Newsletter

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Indian Institute of Chemical Engineers

GUWAHATI REGIONAL CENTRE

Department of Chemical Engineering

IIT Guwahati

Biosorption potential of lignocellulosic biosorbents for heavy metal removal

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1. Presence and impact of toxic heavy metals:

In the past few decades availability of potable water has reduced to a considerable level. Various pollutants over the past few years have made the available water unbearable for health and prone to disease. Among such pollutants are the heavy metals. Increase of industries and improper treatment of waste disposal/sewage water are the main reasons for the contamination of the water sources by heavy metals worldwide. This has created many problems to all living organisms and plants, in particular very much to human beings [1]. Chromium (VI) is one such metal and its present in two oxidation states i.e. Cr(III) and Cr(VI) , out of which Cr(VI) is considered as carcinogenic and mutagenic which leads to severe health effects to living beings such as genotoxicity, mutagenicity, cell transformation and various other health hazards. As per environmental protection agency standards, the maximum permissible limit for Cr (VI) in drinking water is 0.05mg/L [2]. Hence, there exists a need for safe and proper disposal of such toxic metals from the effluents which ensures protective discharge to the environment.

2. Why biosorption?

Biosorption is a physicochemical process which is cost effective and efficient one. This process uses mainly biological materials as biosorbent, especially lignocellulosic biosorbents which are biodegradable in nature and it proves as an efficient alternate method for removing heavy metals from effluents and aqueous solution. There are various other conventional methods used for heavy metal removal such as membrane separation, reverse osmosis, ion exchange, electrochemical precipitation, solvent extraction, foam separation and adsorption by activated carbon etc [3]. However these conventional methods are generally avoided due to certain shortcomings such as the requirement of energy and chemicals, ineffective in low concentrations, generation of further toxic byproducts and being inexpensive. Biosorption has more advantages when compared with the above conventional methods such as biosorbents being cheaper and free of cost, they are more effective, their capability to regenerate and less formation of any other biological or chemical sludge [4].

3. How it's performed?

Biosorption can be performed in both batch and continuous mode. In batch mode, this process can be carried out by adjusting several influencing parameters such as dosage of biosorbent, initial metal concentration, agitation speed, temperature, solution pH, contact time etc. The biosorbent can be separated from the heavy metal ions by means of desorption process and then it can either be reused or left away to the environment. Data obtained can be used for performing isotherm, kinetic and thermodynamic studies by which we can get a clear idea about the nature of biosorption, its mechanism and about the performance of biosorbent in terms of biosorption capacities, Cr (VI) removal ability, regeneration capacity etc. In continuous mode, packed bed column studies can be performed, using such biosorbents by adjusting the operating parameter conditions like initial metal ion concentration, bed height and influent flow rate etc. Modeling can be done using experimental data using various column adsorption models through which we can find the kinetic constants, adsorption capacity and the breakthrough performance.

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4. Researches underwent:

Biosorbents which are mainly lignocellulosic wastes such as leaves, flower petals, peels, stems, outer shells are used for carrying out the study. It can be used in unmodified form as well as in chemically activated form. Researches that were carried out recently are by using unmodified biosorbents such as *Sweetenia mahogany* shell, *Strychnous nux vomica* shell, dry araucaria leaves, tamarind seeds, mangrove leaf powder etc. Chemically activated and modified biosorbents such as modified walnut shell, sulphuric and phosphoric acid modified *Sweetenia mahogany* shell, ferrous modified peanut husk, mangos teen peel by sulfuric acid, wheat residue derived black carbon, activated carbon prepared from Longan seed, sawdust by ortho-phosphoric acid etc. Comparison of biosorption capacities of various biosorbents are listed down in Table 1. Column studies were also done using some of the above said biosorbents and are proved as an efficient biosorbent in removing Cr (VI) from industrial effluents.

Table 1: Comparison of biosorption capacities of various biosorbents utilized in batch studies.

Adsorbent	pH	Adsorption capacity (mg/g)
Wheat residue	1.0	21.34
Parthenium hysterophorus weed	1.0	24.50
Peanut husk	2.0	33.11
Longan seed	3.0	35.02
Sweetenia mahogany shell	2.0	37.03
Sterculia guttata shell	2.0	45.45
Colocasia esculenta leaf powder	2.0	47.6
Sulphuric acid activated *Sweetenia mahogany* fruit shell	2.0	47.61
Phosphoric acid activated *Sweetenia mahogany* fruit shell	2.0	58.62
Mangrove leaf powder	2.0	60.24

Table 2: Comparison of Cr (VI) removal ability by various biosorbents from column studies.

Adsorbent	Removal ability (%)
Phosphoric acid modified eucalyptus seeds	46.42
Activated carbon prepared from *Sweetenia mahogany*	46.33
Sulphuric acid modified *Sweetenia mahogany* shell	64.38
Phosphoric acid modified *Sweetenia mahogany* shell	56.79

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Ionic Liquids as green solvents for Butanol Extraction

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Ionic liquids are salts those consist of organic cations and inorganic/organic anions. Room Temperature Ionic Liquids (RTIL) are liquid at room temperature. They are known as designer solvents due to the possibility of large number of ILs (cation and anion combinations) which impart specific properties. These solvents are more attractive due to desirable special properties, such as wider liquid range, negligible vapor pressure at room temperature, tunable viscosity, low flammability, high heat capacity and favorable solvation properties for polar and nonpolar compounds [1]. These solvents are more stable at high temperature and/or in presence of chemicals and are suitable for the extraction of inorganic and organic compounds [2].

The physical properties of these solvents can be tuned by suitable combination of cation and anion. Some commercially available cations and anions are shown in Fig. 1. The applications of ILs covers many research domains [3-5] like catalysis, nanotechnology, azeotropic separation, liquid-liquid extraction, metal extraction, aromatic-aliphatic separation, membrane science and gas absorption.

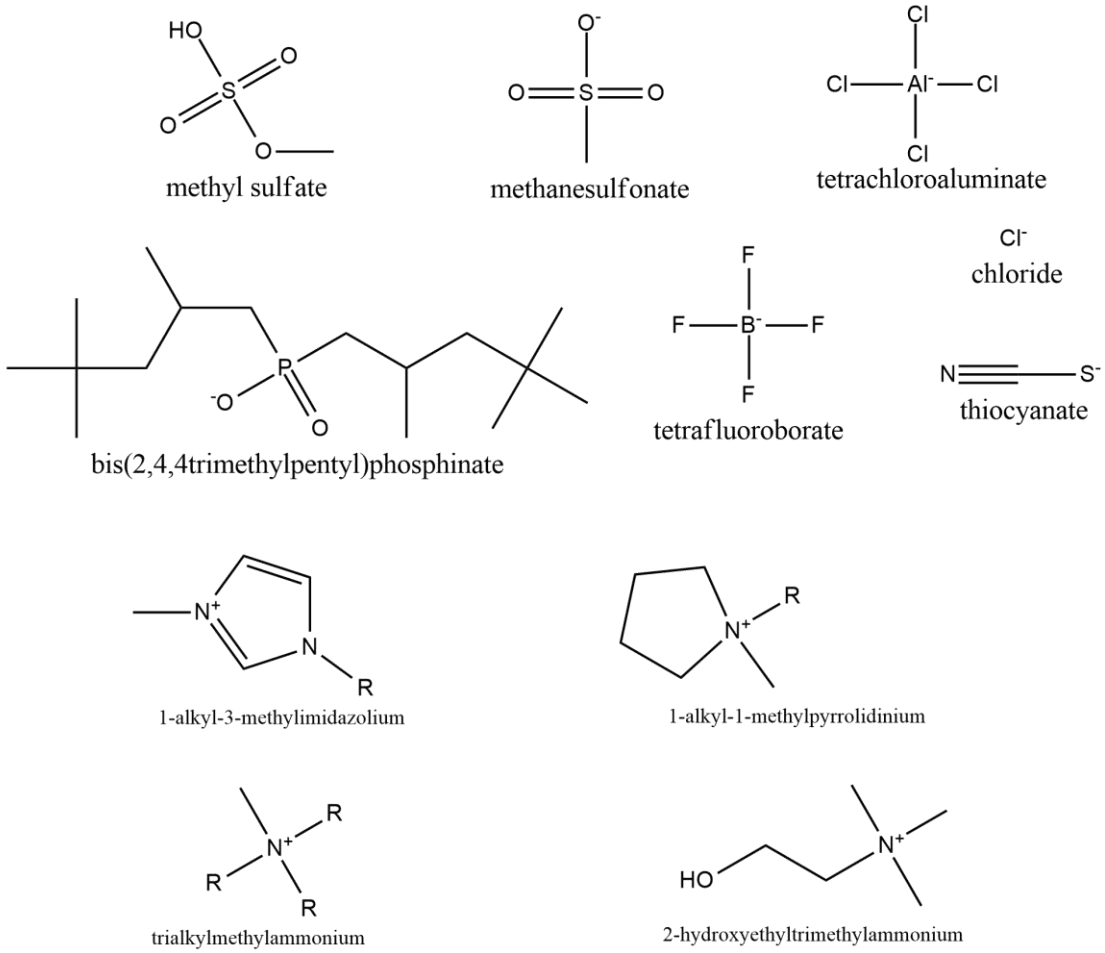

Figure 1. Some commercial cations and anions of ILs

A wide verity of ionic liquids has been used in literature [1-6] for the separation of organic compounds form aqueous solutions. Phosphonium based ILs; Trihexyl(tetradecyl) phosphonium bis(2,4,4-trimethylpentyl) phosphinate [TDTHP][Phosph], Trihexyl (tetradecyl) phosphonium bis(2,4,4-trimethylpentyl) dicyanamide [TDTHP][DCA] and Trihexyl(tetradecyl) phosphonium bis(2,4,4-trimethylpentyl) decanoate [TDTHP][DEC] had been proved better solvents for the extraction of butanol from aqueous solution. The equilibrium data for [TDTHP][Phosph] – butanol – water are plotted in Fig. 2. The separation capability is checked by calculating the distribution coefficient (β) which is defined as,

$$\beta = \frac{x^{E}_{alcohol}}{x^{R}_{alcohol}}$$

where $x_{alcohol}$ and x_W are the concentrations of alcohol and water respectively. The superscript *E* and *R* indicates the extract and raffinate phase respectively.

The distribution coefficient refers to the amount of IL used to effect the separation. Large value of distribution coefficient is desirable since it indicates lesser solvent requirement for particular degree of separation. Further the positive sloping of the tie lines indicates butanol favorably partitions into the IL phase (Fig. 2).

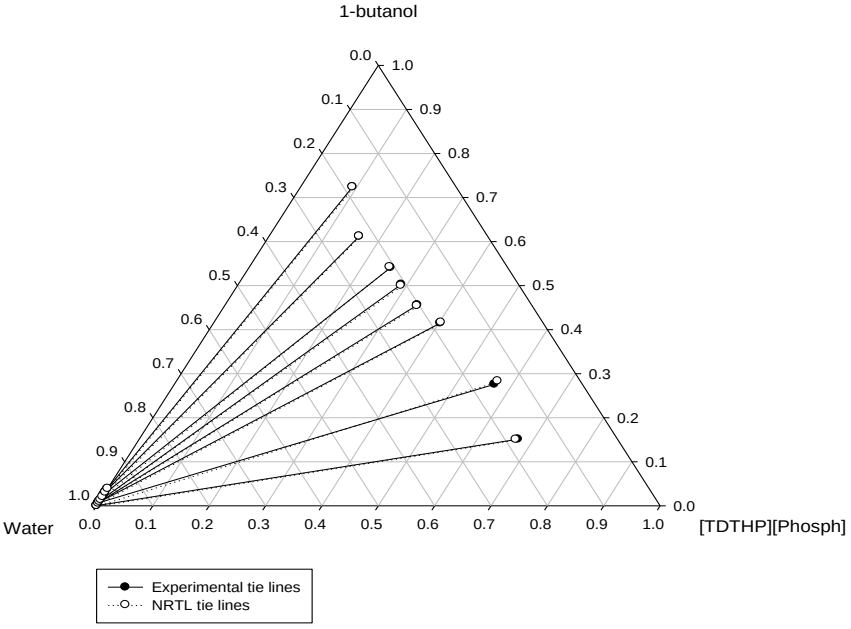

Figure 2. Experimental and NRTL predicted tie lines for the ternary system: 1-butanol/water/[TDTHP][Phosph] at 298.15 K and 1 atm.

The distribution coefficient for [TDTHP][DCA] is twice as compared to the ILs reported by Nann et al. [6] that is, 1-decyl-3-methylimidazolium, tetracyanoborate ([Im10.1][TCB]), 4-decyl-4-methylmorpholinium tetracyanoborate ([Mo10.1][TCB]), 1-decyl-3-methylimidazolium bis(trifluoromethylsulfonyl) [Im10.1][Tf_2N]), and 4-decyl-4-methylmorpholinium bis-(trifluoromethylsulfonyl)imide ([Mo10.1][Tf_2N]). Further it was also observed that the distribution coefficients for [TDTHP][Phosph] and [TDTHP][DEC] are twelve and seven times respectively higher as compared to the same IL's [6].

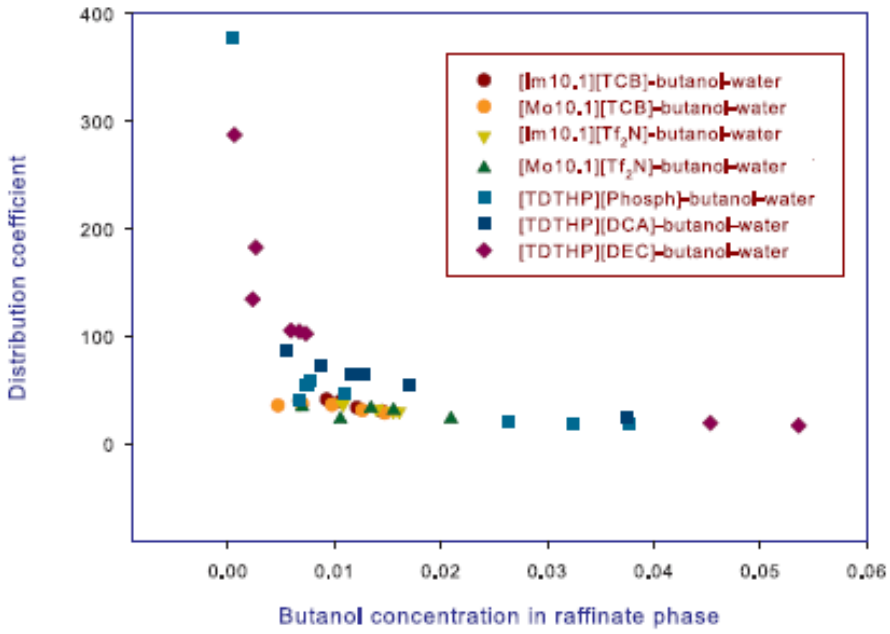

Figure 3. Comparative distribution coefficient of Phosphonium based Ionic Liquids with literature data [6]

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Understanding the structure of viruses through X-ray scattering

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I feel, the best thing in Chemical Engineering research is that it is highly inter-disciplinary, and it enables an inquisitive mind to explore multiple aspects of scientific learning. As an undergraduate student in Chemical Engineering at Indian Institute of Technology Guwahati, I had the opportunity to work in waste water treatment during my summer internship in Taiwan and later, in drug delivery by metal organic frameworks for my Bachelor Thesis Project under the guidance of Dr. Sasidhar Gumma. And after graduation, during my stint as a scientist in Defence Research & Development Organization I could contribute in the process development of high energetic materials for defence applications. Now as a doctoral candidate in Chemical Engineering at The Pennsylvania State University, I am getting to explore a completely different field of scientific research: 'Advanced X-ray scattering of biological assemblies'. Chemical Engineering research has allowed me to learn multidisciplinary approach to problem solving. One of the subjects for my current research is structure of viruses and the following write-up is about the chronological development of X-ray scattering of viruses.

Early X-Ray scattering studies of virus particles were on spherical plant virus particles in solution. The viruses investigated were southern bean mosaic virus (SBMV), tobacco necrosis virus (TNV), tomato bushy stunt virus (TBSV) [1] and turnip yellow mosaic virus (TYMV) [2]. The scattering data were analysed to estimate their sizes and hydration. The radii of gyration were obtained at small angles where Guinier approximation holds and the radii were calculated under spherical assumption ($5\ Rg^2 = 3\ R^2$). They also obtained the radii by fitting the angular distribution of scattered intensity to the scattering function for a sphere of constant electron density. This scattering function exhibits a series of secondary maxima and minima whose positions give an accurate radius of the sphere. The appearance of these maxima and minima in the experimental scattering curves provided an evidence of the near sphericity and monodispersity of the virus particles and also the radii of the particles calculated through the above two methods were in agreement. Moreover, it was observed that the molecular volume calculated for molecules in solution differed significantly from that calculated for dry protein, indicating the presence of internal hydration.

Among the above-mentioned viruses, turnip yellow mosaic virus held a particular interest for the investigators because along with the multiplication of the virus particles in the host body, they also produced a number of virus like protein particles with no nucleic acids in them. Markham [3] had suggested that physically these protein particles were similar to the virus particles with the only difference being that they are hollow spheres. The X-Ray scattering data provided support to Markham's results on size and shape and hollow structure. The size measurements were made for the virus particles as described above. However, when the same analysis was done for the protein particles, the agreement of radii from experimental data with calculated results was very poor. So, the scattering data for protein particles were fitted to the scattering function for a hollow sphere which led to a good agreement between the radius from observed data and the calculated radius.

Like TYMV, wild cucumber mosaic virus (WCMV) also produces protein particles called virus like particles (VLP) in addition to the virus particles in diseased host. The structures of these particles were

investigated through calculating the radial electron density distribution within the particles from Fourier transform of scattered amplitudes [4] . It was found that the observed scattering curves agreed well with the calculated scattering curves for a sphere of uniform electron density, but only at low scattering angles.

The lipid and protein organization within an enveloped virus called Sindbis was investigated by computing the radial electron density distribution by spherical fourier inversion of the transform [5] . It was seen that the spherically averaged electron density when plotted as a function of radius showed a deep minimum which was speculated to be from a lipid layer between layers of protein or RNA. From the electron density profile and electron microscopy images, it was confirmed that the virus particle is made up of three principal structural domains: the lipid, the core and the outer protein.

In later years, it was predicted that the differences between the observed scattering curves and that calculated from sphere of uniform electron density indicate the deviations from spherical symmetry [6]. Jack et al. (1975), calculated the expected diffraction patterns of an icosahedral point model and fitted the observed scattering curves to these patterns. For Wild cucumber mosaic virus and Polyoma virus they found that the scattering curve was in good agreement with a point model of T=3 hexamer - pentamer clustering.

It was hypothesized that certain viruses undergo conformational changes in different pH media. In 1991, Stubbs et al. [7], provided an evidence to this hypothesis for Sindbis virus. They fitted the x-ray solution scattering data to a five shell-model and found the three major structural domains in the virus remained the same at both pH 7.0 and pH 5.0. However, the outer radius increased by 40 Å and density of outermost shell decreased at pH 5.0 as compared to pH 7.0.

A similar hypothesis was proved for Nudaurelia capensis ω virus (NωV) by Canady et al., in 2001 [8] through static and time resolved small angle x-ray scattering. However, unlike the case of Sindbis virus, the protein coat of NωV virus shrinks on lowering the pH. They studied the mechanism of this transition from procapsid to capsid through determining its time scale and pH dependence. From the static scattering curves of procapsids and capsids, the radii of gyration and radii were determined under spherical approximation using indirect Fourier transform, which matched well with those obtained by cryoEM. Through the use of time resolved small angle x-ray scattering, they could identify the transition point from procapsids to capsids and also confirm the presence of an intermediate entity at that point.

The ability of small angle x-ray scattering (SAXS) to provide in-solution structural information of scattering macromolecules also helps to investigate the size, shape and compactness of virus RNA. The radius of gyration is calculated from 1D SAXS data through the Guinier approximation at low q values and the maximum dimension of the scattering particle, Dmax, is determined through the pair-distance distribution function (PDDF) p(r). Kratky analysis is also done to determine the folding of RNA.

Molecular envelopes are also constructed from SAXS data by using the program DAMMIN. A spherical space with diameter D_{max} (from PDDF result) is constructed and filled with atoms as corresponding to the calculated electron density. The envelope is refined in many cycles in DAMMIN through simulated annealing algorithm. The final molecular dimension is chosen based on the fit to the experimental data (χ^2) and reproducibility of the envelopes, indicated by Normalized Spatial Discrepancy (NSD) values. This procedure was applied to study the solution structure of RNA of turnip crinkle virus [9] as a complimentary technique to solution NMR and also for structural characterization of HIV-I RNA [10].

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Teaching Learning Based Optimization: A metaheuristic to solve optimization problems

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Non-linear optimization problems are very common in chemical engineering and metaheuristic techniques have been widely employed due to their ability to obtain a nearby or global optima. Even though these techniques do not guarantee the determination of global optima, these are preferred for solving problems having higher dimensions and are applicable to a wide spectrum of problems irrespective of their landscapes. The increasing complexity of real life optimization problems as well as the 'No Free Lunch Theorem' continue to pave the way for the development of novel metaheuristic techniques. Some of the popular metaheuristics includes Genetic Algorithm (GA) which imitates the natural selection and genetics, Particle Swarm Optimization (PSO) which mimics the social behaviour of bird flocking or fish schooling, Simulated Annealing which is based on the annealing process of metallurgy, Artificial Bee Colony that is based on the foraging behaviour of honey bee swarm. Recently proposed techniques includes Grey Wolf optimization, Gravitational Search, Virus Colony Search, Ying Yang Pair Optimization, Wind Driven Optimization etc. imitates various naturally occurring phenomenon for solving optimization problems. Despite the development of these techniques and their possible superiority over the conventional techniques, these have not been widely adopted for solving chemical engineering problems. In this article, a simple but very efficient technique, Teaching Learning Based Optimization (TLBO) is reviewed.

TLBO was proposed [1] in 2011 and has received significant attention in literature. It is a population based metaheuristic technique and is based on the knowledge transfer in the teaching-learning environment. In TLBO, each solution (population member) is termed as learner, the solution with best objective function value is termed as the teacher and the entire population is considered as the class. Each decision variable of the problem is treated as a subject. Unlike other popular metaheuristic techniques such a GA, PSO, TLBO does not require any tuning parameter (except for the termination criterion and the population size) and thereby relives the user of the tedious parameter tuning. This seems to have contributed significantly to its popularity.

TLBO consists of two phases namely the teacher phase and the learner phase, in which every solutions attempts to improve their positions. Every solution undergoes the teacher phase followed by the learner phase. In teacher phase, a new potential solution is generated with the help of the teacher and the mean of the population. The value of the teaching factor (T_f) governs the contribution of the mean value to determine the new solution in the teacher phase. The value of T_f is set randomly to 1 or 2. In the learner phase, a partner solution is assigned to every solution and a new potential solution is generated with the help of the partner. The greedy selection procedure is adopted for selecting the better solutions to constitute the new population. The modification and the selection of the solution is performed until any of the termination criteria is satisfied. In each iteration, for every learner in the population, two functional evaluations are required for the teacher and learner phase. In addition, N_P (the size of the population) functional evaluations are required to determine the fitness of the initial population. Thereby the total number of functional evaluations performed in N_I iterations by TLBO for solving a problem is determined as $N_p + 2\ N_P N_I$. The pseudo code of TLBO with maximum number of iterations as the stopping criterion is provided herewith.

Input: Fitness function (*f*), dimension of the problem (*D*), lower bound (*lb*), upper bound (*ub*) of decision variables, population size (N_P) and the maximum number of iterations (N_I)

Output: Best solution (X_{best}) and corresponding objective function value ($f(X_{best})$)

1. Initialize a random population (*X*) within the bounds and evaluate its fitness, ($f(X)$)
2. **For** $i = 1$ to N_I
3. **For** $n = 1: N_P$
4. Determine the teacher (X_{best}) and mean of the population (X_{mean})
5. $X_n^{new} = X_n + r\left(X_{best} - T_f X_{mean}\right)$
6. Bound violations in X_n^{new} to its nearest boundaries and evaluate $f\left(X_n^{new}\right)$
7. **If** $f\left(X_n^{new}\right) < f\left(X_n\right)$
8. $X_n = X_n^{new}$ and $f\left(X_n\right) = f\left(X_n^{new}\right)$
9. **End If**
10. Select a solution randomly as partner (X_p)
11. **If** $f\left(X_n\right) < f\left(X_p\right)$
12. $X_n^{new} = X_n + r\left(X_n - X_p\right)$
13. **Else**
14. $X_n^{new} = X_n + r\left(X_p - X_n\right)$
15. **End If**
16. Bound violations in X_n^{new} to its nearest boundaries and evaluate $f\left(X_n^{new}\right)$
17. **If** $f\left(X_n^{new}\right) < f\left(X_n\right)$
18. $X_n = X_n^{new}$ and $f\left(X_n\right) = f\left(X_n^{new}\right)$
19. **End If**
20. **End For**
21. **End For**
22. Determine the best solution (X_{best}) and corresponding objective function value ($f(X_{best})$)
23. **Return** X_{best} and $f(X_{best})$

Several issues have been raised about TLBO due to the significant mismatch between its description and implementation. A MATLAB implementation based on the above algorithm is available (https://goo.gl/RGsbNM). Several improvisations (https://goo.gl/MtXojA) and hybridization have also been proposed. It has also been extended to solve multi-objective optimization problems [2,3].

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Guwahati Regional Centre Activities

Upcoming Events

Nanoparticle - Antibody Conjugates as High Sensitive Reagents for Mass Cytometry

Dr. Jothir Pichaandi, Scientist at Fluidigm Canada will deliver the talk on February 15, 2018.

Mass cytometry (MC) is a recently developed single cell analysis technique to identify several cellular biomarkers simultaneously. This technique combines the power of flow cytometric injection of cells with an inductively coupled mass spectrometer (ICP-MS) coupled with time of flight detection. MC employs metal isotopes to tag the antibodies (Abs) and these metal isotopes have a unique mass that can be detected and quantified by mass spectrometry. Flow cytometry, the most commonly used single cell analysis technique to study cellular biomarkers can measure only up to 8 to 10 cellular biomarkers simultaneously. Beyond the detection of 8 to 10 biomarkers, the technique is limited by the luminescence spectral overlap of the dyes and the quantum dots used to tag the Abs which identifies the specific biomarker on the surface or inside the cell. On the other hand, the number of biomarkers identified using MC depends only on the number of different metal isotopes that can be used to tag the Abs. As with all techniques, there is certain limitation to this technique as well. When compared to flow cytometry, this technique suffers from poor sensitivity due to the fact the current reagents, metal chelating polymers with 40 to 50 metal atoms per polymer chain, cannot generate enough signal to identify proteins which are present in very low copy numbersin cells. MC is a quantitative technique and the fact the signal intensity increases linearly with the number of metal atoms tagged to each Ab, my research is primarily involved in developing antibody conjugates with more metal tags per Ab. To achieve this goal, I am working on developing reagents based on nanoparticles to enhance the detection sensitivity of low copy markers by one or two orders of magnitude than current reagents. I will elucidate the various criteria which have to be satisfied when employing NPs as high sensitive reagents. The synthesis, nucleation and growth kinetics of the various NPs will be discussed in detail. Subsequently, I will talk about two surface modification process to make the NPs biocompatible and their effect on the non-specific interaction of the NPs with various cells lines. The various conjugation chemistries to couple the NPs to Abs will be explored and finally finish with examples of mass cytometry single cell measurements where the NPs exhibit higher signal for various biomarkers when compared to current metal chelating polymer reagents.

Emerging Wastewater Treatment Technologies

Dr. S. Kanmani, Professor & Director, Centre for Environmental Studies, Anna University will deliver the talk on February 22, 2018.

The presence of thousands of contaminants in wastewaters and their impending threats has drawn a significant attention of the scientific community in recent years. The major sources of pollution include domestic wastewater, industrial wastewater and agricultural discharges. Indiscriminate disposal of domestic and industrial wastewater to surface water causes degradation of the environment and degenerative effects on both public health and ecosystem. Conventional suspended biomass reactors (ASP) are widely used for sewage treatment despite their specific drawbacks, such as requirement of large reactor volumes,

large-sized sedimentation tanks and high excess bio-sludge production, while Sequential Batch Reactor (SBR) has lesser footprint but still it has the problem of excess sludge production and high sludge volume index. As a solution to these problems, carrier elements can be added to the aeration tank or SBR. This led to the development of Sequential Batch Biofilm Reactor (SBBR), which improves the quality of bio sludge of the system resulting in improvement of the effluent quality and system efficiency.

The other challenge is the treatment of industrial wastewaters containing recalcitrant organic compounds. The wide range of non-biodegradable organics in waste streams includes textile dyes, pesticides, pharmaceutically active compounds, phenols, tannery and distillery compounds. Most of these effluents are highly coloured in addition to the presence of a high organic load. Advanced Oxidation Processes (AOPs) have gained more attention in the past decades and are seemed as a viable option for complete degradation of non-biodegradable organics. Various AOPs that find application in the treatment of industrial wastewaters are Photocatalysis, UV/H_2O_2, $UV/O_3/H_2O_2$, Fenton's process, Wet Air Oxidation, Sonolysis, Electrochemical Oxidation, Super-Critical Water Oxidation, Non-thermal Plasma, Gamma rays, Electron beam etc. All the AOPs depend on the generation of highly reactive hydroxyl radical ($^{\cdot}OH$) which are non-selective oxidant and react with almost all the organic compounds. In addition, AOPs can also be used in the removal of Persistent Organic Pollutants (POPs), Emerging contaminants and other micropollutants. The cost of the AOPs could be high as they yield almost complete degradation of target pollutants without giving rise to hazardous sludge. Nevertheless, the treatment cost can be reduced by combining the AOPs with biological treatment as the AOP pre-treatment would make any recalcitrant water amenable for biological treatment.

Upcoming Events

Indo-Japan Bilateral Symposium on Future Perspective of Bioresource Utilization

"Indo-Japan Bilateral Symposium on Future Perspective of Bioresource Utilization" with special reference to North Eastern Region will be jointly organized by Indian Institute of Technology Guwahati, India and GIFU University Japan during February 1-4, 2018.

The symposium includes the discussion on the lines: Frontier in bio-resource in NER, Harnessing of bio-resource in NER, bio-industries and bio-based economics for further agriculture in NER, bio-based processing and production, Functional food, Food development and Agrofood science. The symposium will be dedicated towards comprehensive elaboration on production and processing of bio-based resources and their utilization.

Additional details can be obtained from www.iitg.ernet.in/ijbs2017/

Research Conclave - 2018

Research Conclave is organized under the banner of Students' Academic Board (SAB) of Indian Institute of Technology Guwahati (IITG) during March 8-11, 2018.

It is a staunch platform to nurture the young minds towards research, innovation and entrepreneurship, which intends to bring the integrity of the students towards both industries and academia to redress the academic research challenges, concerns of the entire student community and upcoming entrepreneurs around the globe. It is a forum to harness innovative mind to level-up the economic strata of current society from research to industries. The Research Conclave work as catalyst for building leaders through holistic, transformable and innovative ideas. It has started in 2015 with great rhythm and passion, and this year with the same enthusiasm we are conducting this event in a broader spectrum.

Additional details can be obtained from www.iitg.ac.in/researchconclave/

Reflux - 2018

Reflux, the annual Chemical Engineering Symposium of IIT Guwahati, is organized during March 16-18, 2018. It has been a pioneer in chemical industrial and entrepreneurial scene of the country.

The aim of Reflux is to provide an opportunity for budding Chemical Engineers to share scientific expertise and knowledge towards the development of new methods and strategies in different fields of Chemical Engineering. The event is planned to be highly interactive and an excellent learning experience for all the delegates.

Additional details can be obtained from http://www.reflux.in/

We invite articles for the upcoming newsletter. Please write to iiche.grc@iitg.ernet.in for further details. The articles are published as provided by the authors. The opinions expressed in the articles should not be considered as endorsed by Indian Institute of Chemical Engineers – Guwahati Regional Centre or Indian Institute of Technology Guwahati.

IIChE Newsletter is available at http://www.iiche.org.in/pdfs/NLVol9.pdf


Amyloid β aggregation in CSF sample was characterized by Congo Red
absorption spectra red shifting and birefringes in polarized optical microsc
Absorbance (a.u.)
Wavelength (nm)


Fiber Optics – A Brief History &
Technological Impact