Centre for Environmental Technology Dissemination, Demonstration and R&D for Industrial Pollution Abatement

Prepared by

Department of Civil Engineering

Indian Institute of Technology Madras

Submitted to

Tamil Nadu Pollution Control Board

Tamil Nadu Government

PREAMBLE

TamilNadu has been leading the country in the areas of Environment management. Tamil Nadu Pollution control Board has been actively involved in monitoring and regulating the industries. TNPCB proposes to take pollution mitigation one step further by playing the role of an enabler of treatment technology from a mere regulator. This would largely benefit the small and medium scale industries who are willing to mitigate environment damage but are not aware of the appropriate technology for treating their waste. Such units do not have the R&D budget to arrive at appropriate technology for their specific needs. In this context, it is the need of the day to put in place a centre which can play a pivotal role in assimilating the current information on treatment technologies and best practices from all over the country and world, modify them to suit the needs of the different industries. Such a centre will also develop new, improvised and cost effective solutions, demonstrate the same to industries disseminate the information to similar industries and train the industries to adopt these practices to gain the maximum benefit from them. The Indian Institute of Technology Madras will take a leading role in setting up a Center for Technology Development, Demonstration and Dissemination of appropriate technology at IITM which will address all the issues related to Environment Management with special focus on wastewater, solid waste and air quality management in a holistic manner .

VISION

To play a pivotal role in enhancing the knowhow of managing the quality of the water and air by the industries through appropriate research, technology development, demonstration, capacity building and extension services.

MISSION

- To build a repository of available technologies and best practices of wastewater treatment and air quality management for each industry.
- To demonstrate appropriate and innovative techniques for water and wastewater and air sampling and monitoring.

- To disseminate the proven, best practices for water and air quality management using table top models, presentations and posters.
- To network among the industries and facilitate sharing of best practices through site visits and workshops.
- To organize training and demonstration programs for industries to disseminate the best practices.
- Creation of website for knowledge dissemination and set up a virtual knowledge centre to provide online technical support for industries
- To undertake research for development of new technologies to meet the emerging challenges in industries on a need based mode with tie up with requesting industries
- To support industries in installing treatment plant on a need based mode with tie up with requesting industries
- To raise the awareness level of industries to incorporate sustainable management practices for air, water, and wastewater systems by adopting reuse and recycle methodologies.

Proposed Tasks in the first three years

1. Monitoring technologies for air, water and wastewater

2. Demonstration of Industrial Waste water Management **(Any two industries will be taken up initially and later expanded to others as more faculties from other departments get involved in the centre activities)**

1. Sago Industry
2. Tannery Industry
3. Electroplating Industry
4. Textile Industry
5. Pharmaceutical Industry
6. Chlor Alkali Industry
7. Distillery Industry

3. Industrial air quality management technologies

4. Management of E-waste

FACULTY INVOLVED

Faculty Currently consented to be involved in the centre activities

Dr. Balaji Narasimhan

Dr. Indumathi M Nambi

Dr. Sachin Gunthe

Dr. Shiva Nagendra

Dr. K. Srinivasan

Dr. Sudheer K.P.

2.0 Scope of Work

2.1. Institute hereby agrees to carry out the activities of the centre as identified in this agreement paragraph 2.2 in a timely manner in accordance with the terms of the agreement and to the satisfaction of collaborator subject to the collaborator performing its obligations hereunder as specified in the agreement paragraph 2.3 so that the institute will be able to carry out the work and provide the deliverables as stated in the project proposal Annexure 1

2.2. The Institute will be responsible for the following activities of the centre:

2.2.1 To provide an office and meeting space for the centre and lab space for the equipments purchased and demonstration models developed by the centre as a makeshift arrangement initially and a permanent infrastructure at a later stage

I. On Nov 2013, Office space creation and furnishing, Conference room, Work station, AC installation, name board, Interiors works were finished.
II. Lab space creation works finished on Mar 2014.

III. Purchase of laboratory glass wares, consumables and equipment on Jan 2014.
IV. Purchase of laboratory items and other consumables on Mar 2014.
V. Purchase of other laboratory consumables on May 2014.
VI. Purchase of other laboratory consumables on June 2014.
VII. Purchase of air quality monitoring device on July 2014.
VIII. Purchase of micropipettes and chemicals on Aug 2014.
IX. Purchase of online monitoring devices. (pH, ORP and conductivity) on Oct 2014
X. Office space renovation and Lab Space infrastructure on Oct 2014

2.2.2 To identify coordinators among IITM faculty who based on their expertise will take the lead in assimilating best practices and demonstration and dissemination activities for each technology or sector

Faculty Currently consented to be involved in the centre activities

1 **Dr. Indumathi M Nambi**
2 **Dr. Mathav Kumar**
3 **Dr. Sachin Gunthe**
4 **Dr. Shiva Nagendra**
5 **Dr. K. Srinivasan**
6 **Dr. Sudheer K.P.**
7 **Dr. Balaji Narasimhan**
8 **Dr.Venu Chandra.**
9 **Dr. Soumendra Kuiry**
10 **Dr. Mukesh Doble**
11 **Dr. T.S. Chandra**
12 **Dr. Raghuram Shetty**

2.2.3 To recruit project staff required as stated in Annexure 2 as per the existing guidelines stipulated by IC&SR.

Interviews were conducted and the following staff was selected both through interviews and ad-hoc appointments:

Project Officers:

i. Dr. Sivagami, PhD, IIT Madras

Project Associates:

ii. Mr. Sakthivel, B.Tech. Chemical Engineering.

iii. Mr. Krishna Murari, M.Tech., Environmental Engineering, Anna University.

iv. Ms. Pavithra, M.Sc. Applied Microbiology.

v. Mr. Ansaf V Karim, M.Tech., Environmental Engineering, NITK.

Project Assistant :

vi. Ms. Manimegalai, M.B.A.

Mr. Muniyappan, B. Ed was joined as Senior Project Assistant on August 2015.

Mr. Krishna Murari and Mr. Sakthivel got relieved on December 2015 and March 2015, respectively.

Ms. Ramya, M.E, and Ms. Samvita, M.Tech., Project Associate were joined on February 2016 and April 2016, respectively.

2.2.4 To build a repository of available technologies and best practices of wastewater treatment and air quality management for each industry.

Literature collection on Sago industries, biomethanation plants, RDF plants, rice mills, textile dyeing units and electroplating units.

Site Visits to sago units, preparation of reports and laboratory reports on November 2015.

Phase-I of laboratory studies on Kancheepuram CETP effluent and electroplating effluent analysis on February 2016.

Phase-II of laboratory studies on Kancheepuram CETP effluent and electroplating effluent analysis on April 2016.

Site Visits to biomethanation plants in Chennai, Bangalore, and Pune from April to May 2016.

2.2.5 To identify experts from industry/research organizations specialized in the process and treatment technologies in each sector and form expert committees.

The First Technical Advisory Committee meeting of the centre was conducted on Jan 23 at BSB 105, Department of Civil Engineering. IIT-M. Technical advisory committee members included experts and various stakeholders from academia, industries, pollution control board and research centers both in the state and national level. The agenda for the meeting included discussion and brainstorming to identify the strategies and focus industries for the centre.

2.2.6 To prepare and disseminate best practices in treatment of water, waste, and air for selected industrial sector

Manual on best practices, for treatment of Sago waste water and energy generation was prepared and distributed to the workshop participant.

A demonstration was arranged by CETeDDD staff. pH, conductivity and TDS (total dissolved solids) were measured using a probe. Dissolved oxygen (DO) content in wastewater from different stages of treatment was also measured (raw wastewater, effluent from anaerobic lagoon, effluent from aeration tank, final effluent after clarification). Use of an AreaRAE gas monitor to check gases present in the surroundings at ambient temperature was demonstrated. Basic parameters such as DO and pH were explained and the importance of monitoring these parameters was highlighted.

2.2.7 To demonstrate appropriate and innovative techniques for water, wastewater, solid waste and air sampling, monitoring and analysis at the laboratory scale.

Two demonstration workshops were conducted in IIT and Attur at lab scale and field scale.

UASB reactor was designed and fabricated to demonstrate best availability technology for anaerobic process.

Synthetic sago waste water is prepared manually for known concentration alone with 4:1 ratio of anaerobic sludge and feed to upflow anaerobic sludge blanket reactor. Sludge is for the purpose of activating bacteria inside the reactor. Sequence analysis is carried out for following parameters (like COD, pH, Alkalinity and Volatile Fatty Acid). Values are shown in following table, and depicted pictorially in a graph as well.

Combined post treatment of sago effluent to meet irrigation standards

Experiments were performed and it was observed that the treatment efficiency in terms of decolorization and COD & TOC reduction can be improved by sequential treatment of coagulation followed by aerobic process. Coagulation of the waste water with 600 ppm $FeCl_3$ followed by aeration resulted in a maximum of 80 % reduction in TOC and 73.4% reduction in COD were attained with a treatment duration of 5 to 8 days (Fig.). Final pH of the solution was 8.8. However, the TDS of the final treated water was found to be 9435 mg/L.

	TOC reduction %	COD reduction %	Decolorization %	Final pH	Final TDS	Duration Days
Coagulation	39.2	29.4	93.1	4.1	4795.0	
Aerobic	70.4	53.1	87.0	9.3	5122.0	9.0
Aerobic II	68.3	42.4	85.4	9.3	5245.0	13.0
Adapted Aerobic	66.2	75.0	83.5	-	-	5.0
Integrated Aerobic	80.5	73.4	95.7	8.8	9435.0	5-8

Comparison of different methods

Among the different treatment options available, the one with coagulation followed by aerobic treatment resulted in better TOC, COD and colour removal in shorter time duration. However, this has resulted in a sharp increase in the dissolved solids concentration in the final treated water. Aerobic treatment shows promise in that the final TDS is not as high as in the combined approach. The final pH of the water is slightly above the discharge standards. Further experiments are to be carried out to evaluate the effectiveness of adapted aerobes for the treatment. The treatment duration can be considerably shortened by this approach. Also, in treatment plants, a well acclimatized culture of aerobes can be easily maintained in the aeration tanks. A single coagulation step appears to be not sufficient to achieve the desired treatment goals.

2.2.8 To disseminate the proven, best practices for water, waste and air quality management using table top models, presentations, videos and posters for select industries.

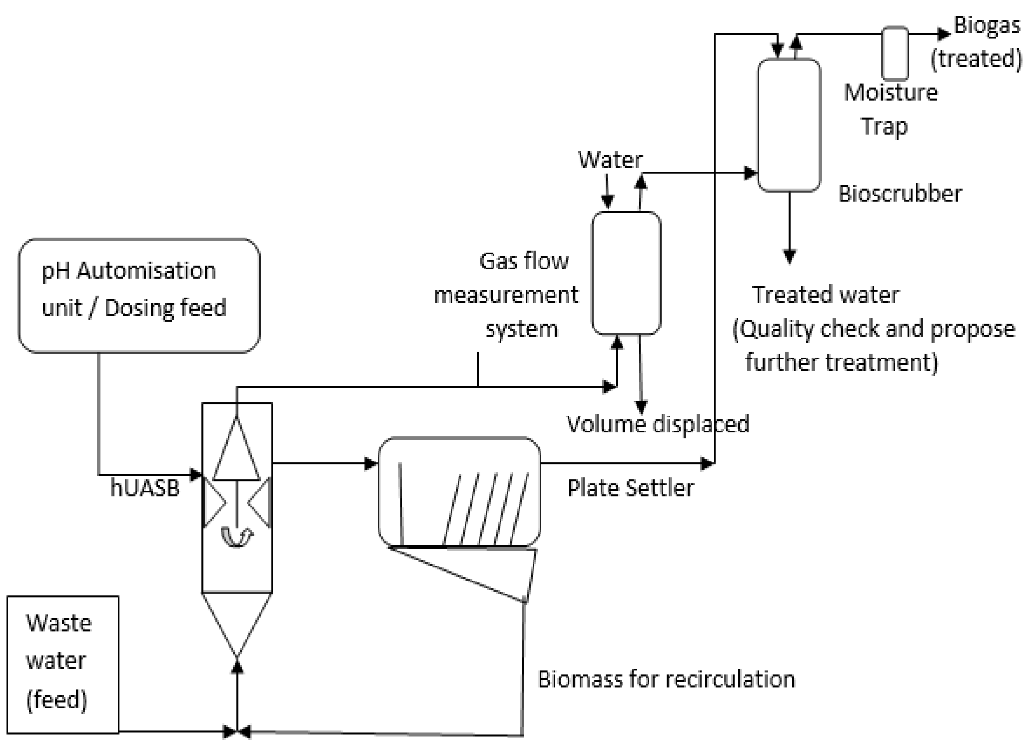
Pilot plant development for anaerobic treatment of sago waste water – UASB reactor designed by CETeDDD for sago wastewater

CETeDDD designed a Hybrid Up flow Anaerobic Sludge Blanket Reactor (hUASB), part of a pilot plant comprising of:

- Automated dosing system
- Plate settler (for recirculation of biomass)
- Bioscrubber (proposed for H2S removal)
- Gas flow measurement system
- Moisture trap, and
- Other utilities for treatment of sago waste water.

This enables us in conversion of waste to energy (biogas) effectively, as the existing anaerobic digestion system with tarpaulin sheets in MSMEs was found to be less effective. The plant operation has started with the acclimatization of biomass and then preceded for further research investigations.

Pilot plant flow scheme:



Process flow scheme for pilot plant

Summary of pilot plant specifications:

- A self-contained, floor-standing Upflow Anaerobic Sludge Blanket (UASB) reactor of volume 20 L
- Stirrer, motor and baffles fixed for hybrid configurations

Hybrid UASB reactor designed by CETeDDD

- Variable depth liquid sampling point
- Recycle pump capable of rates from 0 – 15 L/min
- Measures reactor temperature and vessel pH
- Programmable Logic Controller (PLC) provides pH control
- Jacket heating system with pump and hot water vessel (proposed)
- Complete with automated pH dosing system to maintain the vessel pH within a predetermined range (user programmable)
- User calibration of pH

pH calibration unit

- Gas collection system (vehicular tyre tubes are used)
- Feed flow rates from 0.6 to 6 L/hr (using interchangeable peristaltic hoses)
- Plate settler for recirculation of biomass

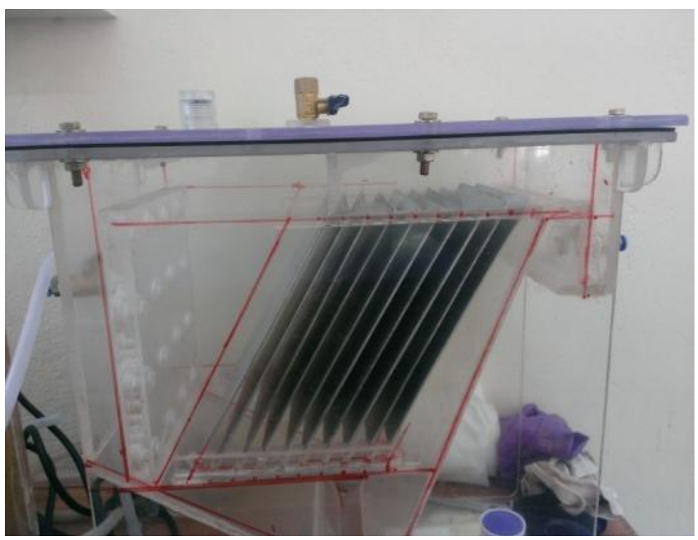


Plate settler

- Bio-scrubber (proposed) for H_2S removal
- Gas flow measurement system and further secondary treatment (proposed)

Summary of experimental capabilities:

- Optimizing reactor start up (acclimatization of biomass)
- Effect of temperature, pH, residence time
- Investigation of hydraulic loading (feed rate)
- Effect of effluent strength and nutrient deficiency
- Effect of recirculation ratio and fluidisation
- Comparing efficiency for various configurations
- Investigation of bacteria culture
- Acidogenesis and Methanogenesis process demonstrations

2.2.9 To undertake research for development of new technologies to meet the emerging challenges in industries on a need based mode with tie up with requesting industries

A series of R&D activities have been undertaken targeting the industrial wastewater treatment as part of the research work of PhD students. Some technologies developed in the past year and a half are

1. Modified Fentons process for Chromium removal
2. Permeable Reactive barrier wall for mixed pollutants in groundwater
3. Electrochemical treatment for pesticides
4. Reduction and Recovery of chromium using Microbial fuel cells.
5. Recovery of chemicals by CO2 sequestration

2.2.10 To support industries in installing treatment plant on a need based mode with tie up with requesting industries

1) Textile industry requested for evaluation of technology electro coagulation for colour removal.
2) Evaluation and selection of RO Plant for distilleries.

2.2.11 To create a website for online technical support and knowledge dissemination and to provide an interface for interlinking and sharing the know-hows of different industries

- Website related work started on Apr 2014.
- Website launch during the workshop on May 2014.
- The CETeDDD website is http://www.ceteddd.iitm.ac.in/.

2.2.12 To network among the industries and facilitate sharing of best practices through site visits and workshops.

The presentation by ENKEM revealed two plans for common effluent treatment. The first plan involved collection of raw effluent from sago factories in Attur, which would then be used to generate biogas. The wastewater would be treated as well, as per TNPCB norms (conforming to Zero Liquid Discharge when the rule comes into effect). In this scenario, the factories would have to purchase both water and biogas from the plant operated and maintained by Enkem, but at a much lower cost. The other plan involved collection of water after preliminary (anaerobic) treatment, which would allow the factories to retain the biogas generated (taking care of their electricity requirements), and the wastewater would be treated by the plant. The water after treatment would be made available to the sago factories.

A team from ADEPT gave presentation regarding water flow meters. ADEPT is an ISO certified company, with a factory unit in Pune, along with in-house laboratory facilities. The presentation touched upon the importance of having water flow meters and the different types that are available in the market as of now (electromagnetic, ultrasonic). It was mentioned that the flow of both treated and untreated water could be checked using these instruments.

BioGasclean (a company based in Denmark) detailed the necessity of installing a bioscrubber in order to remove sulphur content from biogas. The technology used for removal of H_2S was explained – trickling filter technology, which biologically removes sulphur from the biogas. Biogas scrubbing would significantly improve the quality and efficiency of biogas, thereby making the renewable fuel more valuable. The Indian headquarters is in Pune.

The team from GMMCO Caterpillar has been consulted regarding efficient gas engines for sago units. Diesel engines being used currently in sago factories all around the area were identified to be of much lower efficiency. The cost of these engines was said to be about Rs. 5 Lakh, with a lifetime of 4000 hours, and a further maintenance cost of Rs. 1 Lakh every year. These engines corroded rapidly due to the lack of scrubbing (the sulphur in biogas acts as a corroding agent). Caterpillar gas engines cost more; however, they come with a running time of approximately 80000 hours. It was mentioned that Varalaxmi Starch Industries (P) Ltd. have installed this particular Caterpillar gas engine, and are able to generate electricity for their needs. However, the need for a scrubber was again stressed upon.

An environmental company from Bangalore Oasis was contacted for setting up up pilot scale post treatment unit in a sago plant . Discussion were held and visits were made to Aathur Sago units.

Ionexchange and Fujimo Spirals came for discussions on setting up pilot plant for RO for reuse of water for the Sago processing. Visits were made to Sago units in Aathur but since it was end of season the plants were shutting down and hence the plans were postponed to July.

2.3. The collaborator and sponsor TNPCB will be responsible for the following activities of the centre:

2.3.1. Deputation of one engineer and staff from TNPCB to liaison among the Institute, industries and the collaborator. Their salaries will be directly paid by the collaborator/sponsor.

2.3.2 Identify industries which have been successfully implementing treatment technologies for air, water and waste management

2.3.3. Identify the industrial sectors which do not have awareness or access to technology

2.3.4. Contact industries for participation in workshops and demonstrations at the centre.

2.3.5. Obtain permission from industries for the institute faculty and centre staff to visit their facilities to take samples and take stock of their current treatment practices

2.3.6. Provide access to the centre staff and institute faculty to the existing documents, reports and library of TNPCB and facilitate borrowing of these material

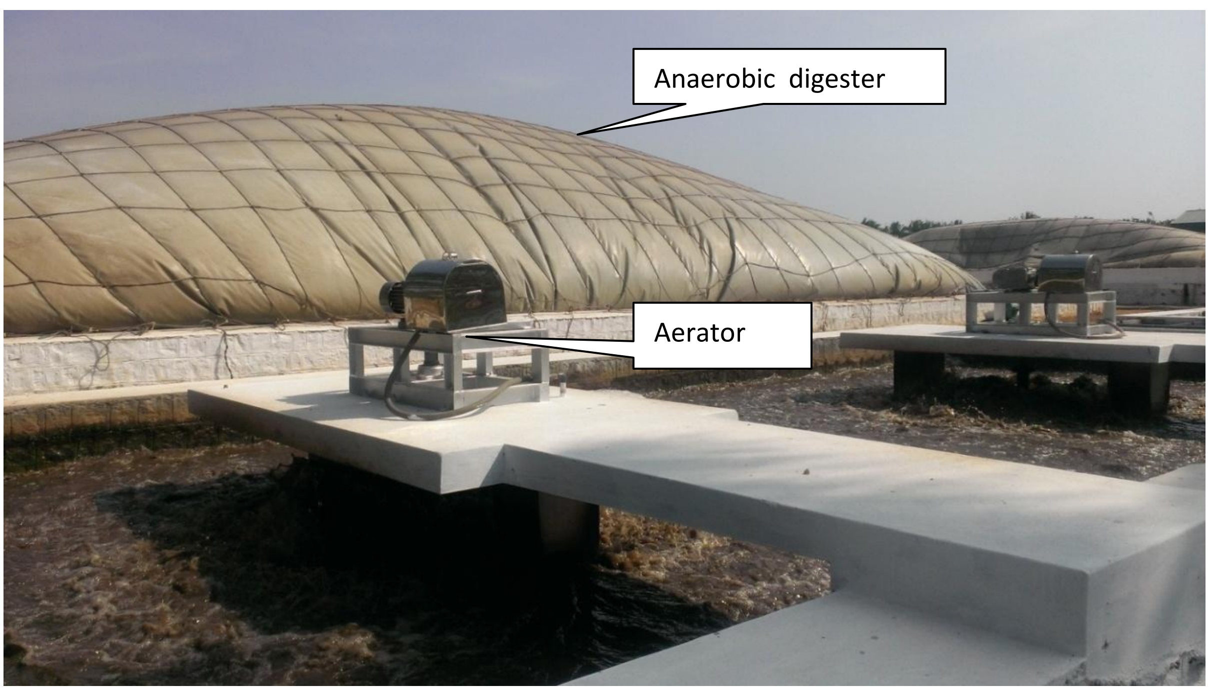
2.3.7. Facilitate contacts with experts in the field and networking with FICCI and CII at the state and national level

Industrial Outreach Program and R&D for industrial waste water

1. Sago Industry

Sago Industry was chosen to be the first to be studied by CETeDDD. The Sago cluster, the largest production capacity in India is located in Salem, Athur, Dharmapuri and Rasipuram districts of TamilNadu. We have visited many of these clusters and assessed the situation. We have collected samples for analysis. We have also fabricated a UASB bioreactor to demonstrate advanced waste water treatment. We have also prepared training documents for operation and maintenance of treatment plants. There are many ways we can contribute to improve the ways they are operating and managing the wastewater treatment facility.

In most of the industries belonging to the Salem sago cluster, the wastewater generated during the processes is treated using an anaerobic lagoon system followed by aeration. The biogas generated from the tarpaulin covered anaerobic lagoon is used in the production process to run the roaster and/or dryer units via a generator that runs on bio-gas. After the anaerobic process the effluent is sent to the aeration pond before being finally discharged onto the agricultural land. The cassava peels generated during the peeling process is segregated and used as a cattle feed.



Picture of the Current Environmental Technology in Place at Aatur Sago Factories.

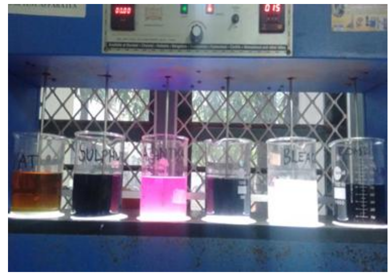
A brief summary of our findings and possible interventions:

1. Their waste water is rich in organic matter with high BOD and COD conducive for biogas production
2. The raw wastewater has low ph and high SS which needs pretreatment to improve performance of anaerobic units
3. The anaerobic units are not adequately sized for the volume of the WW mainly due to want of space. The tanks can go vertical above ground with low cost construction material like GFRG panels.
4. The treatment units post anaerobic treatment are grossly inadequate .
5. They have installed primitive technology of lagoons covered with tarpaulin sheets for biogas generation. We can introduce advanced technology for maximum recovery of biogas
6. The gas is converted to electricity inefficiently using diesel engines which can be improved by advanced engines Jen BAcher/Caterpillar
7. Raw gas is used in the engines which casues corrosion scaling without any scrubbing. We need to fabricate low cost scrubbers for adoption by them.
8. No gas flow meters are installed.
9. There are also serious levels of methane being released from there which can be quantified and captured to get CDM credits.
10. Water utilized for the production process is 5000litres per ton of product. Most of the water is bought at the cost of Rs400/5000litres since the area is water starved.
11. Water conservation methods in the production process primarily in settling starch using decanters.
12. We can also suggest recycling and reuse of wastewater by adequate tertiary treatment.

2. Kancheepuram Silk and Cotton Dyeing Units

Optimization study for Kanchipuram for sludge free decolourization for silk and cotton dyeing units was done. Initial characterization of Silk effluent and optimization study for the Silk effluent was carried out using various decolourisers like Microplus, Dicinol, Animole, catimole. Optimization study was carried out using different coagulants like Lime, Alum and hypochlorite and combinations of different coagulants were tried for optimization of dye effluents.

Silk effluent - Hypochlorite & Sulphuric acid



Optimization study for the Silk effluent was carried out using PAC, Alum and Hydrogen Peroxide, Hypochlorite, Sulphuric acid. Combination of Hypochlorite, Sulphuric acid showed better results. Final Silk effluent characterization was done. Ozonation Study was carried out for Silk effluent and cost estimation was done. Similarly for Cotton effluents optimization study was carried out using various decolourisers like Microplus, Dicinol, Animole, Catimole. . Optimization study for the Cotton effluents were carried out using different coagulants like Lime, Alum and hypochlorite and combinations of different coagulants were tried for optimization of dye effluents.

Ozonation Trial for Decolourization of Dyes

Optimization study for the Cotton effluent was carried out using PAC, Alum and Hydrogen Peroxide, Hypochlorite, Sulphuric acid. Combination of Hypochlorite, Sulphuric acid showed better results. Final cotton effluent characterization was done. Ozonation Study was carried out for Cotton effluent and cost estimation was done. Report was prepared for Kanchipuram dyeing units.

Performance of Micro plus and Dicinol on cotton dyes

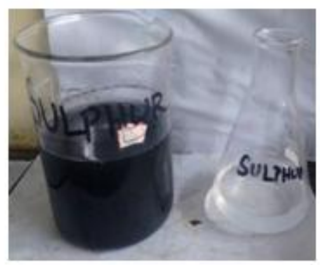
Naptha

Combination of all excluding VAT

Combination of all dyes

VAT

Ajantha



Sulphur

Trials using combination of hypochlorite and sulphuric acid

3. . Evaluation of Existing Biogas plants for Food Waste

BIOGAS PLANTS

India has about 2 million biogas plants of various sizes and capacities ranging from $1m^3$ to about $150m^3$. These plants have either fixed dome type or floating drum type gas holders. Different types of biogas digesters used in India are KVIC design, IARA design, PRAI design, Kamadhenu, Astra model, Jwala model, Ganesh model, Khira model, FRP model, Ferro cement digester model, SERC model, SPRERI model. Detailed description of few of the above mentioned models are given below.

BACKGROUND OF STUDY

At a meeting headed by then Corporation Commissioner Shri Vikram Kapur and TN Pollution Control Board (PCB) chairman Shri K. Skandan, it was decided to make it mandatory to process food waste from hotels and eateries in all the category by setting waste processing plants within their premises or to form cluster groups and set up a facility where waste can be transported and processed in a scientific manner. IIT Madras as the coordinating institute of the technical expert committee with responsibility of evaluating the existing technology providers along with IWMA was appointed by TNPCB.

OBJECTIVE

1. To find the best available biomethanization technology
2. To find other technology involved in solid waste management
3. To find the common solid waste management practices in India
4. To find the economically viable Biomethanization model

Site visits were conducted in Chennai, Bangalore and Pune. Responses for the questionnaire from vendors were compiled and compared and a report was prepared based on Phase I study in finding best available Biomethanation technology. Based on the Phase-I report, Phase II-site visits to Biomethanation plants in Chennai were made.

Otteri Barc Biomethanation Plant-3 MTD, Chennai

Bio-CNG Plant- 10 MTD, MWC, Chennai

Exnora green- 1 MTD, Pammal, Chennai

As part of Phase II study in finding best available Biomethanation technology, site visits to Bangalore based biogas plants were made and a report and presentation on the site visits were prepared. Samples from Biomethenation plants from Bengaluru were collected and analyzed.

Gas Power System 1 MTD Plant In AOL, Bengaluru

Maltose-Agri Product Pvt Ltd-18 MTD

Huskur, Bengaluru (Mailhem)-

Largest BioMethanisation Plant Noble Exchange-300 TPD, Telagon Pune

As part of Phase III study in finding best available Biomethenation technology, one week site monitoring in 5 Chennai based biogas plants were made. Samples were collected from those plants and analyzed for COD, pH, VFA, Alkalinity and performance evaluation was done for a period of three months.

Technology Development

Description of Technology Developed partially funded under CeTEDDD project are summarized below and elaborated in the following pages.

1. Chromium Removal Technology for small scale electorplating and tannery units

2. Removal of toxic organics from pharmaceutical units

3. Electrochemical methods for removal of dyes from textile units.

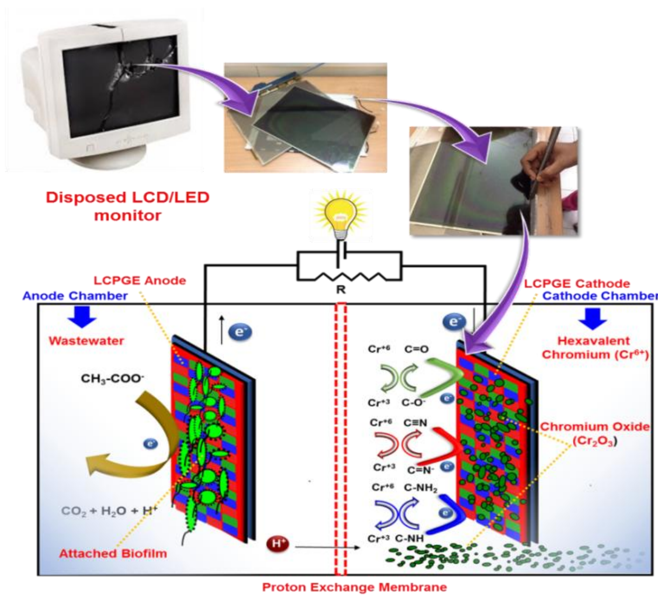
4. Optimisation of process parameters for Sago industry effluent treatment

5. Post polishing treatment for Tannery industry to remove organcis

6. Permeable Reactive Barrier Wall technology for groundwater contaminated with heavymetals such as Chromium

E-WASTE AS A RESOURCE FOR WASTEWATER TREATMENT AND ELECTRICITY PRODUCTION

There is a huge amount of e-waste generated all over the world from the disposed laptop and computer monitors, televisions, smartphones and other electronic devices. In the present study, we have successfully demonstrated the use of e-waste “LED/LCD glass"(liquid crystal coated Polaroid glass) as an electrode material in ‘Microbial Fuel Cells (MFCs)’for the simultaneous reduction and recovery of hexavalent chromium (Cr^{6+}) from synthetically prepared electroplating wastewater. In an MFCs, bacteria generate direct electricity from the oxidation of organic matter at the anode with reduction of oxygen at the cathode, separated by a proton exchange membrane. In this context, a new concept of utilizing “LED/LCD glass", known as Liquid Crystal Polaroid Glass Electrode (LCPGE), as anelectrode material in MFCs for simultaneous reduction of hexavalent chromium (Cr^{6+}) and recovery of electricity from wastewater.



LPCGE as electrodes in MFC for wastewater treatment and energy production.

An MFC consists of anode and cathode chambers connected internally by a proton exchange membrane (PEM) and externally by an electric circuit (Fig.1). Anaerobic condition was maintained in anodic chamber by periodic purging of nitrogen and LCPGE electrode was used as anode.Microorganisms oxidize the organic matter in wastewater to CO_2 and produce electrons and protons in the anode chamber. These electrons are accepted by thesolidLCPGE anode in the anode chamber and reached to theLCPGE cathode in the cathode chamber through an external circuit. Simultaneously, protons will migrate through the proton exchange membrane from the anode chamber to the cathode chamber. At the cathode chamber, Cr^{6+} - bearing wastewater are placed, which readily accepts the electrons and protons that are drifting from the anode chamber. By accepting the electrons, the Cr^{6+} is reduced to non-toxic Cr^{3+}at the LCPGE cathode interfaceand recovered in the form of chromium oxide (Cr_2O_3).

In the present study, 78% of organic waste was removed within 4 days of operation in the anode chamber. Similarly, in cathode chamber 100%Cr^{6+} reduction was achieved within 2 days of operation formingstable nontoxic Cr_2O_3 as confirmed by the X-ray diffraction and X-ray photoelectron spectroscopy analysis. During the reduction process, functional groups present in the LCPGE strongly attract Cr^{6+} ions and converts it into non-toxic Cr^{3+} on the cathode surface. Furthermore $Cr^{3+}$is converted into stable Cr_2O_3 and deposited at the bottom of the cathode chamber. The recovered Cr_2O_3 can be reused as a raw material for tanneries, electroplating industries and other applications. Additionally, energy can be recovered from an external circuit, as the electrons continuously flow from the LCPGE anode to the LCPGE cathode. The maximum power density of 10 mW/m^2 was achieved by adding organic waste and Cr^{+6} wastewater in anodic and cathodic chamber, respectively.

The basic concept that we use in this study is “use of waste to treat waste”. MFCs is a pollution free eco-friendly process and considerably reduces the organic waste treatment cost by producing electrical energy without combustion of fossil fuels. By incorporating E-waste as an electrode material, the overall operation cost of the MFC can be significantly reduced. Cheaper, economical and eco-friendly process of this kind can be utilized for large scale application with suitable process development. In addition, the order of liquid crystals (LCs) in E-waste LCD monitor is highly sensitive to molecular-level events and can be applied for making low-costbiosensors. Hence, other avenues for application of these scrap materials with suitable modifications need to be explored.

References

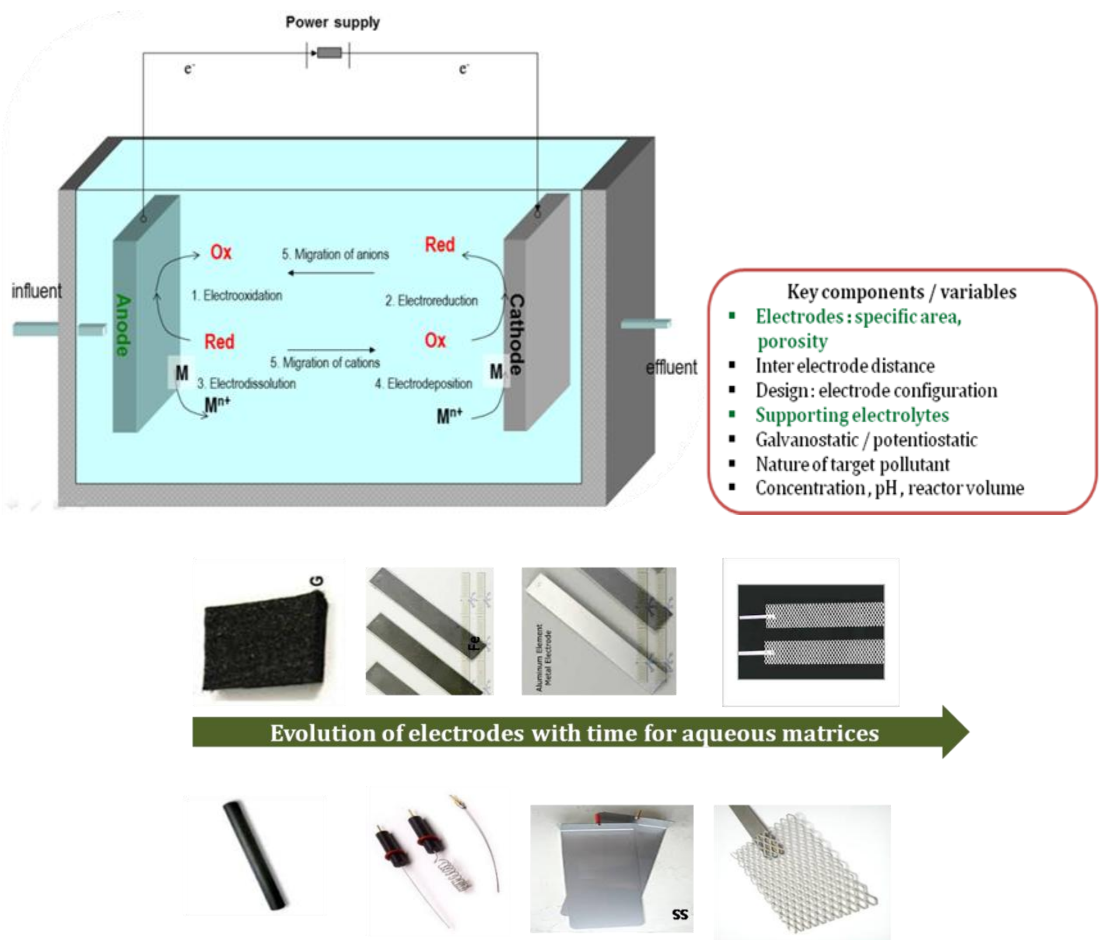
Gangadharan, P., Nambi, I.M., 2015. Hexavalent chromium reduction and energy recovery by using dual-chambered microbial fuel cell. Water Sci. Technol. 71, 353. doi:10.2166/wst.2014.524

Gangadharan, P., Nambi, I. M., & Senthilnathan, J. (2015). Liquid crystal polaroid glass electrode from e-waste for synchronized removal/recovery of Cr+ 6 from wastewater by microbial fuel cell. Bioresource technology, 195, 96-101.

Gangadharan, P., Nambi, I. M., & Senthilnathan, J. (2016). Heterocyclic Aminopyrazinereduced graphene oxide coated carbon cloth electrode as an active bio-electrocatalyst for extracellular electron transfer in microbial fuel cell. RSC Advances.

ELECTROCHEMICAL REMEDIATION OF CHROMIUM CONTAMINATED AQUEOUS MATRICES

Hexavalent chromium (Cr (VI)) in its various speciation forms is carcinogenic and is widely used in electroplating, textile dyeing, paints, pigments and tannery industries pose a major threat to the environment and human life. These industrial discharges ultimately find their way to contaminate the environmental matrices such as surface water, ground water and the soil phase. Traditional remediation techniques include, physico-chemical and biological reduction, electrochemical methods like electro-coagulation, photo-catalytic degradation etc. all of which has been well established. The limitations to scale up the existing techniques are that they are either energy intensive or the process involves only phase transfer of pollutants rather than the complete metal ion destruction, thus attributing them unsustainable for real scale applications.



Despite the availability of many *in-situ* technologies, the electrochemical method offer advantages of no chemical requirement and ease of operation with no residual contamination at ambient room temperatures. We have developed an *in-situ* **"low energy intensive"** prototype for reducing Cr(VI) discharged from electroplating or tannery wastes. The study investigated the use of different organic wastes as suitable electrolyte additive to reduce Cr(VI) to lower non toxic Cr(III). Additionally, the electrode surface was modified and results showed an enhanced degradation performance with 97.7 % at 5 V within 15 mins with an initial metal ion concentration of 100 ppm.

The results of the present investigation can find its applicability in scaling up for Cr(VI) discharges from an electroplating or tanning industries. The stand alone contributions from the present technique would be the following:

i. The cost of operation and maintenance would approximately be twofold to threefold lower on par with many other existing techniques.
ii. Simultaneous treatment of an organic waste and an inorganic waste is achieved.
iii. The chosen electrodes render a longer stability and shelf life, when compared to many other transition metal electrodes which corrodes with time.
iv. The **cost of chemical addition is zeroed down**, as the technology involves no external chemical addition.
v. Post treatment requirement as in case of many other existing *in-situ* techniques such as in chemical precipitation (widely adopted in India) is completely avoided in here; as there is **no sludge generation**.

The process could also be applicable to other inorganic metal ions such as Cu, Zn, Mn etc.

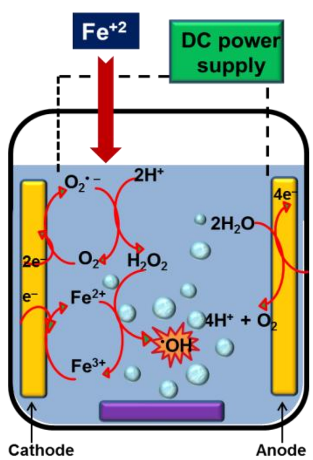
References

Patent Filed: Electrochemical Remediation Of Chromium Contaminated Aqueous Matrices

DEVELOPMENT OF MODIFIED ELECTRO-FENTON PROCESS FOR THE REMOVAL OF EMERGING CONTAMINANTS FROM WATER AND WASTEWATER

In recent decades, occurrence and persistence of emerging contaminants in the aquatic environment has raised as one of the global issues of environmental concerns. Presence of pharmaceutically active compounds (PhACs), personal care products (PCPs), phthalates, polycyclic aromatic hydrocarbons (PAHs), pesticides, surfactants etc. in water and wastewater systems are extensively reported in the literatures. Most of the conventional treatment systems exhibit limited effects in removal efficiency of these emerging contaminants due to the low concentration and restricted availability. Thus the removal of these contaminants from aquatic system requires a multidisciplinary approach. The research is mainly focused on studying the Electro-Fenton process in the following aspects (i) extending the applicability in a wider range of pH, (ii) preventing water contamination with iron, (iii) reducing the iron sludge generation, and (iv) simple and sustainable, cost effective electro-Fenton reactor configuration. The development of the hybrid electrode material which contains impregnated/bound catalyst on its surface can eliminate the problem of iron contamination of treated water. In addition to that, high catalytic activity, long term stability of the electrode with negligible leaching renders this system most suitable for drinking water treatment.

To develop a simple, sustainable water and wastewater treatment technologies for the removal of toxic, persistant organic pollutants using modified electro-Fenton process with synthesized hybrid electrodes immobilized with novel Fenton catalysts.



Schematic illustration of •OH radical formation in electro-Fenton process

The study includes

1. Explored the novel graphene based Fenton catalyst for electro-Fenton application
2. Assessed the various configurations of the electro-Fenton system to be more sustainable for water treatment. The system configurations include the following
    - **Conventional undivided electrochemical cell**
        - Electrodes are coated with Fenton catalyst and external aeration is provided
    - **Rotating disc reactor**
        - Enhanced atmospheric oxygen adsorption on the rotating electrodes
        - Rotating disc electrodes are immobilized with Fenton catalyst and external aeration is not provided
    - **Bifunctional rotating drum reactor**
        - Exploiting both anode and cathode in the in situ generation of reactive oxygen species
        - Integrating two different electrochemical advanced oxidation processes (photo-electrocatalysis and electro-Fenton) in a rotating drum reactor
        - Enhanced atmospheric oxygen adsorption on the rotating electrodes
    - **Granular Activated Carbon (GAC) fixed bed electro-Fenton reactor**
        - GAC bed act as electrode
        - Adsorption and electrochemical oxidation of the organic pollutants
        - Electro-Fenton regeneration of exhausted granular activated carbon adsorbent
        - Sustained reuse of the GAC bed without the frequent replacement
        - Simple and cost effective process

References

G. Divyapriya, I.M. Nambi, J. Senthilnathan, Nanocatalysts in Fenton Based Advanced Oxidation Process for Water and Wastewater Treatment, J. Bionanoscience. 10 (2016) 356–368.

G. Divyapriya, I.M. Nambi, J. Senthilnathan, An innate quinone functionalized electrochemically exfoliated graphene/Fe3O4composite electrode for the continuous generation of reactive oxygen species, Chem. Eng. J. 316 (2017) 964–977.

SUSTAINABLE TREATMENT TECHNOLOGY FOR COUPLED HEXAVALENT CHROMIUM AND PHENOL REMOVAL USING ZERO VALENT IRON

Heavy metals and organic compounds co-exist in many industrial discharges exhibit challenging transport and transformation scenarios, inefficient clean-up technologies and increased remediation expenses. This situation warrants development of effective, optimized and sustainable technique for coupled degradation of the heavy metals and organic chemicals. The Cr^{6+} and phenol have been chosen as the representative compounds due to their wide prevalence in the contaminated sites across India. Studies on conventional biological and physicochemical treatment methods proved that those were unsuitable for large field-scale *in situ* applications and iron based treatment methods are effective for heavy metal and organic compound removal.

Previous studies revealed that the practice of coarse sized zero valent iron (cZVI) is hampered by inconsistent iron corrosion rate, large quantum of secondary sludge production and passive layer formation on ZVI. The use of nZVI hastens corrosion and usage of toxic and expensive stabilizers to prevent agglomeration of nZVI is another major drawback. This necessitates developing an alternative form of ZVI, which can overcome the shortcomings of existing cZVI and nZVI. In addition, to prevent/remove the passive layer formation on the surface of ZVI, chemical corrosive agents such as acetic acid (HAc), aluminum sulphate (Alum) and potassium chloride (KCl) were evaluated as depassivators during contaminant removal that hinders its reactivity of ZVI. The experiments were conducted in batch and continuous column modes replicating ex-situ and in-situ conditions.

The study results proved that the use of micron sized ZVI (mZVI) for coupled Cr^{6+} and phenol performed better by having

- stable iron corrosion,
- effective utilization $Fe^{2+/3+}$ ions,
- less sludge production
- prevent the passive layer formation.

The modified technology developed in this study ensured the reliability of applying the robust and eco-friendly iron-based technology using ZVI in field application by eliminating the current limitations and enhancing the merits especially to remediate the land that contaminated with heavy metals and/or phenol.

References

Ambika S, Indumathi M Nambi, Senthilnathan Jeganathan, Low Temperature Synthesis of Highly Stable and Reusable CMC-Fe2+(-nZVI) Catalyst for the Elimination of Organic Pollutants, Chemical Engineering Journal, 2016, 289 (1) 544–55.

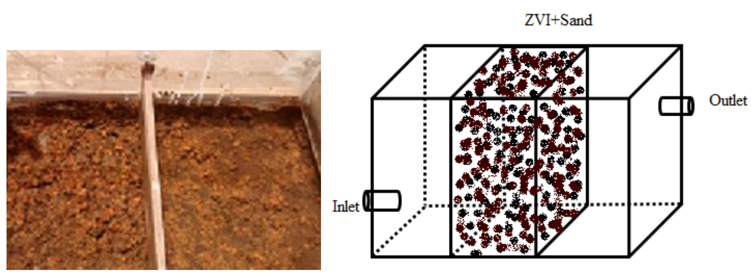
Ansaf V Karim, Ambika S, Indumathi M Nambi, Performance Enhancement of Zero Valent Iron Based Systems Using Depassivators: Optimization and Kinetic Mechanisms, Water Research, 2016, 102, 436-444.

Ambika S, Indumathi M Nambi, Devasena Sridhar, Synthesis and performance of High energy ball milled meso zero valent iron, Journal of Environmental Management, 2016, 1-9.

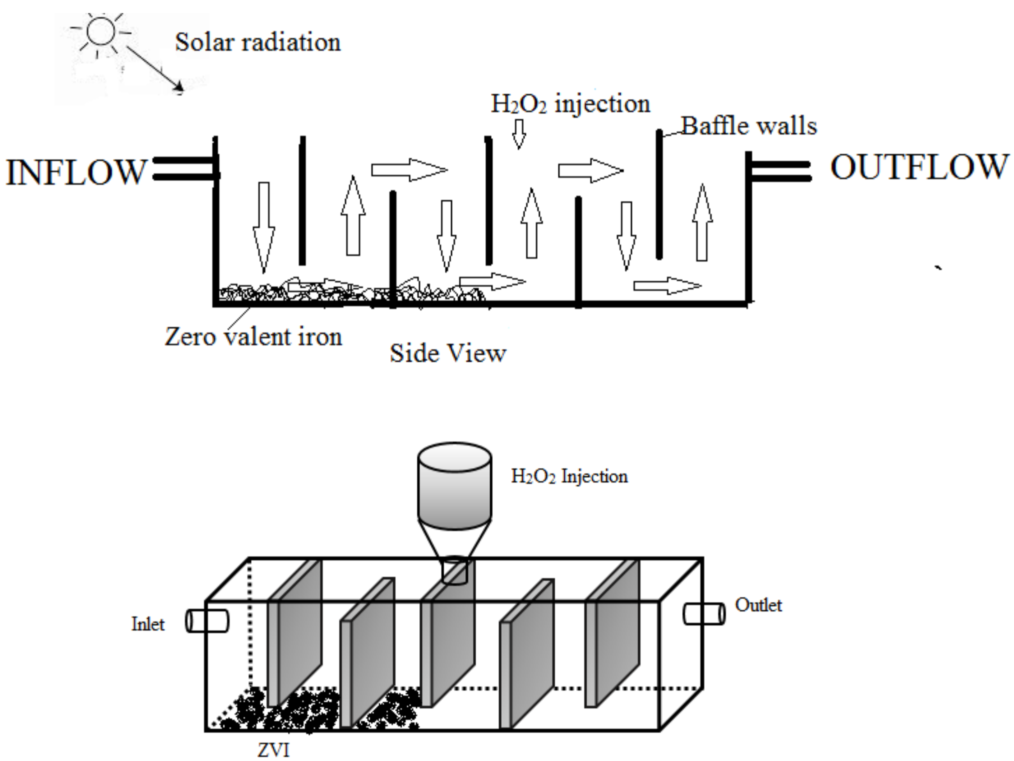
Ambika S, Indumathi M Nambi, Optimized synthesis of methanol-assisted nZVI for assessing reactivity by systematic chemical speciation approach at neutral and alkaline conditions, Journal of Water Process Engineering 13, 2016, 107–116.

INSITU TREATMENT OF LEACHATE RUNOFF USING ZVI BASED TECHNOLOGIES

The leachate stream replicating Perungudi dumpsite, chennai that was contaminated with hexavalent chromium and organic matter was treated by chemical oxidation reduction processes using Zero valent iron based processes. Batch studies were conducted on the reduction of Cr^{6+} and organic matter separately and mixed waste. Investigations were done using batch experiments and column studies. The permeable reactive barrier was designed based on the column studies. Experiments were conducted to evaluate the efficiency of the solar Fenton process in removing the Cr (VI) and Phenol.



Permeable Reactive Barrier filled with zero valent iron



Solar Fenton process with baffle walls

The characterization of leachate showed that the biodegradable matter is very less and biological processes are not effective.

- From the batch experiments the optimum dosage of ZVI for Cr^{6+} reduction was found to be 2 g/L.
- Taking the optimum dosage as 2 g/L, Cr^{6+} reduction was carried by ZVI, ZVI+UV, Fenton and photo Fenton processes and the reaction rates were 0.0313, 0.0329, 0.0069 and 0.0075 m-1 respectively.
- There was no phenol removal with ZVI and ZVI+UV processes. Batch experiments were conducted to oxidize 5mg/L phenol and it required 300 mg/L of H2O2 with Fenton and photo Fenton processes having reaction rates as 0.0218 and 0.0235 m-1 respectively.
- Batch experiments conducted with series removal of Cr^{6+} and phenol showed that the Cr^{6+} reduction rates enhanced and the phenol oxidation retarded. UV light converts Fe2+ to Fe3+ accelerating the Cr^{6+} reduction and phenol oxidation
- Batch studies conducted in the presence of organic matter with sodium acetate as substrate showed that the Cr^{6+} removal rate retarded in the presence of organic matter. The COD removal efficiency with ZVI and ZVI+UV was 47%. Nitrates are reduced by 38% with ZVI.
- With higher dosages of H2O2 for organic matter oxidation of 750 mg/L, the Cr^{6+} reduction rate further decreased and the organic matter oxidation rate increased.
- For the PRB of 10 cm thickness, the Cr^{6+} reduction was 85-90% efficient and COD removal was 27% for 28 days. The efficiency of Solar Fenton process in removing Cr^{6+} was 86% and phenol oxidation efficiency was 80%. Though the ZVI was present in high quantities the Fe concentration in the outlet did not increase much.

The permeable reactive barrier is effective when the flow velocity is low as the thickness of the barrier can be reduced. The ZVI is capable of reducing the heavy metals, aliphatic and aromatic compounds from the toxic form to non-toxic form, but the COD value almost remains same. It is cost effective and since there are no chemicals used and the only material used is scrap iron which is converted to ZVI. This can be easily operated once it is installed because the porosity of the barrier is very high and the precipitates do not affect the retention time for a long duration. Solar Fenton process utilizes the cheapest source of energy i.e. solar energy and enhances the Fenton process. It can be used if the organic content is very high and cannot be easily reduced or oxidized without a strong oxidizing agent.. This system requires continuous maintenance for the precipitation and continuous supply of hydrogen peroxide for the oxidation of organic matter. It is very effective in oxidizing organic matter irrespective of the time as Hydrogen peroxide and iron are present.

TREATMENT OF TANNERY EFFLUENT USING ADVANCED OXIDATION PROCESS

Tannery wastewater was characterized by its strong colour, high COD, BOD, TSS and TDS. The levels of pollutants in tannery wastewater also vary depending upon the process adopted in processing of leather from semi finish to finished. The treatment of tannery effluent depends on the efficiency with which the CETP functions. Hence, the continuous evaluation was a prerequisite for up keeping the efficiency of the CETP. Analysis of chemical characteristics of the wastewater coming into Madhavaram CETP substantiates this claim; while the analysis of post-treatment effluent from Madhavaram CETP indicates that the water being discharged after treatment does not meet the standards set by TNPCB physico-chemical parameters. To evaluate and improvise the performance of the Madhavaram CETP, The following methods have been adopted: Data management and analysis and checking adequacy of current design, periodic monitoring of performance of the CETP, laboratory coagulants dosage optimization study and biokinetic study, trials of new technology for colour, Cr and COD removal.

The effect of pH, hydrogen peroxide, ferrous ions concentration on removal of COD was studied. COD removal rates for secondary settling tank effluent was high when compared to primary settling tank effluent at (1:5) ratio. At 1:20 ratio, for an increase in H_2O_2 concentration COD got increased in the SST effluent due to excess H_2O_2 present in the solution. At acidic pH of 3-4, performance of fenton with PST and SST effluent was better. When the ferrous sulphate concentration increased to 500 mg/L lead to an increase in the unutilized quantity of iron salts, which contribute to an increase in the total dissolved solids content of the effluent stream. Total Organic Carbon reduction in fenton +ozonation was more when compared to fenton process with the secondary settling tank effluent.

The primary and secondary treated tannery effluent after biological treatment was subjected to ozone treatment in a bubble column reactor for further reduction of pollutants like color and residual organics in terms of COD with varying pH. at an ozone flow rate of 1.0 L/min was analyzed. For an increase in contact time with ozone, there is an reduction in COD in the primary (2138-1736) as well as secondary settling tank effluent(1600-450) mg/L. When compared to ozonation, COD reduction in Fenton process is very less. Ozonation of SST effluent gives better TOC removal compared to any other treatment processes. Around 60% of the Total Organic Carbon was removed by ozonation process.

Chemical dosage optimization and pH adjustment studies were conducted for primary and secondary settling tank effluent to identify the treatment efficiency of alum and lime. Removal efficiency was measured in terms of reduction in suspended solid (SS), total dissolved solid (TDS), pH, Alkalinity, chemical oxygen demand (COD). Optimization studies was conducted for combined dosage of lime and alum with different weight ratios in primary settling tank effluent. Physico-chemical characteristics like pH, Volume of sludge settled, TSS, TDS, COD, Turbidity and TOC was measured in PST effluent before and after different dosage of lime and alum. For an increase in pH from 7-12, there was an increase in consumption of 1M lime and volume of sludge settled. TSS, TDS, COD and turbidity values reduced to 1200-20, 460-3991.86, 2560-1540.5 mg/L and 717-0.94 NTU respectively.

Heavy metals and VOC suite analysis also done for identifying the COD constituents for the same effluent. The raw wastewater showed the presence of various organic compounds of which the prominent ones were: Methylene Chloride, Benzene, Toluene, m,p Xylene and 1,4 dichloro benzene. Ethylene Oxide and hexanol is present in both influent as well as in the effluent. Two repeated runs of GC-MS shows different compounds present in various stages of effluent treated.

Fig.1 - Ozone treatment of tannery effluent

Fig.2 - Pilot plant ozonator

Analysis of chemical characteristics of the wastewater coming into Madhavaram CETP substantiates this claim; while the analysis of post-treatment effluent from Madhavaram CETP indicates that the water being discharged after treatment does not meet the standards set by TNPCB physico-chemical parameters. To evaluate and improvise the performance of the Madhavaram CETP, The following advanced oxidation process (AOP) methods Fenton's reagent, UV/ Fe^{3+-}Oxalate/H_2O_2 and O_3/UV Process was evaluated.

Reference

K Sivagami, KP Sakthivel, IM Nambi, Advanced Oxidation Processes for the treatment of tannery wastewater, Journal of Environmental Chemical Engineering, 2017

TREATMENT OF TANNERY EFFLUENT USING ELECTRO COAGULATION TREATMENT

These conventional processes are often inadequate for complete removal of pollutant in tannery industry. The electro coagulation treatment of tannery industry wastewater represents as an economical alternative process when conventional treatment process fails to decrease the pollution load. The study aimed to design and assess the performance of pilot scale electro coagulation (EC) process for the primary treatment of real tannery wastewater using iron and Aluminum electrodes so as to decrease the suspended solids and Chemical Oxygen Demand (COD) on secondary biological process. Lab scale studies of tannery effluent by electro coagulation with Aluminum and Iron electrodes were conducted and parameters such as pH, current density and electrolysis time were optimized. The scale up studies of electro coagulation were conducted under optimal conditions. Batch reactors of 1 and 6.5 L with the sample volume of 0.5 L and 5 L were used for the studies. The 0.5 L reactor showed that

- Removal efficiency of pollutants depends upon the amount of metal hydroxide getting generated and removal is rapid at higher applied current.
- TOC removal is slightly more for iron compared to aluminium
- Iron has better TSS removal compared to Aluminium due to heavier flocs and 98% removal efficiency is observed at 60 min interval with passage of 1.2 A current(Fe electrode)
- BOD removal is more in Iron compared to aluminium ,a 90% removal efficiency is observed at 60 min interval with passage of 1.8 A current(Fe electrode)
- pH 5 - 7 shows better removal efficiency above 50% for aluminium and iron.In Acidic and neutral pH, presence of positively and neutrally charged monomeric, polymeric amorphous species and precipitated $Al(OH)_3$Leading to the adsorption and coprecipitation of pollutant molecules and subsequent removal from the aqueous phase.
- At alkaline pH, presence of negatively charged $Al(OH)_4^-$ species tend to involve in repulsing of anionic pollutant charged spiciesin the solution results in lower removal(Zeta potential -15.9 Mv)
- Iron is found to be good in terms of removal efficiency ,also less energy and elecrode consumption is observed for iron in wide range of pH 6-8 compared to aluminium.
- A high removal efficiency of TOC (68%), TSS (54%) and BOD (45%) when the reactor was operated at 200 rpm .A treatment efficiency of 50% ,60%,46% is obtained for spacing of 1.5 cm

Compared to chemical coagulation, electro coagulation performed to be better in terms of better BOD and TOC removal and less sludge production with significant cost reduction.

TREATABILITY STUDIES FOR HEXAVALENT CHROMIUM BEARING LEACHATE AND RUN-OFF FROM RANIPET SITE

This report details the research proceedings at IIT-M with respect to treatability studies for hexavalent chromium bearing leachate and groundwater from the Ranipet site. Batch and column experiments, characterization of groundwater, leachate and column permeate, precipitation and settling experiments were performed. Reduction was performed using three different reducing agents – ferrous sulphate, sodium bisulphate and sodium metabisulphite. Sodium bisulphate was eliminated in the interim stage, as it did effectively reduce hexavalent chromium. The results obtained indicate that as far as the concern is chemical dosage, sodium metabisulphite is the preferred reducing agent – 0.2 g/L for complete reduction 100 ppm of Cr(VI), as opposed to 2 g/L of $FeSO_4$ for 100 ppm of Cr(VI). The volume of sludge generated is lower when using sodium metabisulphite, at an optimum pH of 9.2-9.5.

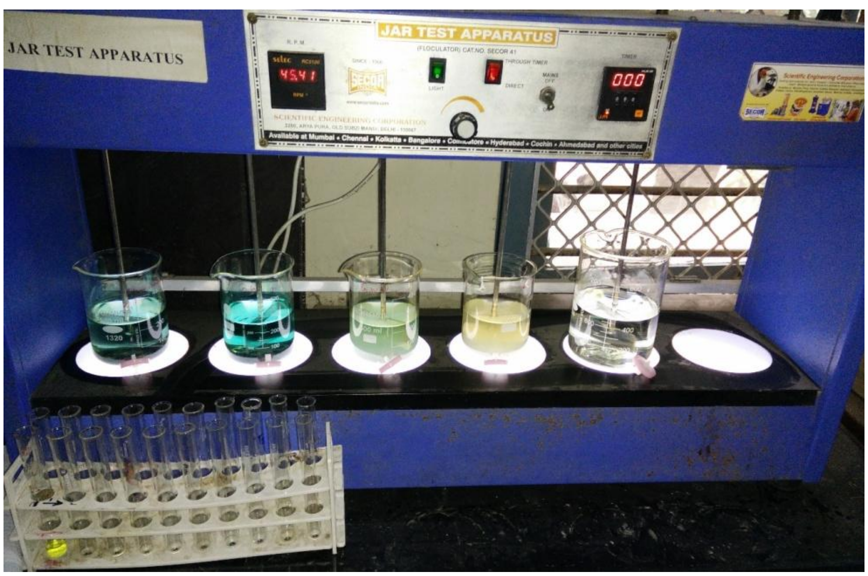


Fig. 1: Reduction of hexavalent chromium using sodium metabisulphite

Sodium metabisulphite is the preferred reducing agent in terms of chemical dosage, amount of sludge produced and turbidity of supernatant. A reaction of 2 hours is necessary to allow the reaction to go to completion, i.e., for all the hexavalent chromium to be converted to trivalent chromium. In case of $FeSO_4$, it was observed that the maximum reduction takes place in the first 15 minutes of the reaction, however, this duration is not sufficient to completely reduce all the hexavalent chromium in solution. In case of $Na_2S_2O_5$, a reaction time of two hours is necessary for complete removal of hexavalent chromium.

ZERO VALENT BASED MIXED HEAVY METALS REMOVAL

The removal of heavy metals by ZVI was found to be dependent on factors like pH, dosage of iron and the form in which ZVI is used in the process. Acidic pH was found to be favorable for the removal of chromium and copper while for zinc acidic pH was not found to be favorable.

- The removal efficiency was found to increase with the increase in the dosage of iron applied in case of both the forms of iron used. The optimum dosages were found to be varying for the different heavy metals for different pHs.
- The nZVI was found to be more effective than ZVI powder in the removal of all the three heavy metals and the reason for this must be the increase in specific surface area, around 45-50 times, of nZVI when compared to ZVI powder, which results in the increase in reactivity.
- The mechanism of removal is believed to be reductive transformation for chromium and copper and combination of sorption and precipitation for zinc. Further studies need to be conducted for confirming the mechanisms of removal of zinc.
- The heavy metal removal efficiency is more in the single metal ion solution than in the mixture for all the three metals while using ZVI powder as well as nZVI. The decrease in removal efficiency of copper in the mixture can be a result of utilization of zero valent copper by Cr^{6+} for its reduction.
- The removal of heavy metals by ZVI powder in single metal ion experiments was found to follow first order kinetics with the concentrations decreasing gradually over a long period of time and in the mixture chromium and copper removal was found to follow zero-order kinetics while zinc removal was first order.
- Nano ZVI showed distinct two stage removal kinetics with an accelerated primary stage followed by a rate limited stage for all the metals. The cause of this effect can be the rapid utilization of the nano zero valent iron due to its high reactivity. In case of chromium, the second stage of reactions proceeds in the presence of Fe^{2+} which can reduce Cr^{6+} to trivalent state.
- The addition silica was found to enhance the reaction rates and the maximum percentage removal of the three heavy metals on using both forms of iron, particularly in case of gZVI. This is due to the amendment of the surface de-activation of the zero valent iron surface by the abrasion of the silica particles. In case of nano ZVI, much effect was not observed due to the higher particle size of silica particles compared to iron.

It can be concluded that nZVI is a better option for the efficient removal of the heavy metals from a wastewater containing a mixture of heavy metals since nZVI can remove the heavy metals to desired limit in wastewater in a much shorter time as well as using a much lower dosage

Summary, Conclusion and Way Forward:

The technology development and Demonstration Centre has visited and done complete assessment of Sago industry, Electroplating industry, Textile dyeing units, Tannery units.

The limitations of the industry to treat their effluents to meet the norms were understood and advanced technology were developed and demonstrated at the lab scale.

In addition at the request of the chairman TNPCB, a detailed assessment of biogas plants in South India was conducted and operation manual and process design and essential requirements for tendering the plants were prepared

Textile industry dyeing units in Kancheepuram and Erode were visited and studied and new technology for colour removal and salt removal were suggested.

Meeting with the industry owners were conducted and demonstration of technology in IITMadras and Salem, Kancheepuram and Ambattur.

Equipments were purchased for analysis of the industrial effluents and conducting electrochemical treatment studies- Microwave digestor, Biologic potentiostat, Mobile TOC, TGA and Biodigestor and reactors

TNPCB Divisional engineers in the respective zones were requested to insist the industries to implement the technology in their industry for better compliance of TNPCB norms.

An Innovation and technology hub was proposed to be created to show case the latest technology in industrial Waste water treatment for use by industry and TNPCB for evaluation of new technology.

Training of TNPCB Scientists and Engineers in monitoring sampling and laboratory analysis was proposed for better utilization of laboratories in TNPCB and Better monitoring of external labs and quality control of their data.