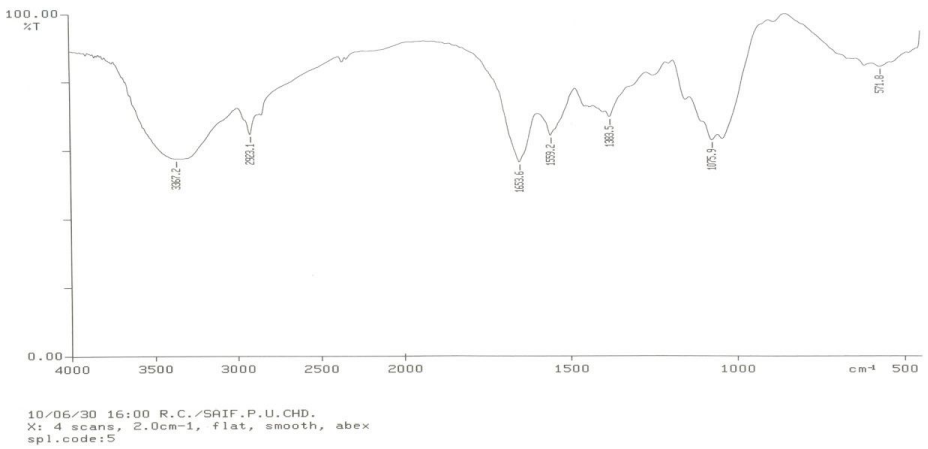


**Figure 4. FTIR of U (VI) loaded *S. cerevisiae* (Acid treated) biomass**

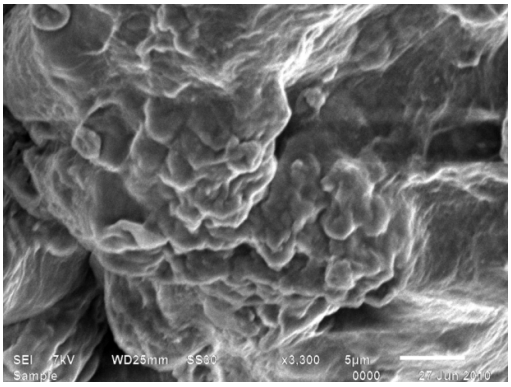


**Figure 5. SEM of unloaded *S. cerevisiae* biomass**

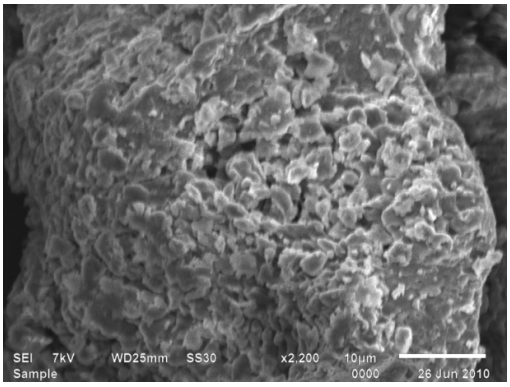


**Figure 6. SEM of U (VI) loaded *S. cerevisiae* biomass**

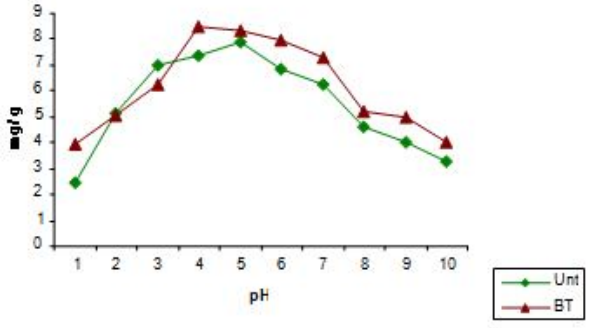


**Figure 7. Effect of pH on biosorption of U(VI) on non-living *S. cerevisiae* biomass**

which serve as a matrix of –COOH and $–NH_2$ groups, which in turn take part in binding of metal ion. The interaction of the matrix with the U ion was determined by the extent of protonation of the cell wall functional groups, which in turn depended upon the solution pH. With increasing pH, these groups got deprotonated and thus formed negatively charged sites. At pH values higher than 5.0, U (VI) ions precipitated out because of the high concentrations of $OH^-$ ions in the biosorption medium.

***Effect of Biosorbent Dose:*** Results on influence of biomass dose showed that Bisorption capacity decreased from 19.84 to 4.2 mg/g and 15.96 to 4.3 mg/g for untreated and base treated biomass respectively, as the biomass concentration increased from 0.25 to 2g (Figure 8). This might be due to the interference between binding sites at higher concentrations or insufficiency of metal in solution with respect to available binding sites, while biosorption percentage increased upto 1.25 g biosorbent dose and later became constant. Higher uptake at lower biomass concentrations could be due to an increased metal to biosorbent ratio, which decreases upon an increase in biomass concentration. Highest uptake was observed at 1.25 g biomass in 100ml U (VI) synthetic solution of 100mg/L concentration.

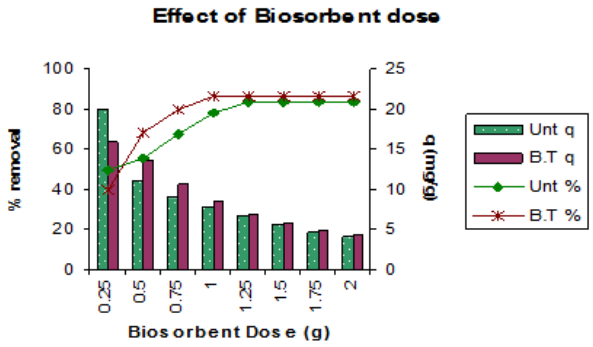


**Figure 8. Effect of Biosorbent dose on biosorption of U(VI) on non-living *S. cerevisiae* biomass**

***Effect of initial metal concentration:*** Figure 9 indicates that the initial metal concentration had a strong effect on biosorption capacity. It can be analyzed from the graph trend that as the metal ion concentration has increased, biosorption capacity has also increased and have reached a saturation value of 13.86 and 14.82mg/g for untreated and base treated biomass respectively, which were achieved at near about 200mg/L concentration of U ions. This finding was similar to the reported data of biosorption of Uranium and thorium ions onto chitosens sorbents (Humelnicu *et al*., 2011). At high metal ion concentration, the number of metal ions sorbed was more than at low metal concentration, where more binding sites were free for interaction.

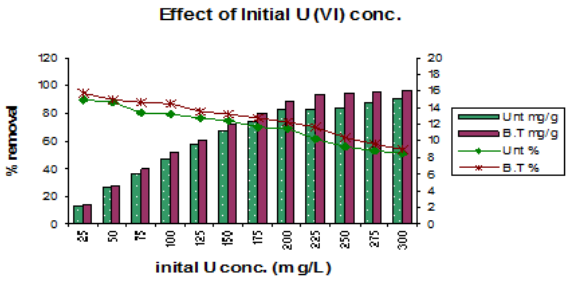


**Figure 9. Effect of Initial metal concentration on biosorption of U (VI) on non-living *S. cerevisiae* biomass**

***Effect of contact time:*** The biosorption capacity of biomass as a function of contact time is presented in Figure 10. It can be seen that fast rate of biosorption was observed within the first 40 min, and which was followed by slower phase till equilibrium. Similar trend was observed by Wang *et al.*, 2010. Equilibrium time was found to be 75 min and after the equilibrium period no further increase in the amount of biosorbed metal was observed. The initial rapid phase is probably due to the abundant availability of active metal binding sites on the biosorbent surface and with the gradual occupancy of those sites. The sorption becomes less efficient in the slower stage as a result of competition for decreasing availability of active binding sites intensities by the metal ions remaining in solution.

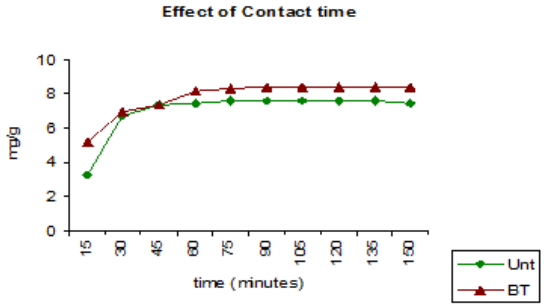


**Figure 10. Effect of contact time on biosorption of U (VI) on non-living *S. cerevisiae* biomass**

***Effect of Particle size:*** It was observed that the biosorption decreased sharply with an increase in particle size from 100µm to 500µm and thereafter it became almost constant as shown in Figure 11. The untreated and base treated *S .cerevisiae* biosorbents were found to biosorb 7.28 and 8.23 mg/g of U (VI)) respectively with a particle size of 100µm. The decrease in biosorption capacity with increase in particle size can be assigned to the decrease of interfacial surface area with increase of particle size.

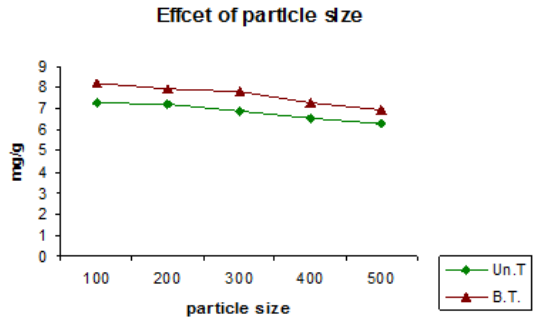


**Figure 11. Effect of Particle size on biosorption of U (VI) on non-living *S. cerevisiae* biomass**

**Biosorption Isotherms:** Equilibrium relationships between sorbent and sorbate are described by adsorption isotherms, which are characterized by certain constants whose values express the surface properties and affinity of the biomass. In this study, two important isotherm models were selected to fit the data, which were Langmuir and Freundlich models. The Langmuir isotherm is often used to describe the sorption of solute from solution in linearized form as Eq. (3):

$$C_e/q_e = 1/(Q_{max}*b) + C_e/Q_{max} \quad (3)$$

Where $C_e$ is the equilibrium solute concentration (mg/L). $q_e$ is the amount of adsorbate adsorbed at equilibrium (mg/g), b is the Langmuir constant related to the energy of biosorption (L/mg), $Q_{max}$ is the maximum sorption capacity corresponding to complete monolayer coverage (mg/g). The Langmuir isotherm is applicable to monolayer sorption of adsorbate. Langmuir isotherm constants were determined from the plots of $C_e$/ *qe* versus $C_e$ as shown in Figure 12.

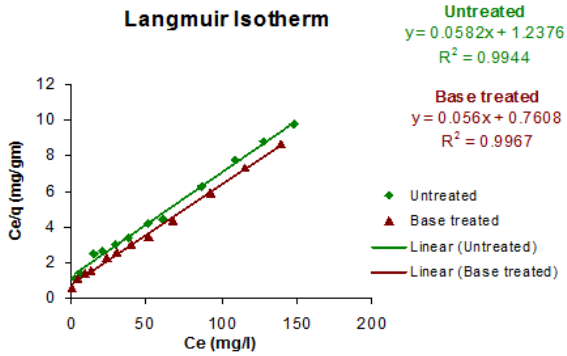


**Figure 12. Langmuir isotherm of U (VI) biosorption on *S. cerevisiae* biomass**

The Freundlich isotherm is an empirical equation employed to describe heterogeneous systems. The linearized form of the Freundlich equation is as following ig Eq. (4):

$$\ln q_e = \ln K_f + 1/n \ln C_e \quad (4)$$

where $K_f$ (dm$^3$ g$^{-1}$) and *n* are Freundlich isotherm constants, being indicative of the extent of the biosorption and the degree of nonlinearity between solution concentration and biosorption, respectively. Freundlich isotherm constants were determined from the plot of ln *qe* versus ln Ce (Figure 13). BET isotherm describes multilayer sorption and can be expressed in following linearized form (Eq. 5).

$$C/(C_s\text{-}C)q = (1/BQ)+(B\text{-}1/BQ)(C \quad (5)$$

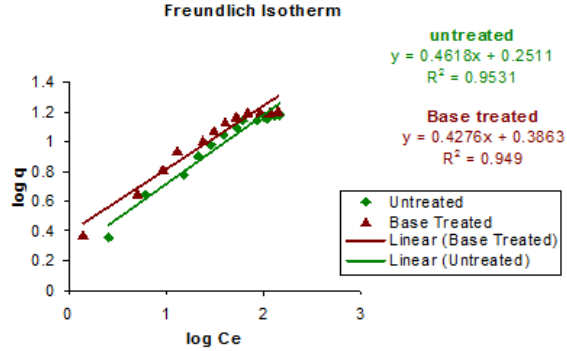


**Figure 13. Freundlich isotherm of U (VI) biosorption on *S. cerevisiae* biomass**

where q is the amount of solute adsorbed per unit weight of adsorbed (mg/g), C is the concentration of solute remaining in solution at equilibrium (mg/l), $C_s$ is the saturation concentration of the solute

**Table 1: Langmuir and Freundlich isotherm constants for biosorption of U(VI) on *S. cerevisiae***

| | Langmuir isotherm | | | Freundlich isotherm | | | BET | |
|---|---|---|---|---|---|---|---|---|
| | $q_{max}$ | b | $R^2$ | 1/n | $K_f$ | $R^2$ | Q | $R^2$ |
| Untreated | 17.182 | 0.0470 | 0.9944 | 0.4618 | 4.6419 | 0.9531 | 8.5405 | 0.978 |
| Base treated | 17.857 | 0.0736 | 0.9967 | 0.4276 | 4.9465 | 0.949 | 10.2466 | 0.974 |

(mg/l), Q is the amount of solute adsorbed per unit weight of adsorbent in forming a complete monolayer on the surface (mg/l) or maximum adsorption capacity. Q is determined from slope and intercept of graph plotted below as Figure 14. The parameters of the Langmuir, Freundlich and BET equations are given in Table 1. High value of correlation coefficient for Langmuir isotherm and deviation of Freundlich and BET plots from linearity clearly depicts that data is more correlated to Langmuir model as compared to Freundlich model. The agreement of the experimental data with the Langmuir model strengthens the assumptions that monolayer adsorption and constant adsorption energy existed for the experimental conditions used.

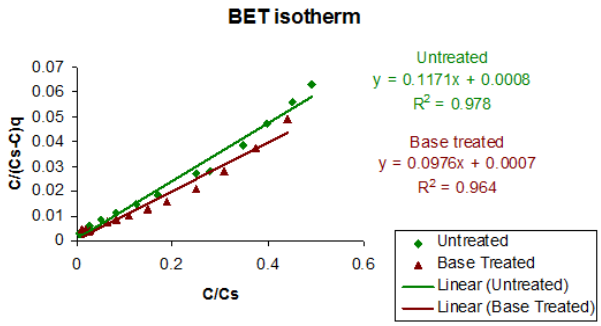


**Figure 14. BET isotherm of U (VI) biosorption on *S. cerevisiae* biomass**

### Biosorption Kinetics

In order to investigate the biosorption processes of Uranium on the *S. cerevisiae*, pseudo-first order and pseudo-second order kinetic models were used. The pseudo-first-order, rate expression of Lagergren is given by Eq. (6):

$$\ln (q_{eq} - q_t) = \ln q_{eq} - (t * k_1/2.303) \quad (6)$$

Where $q_t$ *is* the amount of adsorbate adsorbed at time *t* (mg/g), $q_{eq}$ is the biosorption capacity at equilibrium (mg/g), $k_1$ is the pseudo-first-order rate constant ($min^{-1}$), and *t* is the contact time (min). $k_1$ was determined experimentally by plotting of $\ln (q_{eq} - q_t)$ versus t (Figure 15). Experimetal data were also tested by Pseudo-second-order kinetic model which is given as Eq. (7):

$$t/q_t = 1/k_2 q_{eq}^2 + t/q_{eq} \quad (7)$$

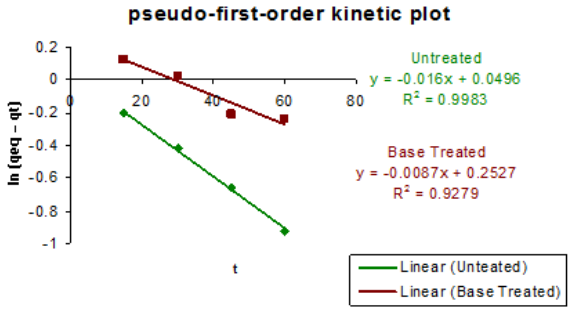


**Figure 15. Pseudo-first-order kinetic modeling of U (VI) biosorption on *S. cerevisiae* biomass**

where $k_2$ is pseudo-second-order rate constant (g/mg min), $q_t$ is the amount of adsorbate adsorbed at time *t* (mg/g), $q_{eq}$ is the biosorption capacity at equilibrium (mg/g). The linear plot of $t/q_t$ versus t gives value of $k_2$ (Figure 16). The comparison of rate constants and correlation coefficients for two analyzed kinetic models are given in Table 2. Much higher value of $R^2$ for pseudo-second-order reaction shows that the pseudo-second-order kinetic model is more applicable to all the sorption data. This conclusion is in agreement with Chhikara *et al.*, 2010.

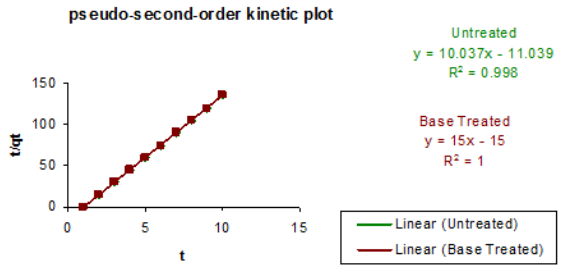


**Figure 16. Pseudo-second-order kinetic modeling of U (VI) biosorption on *S. cerevisiae* biomass**

**Table 2: Adsorption rate constants for pseudo-first and pseudo-second order adsorption for *S. cerevisiae***

| | Pseudo-first-order | | Pseudo-second-order | |
|---|---|---|---|---|
| | $k_1$ | $R^2$ | $k_2$ | $R^2$ |
| Untreated | 0.0368 | 0.9983 | 9.129 | 0.998 |
| Base treated | 0.0200 | 0.9279 | 15 | 1.000 |

### Conclusion

The spectral analysis of biosorbent demonstrated that *S. cerevisiae* contains abundant chitin–chitosan units and reasonable amount of protein and amino acids like hystidine, which serve as a matrix of –COOH and $–NH_2$ groups, which in turn take part in binding of metal ion. FTIR spectra of native and pretreated fungus confirmed the biosorbents heterogeneity and showed that the presence of different characteristic peaks are in agreement with presence of amino, carboxylic, hydroxyl and carbonyl groups etc. The results indicated that the chemical interaction such as ion exchange and physical adsorption between the hydrogen atom of carboxyl (-COOH), hydroxyl (-OH), amine ($-NH_2$), groups of biomass and the metal ions were mainly involved in the biosorption process. It was observed that base treatment of biomass significantly improved the availability of interaction sites by modifying the functional groups on biomass surface and thus has enhanced its biosorption efficiency in comparison to untreated one. The effectiveness of the removal process also depended mainly on pH followed by amount of biomass and initial U (VI) concentration, contact time and particle size. Optimum removal of U (VI) by *S. cerevisiae* were found at pH 5 and 100 µm particle size, adsorbent dose of 10g/L and initial metal concentration of 100mg/L. It was seen that the adsorption equilibrium and kinetic data confirmed well with the Langmuir and pseudo-second-order kinetic model, respectively.

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