वार्षिक प्रतिवेदन
Annual Report

2012-13

सीएसआइआर – भारतीय पेट्रोलियम संस्थान, देहरादून

CSIR-Indian Institute of Petroleum, Dehradun

वार्षिक प्रतिवेदन
ANNUAL REPORT
2012-13

सीएसआइआर-भारतीय पेट्रोलियम संस्थान, देहरादून

CSIR-Indian Institute of Petroleum, Dehradun

Chief Editor
Dr S K Sharma

Asstt. Editor
Mr M C Ratori

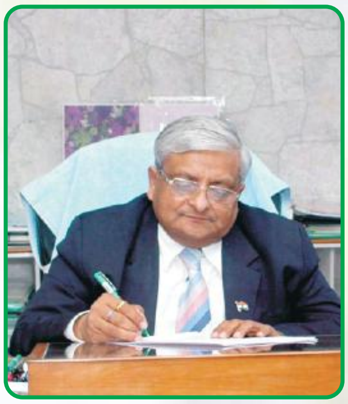
Editorial Team & Assistance
Mr Vikram Singh Rawat
Mrs Pratima Bagga
Mr Bijendra Dutt
Mr Pankaj Bhaskar

Digital Imaging & Photography
Mr Pradeep Pundir

Acknowledgements to
All Heads of Divisions/Cells/Sections for providing inputs for the report

Published by
Dr M O Garg
Director
CSIR-Indian Institute of Petroleum
Dehradun

Designed and Printed by
M/s Saraswati Press
2, Green Park, Niranjanpur
Sabzi Mandi, Dehradun
Tel.: 0135-2726694, 9359211333



प्राक्कथन
2012-13

26 सितंबर, 2012 को वैऔअप ने देश के विकास हेतु विज्ञान एवं प्रौद्योगिकी में अपने सहयोग के 70 गौरवशाली वर्ष पूरे किए। जहाँ एक ओर दिल्ली में इस अवसर पर विभिन्न गतिविधियाँ आयोजित की गई, वहीं हमने श्री आर एस् बुटोला, अध्यक्ष एवं प्रबंध निदेशक, इंडियन ऑयल कॉर्पोरेशन को मुख्य अतिथि तथा डॉ० आर के मल्होत्रा, निदेशक, आइओसी (अनु.-वि) को विशिष्ट अतिथि के रूप में आमंत्रित कर इस दिवस को मनाया।

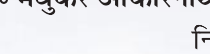
हमने अपना स्थापना दिवस भी 14 अप्रैल, 2013 को श्री सुधीर वासुदेव, अध्यक्ष एवं प्रबंध निदेशक, ओएन्जीसी के साथ मनाया। यह हम सबके लिए एक स्मरणीय दिवस था।

हमारे संस्थान में तीन राष्ट्रीय स्तर की बैठकों का समन्वयन तथा आयोजन किया गया : इनमें प्रथम थी, पेट्रोलियम एवं प्राकृतिक गैस मंत्रालय की वैज्ञानिक सलाहकार समिति की 71वीं बैठक और उसके बाद 'उत्सर्जन विधान कार्यान्वयन की स्थाई समिति' (एस् सी आई) की बैठकें तथा साथ ही 'केंद्रीय मोटर वाहन नियमावली' तथा 'तकनीकी स्थाई समिति' की बैठकें। संस्थान को दो प्रमुख राष्ट्रीय स्तर की वैज्ञानिक बैठकों के लगातार आयोजन के आतिथेय का श्रेय जाता है : एक हाइड्रोकार्बन के लिए और दूसरी ऑटोमोटिव क्षेत्र हेतु।

दो विशेष रूप से उल्लेखनीय उपलब्धियां (जो इस दौरान हुईं) भी सीएस्आइआर-भापेसं के इतिहास में स्वर्णिम अक्षरों में लिखी जाएँगी। इनमें पहली थी, केंद्रीय विद्यालय संगठन के साथ, केंद्रीय विद्यालय, सीएस्आइआर-भापेसं को एक नए भवन के निर्माण के लिए भूमि के हस्तांतरण पर किए गए एक करार पर हस्ताक्षर। यह उस सपने का वास्तविकता में बदलना है, जिसके लिए हमने अथक प्रयास किए। दूसरी उपलब्धि थी, एफसीसी नैफ्था से शुद्ध बेंजीन व यू एस श्रेणी की गैसोलीन के युगपत् उत्पादन हेतु सीएस्आआर-भापेसं की प्रौद्योगिकी के क्रियान्वयन के लिए रिलाइएंस द्वारा लिया गया निर्णय। आरआइएल्, जामनगर में रु० 150 करोड़ की लागत से बनने वाला यह संयंत्र विश्व में अपनी तरह का पहला संयंत्र होगा। संस्थान का चयन कड़ी वैश्विक प्रतिस्पर्द्धा के चलते किया गया। इससे, विलायक निष्कर्षण क्षेत्र में हमारी क्षमताओं को अंतर्राष्ट्रीय पहचान मिली है।

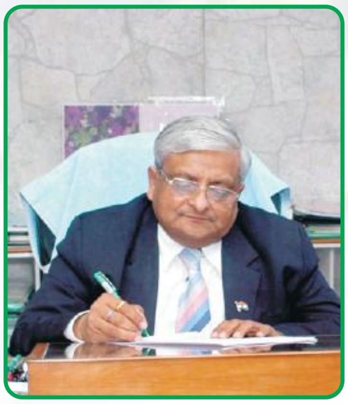
यह बहुत प्रसन्नता की बात है कि हमारे संस्थान के इतिहास में हमने पहली बार रु० 15 करोड़ से अधिक की ईसीएफ् का अर्जन किया है। यह उल्लेखनीय है कि इसमें से आधी राशि प्रायोजित अनुसंधान एवं विकास से है जबकि एक उल्लेखनीय अर्जन रॉयल्टी तथा हमारी परामर्शी सेवाओं से भी हुआ है। यह कहना होगा कि ऐसा हमारे साझेदारों के सहयोग और शुभकामनाओं तथा हमारे वैज्ञानिकों व कर्मचारियों के अथक प्रयासों के बिना संभव नहीं था।

रिलाइएंस द्वारा संस्थान के चयन के माध्यम से हमने विश्व-स्तर पर अपनी प्रौद्योगिकियाँ दे सकने की अपनी क्षमता को सिद्ध किया है। मैं आपके द्वारा हममें प्रदर्शित विश्वास के लिए आपका धन्यवाद व्यक्त करता हूँ।



(डॉ० मधुकर ओंकारनाथ गर्ग)

निदेशक



Foreword 2012-13

On 26th September, 2012, CSIR completed 70 glorious years of its contributions in science and technology for the development of the nation. While various events were organized in Delhi to mark this event, we invited Shri R S Butola, Chairman and Managing Director, Indian Oil Corporation as Chief Guest and Dr R K Malhotra, Director, IOC R&D as Guest of Honour to celebrate this event in our Institute.

We also celebrated our own Foundation Day on 14th February, 2013 with Shri Sudhir Vasudeva, Chairman & Managing Director, ONGC. It was a day for all of us to remember.

Three national-level meetings were co-ordinated and organized at our Institute; the first one was the 71st meeting of the Scientific Advisory Committee of the Ministry of Petroleum & Natural Gas, followed by the meetings of the Standing Committee on Implementation of Emission Legislation (SCOE) as well as Central Motor Vehicles Rules and a Technical Standing Committee Meeting. The Institute can boast of having hosted two major national-level scientific meetings back to back: one for the hydrocarbon and the other for the automotive sector.

There were two landmark achievements which will go down in golden letters in the history of the CSIR-IIP. The first one was the signing of the agreement with the Kendriya Vidyalaya Sangathan for transferring of land to Kendriya Vidyalaya, CSIR-Indian Institute of Petroleum, for construction of a new building. This has been a dream come true for which we worked untiringly. The second was the decision taken by Reliance to implement the CSIR-IIP technology for Simultaneous Production of Pure Benzene and US Grade Gasoline from FCC Naphtha. This plant to come up at RIL Jamnagar at a cost of Rs. 150 crores would be the first of its kind in the world. The CSIR-IIP was selected against tough international competition. This has provided us international recognition to our capabilities in the solvent extraction area.

It is with great joy that I say that for the first time in the history of our Institute we have crossed an ECF of Rs. 15 crores. It is noteworthy that half of this is from sponsored R&D while significant earning came from royalty as well as our consultancy services. Of course this would have not been possible without the support and well wishes of our stake-holders and the untiring efforts by our scientists and staff.

With selection of the CSIR-IIP by Reliance we have proved our capability to deliver technologies at global level. I thank you for your confidence in us.

(Dr Madhukar Onkarnath Garg)

Director

Contents

1

Contributions to Science & Technology

1.1 SEPARATION PROCESSES

1.1.1 Aromatic Extraction

- **Technology Development for Simultaneous Production of Pure Benzene and US Grade Gasoline from FCC C6 Heart Cut (Deisohexaniser side cut)**

M/s Reliance Industries Ltd. (RIL) produce 33 KTD of gasoline from their two world class refineries and petrochemical complex at Jamnagar, India. Gasoline specfication on benzene (Bz) in US has been revised to maintain 0.62% vol max., effective from 2011. Many other countries are bringing stringent specification for benzene content in gasoline to 1% vol max., by 2014 from current 3% vol max.

At M/s Reliance Jamnagar, FCC Deisohexanizer side cut is the major contributor of benzene in gasoline pool. This stream (3 KTD) is rich in benzene to the tune of 11 to 19% wt. It is imperative to remove benzene from this stream in order to meet forthcoming benzene limit in gasoline pool. M/s Reliance also intend to upgrade the recovered benzene meeting product quality standards.

M/s Reliance approached the CSIR-IIP to study the feasibility of extracting pure benzene from light FCC gasoline. The CSIR-IIP carried out extensive studies on the Reliance feedstock to establish the optimum solvent, operating conditions as well as the process configuration to achieve the desired objectives. An extractive distillation based technology was conceptualized to achieve the desired objectives. The CSIR-IIP simulation model was used to simulate all these laboratory runs and the interaction parameters for the components were fine-tuned to match the experimental data.

The simulation model so developed was used to establish the optimum process operating parameters.

A comprehensive Process Design Report summarizing the process that CSIR-IIP developed for Reliance was submitted to Reliance in June 2012.

Finally, a detailed Technology Information Package (TIP) comprising the process description, process flow diagram, process stream summary, heat and material balance data sheets, equipment data sheets, utility summary sheets, column data sheets, effluent summary, chemical and additives summary, etc was submitted in September 2012.

Process Advantages

- Gasoline fraction with less than 0.4 wt. % benzene, high yield and minimal loss in octane value.
- Recovery of benzene is at the maximum (more than 98% from catalytically cracked FCC C6 heart Cut)
- Benzene purity achieved is more than 97 wt. %
- Solvent/co-Solvent combination, used in the Extractive Distillation system, is tailored to remain thermally and oxidatively stable all throughout the operation
- There is selective removal of sulphur compounds from FCC gasoline feedstock (DIH side cut)

- **Synthesis of Room Temperature Ionic Liquids (RTILs) and to Study of their Application for Extraction of Sulphur, Nitrogen and Aromatic Compounds from Petroleum Feedstocks**

The work was initiated in April, 2007. The study covered the following applications of synthesized and commercially available RTILs.

Dearomatization studies: Using model feedstocks of (toluene + n-heptane + IL and benzene + n-heptane + IL)

Extractive desulphurization studies: Using model feedstock of(toluene + decane + DBT/4, 6 – DMDBT + IL)

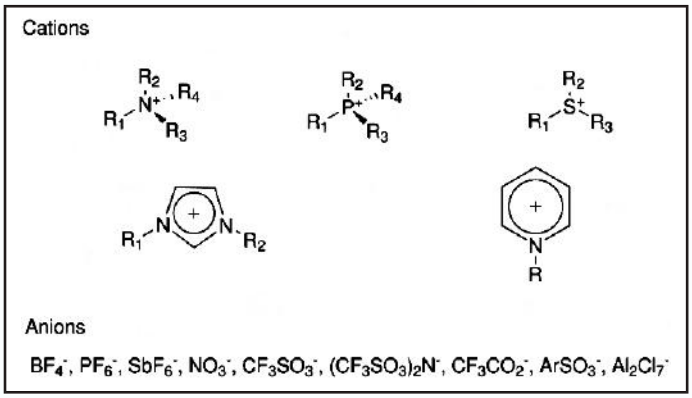
Extractive catalytic oxidative desulphurization (ECODS): Experimental studies were performed using model oil (Dibenzothiophene (DBT) + toluene + n-decane), oxidant (H_2O_2), catalyst (formic acid) & employing various ionic liquids (ILs). N-hexyl 3-methylpyridinium Bis {triflouromethylsulfonyl} imide showed the highest rate of sulphur removal up to 95.7 %.

Denitrogenation: Experimental studies were performed using coker oil employing various ILs.

Acitivity coefficients at infinite dilution of various hydrocarbon solutes in laboratory-synthesized ionic liquids were determined.

A process simulation model, representing a liquid-liquid extraction operation on a toluene - heptane feed mixture using an ionic liquid as the extracting agent, was developed and the stream results were generated using a commercial process simulator. The aliphatic recovered was 99 % pure and the aromatic recovered was above 98 % in purity. Final report on outcome of studies was submitted to CHT and approved in SAC Meeting June 2012. Summary of Learning from the project was also submitted and the RTILs recommended as solvents for different applications are:

Dearomatization Studies	N-Me-Butyl PyridniumTerafluoroborate
Extractive catalytic oxidative desulphurization (ECODS)	N-Hexyl 3-Methylpyridinium-Bis-{triflouromethylsulphonyl} imide
Extraction based Denitrogenation	N-Butyl-Me-Imidizolium Terafluoroborate



Cations and Anions present in typical ionic liquids

- **Upgradation of Residual Fuel Oil using non-HDS route such as Solvent Extraction/oxidation**

Residual fuel oils (RFOs) are the products produced by blending residues obtained from various processes of refinery, such as mixture of vacuum-flashed VB residue, atmospheric VB gas oil, vacuum residue from high sulphur crude, PDA pitch, heavy extracts etc. Hence, RFOs may contain significant quantities of impurities such as asphaltenes (3-10%), nitrogen (0.25-0.6%), and sulphur (3-5.5%) along with some metals. High levels of impurities in residual fuel oil are hindrance to catalytic reactions as these impurities poison the catalyst and are responsible for coke production. Fuel oils have a broad range of volatility and viscosity. Hence processing of residual fuels to meet the required specifications by hydrodesulphurization will pose problems. Since fuel oil is also used on board ships to generate powers for the engines, it is also known as bunker fuel. Disposal of this product as such in future will pose a problem to the environment.

Air pollution considerations are important in determining the allowable sulphur content of fuel oils. Sulphur content is frequently limited by legislation aimed at reducing sulphur oxide emissions from combustion equipment. These laws require sulphur content to be below a certain level, usually 1.0, 0.5, or 0.3%. Hence specifications of residual fuel oils become increasingly stringent with respect to sulphur content.

Considering future specifications of residual fuel oils (RFOs) & the limitations of HDS process, there is an urgent need for development of an innovative process based on non-HDS route. This will also help save hydrogen in enormous amount and subsequently reduce green house gases.

Highlights:

- Different samples of RFOs-blending components received from M/s CPCL, Chennai are: Vistar (VBU FO) Gas oil, Extract (Light & Heavy), PDA Pitch, Vacuum Residue and Fuel Oil

RFO upgradation

- Characterization of samples was done for total sulphur content and viscosity at different temperatures
- Literature review report submitted to CHT, New Delhi in Aug 2012.
- Batch LLE data experiments completed with various solvents and feed mixtures. Reduction up to 1 mass% of sulphur was achieved in the two-stage solvent extraction (repeat extraction of raffinate).
- Preliminary oxidative desulphurization study was carried out-with encouraging results.
- **Production of Rubber Solvent from NGL using Solvent Extraction Route**

Natural gas liquid (NGL) rich in C_5 and C_6 hydrocarbons, especially n-paraffins, is not suitable for gasoline fuel as it exhibits very high Reid Vapor Pressure (RVP) and low octane numbers (RON). The availability and composition of the NGL from various M/s GAIL fields indicate its potential applications for its value-addition e.g. dearomatization of NGL for SBP solvents for rubber industry as well as production of aromatic extracts.

In this connection, during the different teleconferences and meetings, M/s GAIL enquired about the feasibility of production of SBP solvents from dearomatized NGL as well as production of pure benzene component from extract phase. The CSIR-IIP having expertise in dearomatization/

solvent extraction area, sent technical, as well as commercial, proposal to M/s GAIL, finally delivered Letter of Award (LOA) to the CSIR-IIP for the same.

Following activities were carried out to meet the objectives of the project

- ❖ Characterization of feedstocks
- ❖ Generation of phase equilibrium data with actual feedstocks to explore the possibility of production of rubber solvent
- ❖ Studies in Oldershaw distillation unit as ED column for achieving the targeted product.
- ❖ Studies in Oldershaw distillation unit for solvent recovery-studied SRC column
- ❖ Simulation of the experimental data generated above

Oldershaw Extractive Distillation Set-up

Highlights: The experimental results indicate that with the use of combination solvent and water it is feasible to produce aromatics of the desired purity.

- **Feasibility Study for Dearomatization and Desulphurisation of the Heavy Kerosene Stream for Producing Value-added Product D-80**

Farabi Petrochemicals Company (FPC) Ltd., KSA is a manufacturer of n-Paraffin and Linear Alkyl Benzene (LAB) using UOP technology since 2006. The company has one n-paraffin and two LAB units located at Al-Jubail, KSA. The study aimed at dearomatization of various return kerosene streams generated in the n-Paraffin production process by using solvent extraction followed by hydrotreatment or adsorption.

The targeted streams for dearomatization are:

1. **Light Kerosene (Faranorm): C_9-C_{10}, 18-22 % Arom.**
2. **Heavy Kerosene (Farasol B): C_{13}-C_{14}, 18-22 % Arom.**
3. **Molex Raffinate Bottom (Farasol A): 20 % Arom.**

Continuous Counter-Current Extraction Column Set-up

The objective is to obtain final dearomatized products from the above-mentioned streams which meet the standard specifications of the commercially available solvent products such as: white spirit, D 40, D 60 and D 80.

The objective of Phase I study was to establish the capability of CSIR-IIP's solvent extraction technology followed by secondary processes (like hydrotreatment/

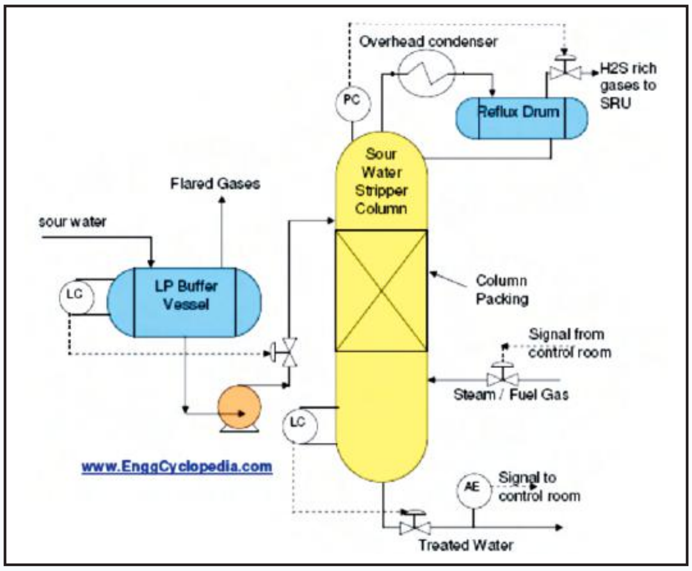
adsorption) for de-aromatization of heavy kerosene while meeting the FPC target specification for the D 80 product.

Highlights: The experimental results indicate that with the combination of solvent extraction followed by adsorption or hydrotreatment, it is feasible to produce the aromatic lean heavy kerosene (aromatic content < 100 ppm) of the desired purity.

- Experimental data indicates the feasibility of aromatic lean heavy kerosene production with desired purity.
- A process flow scheme for the proposed operation has been conceptualized.

1.1.2 Mathematical Modelling and Simulation Area

- **Revamp of Sour Water Stripper Unit at CPCL, Chennai (Phase II: The Basic Engineering design package)**



Typical PFD for a Sour Water Stripper Column

M/s. Chennai Petroleum Corporation Limited (CPCL), Chennai had put up a crude unit of 2.8 MMTPA capacity in 1984. This unit was revamped to 3.7 MMTPA in 1993. They are planning another revamp of the crude unit to increase the capacity to 4.3 MMTPA.The revamp was scheduled in 2012. The Sour Water Stripper (SWS) unit is excluded in this revamp. The sour water stripper unit catering to this unit is having a design capacity of 35 m^3/hr. This unit is designed to treat the combined sour water stream from crude & FCCU units. This sour water stripper unit was not revamped in 1993 and the existing SWS unit itself had been catering to the sour water treatment requirement of the revamped crude unit. The existing SWS unit was found to be overloaded and operating with certain limitations. Consequent upon the proposed revamp of crude unit, feed rate to SWS unit is expected to increase up to 45 m^3/hr compared to the design feed rate of 35 m^3/hr.

Design data provided by M/s CPCL was simulated using the CSIR-IIP simulation model. The close match between the simulated and the design data values confirm the validity of the model to be used for further studies. In the proposed revamp, feed rate to SWS unit is to be 45 m^3/hr compared to the design feed rate of 35 m^3/hr. The target stripped water specifications for stripped water were H_2S<50 ppm and NH_3< 100 ppm.

Various case studies were carried out to meet the process objectives. A solution involving change of internals alone (higher efficiency tray) and some pipelines and valves was recommended to M/s CPCL in the Phase-I report. For the recommended solution, a detailed basic engineering design package was prepared. This basic engineering package includes process flow diagram P&ID, Heat and material balance, equipment list, sizing of major equipment, adequacy of column, heat exchanger and valves etc.

- **Crude Preheat Maximization Study for CDU-I &II, HPCL, Vizag (Vishakhapattanam)**

The CSIR-IIP has immense expertise in pinch analysis and has already carried out many projects in this area for the oil refining industry.

CSIR-IIP carried out the pinch analysis of CDU-I. Executive summary of the study for the CDU-I, HPCL Vizag Refinery pinch analysis is given below:

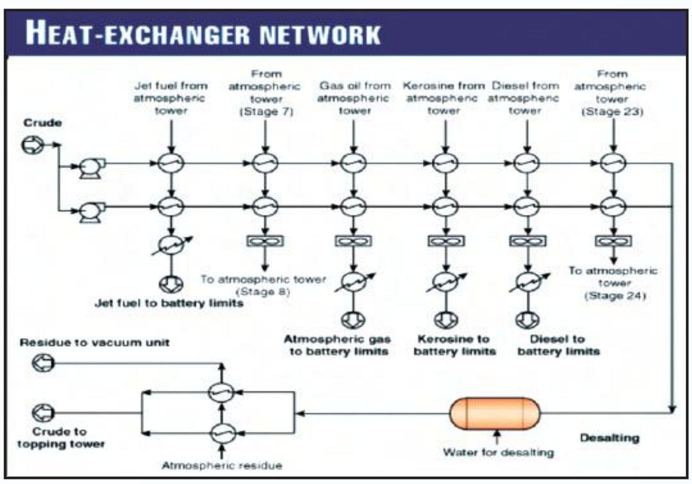
- ❖ The main objective of the study was to increase preheat temperature
- ❖ Design data provided by M/s HPCL was simulated to validate the model used for further studies
- ❖ The simulation of ADU unit was carried out again after inclusion of flash drum at 220 ˚C.
- ❖ The stream data required for pinch analysis were tabulated along with the target (run down) temperature for products and return temperature for PA which were also finalized after discussion between IIP and HPCL, Vizag Refinery
- ❖ The composite curve and grand composite curve were generated for the extracted stream data.

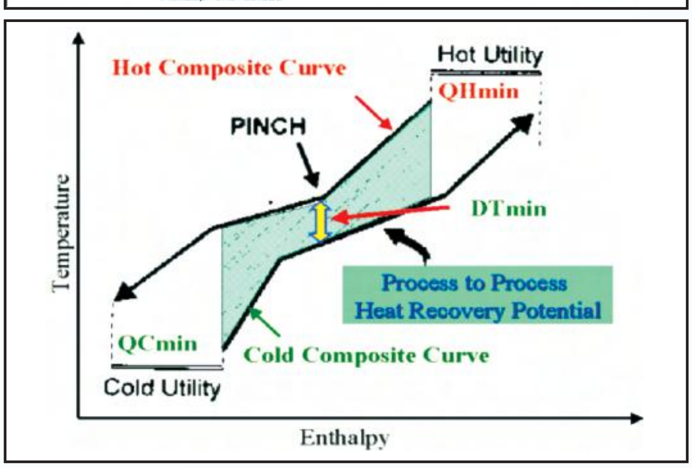
❖ Proposed heat exchanger was designed based on the following considerations:

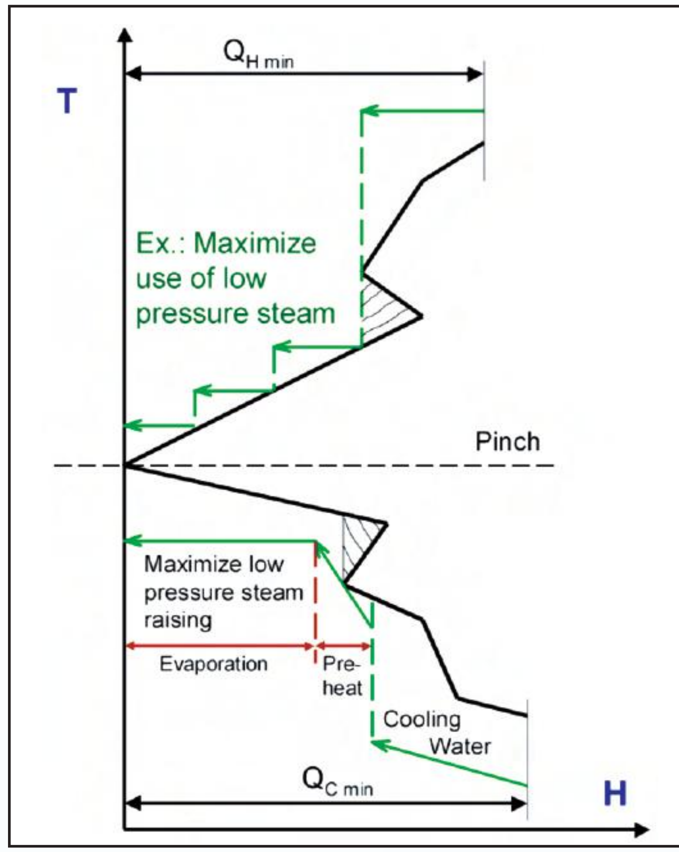
- Observations of composite and grand composite curves
- Minimum possible changes in existing heat exchanger network
- Maximum utilization of existing heat exchangers
- Minimum number of new heat exchanger inclusion
- Pumparound returning temperature

❖ The modifications required in the proposed heat exchanger networks are as follows :

- With eight new heat exchangers: Preheat improvement by ~ 17 ˚C
- With 3 new heat exchangers: Preheat improvement by 9 ˚C
- With two new heat exchangers: Preheat improvement by 5 ˚C
- Some rerouting of crude and hot streams







Heat Exchange Studies

- **Comparative Study of Diesel Reforming Processes (SDR, POX and ATR) using Process Simulator**

Diesel is the most abundantly available fuel used in submarines. The method to produce hydrogen from diesel is to lucrative to avoid the issue of handling multiple fuels. Hydrogen has a long tradition as an energy carrier as well as an important feedstock in the chemical industries and

Reforming Process Studies

refineries. It has a very high energy density. Hydrogen-based PAFC fuel cell application in submarines needs a suitable on-board reformer. The possibility of reducing the sulphur content of diesel below 10 ppm drives its application as a reforming feedstock preferably in submarine. In principle, there are three types of reforming processes used for hydrogen production:

- Steam Reforming
- Partial Oxidation
  - (Non-Catalytic) Partial Oxidation (POX)
  - Catalytic Partial Oxidation (CPO)
- Auto thermal Reforming

To start with, the study simulation model to be used in the study was validated using the relevant literature data. The various cases studied for different operating parameters.

From the study it is clear that SDR produces the maximum amount of hydrogen at the cost of the maximum oxygen consumption; POXDR and ATDR provide almost the same H_2 production and O_2 consumptions. Moreover, in POXDR and ATDR processes tail gas utilization from PSA needs to be identified.

Major observations of the study are given below:

- Although steam reforming of diesel with reformer temperature 850˚C and steam-to-carbon ratio 3 produces the maximum amount of hydrogen, the process is not self sufficient in energy-as the reformer duty is quite higher than the duty produced by burning the tail gas in the furnace with 5% excess oxygen.
- For reformer temperature 850˚C and steam-to-carbon ratio 3, the additional energy requirement can be met by burning additional diesel with the tail gas and oxygen so as to increase the duty of the furnace until it becomes slightly greater than the reformer duty.
- However for the self-energy-sufficient process scenarios, the hydrogen produced/1000kg of diesel consumed is the maximum with the reformer temperature being 850˚C and steam-to-carbon ratio being 2.5.
- Partial oxidation produces less hydrogen and consumes less oxygen as compared to steam reforming of diesel but 30.11 MMkcal/hr of excess energy is available in the PSA tail gas. The utilization of PSA tail gas needs to be explored.
- Auto-thermal reforming of diesel produces more hydrogen as compared to partial oxidation but less than steam reforming. Excess energy available in the tail gas is 29.64MMkcal/hr. The utilization of PSA tail gas needs to be explored.

1.1.3 Wax Rheology Area

- **Conversion of Waste Plastics to Value-added Hydrocarbons**

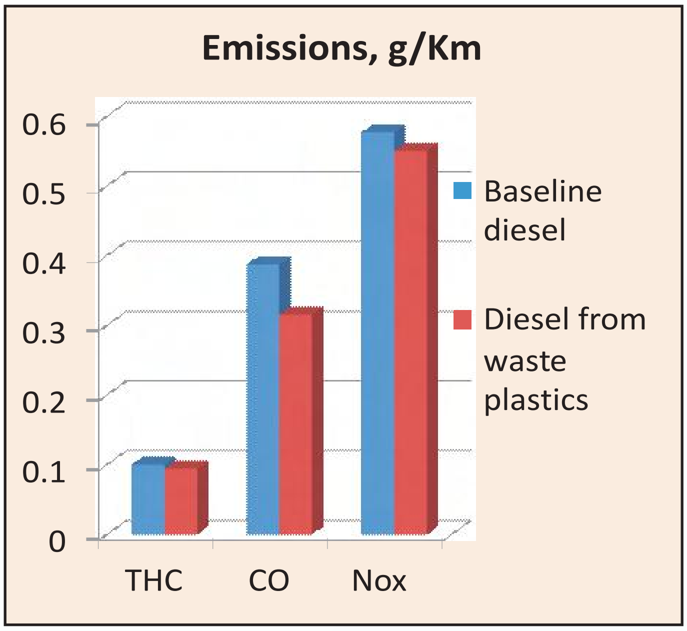
(A) Engine testing of diesel produced from waste plastics

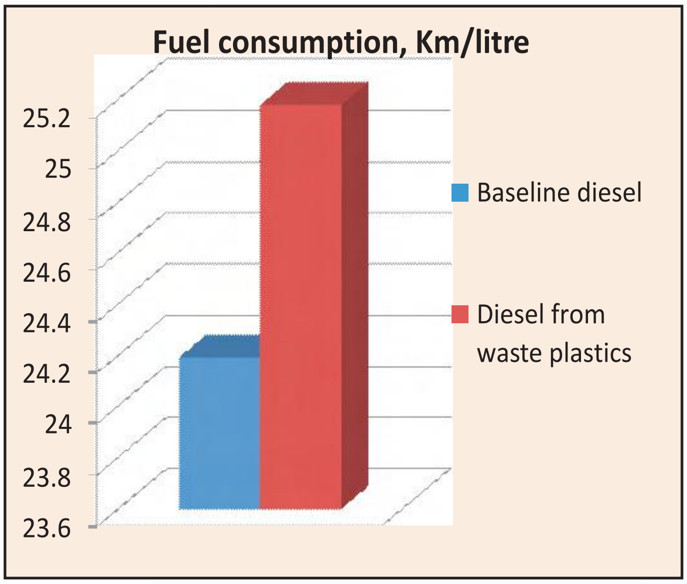
The CSIR-IIP has developed a novel process for converting waste plastics, particularly polyolefins to value-added products like the automotive-grade fuel and petrochemicals feedstock. A bulk quantity of diesel has been produced from the waste plastics bench scale unit and has been evaluated on an engine. The tests were performed on a chassis dynamometer on a Euro II-compliant passenger car on the regulatory transient cycle i.e. Modified Indian Driving Cycle (MIDC). The research facility comprised of light duty dynamometer suitable for certification and research. The test facility also comprised of an chassis dynamometer which can simulate inertia from 150 kg to 6500 kg. It can measure the speed and force with an accuracy of ±0.01% and ±0.10%, respectively. The driving cycle simulation is carried out using a driver's aid. Test chamber ambient temperature can be fixed at 25 ±5ºC and relative humidity of 65% ±5%.The results have been compared with engine tests of commercial diesel.

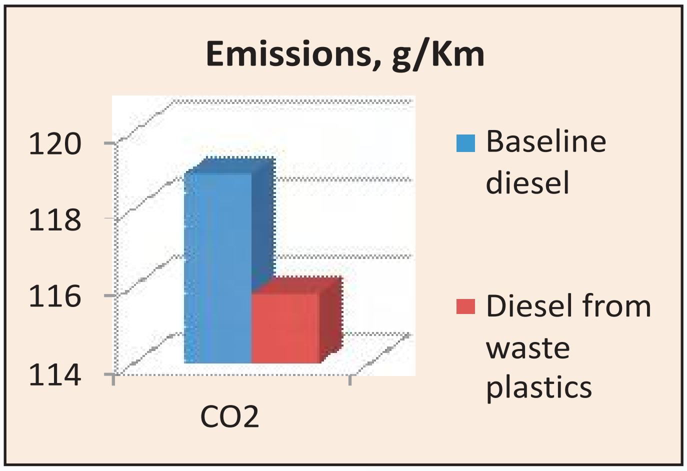
Characteristics of the diesel obtained from waste plastics

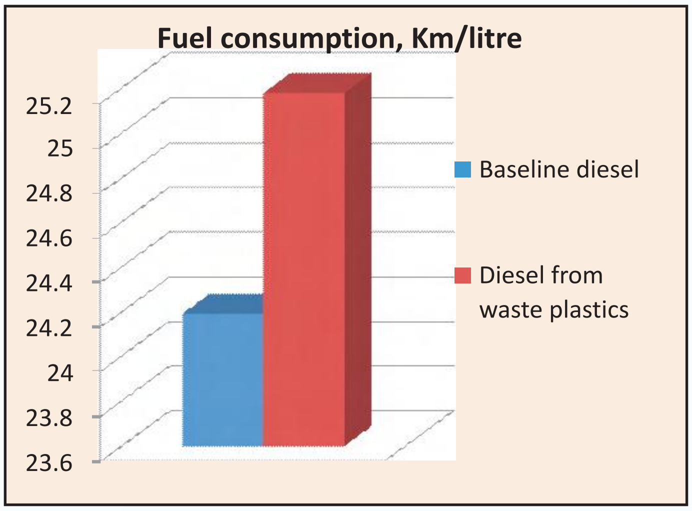
Density, Kg/m3	825
Kinematic Viscosity@ 40 °C, cst	2.2
Cetane Index	51
Pour Point °C	+6
CFPP °C	6
Polyaromatic content, Wt. %	6
FBP, °C	360

The diesel obtained from waste plastics has shown improved emission characteristics with respect to CO_2, CO, total hydrocarbons, NOx and equivalent particulate emissions as compared to the commercial diesel. Moreover the fuel consumption of the diesel from waste plastics is lower than the commercial diesel.









Diagrammatical representation of the study on emissions and fuel consumption

(B) Coke formation and catalyst regeneration

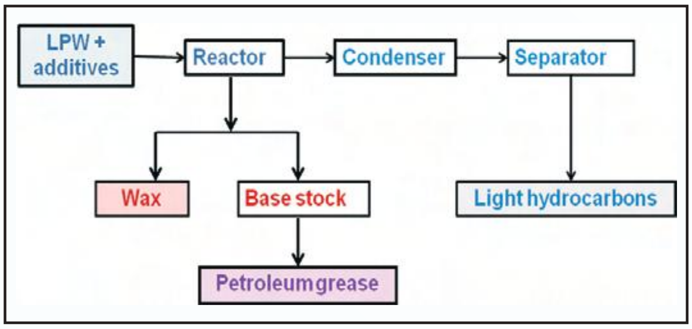
Studies were carried out to determine the run length of the catalyst and the periodicity of regeneration. A significant coke formation is observed (20%) and the catalyst requires a regeneration every 24-36 hours. The catalysts were regenerated in the waste plastics unit and the deactivated, as well as the regenerated catalysts were characterized by different techniques like TGA, XRD etc.

(C) Simulation studies

There is a plan on the anvil to set up a pilot plant of 10TPD feed capacity for validation of the bench-scale studies and for establishment of various technological parameters that would facilitate successful commercialization of the technology. Simulation studies have been done for downstream process equipments like fractionators, heat transfer equipment and for heat integration.

- **Feasibility Study for Value-addition to Low Polymer Wax (LPW)**

During the production of HDPE by the Mitsui technology of Japan, approximately 5-7 % low molecular weight polymer is obtained as a byproduct. This product has molecular weight lower than HDPE but higher than that required for petroleum waxes and hence it is a low-value product, having limited utility. In order to effectively utilize this low-value product, attempts have been made to chemically modify this polymer industry waste. This low-polymer wax has been degraded in an inert atmosphere in the presence of different additives and under different process conditions in a glass reactor to obtain different types of waxes and base stocks. The waxes have been refined and the base stocks formulated into grease. It has been observed that it is feasible to chemically convert LPW into paraffin wax of type BIS grade 2A & 3, microcrystalline wax of type BIS grade C & D as well as greases conforming to NLGI type 2 & 3.



Process flowsheeet for producing wax and grease from LPW

Properties	TYPE C		TYPE D	
	BIS Specs.	Result	BIS Specs.	Result
Drop m.pt, °C	70-80	79	85-95	93
Oil content, wt.%, *max*	2.0	1.8	1.5	1.5
Ash (wt)%, *max*	0.03	0.02	0.03	0.02
Penetration, dmm	25-35	26	2-10	2
Viscosity, cst @98.9 °C	15-20	17	15-20	18
Acidity	0.10	nil	0.10	nil

Properties of microcrystalline wax obtained from LPW

Properties	TYPE 2A		TYPE 3	
	BIS Specs.	Result	BIS Specs.	Result
Drop m.pt, °C	58 min	76	45-75	74
Oil content (wt) %, *max*	1.5	1.5	3.5	3.1
Ash (wt)%, *max*	0.03	0.02	0.03	0.02
Acidity	0.10	nil	0.10	nil
Sap value , mgKOH/g	1.0	nil	1.0	nil

Properties of paraffin wax obtained from LPW

Characteristics	NLGI 2 TYPE		NLGI 3 TYPE	
	Specs.	Result	Specs.	Result
Drop point, °C	-	81	-	92
Cone penetration	265-295	267	220-250	245
Anti-friction & anti-wear	passes	passes	passes	passes
Corrosion	passes	passes	passes	passes

Properties of grease obtained from LPW

1.1.4 Sweetening

- **Development and Commercialization of New Ammoniacal Water Soluble Fixed-bed Sweetening Catalyst**

The MoU between IIP and BPCL (R&D) was signed for collaboration in this project which began in August, 2012. Fifteen batches of catalysts have been prepared upto now. Three batches were screened based on solubility in ammoniacal water. These have more solubility than the commercial catalyst. Activity evaluation of these selected batches in glass reactor has been started. A bench-scale pilot unit has been put uo for catalyst performance evaluation.

- **Commercialization of Catalyst Thoxcat ES for Sweetening of LPG**

  ❖ The trial run which started in September, 2011 in Sat LPG Merox unit of M/s RIL was continued up to November, 2012. It was observed that the consumption rate of our catalyst Thoxcat ES is much less than that of the other commercial catalyst being used earlier in the same unit. In spite of a large variation in the mercaptan content in the feed, Thoxcat ES has been able to maintain total product sulphur within 15 ppm. This confirms that Thoxcat ES catalyst has performed better than commercial catalyst being used earlier.

  ❖ Based on the performance in the above trial and the earlier trial in Unsat LPG Merox unit (where the feed was a mixture of cracked and coker LPG) in 2007, M/s RIL placed an order of 200 kgs of catalyst of which the first batch of 50 kgs of catalyst was supplied by M/s Lona Industries in the month of October, 2012. M/s RIL has started the regular use of Thoxcat ES catalyst in their Sat LPG Merox unit.

  ❖ The possibility of using the Thoxcat ES catalyst in Pentane Sweetening as proposed by M/s RIL was investigated. Mercaptan oxidation was studied as per mercaptan composition in feed and operating conditions in pentane sweetening unit of M/s RIL. It was found that the Thoxcat ES can also be used in pentane sweetening.

  ❖ As proposed by M/s IOCL, Gujarat a trial run of the Thoxcat ES catalyst in their LPG Merox unit has been agreed upon. It was learnt that they would need 30 kgs of the catalyst for a six-month trial.

The CSIR-IIP agreed to arrange the supply of this catalyst free-of-cost.

- **Development of a New-generation Solid Basic Oxide or Hydrotalcyte Supported Catalyst for Fixed-bed Sweetening of Heavier Petroleum Fractions**
  - ❖ A nano-crystalline magnesium oxide support has been prepared.
  - ❖ Sodium salt of cobalt phthalocynine tetra sulphonate supported on nano-crystalline magnesium oxide has been prepared and it has been found that it can be used as catalyst for thiol oxidation.

1.1.5 Gas Absorption Area

- **Supportive Laboratory Data Generation on CSIR-IIP – EIL – NRL SO_2 Recovery Process to Prepare BDEP for M/s Numaligarh Refinery Limited**

Objectives: Laboratory-scale experimentation for supportive data generation on absorption of SO_2 in CSIR-IIP formulated solvents.

Activity: The following activities were carried out to fulfil the scope of the work:

❖ Fabrication of batch and continuous experimental set-up for carrying out absorption/regeneration with all the accessories like analytical cells for analyzing gas and liquid streams (Figure GSL1)

❖ Testing and commissioning of the two set-ups.

Continuous absorption set-up

❖ Streamlining the experiment for fine data generation. This included the actual absorption experiment along with analysis of gas and liquid samples by wet chemistry method. The analysis was done at regular intervals of time right from start till the end of the experiment.

❖ Validation and data generation of the earlier results with solvent shortlisted – in batch.

❖ Data generation in the continuous unit for use for BDEP by M/s EIL

❖ Measurement of physico-chemical parameters

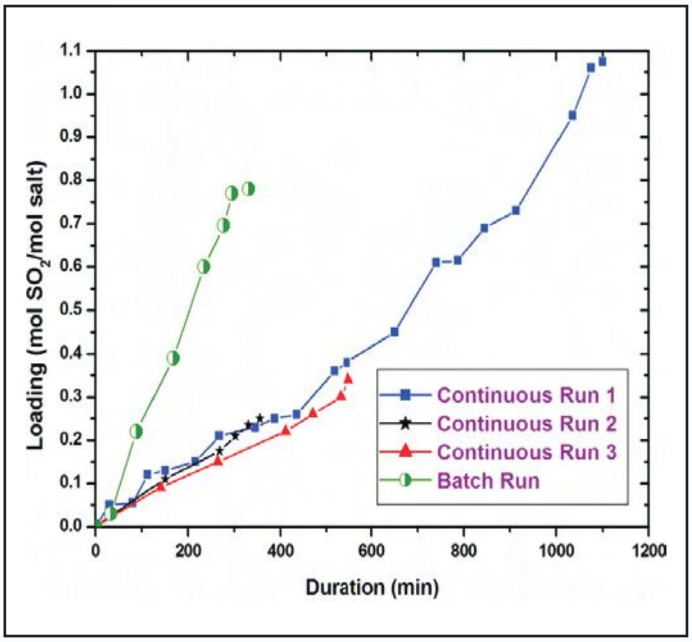
❖ Final report submission

Highlights: The CSIR-IIP had carried out an elaborate screening study in 2003-06 for a suitable SO_2 absorbing solvent which had then resulted in the short-listing of a few solvents. A few laboratory-scale experiments and pilot-plant study were also carried out at the EIL to confirm the final outcome on screening of solvents. With this background, the CSIR-IIP and the EIL signed am MoU with the NRL as joint partners in the technology, for implementation of the developed SOR technology in the NRL. For implementation of the above mentioned developed process, the EIL needed some supportive data for the absorption of SO_2 from gas mixture to generate BDEP for NRL.

Findings of the project:

Absorption :

❖ Run 1, Run 2 and Run 3 represent continuous SO_2 absorption in CSIR-IIP formulated solvents of a different initial pH carried out in packed glass column (column length 100 cm and ID 3.8 cm)

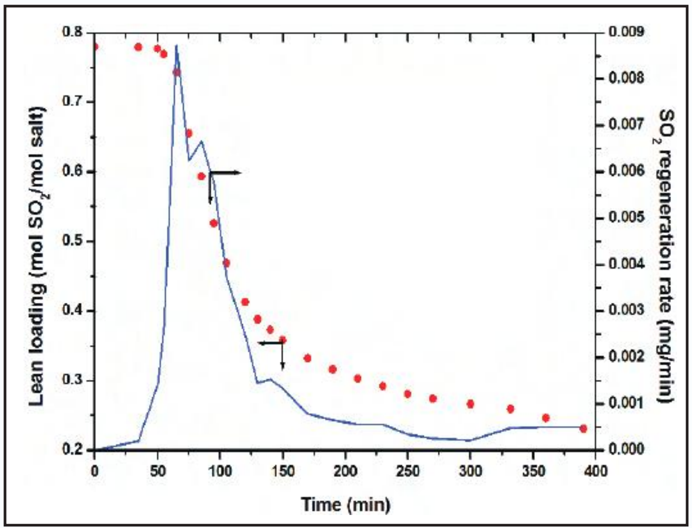


SO_2 loading in solvents with respect of time

- Solvent with a higher pH in Run 1 exhibits a higher SO_2 loading
- Run 1, Run 2 and Run 3 also represent repeatability of experimental results
- The pH of the starting solution in batch run is lower than that of the continuous Run 1 but higher than that of continuous Runs 2 and 3.
- The rate of absorption is higher in batch absorption due to higher gas-liquid contact area
- This shows that solvent pH is important factor for SO_2 absorption

Regeneration :

- Regeneration was carried out at 2.5 bar pressure and 129°C temperature in SS batch desorption cell
- The red curve represents lean SO_2 loading of the solvent with time
- The blue curve represents SO_2 desorption rate with time



SO_2 lean loading and regeneration rate with time

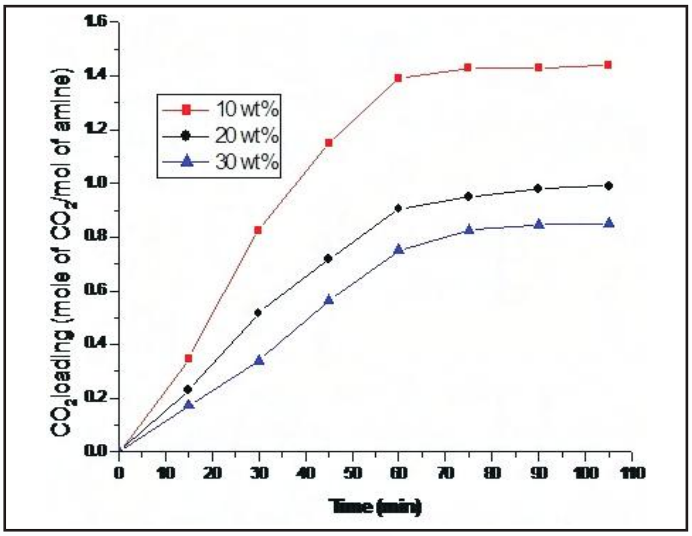
Based on the results of the study of the present work it is recommended that a little more fine-tuning may be done with respect to the solvent in terms of the following points:

- Optimization of the best solvent vis-a-vis its cost
- Use of mixed solvents – a few combinations to be explored
- Optimization of pH on the best performing solvent/formulation

This is directed towards a better performance and cost.

- **Development of Clean Coal Technologies**

Objectives: Development of advanced solvents and blended formulations for CO_2 capture, with lower regeneration energy requirement.

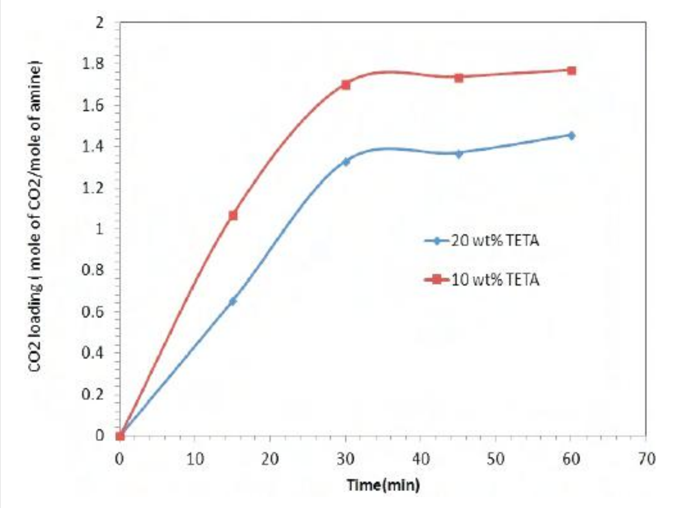


CO_2 loading in aqueous solutions of TMHDA

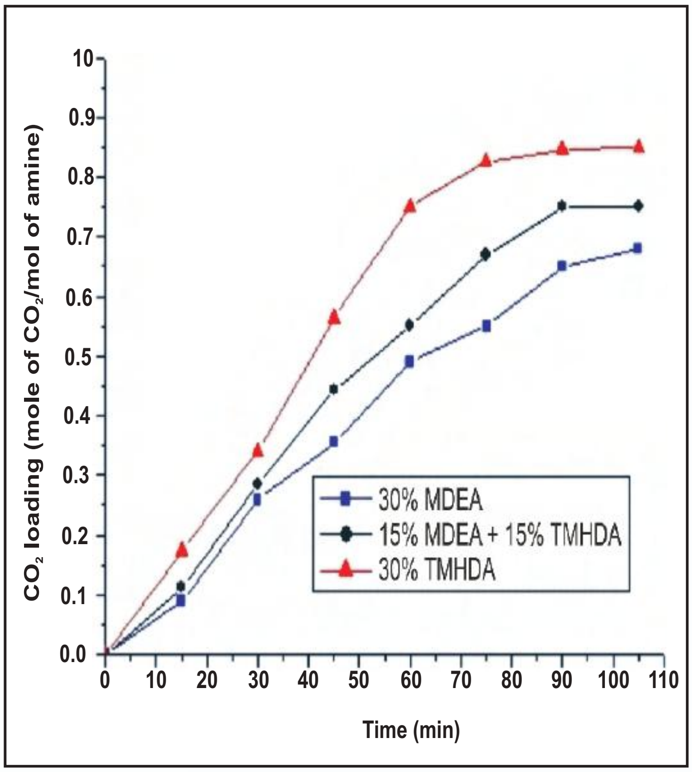
Activity:

- Screening of different single and blended formulations to absorb CO_2
- Measurement of CO_2 loading in different solvents at absorption and regeneration conditions
- Comparison of CO_2 reaction kinetics in different solvents
- Measurement of physico-chemical parameters
- Simulation of CO_2 absorption-regeneration system

In this phase of the study, the absorption of CO_2 was investigated in different amine activators e.g.



CO_2 loading in aqueous solutions of TETA



CO_2 loading in aqueous blends of TMHDA and MDEA

triethylenetetramine (TETA) and tetramethyl-1,6-hexane diamine (TMHDA). These activators are also blended with different alkanolamine solvents, e.g., *N*-methyldiethanolamione (MDEA). Some typical results are described here.

Figures GLS4 a and b show the loading of CO_2 at 40 °C in aqueous solutions of TETA and TMHDA, respectively. In both the cases, loading decreases with increase in amine concentrations in the solvents.

The absorption of CO_2 in aqueous blends of TMHDA and MDEA at 40 °C. Concentrations of amines in the blends are varied from 15 to 30 wt% to investigate the effect of blend composition on CO_2 absorption behaviour. As shown in Figure CO_2 loading in the blends increases with increase in TMHDA concentration. This is due to the fact that, TMHDA structure contains more than one amine group which leads to more CO_2 capacity

- **Carbon-Free Hydrogen Production using H_2S in Petroleum Refinery**

Objective: Experimental study of carbon-free hydrogen production by carrying out Bunsen reaction and HI decomposition.

Activity:

- ❖ Design of experiments and set-up to carry out study on Bunsen reaction and HI decomposition
- ❖ Study of effects of different parameters
- ❖ VLE study

Findings of the project:

There are two primary oxidation routes of H_2S as a source of SO_2. These are i) direct incineration of H_2S to SO_2 in the presence of air and ii) oxidation of H_2S with concentrated sulphuric acid. H_2S oxidation via incinerator is more preferable thermodynamically.

- Bunsen reaction, is an important step in the SI cycle that decides the purity and concentration of the resulting acid phases for the efficiency of downstream processing. Quite a few interesting findings with respect to the reactants, the products formed and their purity *vis-à-vis* the operating variables, conditions under which there is occurrence of side reactions that result in the formation of sulphur and H_2S, the reverse Bunsen reaction that is now being explored for purification of the two acid phases for higher hydrogen yield from HIx, have been revealed. Many directions reported for enhancing the Bunsen reaction such as the use of membranes, TBP, liquid SO_2 and organic solvents, metathesis reactions etc. are presented so as to help in the next phase of actual experimental studies to arrive at an economic solution for this reaction.

- A state-of-the-art developed on the next important step in the open loop cycle, that is, the HIx decomposition by reactive distillation to yield hydrogen and iodine. However, for an efficient HIx decomposition, the problem of excess iodine and water, the side reactions etc. need to be tackled in the Bunsen reaction. Reaction conditions for this dissociation reaction along with the state-of-the-art route on an important aspect, i.e., the catalysts, used so far in the literature have been detailed.

1.2 BIOFUELS

1.2.1 Chemical Conversion

- **Valorization of Glycerol for Biodegradable base fluids and new Biofuel formulations**

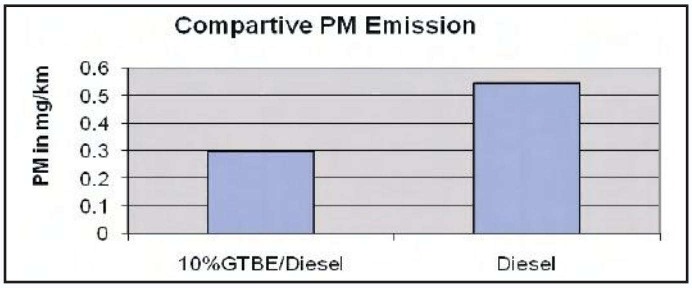
Glycerol is the inevitable by-product of the transesterification process. The recovery of high quality glycerol as a biodiesel by-product is the primary option to be considered to lower the cost of biodiesel. Glycerol cannot be added directly to fuel due to its decomposition, polymerization & consequential engine problems at high temperatures. Therefore, serious R&D efforts are required to have a new generation of lubricants with increased thermal stability and mechanical stress ability along with lower consumption, ecological safety and rapid biodegradability together with a new class of reformulated fuels in terms of pollutant emissions.

Products have been developed for application as :

❖ Metal working Fluids

❖ Gear Oils

❖ Glycerol tertiary butyl ether(s) – fuel Oxygenate



Comparison of PM Emission from Neat Diesel and GTBE-blended diesel

- **Production of Bio-diesel from Low-cost Feedstocks using Heterogeneous Catalyst**

Feed stocks like *Jatropha curcas* (non-edible oil), acid oil were collected and physico-chemically characterized and compiled in the table below.

S.No.	Characteristics	Unit (ASTM)	JC oil	Acid oil
1.	Density at 15 °C	Kg/m^3	918	928
2.	Kinematic viscosity at 40 °c	cSt	34.03	47.79
3.	Copper corrosion	--	1.0	1.0
4.	Acidity total	mg KOH/g	39.1	110.8
5.	Flash point	°c	247	198
6.	Pour point	°c	0	-15
7.	Ash content	% wt.	0.039	0.053
8.	Moisture content	% wt	0.14	0.8
9.	Molecular wt.	g/mole	890	487

Physico-chemical properties of feedstocks

- **Development of Heterogeneous Catalyst for biodiesel production**

Transesterification using a conventional alkali process gives high conversion levels of triglycerides to their corresponding methyl esters in a short time. The reaction has several drawbacks: it is energy-intensive; recovery of glycerin is difficult; the catalyst has to be removed from the product; the alkaline waste-water requires treatment and free fatty acids and water interfere with the reaction. In order to minimize the homogeneous process problem, development of heterogeneous catalyst for biodiesel production is required.

Attempts were made for production of fatty acid methyl esters (FAME) from different feedstocks having high FFA (*Jatropha* oil 20% FFA, acid oil 55% FFA). Following activities were carried out:

❖ Batch studies for evaluation of the catalyst activity for transesterification reaction were carried out in pressure reactor (Parr reactor) at a high temperature and autogenous pressure.

❖ Four catalysts were screened for the production of biodiesel from non-conventional feeds like *Jatropha* oil having FFA 20%.

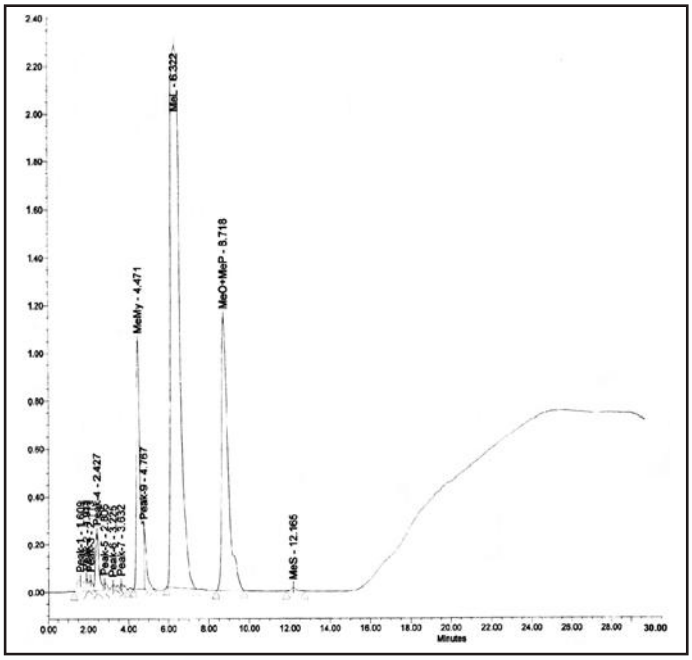
❖ The progress of the reaction was monitored by reverse phase high performance liquid chromatography (RP-HPLC) with UV detection at 215 nm.

❖ Results based on one of the screened catalysts (metal oxide) were found encouraging (on recycling basis) for low-cost feed-stocks like *Jatropha* oil (having high FFA 20%), acid oil (FFA 55%) etc.

S. No.	Characteristics	Unit Specs. ASTM	ASTM D-6751	BIS 15607:2005	B D (JC oil)	BD (Acid Oil)
1.	Density at 15˚C	Kg/m^3	Kg/m^3	860-900	888.6	883.0
2.	Total sulphur	ppm	< 500	<500	< 1	< 30
3.	Kinematic viscosity at 40	cSt	1.9-6.0	2.5-6.0	4.55	4.43
4.	CCR, 10% residue	% wt	<0.05	<0.50	0.13	----
5.	Copper strip rorrosion, ~3hr at 100 C	------	<No. 1	<1.0	1.0	1.0
6.	Acidity total	mg KOH/g	<0.8	< 0.50	0.49	0.46
7.	Cetane index	------	min. 47	min. 51	56.6	57.1
8.	Flash point	°C	>100	>100	135	168
9.	Pour point	°C	-15 to 10	Unspecified	+ 3	-3
10.	Cloud point	°C	-3 to 12	Unspecified	+8	+2

Comparison of biodiesel (IIP Process) with national and international specifications

The biodiesel quality produced by the process under optimized conditions meets the specifications as per ASTM/BIS and is summarized in the figure below.



HPLC separation of components of biodiesel of acid oil

The conversion, purity and identification of the components of the biodiesel were determined by GC and HPLC technique.

- **Optimization of Process Parameters in Continuous Mode**

Process parameter optimization in continuous novel reactor was initiated at different temperatures (150-200^{0}C) and at different flow rates 250ml-1 lit/hr.

We also developed few catalysts for transesterification of low-cost feedstocks (*JC* oil, acid oil etc.) to biodiesel and conversion up to > 95 % in batch mode. Studies using the pilot plant for biodiesel production in continuous mode (already installed) using novel reactor were initiated. Optimizations of parameters were carried out for *Jatroph*a oil having high free fatty acid using heterogeneous catalyst in this plant. Conversion up to > 90% (single pass) was observed and further studies with this plant are on.

- **Development of New-generation Lubricants for Micro-electro Mechanical Systems (MEMS)**

In this project we will be working on developing ester lube base-stocks, optimizing parameters, their physico-chemical characterization, tribological performance, biodegradability and toxicity determination which will aid in developing products intended for lubrication of MEMS viz. computer hard discs, refrigerator compressors, ink jet printers, sensors, optical circuits and in digital micro mirrors.

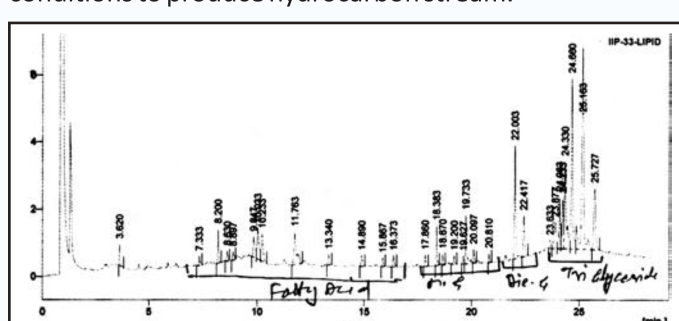
1.2.2 Biotechnology Conversion

- **Conversion of Lignocellulosic Biomass to Middle Distillate Hydrocarbons (C_{12}-C_{18}) Through Biotechnology Route**

Biochemical conversion of sugars to lipids is a slower process in plants (6 months) compared to algae (20 days) and yeast (80 hrs). Oleaginous yeast has a higher growth rate and lipid accumulation rate using fermentable sugars. Moreover, the composition of the lipid in terms of carbon chain length and degree of saturation can be altered with variation in certain physical parameters like temperature. Therefore, the application of yeast would be beneficial for the process development on lipid production for the hydrotreatment of specific type of lipids for different types of fuels like bio-jet, gasoline or diesel. Microbial lipids can be produced in a sustainable and cost-effective way as compared to plant or animal lipids and in less time. In this work, we targetted at developing a process on the conversion of fermentable sugars to microbial lipids which were further converted into hydrocarbons with drop-in characteristics. The work focussed on the following objectives:

1. Pretreatment and saccharification of lignocellulosic biomass
2. Yeast biomass generation and further fermentation of biomass hydrolysate for lipid body maturation
3. Recovery of lipid through solvent extraction
4. Hydrotreatment of lipid-to-hydrocarbon

The raw material used in this study was sugarcane bagasse (SCB) which was air dried, milled, screened through 60 size mesh and processed with steam and dilute acid to extract pentose-rich fraction. Pentose stream was neutralized by over-liming utilized further. *Rhodotorula minuta* IIP-33, an oleaginous yeast grows and produces lipid body with xylose as a sole carbon source and is grown in a bioreactor and is further matured for intracellular lipid body production with an elevated C/N ratio. The lipid was recovered by solvent extraction from dried yeast biomass. The extracted lipid was hydrotreated under optimized conditions to produce hydrocarbon stream.



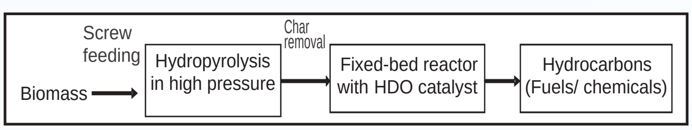
GC analysis of the lipid recovered from oily yeast grown and fermented with pentose-rich SCB hydrolysate

1.2.3 Thermocatalytic Processes

- **Hydropyrolysis of Lignocellulosic Biomass to Value-added Hydrocarbons**

It is highly desirable to produce liquid bio-fuel in a sustainable manner for the transportation sector in order to overcome the rising concerns of energy security, oil peaking, high crude oil prices and global warming. The only sustainable environment-friendly source of carbon for liquid fuel production is biomass which is fixed by plants using atmospheric CO_2. Therefore, biomass can be a sustainable source for liquid fuel production. However, a major challenge for biomass-based routes is to economically produce the enormous quantities of liquid fuel/chemicals needed by the liquid hydrocarbon fuels/chemical sector.

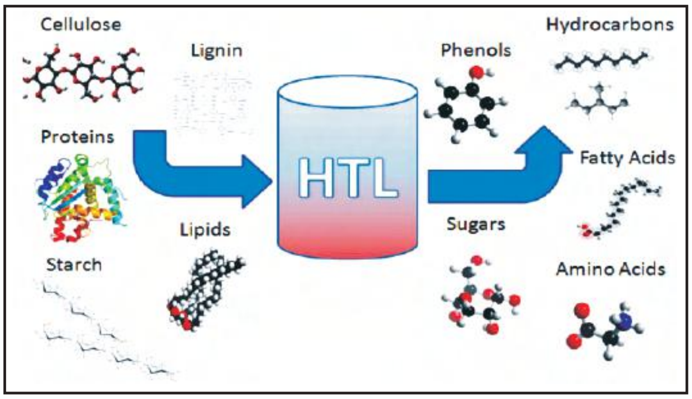
Bio-oil can be produced from various thermo-chemical methods of conversion like fast pyrolysis, BTL, gasification followed by Fischer-Tropsch synthesis and hydrothermal treatment. There have been many studies on the pyrolysis of lignocellulosic biomass using various catalysts for production of liquid hydrocarbons. The fast pyrolysis oil possesses many undesirable properties, its inherent low energy density makes pyrolysis oil expensive to transport and the high TAN makes it metallurgically incompatible with conventional transport vessels and refinery hydroconversion equipment. With this scenario, the development of novel catalysts and integrated hydropyrolysis is of immense importance to convert lignocellulosic biomass into value-added hydrocarbons in a single step. Work was carried out on Hydropyrolysis of lignocellulosic biomass to value-added hydrocarbons.



Various lignocellulosic biomass feedstocks have been treated in the slow batch hydropyrolysis reactor and the products are being characterized. Several supports have been prepared to be loaded with metals and then used for production of hydrocarbons. The detailed design for the continuous hydropyrolysis unit with a second-stage fixed-bed reactor was carried out.

Hydrothermal Liquefaction

Hydrothermal upgradation (HTU) is also a promising process as it can be used for conversion of a broad range of biomass feedstocks (aquatic, agro, forest and other). The process is especially best suited for wet materials, as the drying of feedstocks is not necessary. HTU has the potential for producing liquid hydrocarbons with much higher caloric values and a range of valuable/functional chemicals from a wide range of feedstocks. The CSIR-IIP performed the hydrothermal upgradation (non-catalytic and catalytic) of various biomass feedstocks (forest, agro and aquatic biomass) and biomass components to understand the mechanistic pathways.



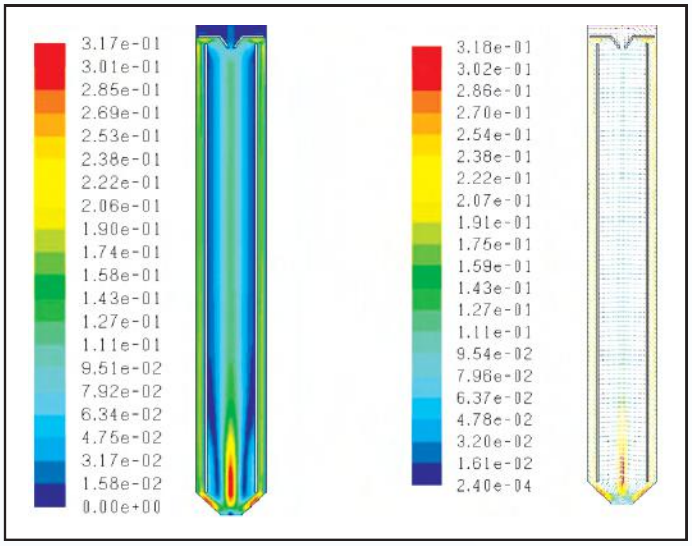
Macromolecule breakdown

1.2.4 Biofuel Modelling

- **CFD Design of an Airlift Fermentation Reactor with New Funnel Internals**

A funnel-shaped internal at the end of the internal draft tube was suggested in literature by Zhang et al. (2012) in order to improve the gas hold-up as well as liquid recirculation. Both of these are essential for a better reactor performance and improved product yield.

A detailed study of flow patterns was planned and carried out to completely evaluate the flow behaviour using FLUENT CFD software. The CFD simulations were carried out using 2D geometry of the reactor with the same details as reported Zhang et. Al. (2012).



Contours and velocity vectors of velocity magnitude of water (m/s)

1.3 CHEMICAL SCIENCES

1.3.1 Speciality and Applied Chemistry

The main objective of the research is to develop cost-effective technologies for the widely used petrochemicals, additives for lubricating oils and fine chemicals. Another objective is to develop new approaches for the utilization of carbon-di-oxide for production of value-added chemicals. Photocatalysis including photo-assisted reduction of carbon-di-oxide to hydrocarbon fuels is another prime objective.

- **Development an Indigenous Process for the Synthesis of *N*-methyl-2-pyrrolidone (NMP)**

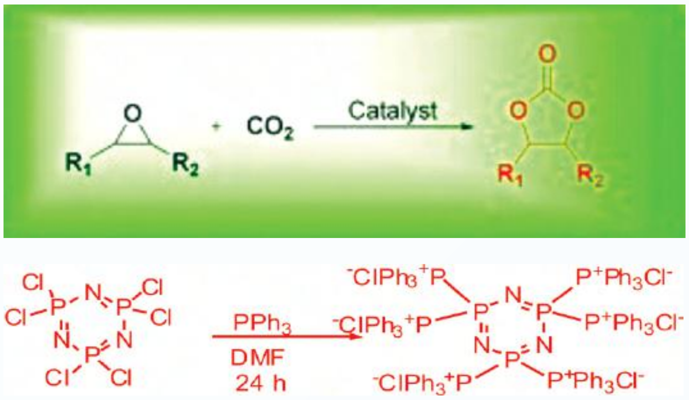
N-Methyl-2-pyrrolidone (NMP) is one of the most important industrial solvents based on fossil resources. Due to its high chemical and thermal stability it is suitable for a range of applications including the petrochemical industry, the microelectronics fabrication industry and the manufacture of various compounds, including pigments, cosmetics, drugs, insecticides herbicides, and fungicides. An increasing use of NMP is as a substitute for chlorinated hydrocarbons. The global annual production of NMP is estimated to be 100-150 kton per annum. As India does not have any commercial plant for the synthesis of NMP, we have successfully developed lab-scale batch type non-catalytic process for the synthesis of NMP starting from readily available gamma-butyrolactone and monomethylamine.

- ❖ An improved microwave-assisted synthesis of NMP starting from succinic anhydride and methylamine has been developed.
- ❖ An efficient photo-assisted approach for synthesis of gamma-butyrolactone (GBL) by using TiO_2 doped selenium for oxidation of tetrahydrofuran (THF) and hydrogen peroxide as oxidant was developed. The maximum yield of the GBL was found to be 75 % with 100 % selectivity for the desired product.

- **Conversion of CO_2 to Useful chemicals:**

The utilization of CO_2 as a source of carbon for the synthesis of fine or bulk chemicals is earning interest in recent years and a variety of synthetic processes have been developed. The chemical transformation of carbon-di-oxide to useful products is a desirable goal from both economical and environmental points of view. In this context, we developed new catalysts and methods for conversion of CO_2 to value-added chemicals:

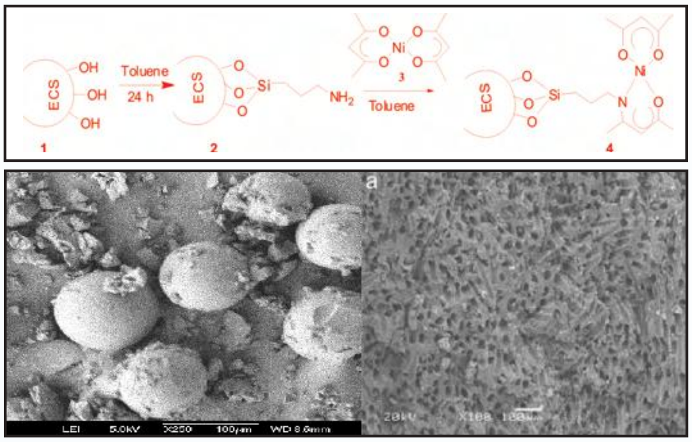
- ❖ A novel organocatalyst, i.e., chlorotriphosphazenyl-anchored triphenylphosphenes-containing multiple reactive sites, has been developed for synthesis of cyclic carbonates *via* coupling of CO_2 with epoxides. The developed catalyst was prepared by the reaction of hexachlorotriphosphazene ($N_3P_3Cl_6$) and triphenylphosphene as shown in Scheme 1. The prepared catalyst showed higher catalytic activity due to the presence of multiple reactive sites and provided excellent product yield without adding any co-catalyst or additive under milder reaction conditions.



Scheme 1: Synthesis of triphosphazene-supported organocatalyst

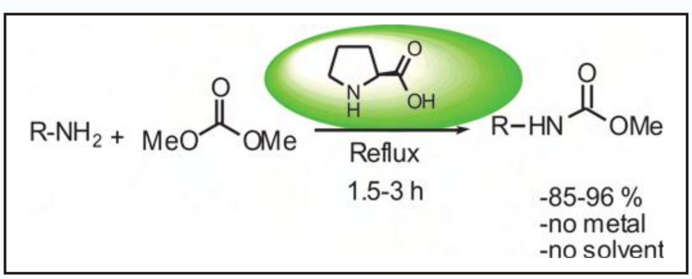
- ❖ A simple and convenient base-catalyzed synthesis of asymmetrical carbonates from primary alcohols with dimethylcarbonate (DMC) was developed. The method is advantageous in many ways in that it gives selective synthesis of unsymmetrical carbonates in high yields, uses an environmentally-benign and non-toxic reagent, e.g. dimethylcarbonate in place of toxic chemicals such as phosgene, carbon monoxide and requireds simple basic conditions under comparatively lower reaction temperature.
- ❖ A new heterogeneous catalyst by using chemically-modified expended starch as support and Ni-acetylacetonate as grafting moiety was developed. Starch is a renewable, biodegradable and a relatively inexpensive material, and has been used for the grafting of nickel (II) acetylacetonate by covalent linkage. The morphology of the prepared catalyst was studied using the SEM. The surface of ECS-Ni(acac)$_2$ was found to be fine homogeneous powder with the clear appearance of catalyst loading. The prepared material in combination with tetrabutyl ammonium bromide (TBAB) is found to

be a very active, selective and recyclable catalytic system for the cycloaddition of CO_2 and epoxides without co-solvent under relatively mild reaction conditions. The hydroxyl groups of starch surface showed a promoting effect on the catalytic activity of $Ni(acac)_2$. Importantly, the starch-grafted nickel catalyst and TBAB is easily recovered after the reaction and can be reused many times without any loss in catalytic activity (Scheme 2).



Scheme 2: *Grafting of Ni-acetylacetonate to chemically modified ECS- support*

- A new methodology for the synthesis of carbamates from the reaction of primary amines and dimethyl carbonate (DMC) by using L-proline as catalyst in the presence of catalytic amount of tetrabutyl ammonium bromide was developed (Scheme 3). Operational simplicity, environmentally benign nature of the DMC, and metal-free catalysts and excellent chemical yields are key features of the present protocol.



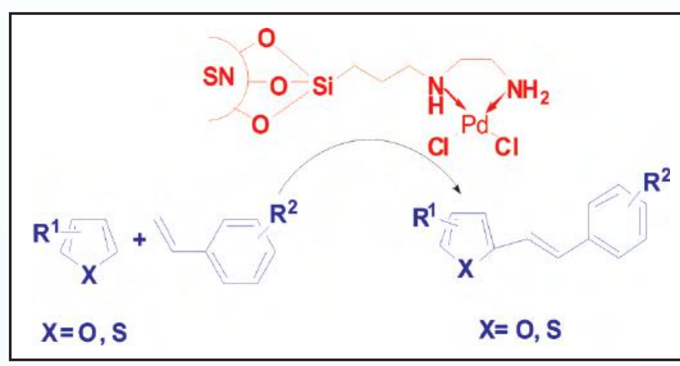
Scheme 3. Synthesis of carbamates

- **Developed Novel Ionic Liquid-based Metal, Phosphorous-free Additives as Substitutes for Zinc di-alkyl di-thiophosphate (ZDDP)**

Zinc di-alkyl di-thiophosphate (ZDDP) has been used for a long time as a multifunctional additive (MFA) including an anti-wear agent in the engine oil and its use is considered to be essential even now. However, it contains a metal component, a phosphorus component and a sulphur component, which adversely affect the performance of engine oil and other devices. Similarly, future generations of passenger car motor oils and heavy-duty diesel engine oils require lower levels of phosphorus and sulphur in order to protect pollution control devices since phosphorus and sulphur-containing additives may poison or reduce the effectiveness of the pollution control devices. Thus, we have developed amino acids such as aspartic acid- and glutamic acid- derived ionic liquids containing tetrabutyl ammonium cation as high performance anti- wear and friction reducing additives for base oils. The tribological performance evaluation of the lubricant blends, prepared as 1000 ppm and 2250 ppm of C, H and N into the base oil, is carried out on the Four-Ball tribo-tester. The concentrations of carbon, hydrogen and nitrogen influenced the tribological performance of the synthesized additives. The synthesized ionic liquids exhibited excellent anti-friction and anti-wear characteristics. The anti-friction behaviour was more prominent with a reduction in coefficient of friction by the order of 70% in comparison to reduction in wear.

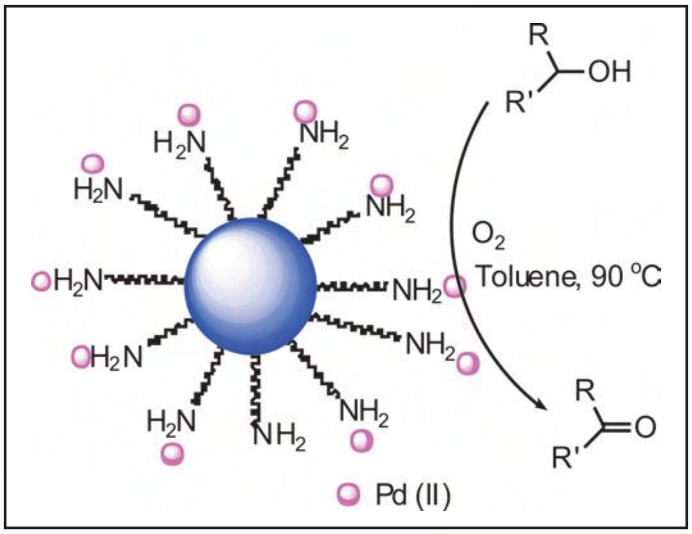
- **Nanocrystalline Starch as Expedient Support for Homogeneous Catalysts:**

We demonstrated the first successful synthesis of nanocrystalline starch-supported Pd(II) ethylenediamine complex and its application as a catalyst for the dehydrogenative Heck coupling reaction as shown in Scheme 4.



Scheme 4. Heck reaction

We have synthesized highly-dispersed Pd-nanoparticles grafted onto amino-functionalized nanocrystalline starch for oxidation of a variety of alcohols to their corresponding carbonyl compounds by using molecular oxygen as the oxidant. The prepared catalyst was found to be selective for oxidation of primary alcohols to aldehydes without giving over oxidation products and was recycled several times without any leaching of the metal into the solution.



Scheme 5. Oxidation of alcohols

- **Development of a Process for *n*-Dodecane Fraction from Straight-run Kerosene Obtained from Petroleum Refinery**

n-Dodecane is found in the straight-run kerosene (boiling range 140-250°C) and there is an enormous potential for production of such a valuable component from the mentioned hydrocarbon stream. We have developed an indigenous process for production of normal dodecane fraction from such straight-run kerosene that can be used for, namely, in reprocessing of spent nuclear fuels which otherwise add value to such hydrocarbon streams. Urea molecules are known to form reasonably stable crystalline hexagonal structure, wrapping inside linear (straight-chain) paraffins-containing six carbon atoms or above in the form of adducts at room temperature. This property of urea in the presence of an activator followed by decomposition of the adduct has been studied with a suitable fraction of kerosene for development of a process for production of normal dodecane fractions.

- **Photoassisted Reduction of Carbon Di-oxide to Hydrocarbon Fuels**

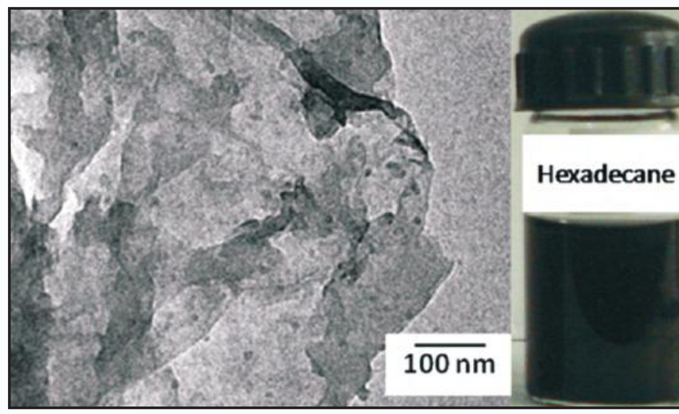
We have designed and synthesized few transition metal-based macrocyclic complexes to be used as efficient photocatalysts for photocatalytic reduction of CO_2.

1.3.2 Speciality Products

Poor lubrication in mechanical systems leads to significant loss of energy and materials because of high friction and wear, respectively. The increasing demand for energy efficient machineries, rapid technological changes in machine design, and replacement of iron-based mechanical componenst by light-weight aluminium alloys and ceramic materials, requires effective lubrication.

- **Dispersion and Lubrication Properties of Chemically-Functionalized Graphene**

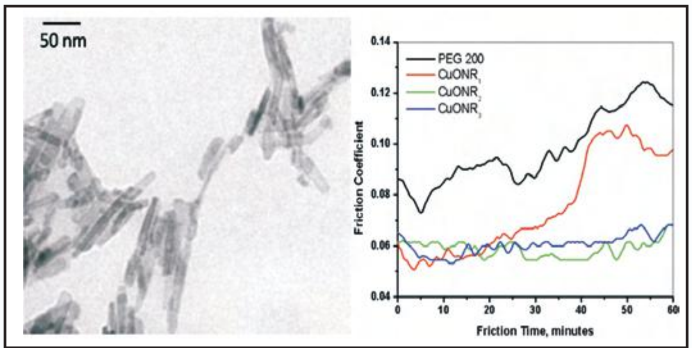
The alkylated graphenes with variable alkyl chain lengths (C_n = 8, 12, 18) are developed on a large scale by the coupling of alkylamine with carboxylic groups of graphene oxide (GrO). The FTIR, UV Visible, and TGA results reveal that, during alkylation, the oxygen functionalities of GrO are reduced significantly and the average size of the sp^2 carbon domain increased, which is further supported by the Raman characteristics. It is observed that the dispersibility of alkylated graphene in hydrocarbon solvents increases on increasing the chain length of (a) hydrocarbon solvents used for dispersion and (b) alkyl groups attached to the graphene. The van der Waals interaction between methylene units associated with alkylated graphenes and hydrocarbon solvents plays a crucial role in determining their dispersion characteristics, and such an interaction increases with increasing methylene units. Octadecylamine functionalized graphene (ODA-Gr) dispersion in hexadecane is found to have long-term dispersion stability due to its high degree of cohesive interaction. The lubrication characteristics of hexadecane containing ODA-Gr were probed by evaluating its friction and wear properties. The results reveal that hexadecane doped with an optimized dose of 0.06 mg mL^{-1} ODA-Gr reduced friction and wear by 26% and 9%, respectively, compared to hexadecane. The lubricity enhancement could be attributed to uninterrupted supplies of graphene nanosheets under the rubbing surfaces, where these nanosheets prevent direct contact between the rubbing surfaces, providing low resistance to shear.



Lubricity studies

- **Ultrasound Assisted Shape Regulation of CuO Nanorods in Ionic Liquids and their use as Energy Efficient Lubricant Additives**

CuO nanorods ($CuONR_1$) were prepared by processing an aqueous solution of copper salt with an excess concentration of alkali solution. This was followed by sonication of $CuONR_1$ with two different ionic liquids having imidazolium and ammonium cations, which guided morphological changes in $CuONR_1$ and formed the nanorods ($CuONR_2$, and $CuONR_3$) with high aspect ratio. XRD and TEM analyses of CuO nanorods revealed that the monoclinic crystal structure of $CuONR_1$ remained intact during their sonication in the presence of ionic liquids; however, the morphological features changed significantly. CuO nanorods as additives in PEG 200 and 10W-40 oil exhibited excellent friction reduction and anti-



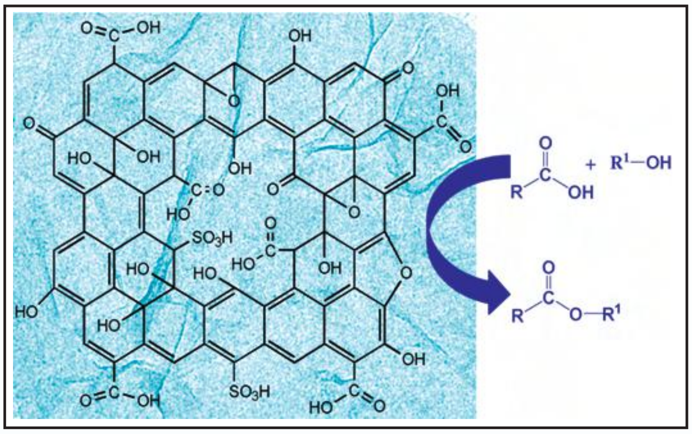
CuO nanorods studies

wear behaviours. The dispersion stability of CuO nanorods and their aspect ratio (length/breadth) play an important role in monitoring the lubrication characteristics. $CuONR_1$ with low aspect ratio and poor dispersion stability possesses a higher friction coefficient and WSD compared to those of $CuONR_2$ and $CuONR_3$. At the optimized concentration (0.075 mg mL^{-1}) of $CuONR_2$, the friction-coefficient and WSD were reduced by 43 and 27%, respectively. However, $CuONR_3$, which possesses a higher aspect ratio compared to $CuONR_2$, exhibited even better anti-wear properties (43% reduction in WSD). This study reports an excellent degree of improvement in lubrication characteristics by using CuO nanorods, which is associated with their dimensions (high aspect ratio) and dispersibility. It was deduced that CuO nanorods working as a roller between the contact surfaces result in a significant improvement in lubrication properties of CuO-blended PEG 200. The tribological performance of CuO nanorods was also evaluated in a commercial oil (10W-40), which contains friction modifiers and anti-wear additives. However, still $CuONR_3$ has shown the maximum reduction in friction coefficient and WSD by 21 and 40%, respectively. The excellent performance of CuO nanorods as lubricant additives is due to their good dispersion stability and rolling effect mechanism.

- **Graphene Oxide as a Solid Bronsted Acid Catalyst**

Graphene oxide, a distorted ultra-thin sheet of carbon having ample acidic sites, is found to be a highly-efficient and reusable solid acid catalyst for the esterification of various carboxylic acids with a variety of alcohols to furnish corresponding esters in excellent yields.

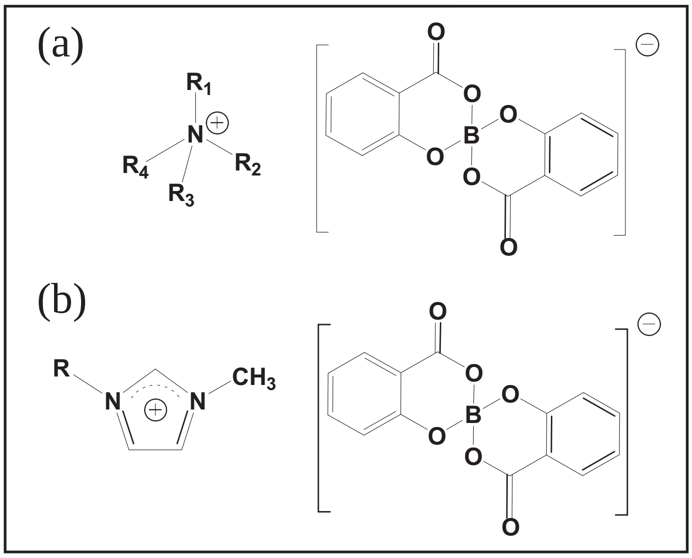
The apparent acidity of graphene oxide is estimated to be 4.3 m.mol.g^{-1}. Phenolic groups attached to conjugated sp^2 domains in graphene oxide resonantly stabilize their deprotonated species (phenoxide ions) by delocalizing the negative charge, consequently of high acid strength. The presence of ample hydroxyl groups nearby carboxyl and phenolic functionalities, particularly on *ortho* position, stabilizes the deprotonated species through intra-molecular hydrogen bonding, which adds to, their acidic



strength. Thus, graphene oxide as a whole shows very high acidity and easily provides hydrogen ions to facilitate the esterification reactions. As a whole, efficient catalytic activity of graphene oxide is attributed to the synergistic effect of high acidic strength, good dispersibility in reaction media, and excellent surface area having ample catalytic sites, which are easily accessible to the reactants.

- **Halogen-Free Ionic Liquids Composed of Bis(salicylato)borate Anion as Lubricant Additives**

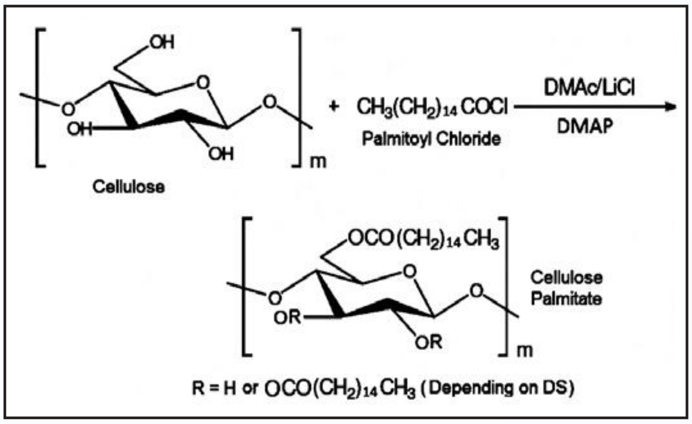
In recent years, ionic liquids have attracted significant attention for their diversified range of applications owing to combination of their unique and tunable physico-chemical characteristics such as low vapour pressure, good thermal stability, non-flammability, excellent conductivity and high viscosity. These features make ionic liquids as potent candidates for tribological applications to reduce friction and wear. We have synthesized halogen-free ionic liquids, composed of bis(salicylato)borate anion having two different categories of cations i.e. imidazolium and



ammonium. In each category of ionic liquids structural changes have been made by changing the alkyl chain length to probe their effect on tribological properties. The synthesized ionic liquids were thoroughly characterized by NMR, FTIR and TG-DTA analyses. Poly(ethylene glycol)-200 and finished commercial engine oil 10W-40 were selected as lube base-stocks to probe the lubrication properties of bis(salicylato) borate anion-based ionic liquids. These ionic liquids were found to have good miscibility in both the lube base-stocks. All tribological tests were conducted on Four Ball Test Machine as per the ASTM D-4172 standard test method. Bis(salicylato)borate anion based ionic liquids as additives in PEG 200 and 10W-40 oil exhibited excellent friction-reduction and anti-wear behaviour. At optimized concentrations of alkylmethylimidazolium bis(salicylato)borate (Alkyl: Cn = 2, 4 and 6) ionic liquids, the friction-coefficient and WSD were reduced by 12 - 20 % and 17 - 30%, respectively. Tetraalkylammonium bis(salicylato)borate (Alkyl: Cn = 1, 4, 5 and 8) also exhibited significant reduction in friction and anti-wear properties (10 - 22 % and 22 - 26 % reduction in friction coefficient and WSD, respectively). The microstructural and elemental analysis on the worn surfaces based on FESEM and EDX measurements, respectively, reveals the role of ionic liquids for the improved lubrication characteristics.

- **Synthesis, Characterization and Triboevaluation of Cellulose Fatty Esters for Biolubricant Applications**

Cellulose fatty esters were prepared in the laboratory by an esterification reaction of micro-crystalline cellulose with fatty acid anhydride e.g. dodecenyl succinic anhydride (DDSA) and acid chlorides e.g. palmitoyl chloride ($CH_3(CH_2)_{14}COCl$). A combination of N, N-dimethylacetamide (DMAc) and lithium chloride (LiCl) is used as a solvent for cellulose. Different reactions were done for different concentrations of DDSA and Palmitoyl chloride. The catalyst used was DMAP (4-Dimethylaminopyridine). The synthesized samples with different DS's (degrees of substitution) were then characterized using Infrared (IR) Spectroscopy, Nuclear



Magnetic Resonance (NMR) Spectroscopy, Scanning Electron Microscopy (SEM) and Thermogravimertric (TG) Analysis. The cellulose fatty esters (cellulose dodecenyl succinate and cellulose palmitate) were tested for lubricating properties as per the ISO-12156 (ASTM 6079) method using High-frequency Reciprocating Rig (HFRR). It was observed that the cellulose esters show good lubricity and the lubricity increases with the increase in the value of degree of substitution.

1.4 ANALYTICAL SCIENCES

1.4.1 Advanced Crude Oil Evalaution

- **Studies on Crude Oils from CAIRN India Ltd.**

Studies on evaluation of two crude oils from the Rajasthan fields received through M/s Cairn Energy India Ltd., were carried out for the bench-mark pricing of crude oil samples.

- **Detailed Evaluation Studies of Balmer crude oil from M/s Cairn Energy India Ltd.**

Studies on detailed evaluation were carried out to determine the potential of value-addition to the straight-run cuts of crude oil from M/s Cairn Energy India Pvt. Ltd. Such information on a crude oil gives an idea of the intrinsic value of the crude oil for its marketability and helps assess the feasibility of producing value-added products which further aimed at increased profit margins of a refinery.

- **Effect of Blending Bio-oil with Conventional Fuel**

This study was aimed to produce bio-fuel. A success was achieved in the blending of bio-oil and its fractions with the conventional fuels by various methods.

- **Studies of Naphtha and Wash oil Samples**

Detailed studies on characterization and compositional aspects of naphtha and wash oil samples from a client were conducted.

- **Studies on Creosote Oils**

Coal tar which is a product of steel plant obtained from the carbonization of coal is distilled. During distillation of coal tar, creosote oil crude 3 (light and heavy) is separated on the basis of temperature cuts. Thereafter, naphthalene is separated by chilling the crude creosote oil and the separated product from the chilling plant is known as creosote oil. These creosote oils were studied *vis-à-vis* the specifications of furnace oil and light diesel oil.

1.4.2 Trace Metal Analysis and Electron Microscopy

- **Studies on Metal Concentrations**

Vegetable oils, catalysts, bio-oil, bio-mass, high speed diesel, sweetening catalyst, tar sand, gas condensate, transmission oil, used oils, gear oils, RFO feed, Bio-lubricants, RR fuel, short residues and plant materials etc. were estimated for different metal concentration.

- **Quantitative Estimation of Metals**

Metals like Na, Mg, P, Co, V, Zn, Cd, Fe, Ti, Ca, Mn, Ni, Cu, Al, Cr, Si, Ba, Ce, Mo, Pb, Pd & K were estimated quantitatively at ppm/ppb level. A large number of samples like crude oil, naphtha, high speed diesel, and other samples were taken up.

- **Morphological Studies**

Petroleum cokes, metal balls for tribological studies, solar cells and catalysts were analyzed for morphology. These were characterized through the Scanning Electron Microscope and elemental analysis with Energy Dispersive X-Ray analysis for elemental mapping.

1.4.3 Mass Spectrometry

- **Development of Analytical Method for Particulate Matter Analysis**

An analytical method involving gas chromatography-mass spectrometric (GC-MS) detection and quantification of polycyclic aromatic hydrocarbons (PAHs) besides qualitative estimation of soluble organic contents was developed for characterization of particulate matter from diesel exhaust emissions. The PAHs selected the for study were identified as potential pollutants and as being highly carcinogenic by the United States Environmental Protection Agency (USEPA). A total method comprising 15 PAHs was optimized out of which 13 were detected and quantified in emission samples through GC-MS operating in selected ion monitoring (SIM) mode. In addition to this, a large number of aliphatic hydrocarbons were also identified through mass spectral database.

- **Hydrocarbon Type Analysis of Middle Distillates**

Kerosene samples were carefully studied with the high-resolution mass spectrometer (HRMS) to disclose compositional information into 22 hydrocarbon types primarily including saturated, aliphatic and alicyclic hydrocarbons comprising upto 7 rings, mono-aromatic, alkyl benzenes, naphthalene(s), PAHs, sulphur and nitrogen-containing hydrocarbons. The relative hydrocarbon composition in this format was de-convoluted from the high resolution (up to 4^{th} decimal of the elemental mass) mass spectra of the kerosene samples on the basis of which de-aromatization and de-sulphurization studies were carried out.

- **Bio-oil Characterization**

Bio-oils derived from slow and fast pyrolysis are useful precursors to bio-fuels and value-added chemicals. In the first phase, compositional analysis of biomass slow pyrolysis oils was carried out with GC-MS. A detailed sample preparation protocol was adopted to extract and enrich valuable organic chemicals from aqueous as well as organic fractions of bio-oil. Adequate sample pre-treatment strategy was also optimized prior to analysis and identification with the help of existing mass spectral database.

- **Analytical Support**

Being crucial for all the on-going in-house or sponsored projects of the Institute, around 750 samples were analyzed with GC-MS and HRMS. More than 200 mass spectral experiments were carried out on the newly-installed HRMS instrument. The samples were largely analyzed for structure elucidation, molecular weight information and/or monitoring of chemical reactions.

- **Optimization of ASTM Methods for Petroleum Analysis**

Petroleum analysis through low-resolution and high-ionizing voltage mass spectrometry is usually carried out through ASTM 2789, 2425, 2786 and 3239. After the complete installation and commissioning of HR-GCMS, in January 2012, all standard methods were fully optimized and validated with the respective samples. Since the instrument is a double-focussing magnetic analyzer with a resolving power of 80000, the HC22 programme was also used for generating 22 Hydrocarbon type analytical data.

1.4.4 Ultraviolet-Visible (UV-Vis) Spectroscopy and Nuclear Magnetic Resonance (NMR)

- **Studies on Moelcular Composition**

A total of around 500 samples of NMR and 350 samples of UV for structural and molecular composition and for aromatic distribution were analysed respectively for various in-house and sponsored projects.

1.4.5 Gas Chromatography (GC), High-performance Liquid Chromatography (HPLC), Supercritical Fluid Chromatography (SFC)

- **Studies on Compounds Etc.**
  - ❖ More than 200 liquid and gaseous samples were analyzed with GC for hydrocarbon type compounds, paraffinic carbons and for composition of gases.
  - ❖ HPLC and SFC analytical inputs were provided to various sponsord & in-house projects.

1.4.6 Fourier Transform Infrared Spectroscopy (FTIR)

- **Analysis of Samples**

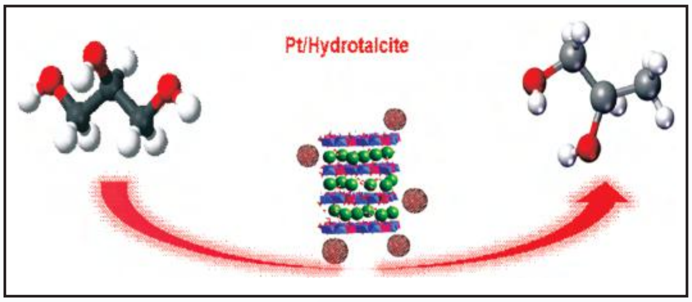
More than 700 samples were analyzed through FTIR for serval in-house & sponsored projects.

1.5 CATALYTIC CONVERSION PROCESSES

1.5.1 Nano Catalysis

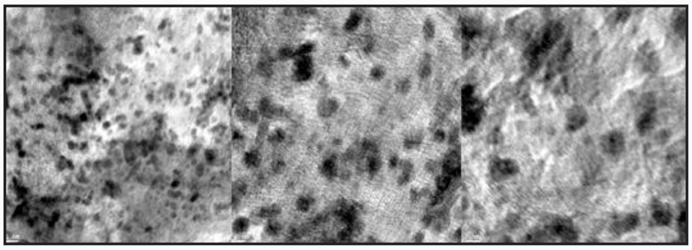
The Institute also forays into many strong and expanding activities in nano-catalysis for energy, petrochemicals and environmental applications, as it provides efficient, sustainable and economical ways to convert raw materials into valuable chemicals and advanced future fuels. Moreover, the fundamental physics and chemistry of surfaces by using advance characterization techniques are also investigated which has led us to a molecular-level insight between nanoparticle properties and catalytic performances.

- **Aqueous Phase Reforming of Glycerol to 1, 2-propanediol Over Pt/Hydrotalcite Catalyst**



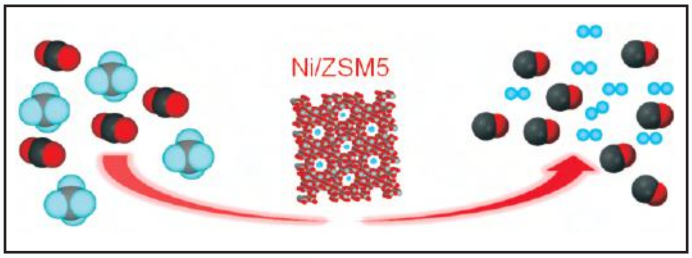
Aqueous phase reforming of glycerol

Glycerol is the by-product during the production of biodiesel by trans-esterification of seed oil with methanol. Research efforts to find new applications for glycerol as a low-cost feedstock for functional derivatives have led to the introduction of a number of selective processes for converting glycerol into commercially-valued products. Here we report the aqueous phase reforming (APR) of glycerol over Pt-loaded hydrotalcite (HT) in a batch reactor at an initial N_2 pressure. A glycerol conversion of upto 95% with a selectivity of 65% for 1,2-propanediol was achieved, without the use of any external H_2. We also found that by addition of a small amount of alkali (NaOH), the product formed is only gas which contains almost 75% of H_2 and rest is mostly CO_2.



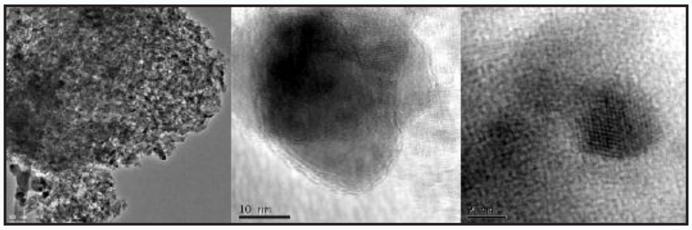
TEM pictures of Pt/Hydrotalcite

- **Development of Speciality Inorganic Materials for Diverse Application**



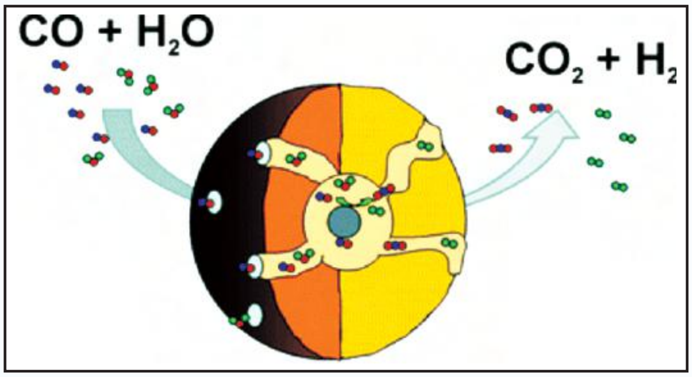
Dry reforming of methane over Ni-nanoparticles supported on mesoporous ZSM-5

Natural gas appears to be a clean and ecological source of energy and is now viewed as an area of competiveness for the major oil companies for improving their performance. One of the processes that has been commonly used in recent years is the dry reforming of methane. Indeed, this process is of a particular interest because it uses two greenhouse gasses via the reaction ($CH_4 + CO_2 \;\; 2CO + 2H_2$). We have found that Ni-nanoparticles supported on mesoporous ZSM-5 show very good activity and selectivity. A conversion of 92.8 % with ~ 100% CO selectivity (CO: H_2 molar ratio = 1:1) was achieved at 1073K.



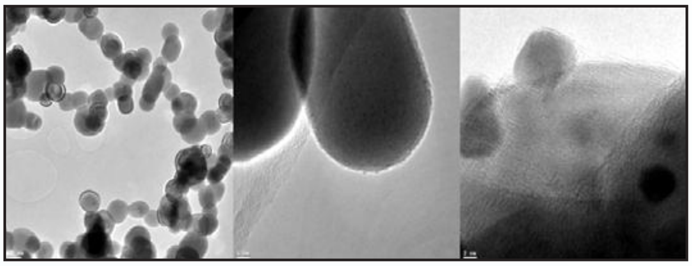
TEM pictures of Ni/ZSM-5

- **Low Temperature Water-Gas-Shift Reaction over Cu-nanoclusters supported on $CeO_2/ZnO/Al_2O_2$**



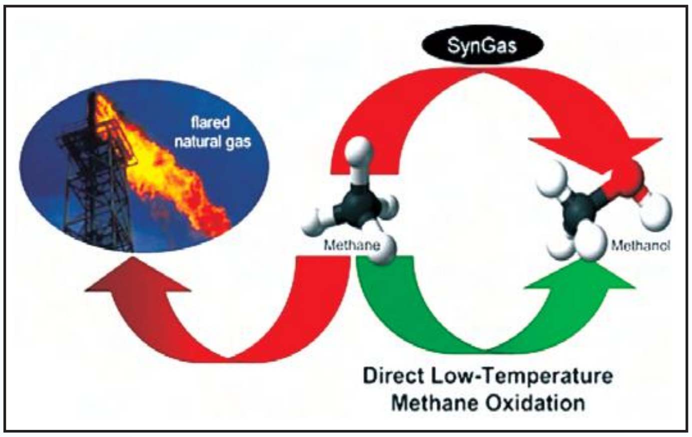
Water-gas-shift reaction

With the recent development and beginning of commercialization of polymer electrolyte membrane fuel cell (PEMFC), the demand of CO-free hydrogen has increased to a great extent. In fact, the development of a technology for production of pure hydrogen (with little or no CO) conventionally and at a low cost is one of the challenges posed before the hydrogen-economy sector. Conventionally, water gas shift reaction (WGSR), $CO + H_2O = CO_2 + H_2$, is applied in most hydrogen production facilities to decrease the concentration of CO and to increase the production of H_2 simultaneously. The supported Cu-nanoclusters were prepared hydrothermally in presence of a surfactant, cetyltrimethylammonium bromide. It has been observed that the small Cu-clusters supported on ZnO, Ceria and Al_2O_3 are active for the water-gas-shift-reaction. It is very interesting to note that when a small amount of Pt (0.5wt %) was added with these catalysts, the activity increases dramatically. Pt/Cu-Ce shows a CO conversion of 92.8% after 0.5 h reaction time at 423 K.

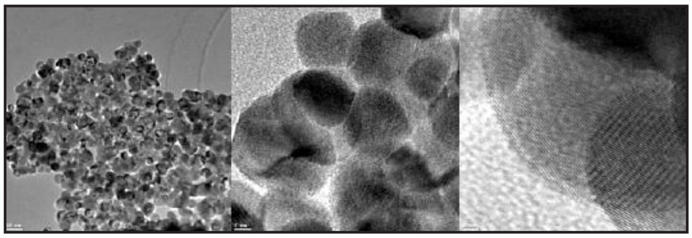


TEM pictures of $Cu/CeO_2/ZnO/Al_2O_3$

- **Selective Oxidation of Methane to Methanol over Supported Nano Cluster**

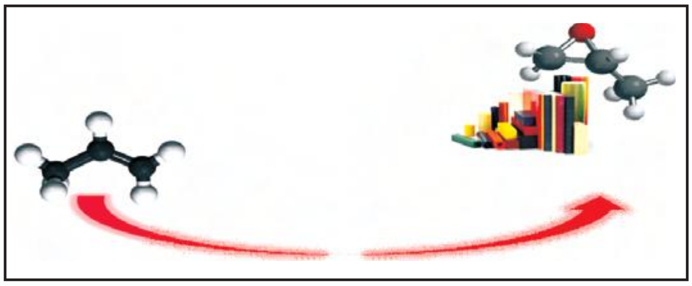


Preparation of nanoclusters where the particle size is below 1 nm, appears the most challenging research in terms of preparation, characterization and potential enhancement of reactivity. The development of such a novel material is a fundamental focal point of chemical research; and this interest is mandated by advancement in all areas of industry and technology. Methane is the most abundant and the least reactive of the hydrocarbon family, thus the selective oxidation of methane to methanol is one of the most challenging chemical problems, in addition to being of great practical importance.



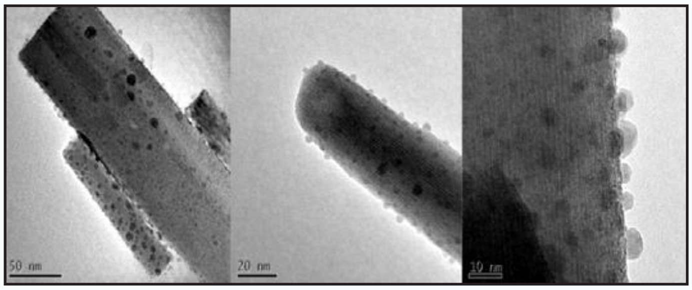
TEM pictures of Ni/CeO_2-ZrO_2

- **Selective Oxidation of Propylene to Propylene Oxide with Molecular Oxygen Over Ag-W-oxide Catalysts**



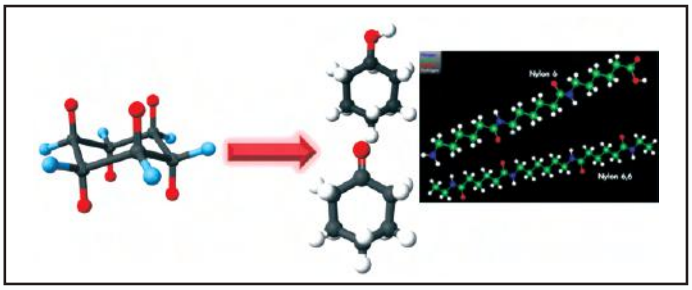
Selective oxidation of propylene

Propylene oxide (PO) is a versatile chemical intermediate used in a wide range of industrial and commercial products including polyether polyols, propylene glycols and propylene glycol ethers. By volume, it is amongst the top 50 chemicals produced in the world with an annual production of about 5 million tonnes. Industrial production of propylene oxide is mainly from co-oxidation of propylene with other chemicals but these technologies create additional side products. The major conventional manufacturing methods of PO are the chlorohydrins process and the Halcon process. The chlorohydrin process is being phased out because of environmental pollution, while the latter has the by-product limitation. So a new environmentally-benign technology has to be developed for the production of propylene oxide. We have found that nanocrystalline Ag-W catalyst shows a propylene conversion of ~46% with ~100% propylene oxide selectivity using molecular oxygen as an oxidant at 623K.



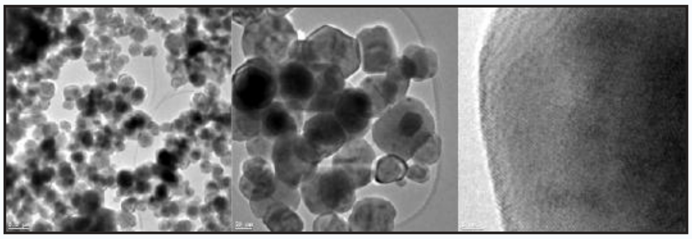
TEM pictures of Ag/WOx

- **Room Temperature Selective Oxidation of Cyclohexane with H_2O_2 over Cu-Cr_2O_3 Catalysts**



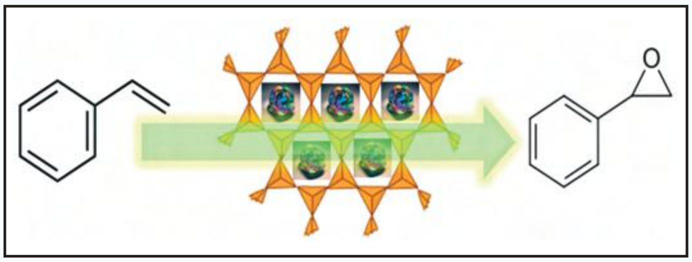
Selective oxidation of cyclohexane

The oxidation of cyclohexane due to the large demand for cyclohexanone and cyclohexanol, which are important raw materials for production of adipic acid and caprolactam was finally used in the manufacture of nylon-6 and nylon-66 polymers. However, the oxidation of cyclohexane turns out to be least efficient of all major industrial processes. The present worldwide industrial process for cyclohexane oxidation is carried out at 423 K and 1-2 MPa pressure, employing metal cobalt salt or metal-boric acid as a homogeneous catalyst. There is no heterogeneous catalyst reported to date which can be used in the industry. We have found that Cu-supported on Cr_2O_3 prepared by hydrothermal method shows 100% cyclohexane conversion at room temperature with selectivity of 85% cyclohexanone and 15% cyclohexanol with H_2O_2 as oxidant.



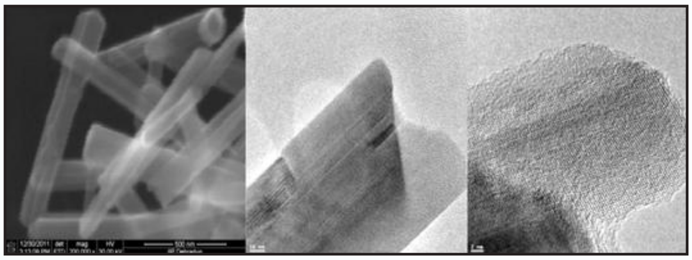
TEM pictures of Cu/Cr_2O_3

- **Room Temperature Selective Oxidation of Styrene to Styrene Oxide over Ce-SiO_2**



Selective oxidation of styrene

The design of rational synthesis pathways for nanocrystalline materials is significant due to their potential application as advanced catalysts, adsorbents, optical guides and sensors. In modern science, extensive research efforts have been devoted to the synthesis of porous inorganic materials with different structural coherency over a wide range of length scale. We have successfully synthesized Ce nanoparticles supported on SiO_2. The catalyst is highly active for the selective oxidation of styrene to styrene epoxide.

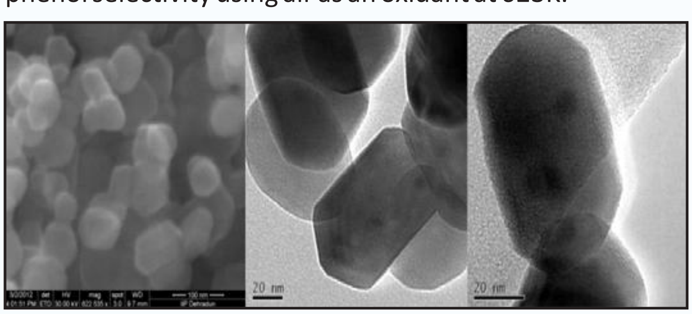


TEM pictures of Ce/SiO_2

- **Selective Oxidation of Benzene to Phenol with Molecular Oxygen over Cu-Cr-oxide Catalysts**

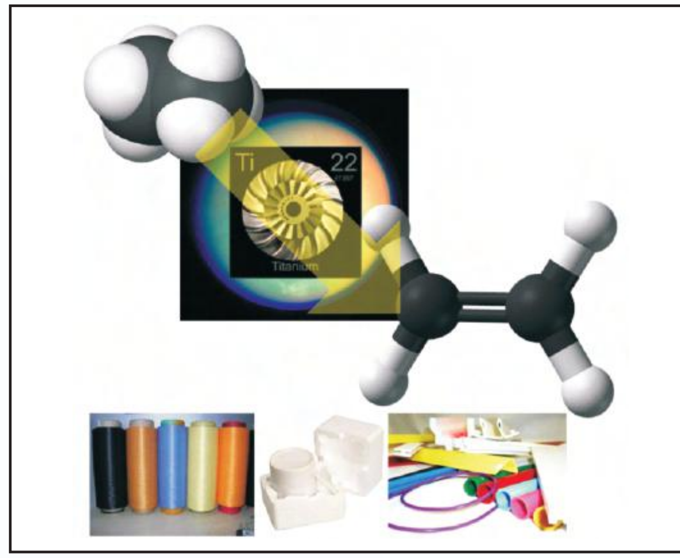
Selective oxidation of benzene

Phenol is one of the most important chemicals in industries, where the world production exceeds 7.2 megatonnes per year. Industrially, phenol is produced from benzene by the three-step cumene process, which is not only energy-consuming but is also less efficient, showing very low phenol yield (~ 5 %, based on the amount of benzene initially used) and producing lots of by-products such as acetone and –methylstyrene. Direct phenol synthesis from benzene is an alternative way to overcome these problems. We have found that CuCr catalysts show a benzene conversion of ~30% with ~98% phenol selectivity using air as an oxidant at 623K.



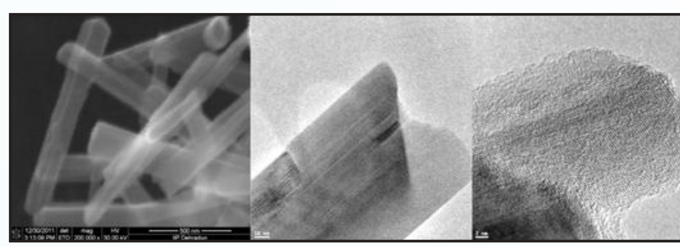
SEM & TEM pictures of Cu/Cr_2O_3

- **Dehydrogenation of Ethane to Ethylene over Nano crystalline TiO_2**



Dehydrogenation of ethane

Ethylene is a very important chemical, which does not occur in nature but still represents the organic chemicals consumed in greater quantity worldwide. It is mainly the raw material for a large number of industrial products, such as poly-ethylene, polyvinyl chloride, polystyrene, polyester, etc. The global demand of ethylene is over 140 million tonnes per year with a future growth rate of 3.5% per year. We have successfully developed a nanocatalyst containing TiO_2 nanorod-supported Mo or Pt nanoparticles, which shows an ethane conversion of ~92% with ~85% ethylene selectivity at 973K.

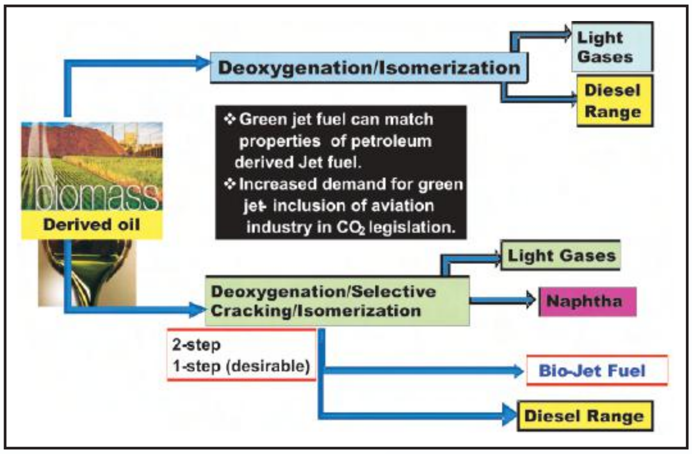


TEM pictures of nano crystalline TiO_2

1.5.2 Catalytic Reforming: Advanced Materials For Hydrocarbon Conversion

- **Hydroprocessing**

Our innovation is a novel single-step catalytic process for conversion of plant-derived, non-edible, waste, low-cost oils to produce drop-in biofuel for air-transport purposes. Plant-derived oils (soya, *jatropha*, *karanja*, algal) are deoxygenated, selectively cracked and isomerized over a single catalyst to produce aviation fuel with 35-55% yield and with properties and compositions exactly the same as those required for aviation fuel. It is a unique single-step process to produce aviation fuels from renewable sources.



Production of bio-jet from vegetable oil both single-setp and two-setp processes

- **Biojet Production**

➢ Bulk production of the biojet fuel on existing pilot-plant (continuous pilot plant run)is going on smoothly for engine testing. Approximately 2000 litres of *jatropha* processed and ~300 litres of biojet were prepared.

➢ Models were developed to know the product pattern while the conditions were optimized.

➢ New experiments were planned and have been carried out on different catalyst-bed arrangements, lower hydrogen/feed ratio, WHSV and pressure variations on a pilot plant.

➢ 120 litres of biojet has already been supplied to M/s Pratt and Whitney, Canada for, engine tests while 65 litres of were sent to the IOCL for further testing.

➢ A pilot plant is currently in operation where almost 15 litres of biojet per day could be produced.

➢ The targetted production is the supply of 120 litres of biojet for testing at the IIT, Kanpur.

- **Production of Second- and Third-Generation Biofuels (Biomass-to-liquid)**

The main objective was the demonstration of pilot-scale production of second-generation bio-fuels by single-step route from non-edible oil triglycerides and free-fatty acids besides techno-economic feasibility studies. The other objective of the project was to design and develop a micro-channel reactor for conversion of non-edible oil and biomass-derived oil (pyrolysis-oil) as also biomass-derived gases (syn-gas) to second- and third-generation biofuels. Following work was completed during the year.

➢ Continuous production of green diesel at pilot-scale and optimization of reaction conditions.

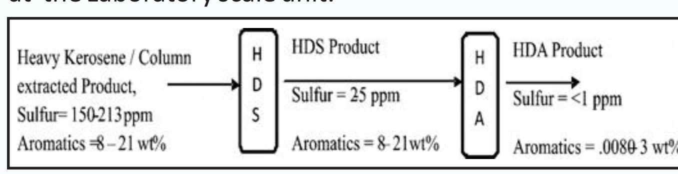
➢ Emission tests Engine Testing Laboratory with the produced green diesel. The results were quite encouraging, with reduced HC, SOx and NOx emissions.

➢ Initial catalyst coating along with characterization was completed and preliminary runs were performed.

➢ Improvement in the design of micro-channel reactor was carried out.

- **Feasibility Study for Value-addition of heavy Kerosene (HK) by Producing the D-80 Product**

The objective of the project was to do a feasibility study for production of D-80 solvent. The heavy kerosene feed which was used as a feedstock for HDS reactions contained 142 ppmw sulphur and 17% mono-aromatics, 3.8% polyaromatics. Two-step process approach was suggested - hydrodesulphurization followed by hydrodearomatization. Various catalysts were screened and experiments were carried out to meet the final specifications. The desired product specifications (like sulphur, aromatics, colour, density, boiling range and Refractive Index) were achieved at the Laboratory scale unit.



- **Work under India-Ukraine Bilateral Co-operation**

This activity involves : research into the new processes of motor fuel production from wastes, hydrogen and synthesis gas generation from solid biomass and domestic wastes and, conversion of biomass-derived gases (syn-gas) to second- and third-generation liquid biofuel using nanocatalysts. Following work has been completed during the year.

➢ Development of catalysts and their evaluation for the processes of conversion of solid fuel in synthesis gas at Ukraine

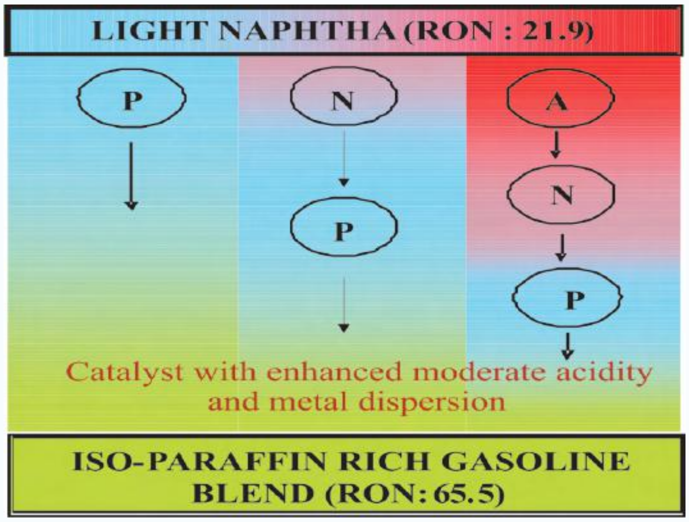
➢ Porous nickel catalysts prepared at the Institute were magnetic; hence they were easily separable from biomass after reaction and could be re-used.

- ➢ Synthesis gas using indigenous feed-stocks gasification was produced at the Institute.
- ➢ Preliminary catalyst formulations were made the Institute for FT conversion reactions using synthesis gas as the feed-stock.
- **Hydroprocessing of Biomass Derived Oil: Fractional Distillation and Detailed Studies on Fractions**
- ➢ Commissioning of 20 litres of a Distillation Unit.
- ➢ The fractionation range for renewable aviation fuel production from hydroprocessing of triglycerides especially from *jatropha* oil was optimized.
- ➢ IBP was selected as 130°C and FBP as 270°C after comparing the freeze point and density results of various blends.

1.5.3 Lightstock Processing and Catalytic Reforming : Advanced materials for Hydrocarbon Conversion

- **Studies on Cracking and Isomerization Functionalities of Bi-metallic Zeolites**

Several mono- and bi-metallic Pt- and Cr- supported zeolite samples (H-BEA and H-Y) were prepared, characterized for their physico-chemical properties and evaluated for their performance towards the conversion of n-heptane as well as two industrial naphtha feedstocks. Among these, the bi-metallic Pt-Cr-HBEA catalyst exhibited enhancement in catalytic properties responsible for high isomerization and octane boosting. Detailed studies envision that the role of Cr is bi-functional, namely, to change the acidity of the zeolite support towards the moderate strength responsible for controlled cracking and to promote the reduction and dispersion properties of Pt for an effective isomerization reaction. This has resulted in enhancement of the research octane number (RON) of two naphtha feedstocks to 22 and 43 units with almost a negligible amount of aromatics, especially benzene. This makes the product suitable for gasoline applications. The catalyst exhibited constant performance in the studied period of 70h.



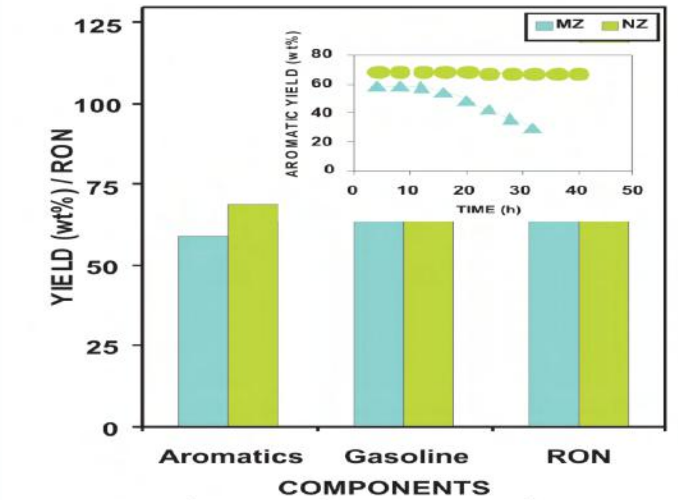
Cracking and isomerization studies

The introduction of Cr species on H-BEA zeolite through ion-exchange prior to Pt impregnation resulted in enhancement in the medium acid sites of H-BEA while Pt impregnation on the resultant Cr-HBEA resulted in improvement in metallic properties of Pt such as reducibility and dispersion of Pt. The resultant Pt-Cr-HBEA catalyst exhibited an effective isomerization of paraffins with minimum cracking useful for octane boosting of the low-value industrial naphtha feedstocks. The interaction between Pt and Cr in the Pt-Cr-HBEA seems to provide a synergetic effect on catalytic properties, where the interaction of Pt shifts the strong acid sites related to Cr into moderate strength responsible for lowering the cracking activity; and the interaction of Cr reduces the undesirable hydrogenolysis activity of Pt to effectively drive the reaction towards isomer formation.

Though the formation of a low amount of lower iso-paraffins (iC_4-iC_6) in the product envisions the mild cracking activity of the catalyst, but it does not affect the product nature. Rather, it is observed to be beneficial for octane boosting (as RON values of lower isoparaffins are higher than those of the higher isoparaffins) of the product. This catalyst development activity is extremely timely in the present scenario of environmental concerns and its impact on the quality of fuels with help produce desirable aromatic-free isomerate-rich high-octane fuel from a variety of mixed feedstocks. The process stands complementary to the existing refinery processes such as reforming and FCC.

- **Synthesis and Catalytic Applications of Nano–crystalline ZSM-5 to ATG (Acetone-to-Gasoline) Reaction**

Two ZSM-5 zeolites exhibiting micro (MZ) and nano (NZ) range crystal size have been synthesized and evaluated for their activity towards acetone to gasoline (ATG) reaction. The NZ possessed comparable acidity with that of MZ, but a significant increase in porosity (two-fold increase in pore volume) was observed in the case of NZ. The hierarchical pore system in NZ was observed to be responsible for enhanced catalytic activity of this material in terms of higher aromatic yields, higher octane number and increased time-on-stream stability in Acetone-to-Gasoline reaction.



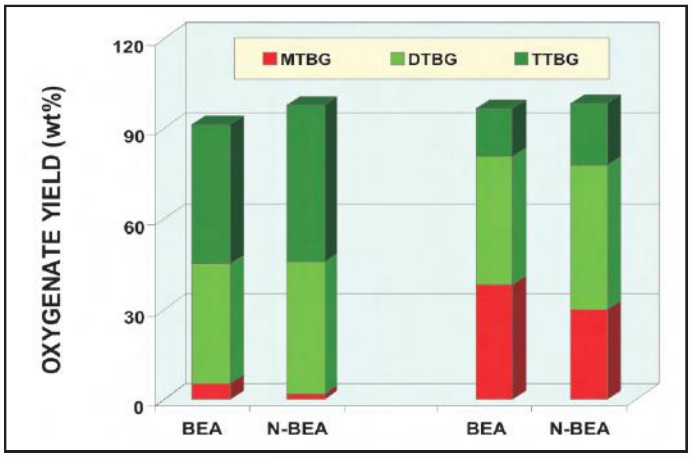
Catalytic applications studies

The nano-crystalline ZSM-5, with its hierarchical porosity created by zeolitic micropores in combination with additional mesopores and macropores, exhibits promising catalytic activity in acetone aromatization reaction to produce low-benzene, toluene-rich and xylene-rich liquid pool possessing a very high octane number of ~120 suitable for gasoline applications. The catalyst also exhibits lower selectivity to C_9+ hydrocarbon, a coke precursor that helps to improve the time-on-stream stability of the catalyst suitable for industrial applications.

- **Development of Zeolite-based Catalysts for Improved Production of Glycerol Oxygenates**

Various resin- and zeolite- based catalysts were prepared, characterized and evaluated for their catalytic performance towards the etherification of glycerol with tertiary butyl alcohol. Resin-based catalysts exhibited higher glycerol conversions and selectivities to ether products at relatively lower reaction temperature (75^{0}C) than the zeolite-based catalysts (90^0-110^{0}C) but the zeolite-based catalysts performed better in terms of stability in activity to produce high amounts of di-tertiary butyl (DTBG) and tri-tertiary butyl ether (TTBG) of glycerol (oxygenate stock). Though acidity is important for the etherification reaction, zeolites exhibiting better porosity rather than acidity could yield higher oxygenates. The presence of inter-crystalline mesopores in N-BEA further improved the oxygenate production and time-on-stream activity of the catalyst. At optimized catalyst parameters and reaction conditions, Nano beta (N-BEA) zeolite catalyst exhibited above 95% conversion of glycerol with more than 45% and 54% selectivities to DTBG and TTBG, which are potential blending stocks for diesel.

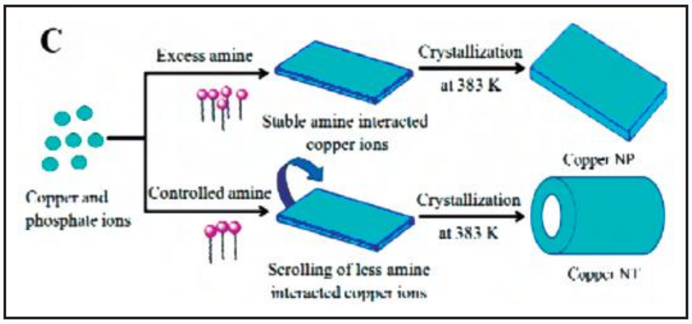
Catalytic properties were observed to influence glycerol etherification with TBA to produce diesel blending



oxygenates (DTBG + TTBG). Among the zeolitic properties, pore size and pore volume have played a vital role, as in the case of BEA and N-BEA catalysts, in producing highly-desired DTBG and TTBG (as high as 99% selectivity at >95 % glycerol conversion). The presence of mesopores originating from inter-crystalline voids in N-BEA made it possible to improve the oxygenate production with stability in activity performance of the catalyst.

- **Synthesis and Catalytic Applications of Amine-interacted $Cu_2(OH)PO_4$ Nano-plates (Copper NPs) and Tubes (Copper NTs)**

A simple method is reported for the synthesis of "alkyl amine interacted $Cu_2(OH)PO_4$ nano structures" viz. nano plates (Copper NPs) and nano tubes (Copper NTs) exhibiting interesting surfactant and amphiphilic properties suitable for solvent-free catalytic applications

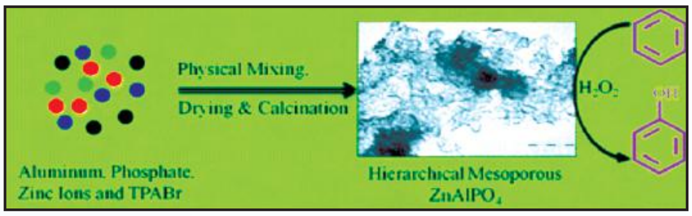


Synthesis of nano-structures

The present work demonstrates a simple method for selective synthesis of the desired nano structure (Copper NTs/ Copper NPs) by controlling the concentration of structure-directing amine, i.e., HDA, in the initial synthesis mixture. In other words, the present method provides a simple technique of variation of amine composition for the synthesis of a specific nano structure; Copper NTs at lower HAD concentrations and Copper NPs at higher HDA concentrations, are reportedly novel concepts. This theory may also be applicable for the synthesis of other metal/non-metal containing nano-structures.

- **Synthesis and Catalytic Applications of Hierarchical Mesoporous $AlPO_4$/$ZnAlPO_4$ for Direct Hydroxylation of Benzene to Phenol using Hydrogen Peroxide**

Amorphous hierarchical mesoporous $AlPO_4$ and $ZnAlPO_4$ materials have been successfully synthesized for the first time by a simple physical mixing method, where tetrapropyl ammonium bromide acts both as a template and a structure directing agent. The materials exhibited excellent catalytic activity for the production of phenol from benzene (99% conversion with 85% selectivity).



Synthesis of mesoporous materials

The material exhibited promising benzene conversion for an efficient production of phenol by selective hydroxylation of benzene. Furthermore, the material shows its reusability with excellent catalytic performance even after three reaction cycles. The subject opens up a new property of the metal $AlPO_4$ materials as suitable catalysts for selective oxidation reactions, and has scope in the improvement of the catalytic activity through the optimization of the synthesis procedure of $ZnAlPO_4$ for expansion of its applications to other selective hydroxylation reactions.

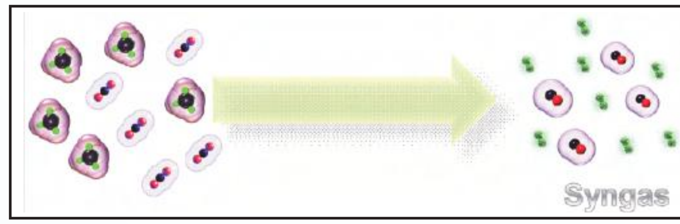
- **Functionalized Hierarchical Nano-composites for Synthetic and Renewable Fuels Production:**

  A collaborative project was initiated with the CSIRO, Australia under the Australia-India Strategic Research Fund (AISRF) (Round 6) programme. The work plan involves the strategic development of functionalized hierarchical mesoporous carbon and carbon-silica composite materials for their catalytic applications in FT and bio-oil conversions.

1.5.4 Gas-to-Liquids (GTL)

Gas-to-Liquids technology (GTL) is a process for converting natural gas into liquid synthetic fuel either directly or via syngas as the intermediate. Our research team has several strong and expanding activities in the field of heterogeneous catalysis to convert natural gas to clean fuels. We are keenly interested in design and development of effective heterogeneous catalytic systems for the production of alternative fuels to be used primarily for transport.

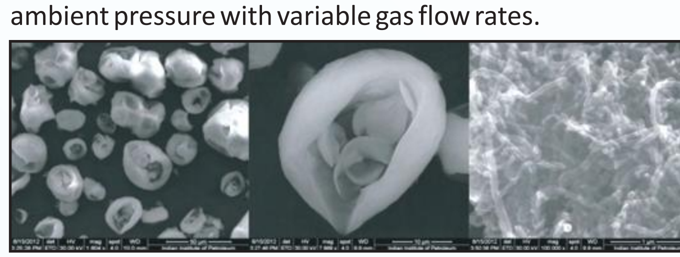
- **Development of Catalyst for the Production of Syngas from CO_2 and Methane**



Syngas production

A variety of catalysts have been developed for dry reforming reaction. Among them, the catalysts based on noble metals are reported to be less sensitive to coking than the Ni-based catalysts. Considering the high cost and limited availability of noble metals, however, it is more profitable to develop a Ni-based catalyst, which is resistant to coke accumulation and exhibits long term stability. It has been proved that the type of support and the presence of modifiers greatly affect the coking tendency. Therefore, Ni-supported catalysts were chosen as the targetted catalysts for conversion of methane and CO_2 to syngas.

A series of Ni-based catalysts with different loadings were prepared for dry reforming reactions with different support materials, i.e., sodium zeolite, ultrastable zeolite, mesoporous ZSM-5, alumina and magnesia-alumina. Catalysts have been well characterized with different characterization techniques such as nitrogen Physisorption, Temperature-programmed reduction, X-ray Diffraction and scanning electron microscopy. A few of the newly-prepared catalysts were evaluated in the fixed-bed reactor with different temperatures (650-800˚C) at ambient pressure with variable gas flow rates.



SEM micrographs of fresh and spent catalysts

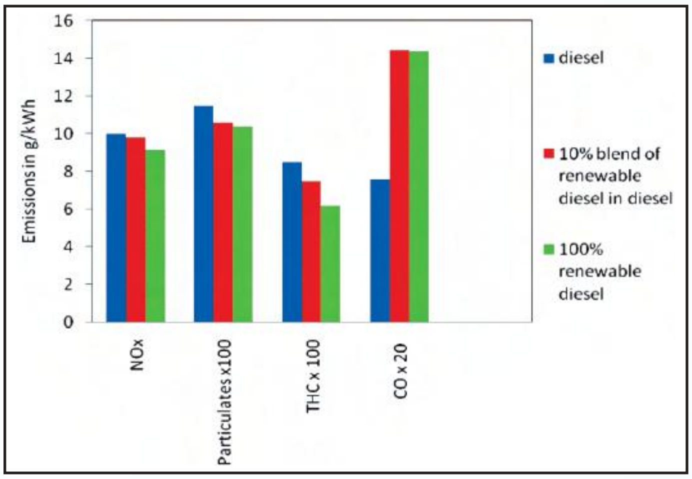
1.6 AUTOMOTIVE FUELS AND LUBRICANTS APPLICATION

- **Hydroprocessed Diesel Produced as a By-product of Biojet Fuel Process**

Non-edible vegetable oils are typically converted into diesel fuel by transesterification (biodiesel) or hydroprocessing. Biodiesel contains oxygen atoms whereas hydroprocessed vegetable oil is a pure hydrocarbon (drop-in fuel) with no oxygen atoms. However, both the fuels are costlier than the conventional diesel and are therefore not economical to be used in diesel engines inspite of having higher cetane number.

In view of the above, the Institute developed an innovative technology to convert non-edible vegetable oils such as *Jatropha Curcas* Oil to hydrocarbon mixture by hydroprocessing. The technology involves pre-treatment of plant-oil followed by hydro-deoxygenation, hydrocracking, hydroisomerization and aromatization. The innovativeness of this technology lies in the fact that all these steps can be carried out by a single catalyst. The product, hydrocarbon mixture, is distilled into gasoline, kerosene (jet fuel) and diesel-range products. About 40% of the product is kerosene which meets all jet fuel specifications, while another 40% meets the diesel specifications. While the jet fuel has been supplied for final runs to a project partner from overseas, the diesel produced was evaluated both in a heavy-duty diesel engine at a newly installed state-of-the-art transient dynamometer facility and in a passenger car tested on a chassis dynamometer.

The engine evaluation emission results showed 2% reduction in NOx with 10% blend and 8.5% reduction in NOx with 100% renewable diesel produced by hydroprocessing route as compared to the conventional diesel (as given in figure). The reduction in PM was 7.8% with 10% blend and 9.6% with 100% renewable diesel produced by hydroprocessing route as compared to conventional diesel. The specific fuel consumption was the same for 10% blend and reduced by 2.1% with 100% renewable diesel produced by hydroprocessing route as compared to the conventional diesel. The vehicle evaluation study also showed similar trends with emission reduction in the range of 5~10% on the 100% renewable diesel produced by hydroprocessing route as compared to the conventional diesel. The study- the first of its kind- showed that the diesel produced as a by-product of hydroprocessing of *Jatropha Curcas* Oil (to jet fuel) has a better engine performance and emission characteristics as compared to the conventional diesel. The improved performance of renewable diesel vis-à-vis the conventional diesel may be attributed to lower (poly)aromatics, lower sulphur and lower nitrogen content in the former.



Comparison of emissions

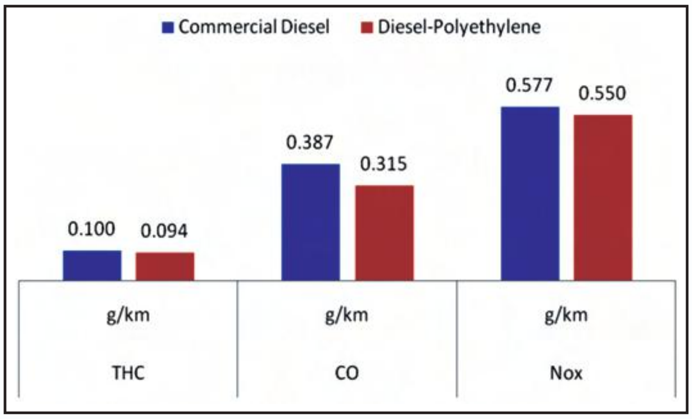
- **Diesel from Waste Plastics: Use in Vehicles**

The growth of the plastics industry has resulted in the ever-increasing accumulation of waste plastics that require an effective and environmental friendly solution. Transforming these wastes into automotive grade fuel could provide a viable remedy to this burgeoning global problem. The waste polyolefins (like the HDPE, LDPE, PP etc, which account for 60-70 % of the total plastic wastes being generated worldwide), have been converted into diesel on a bench-scale unit (feed capacity 10-15 Kg/per day) by a process involving pyrolysis and catalytic conversion followed by condensation and fractionation. Approximately 850 ml of diesel per Kg of clean polyethylene waste was obtained. This Study was aimed at unerstanding vehicle performance and emission characteristics of the diesel derived from polyethylene waste with commercially available EURO-III diesel fuel.

The tests were performed on a chassis dynamometer on a Eur- II compliant passenger car on the regulatory transient cycle, i.e. the Modified Indian Driving Cycle (MIDC). The research facility comprised of light-duty dynamometer suitable for certification and research. The test facility comprises of a chassis dynamometer, which can simulate inertia from 150 kg to 6500 kg. It can measure the speed and force with an accuracy of±0.01% and±0.10%, respectively. The driving cycle simulation is carried out using a driver's aid. The test chamber ambient temperature can be fixed at 25±5ºC and relative humidity at 65%±5%.

The tests were first performed on the conventional diesel and then on the diesel derived from polyethylene. The gaseous regulated emissions, e.g., THC, CO and NOx with the diesel derived from polyethylene were observed to be

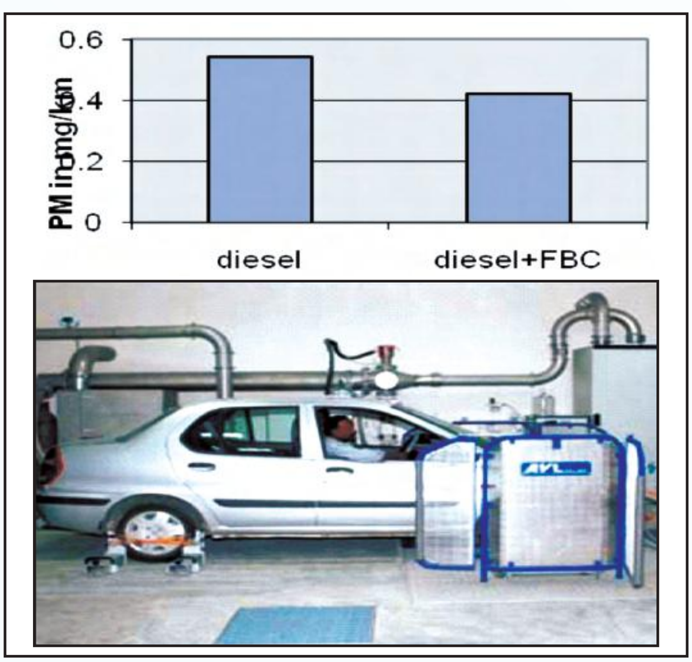
0.09, 0.32 and 0.550 g/km respectively, as compared to conventional diesel fuel which were 0.10, 0.38 and 0.57 g/km, respectively (see figure below). The Particulate



emissions were observed to be the same as 0.036 mg/km for both the fuels. Fuel economy and CO_2 emissions were also observed in the similar range. It may be concluded that the diesel derived from polyethylene waste meets the performance and emission targets of the conventional diesel fuel; in fact, it can even prove to the be better one.

- **Particulate Reduction Studies With the Fuel-Borne Catalyst**

A study was carried out with ceria-based fuel-borne catalyst to reduce PM emissions from diesel exhaust.These porous nano-catalysts, easily dispersible in the fuel, will be completely novel and can reduce PM emissions and improve fuel efficiency in automobiles in addition to being economical to produce indigenously. Reduction in PM emissions and change in the morphology of PM was observed.

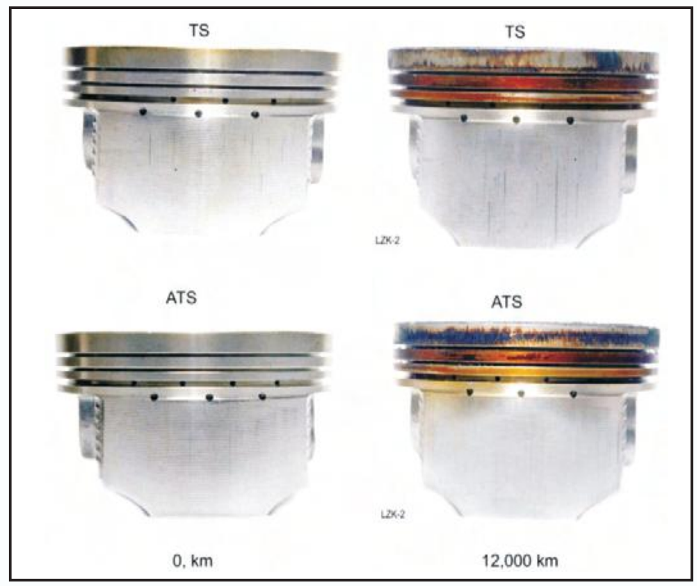


Comparative particulate emission

- **Field Trials to Evaluate Performance of Motorcycle Oils in Four-Stroke Motor-cycles**

Field trials were carried out using two different models of motorcycles on four different four-stroke motorcycle oil formulations received from an additive manufacturer. The trials were aimed at investigating and demonstrating the performance of these four oils with respect to engine cleanliness and general performance under typical Indian field operating conditions.

The motorcycles completed the trial satisfactorily. No technical or operational problems necessitating modifications in the trial scheme was observed, and hence, all the data obtained in the trials is acceptable for the purpose of analyzing the behaviour of the oils.



- **Investigating the of Role of Engine Lubricant Film on Cylinder Wall on HC Emissions of SI Engine**

Fuel hydrocarbons can be absorbed in the oil film present on the cylinder walls during intake and compression stroke, which later gets desorbed into the burned gases during combustion and expansion. As the pressure increases, the partial pressure of the fuel in the mixture increases and the fuel gets absorbed in the oil film. On combustion, at the end of expansion stroke the partial pressure of the fuel in the gases is nearly zero. Therefore, the fuel gets desorbed from the oil and gets diffused back into the burned gases during the exhaust stroke. Absorption and desorption of fuel vapours into lubricating oil were modelled using Henry's Law for dilute solutions in equilibrium. This model would predict the contribution of lubricating oils in HC emissions.

1.7 TRIBOLOGY & COMBUSTION

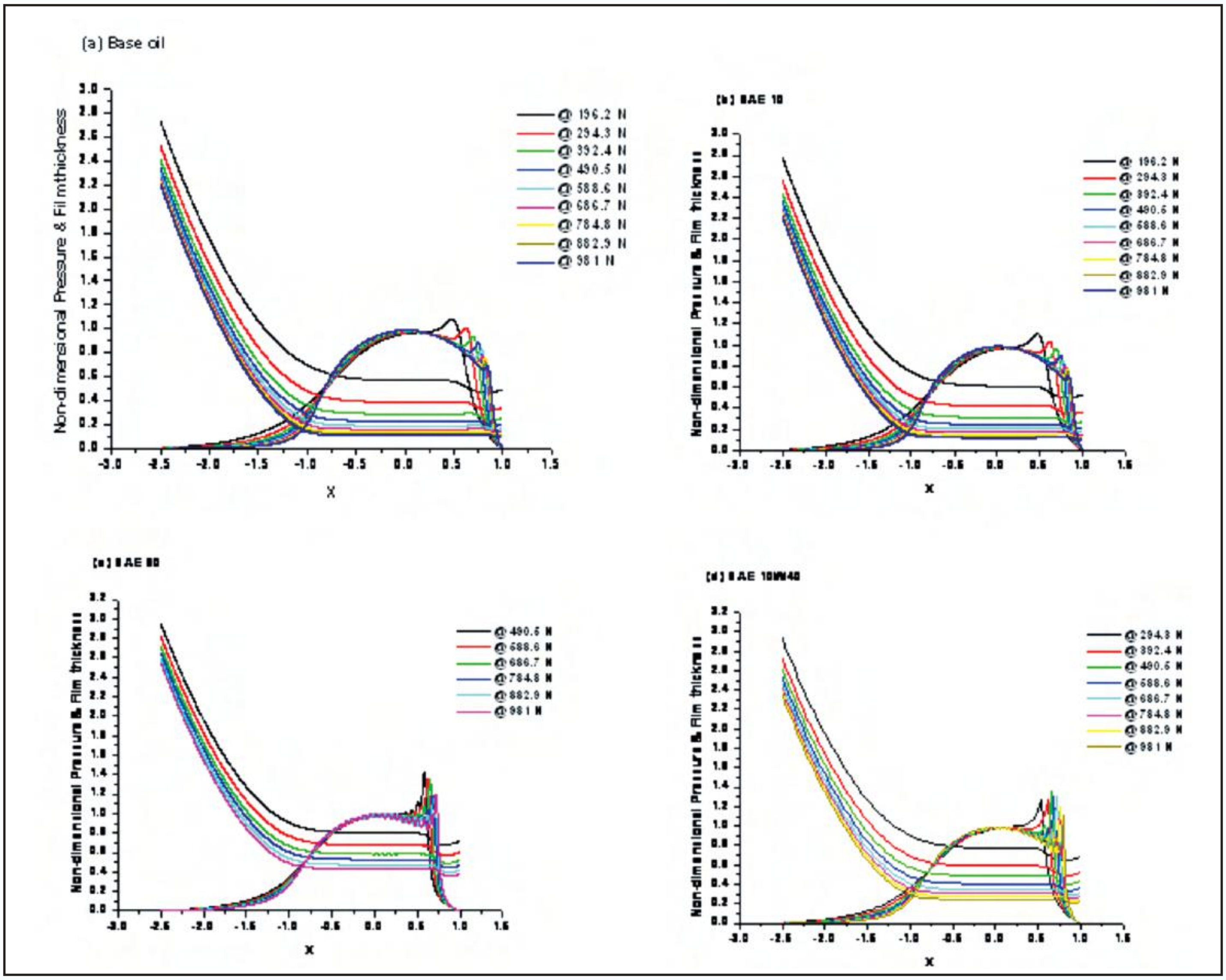
1.7.1 Tribology

- **Valorization of Glycerol for Biodegradable Base Fluids and New Biofuel Formulations**

The project was intiated with the objective of synthesis of glycerol and its value-addition as lubricant base fluids. The tribo-performance characterization and formulation of the lubricant blends has been carried out. Various products synthesized were characterized and the suggested end use of these products was finalized. The developed products are capable of developing Industrial Gear Oils, Neat Cutting oils etc. Further processing and characterization of the lubricants in process.

- **μ – EHL and Failure Investigations in Line Contacts**

EHL is a common phenomenon occurring during critical operation of gears, rolling contacts & rubber-lined bearings. For improved & reliable component performance, accurate predictions of contact pressure, lubricant film thickness & subsurface stress fields under realistic conditions are highly desired. However, these reliable predictions can be achieved by developing a coupled EHL and failure model with the extended experimental backing at micro-level. Therefore, it was proposed to develop a transient- thermal- EHL- model involving real surface roughness and non-Newtonian lubricants, using FEM techniques. Further the model would be augmented with a failure model using sub-surface time-varying stress histories & material strain due to high-contact EHL pressures to predict component



Non-dimensional pressure and film thickness distribution within line contacts failures (micro-pitting, scuffing, scoring etc.). The developed computational tool will be used by designers to predict the directions for improving the lubrication conditions in order to prolong the life of components and to reduce friction.

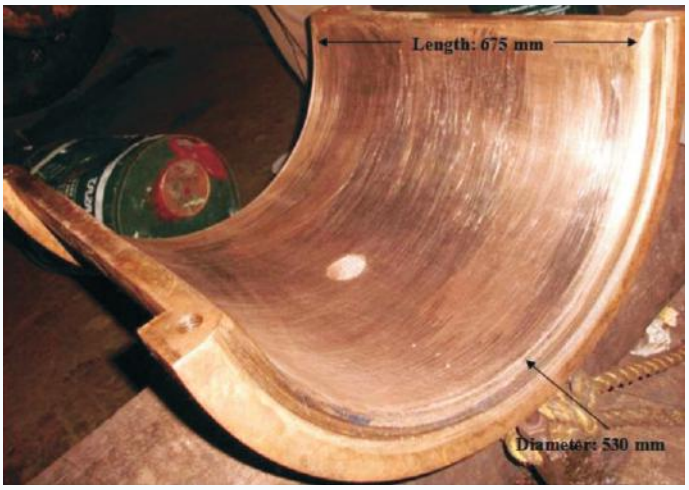
In this context, an EHL code for smooth surfaces was developed and experimental investigations were carried out on line contacts. The load-bearing capabilities of different types of commercial grade lubricants were investigated. The figures show the simulated results for contact pressure and film thickness in the given line contact.

- **FZG Gear-scuffing Performance Evaluation of Lubricating Oils**

The concentrated gear contacts are prone to scuffing and scoring during their operating span. The lubricants used in these contacts have a significant role to play in predicting the useful life of the gears. In this context, the gear oils developed by a client was studied for their scuffing performance on the FZG gear test rig.

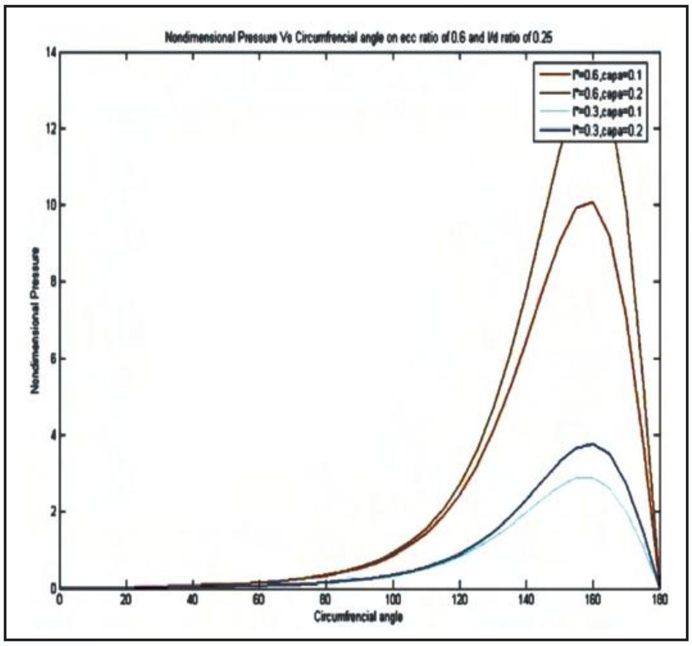
- **Design & Development of Novel type Maintenance Free Bearings**

The hydrodynamic bearings used in Industrial applications are susceptible to frequent start-up and stop-down operations leading to excessive wear and damage as shown in the figure below. The CSIR EMR-II-funded project on the development of Novel Maintenance-Free Bearings was carried out in participation with the Indian Institute of Technology, Delhi, with the aim to develop a hybrid bearing by merging the concepts of hydrodynamics and magnetic levitation.



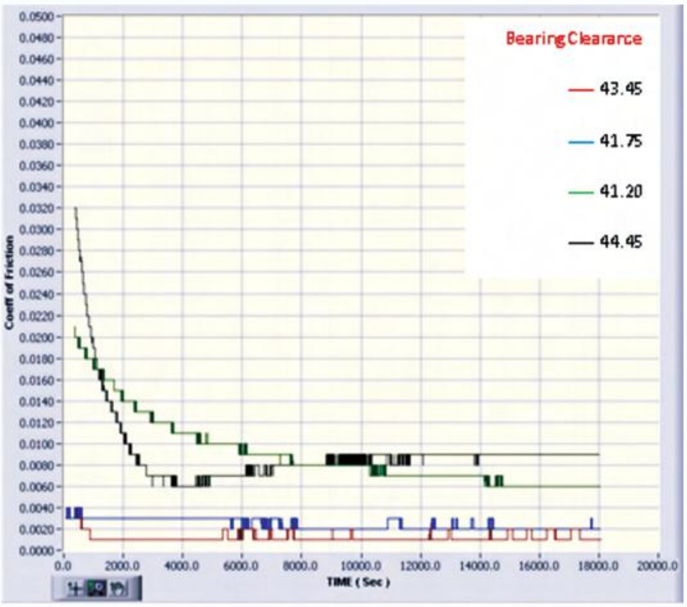
Worn-out damaged journal bearing

Prior to the development of hybrid bearings, extensive modelling and experimentation of the hydrodynamic bearings were carried out. The figure below shows the results pertaining to pressure generated within the hydrodynamic bearings modelled by using the coupled stress fluid theory.



Pressure generated within the hydrodynamic bearing

Experiments were performed on gun metal bearings using different commercial-grade lubricants and the influence of cylindricity, run-out, clearance and lubricant viscosity on the performance of the bearing was investigated. The figures below show the experimental results for the gun metal bearings.

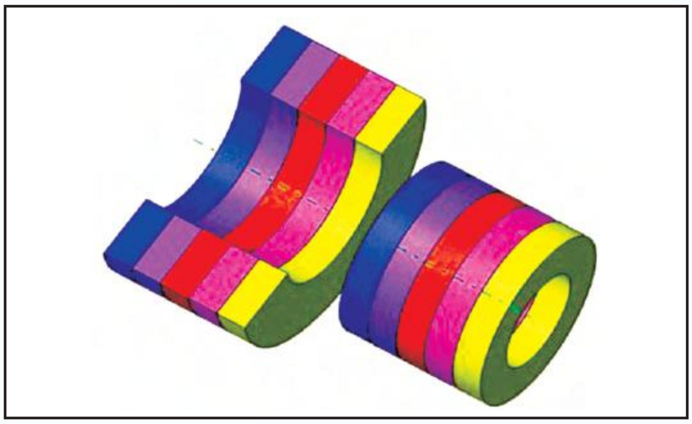


Friction behaviour of the gun metal bearings with different clearance and lubricants

The figures below show the images of the test bearings after the experimental runs. Wear on the inner surfaces of the bearings is clearly visible.

Worn-out bearing test specimens after experimentation

On the basis of the experimental and theoretical results obtained from the hydrodynamic bearings magnetic bearings were modelled. The figure below shows the schematic arrangement of the magnets in the hybrid bearings.



Schematic layout of the magnets on the outer surface of a journal and the inner surface of bearings in a hybrid bearing

The hybrid bearings fabricated are shown in the figures below:

Extensive experimentation on the fabricated bearings has contiuned. The damping and stability of the hybrid bearings were investigated.

Arrangement and assembly of magnets in hybrid bearing

- **Study on Compatibility Behavior of New-generation lubricants with Engineering Materials**

The research in the area of development of new-generation lubricants is based on the development of (i) energy-efficient lubricants, (ii) less viscosity to eliminate the inter-layer shearing forces and (iii) better affinity to the materials in forming the boundary layers. However, these lubricants are often developed and their performance evaluated in the context of the most commonly-used steels in engineering applications.

The new-generation lubricants include the chemical compounds blended with various additives, especially the EP and boundary additives, to achieve the desired performance. The lubricants and additives made from the ionic liquids too fall under this category. Ionic liquids possess extraordinary physico-chemical characteristics such as higher thermo-oxidative stability, negligible volatility, broad liquid range, non-flammability and good heat conductivity all of which meet the requirements of high-quality and energy-efficient lubricant additives.

The present project aims to understand the synergism between the lubricant and the engineering materials considering the aspects of lubricant rheology and the surface characteristics involved in the contacts.

1.7.2 Nano-Tribology & Tribochemistry

- **Boundary Lubrication Capabilities of Ionic Liquids and its Futuristic Applications to Lubricant Development**

This work envisaged synthesizing ionic liquids through different chemical routes and studying their lubrication properties. The imidazolium-based ionic liquids has been extensively synthesized and their role in reducing friction and wear has been understood.

- **Chemically-Derived Graphene Nanosheets as a New-generation Lubricant Additives**

One-dimensional graphene nano-sheets are being looked up to as the promising materials to be used in lubricant development. The hexagonal bi layered structure offer lubricating capabilities that can be harnessed in order to develop new-generation lubricants and additives.

This study envisaged development/synthesis of graphene nano-sheets, characterizing them and using them in the blending of lubricants. The lubrication capabilities of the synthesized material were evaluated on tribo-testers.

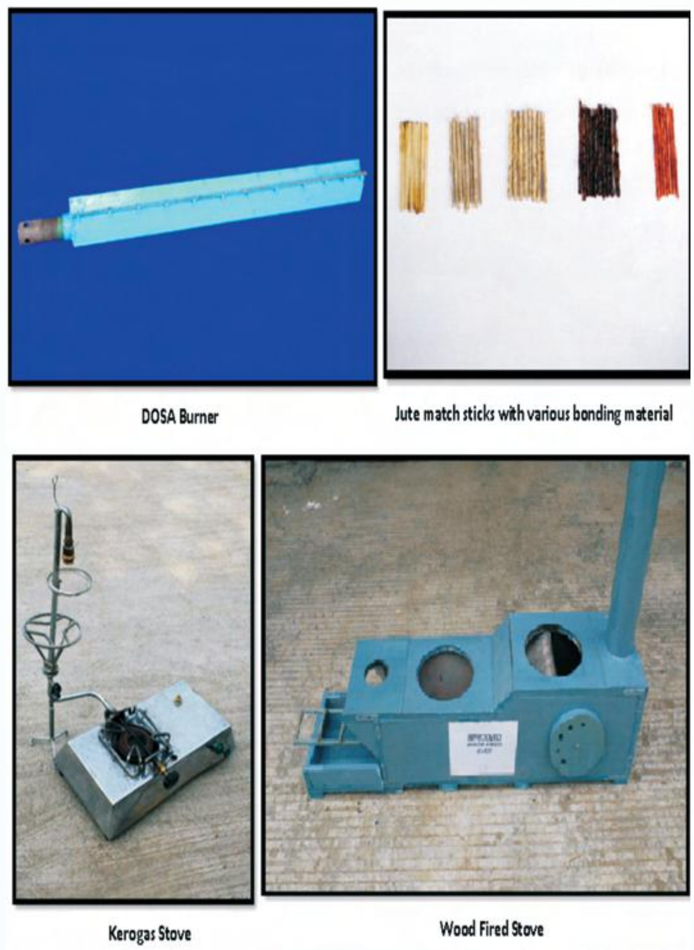
1.7.3 Industrial & Domestic Combustion

- **Evaluation of FRHF Samples.**

A lubricant manufacturer's prime motive is to ascertain the fire-resistant characteristics of these lubricants in actual operating environment. Fire-resistant hydraulic fluids synthesized and manufactured by M/s. Fuches Lubricants India Pvt. Ltd. are tested and their fire resistant characteristic properties were assessed and evaluated. The properties of interest include the Autogenous Ignition Temperature, Temperature-Pressure Spray Ignition and Flame Propagation.

- **Testing, Evaluation & Value-addition of Grassroots Innovations**

The CSIR-NIF sponsored project included the testing evaluation and value addition of grassroots innovations developed by the common man during their day-to-day research activities. The innovations pertaining to the dosa burner, jute matchsticks, wood-fired stove and the kero gas stoves were exhaustively tested and their performance assessed. The suggestions for their value-addition and probable commercialization were provided. Minor modifications to the developed innovations were proposed for improving their performance. The figures below show the innovations that had been successfully upgraded and their commercial value enhanced.



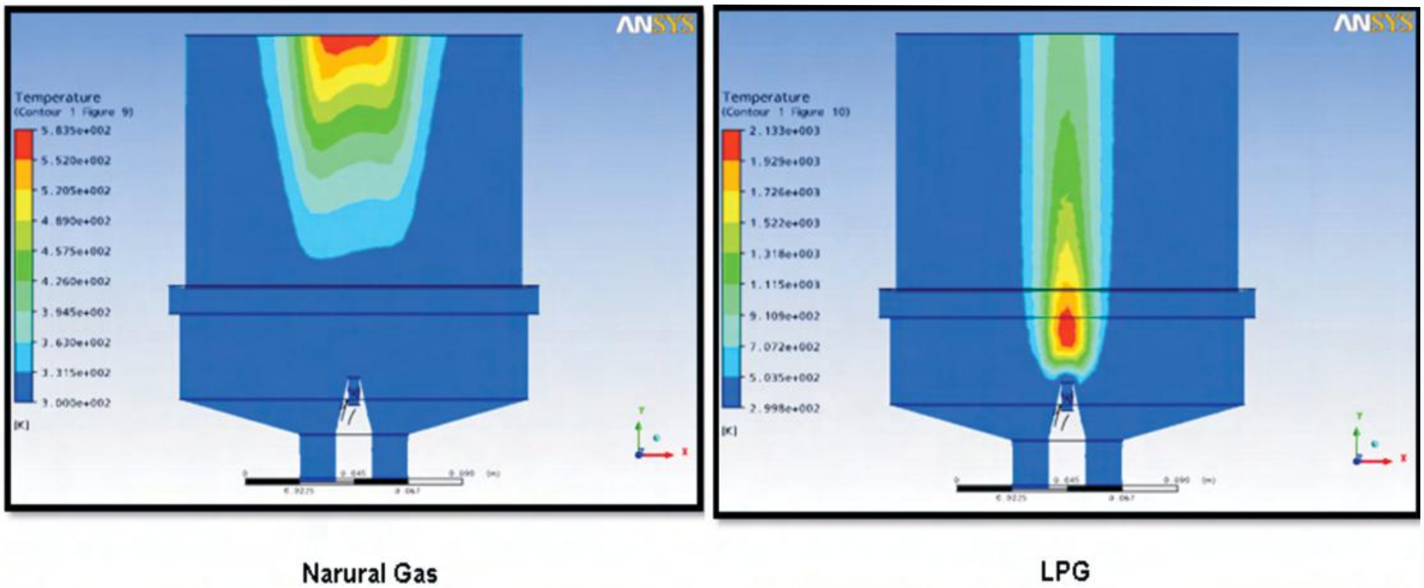
Investigation of grassroot innovations

- **Optimization of Domestic Gas Stove Burner Design (LPG/NG) for Enhanced Performance by Mathematical Modelling & Experimental Methods**

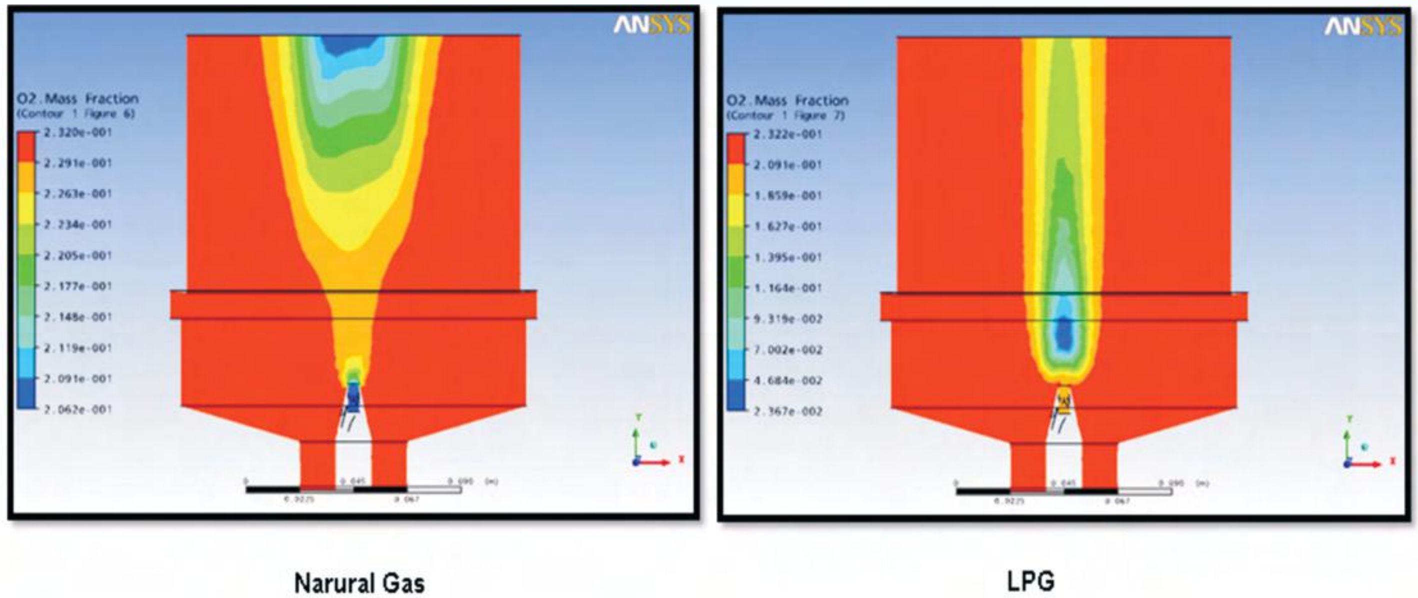
The present work involved the basics of burner design and other important parameters such as Calorific Value, Wobbie Index, Gas Modulus, Burning Velocity and Flame Temperatures which were studied for a single-port burner. Flame Stability, Limit of Flammability and Parameters for Stabilization were discussed. A calculation was carried out for the design of a Natural Gas Burner of 4.4 KW.

A flame of Natural Gas, LPG and DME was simulated in ANSYS-CFX. Flow rate was assumed to be 5 m/s with 50% primary aeration with the port diameter as 5 mm. Flame Lift-off turbulences, Mixing of secondary Air and Temperature Distribution are studied in order to optimize the performance of the burner. The findings of this study will be useful in simulating flames and optimum performance in multi-port domestic burner and after fabrication of the prototype burner the results are validated through experimental methods.

The figure below shows the CFD-based simulation of the flame propagation carried out in the project work.



Flame-temperature profile of a single-port at mid-plane for 5mm port dia, burner at 5 m/s, and fuel inlet at 50% aeration.



Mass fraction of oxygen in domain

1.8 DIRECTOR'S RESEARCH DIVISION

1.8.1 Adsorption and Membrane Separation

- **Technology Development for Adsorbed Natural Gas**

Natural gas is now emerging as a preferred transportation fuel due to its lower cost, increased availability and clean burning characteristics.

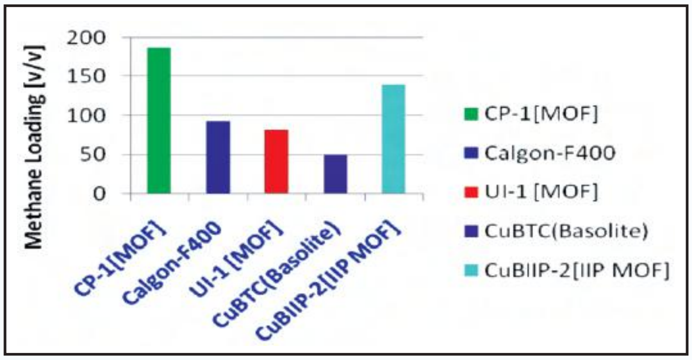
As a vehicular fuel, natural gas is used in the form of CNG (Compressed Natural Gas). A major drawback of CNG is its lower energy density (3.7 to 4 times lower) on volume basis as compared to the conventional transportation fuels such as gasoline and diesel, respectively. As a transportation fuel CNG is stored and distributed in containers at a pressure of 200–250 bars, usually in cylindrical or spherical shapes.

One strategy for maintaining similar energy density of CNG, but under reduced pressure, is by applying the concept of Adsorbed Natural Gas (ANG) . Here natural gas is stored in a special micro-porous material placed inside the pressure vessel.

The objective of the present work was to develop MOF-based sorbent materials having sufficient methane gas storage capacity at moderate pressure and ambient temperature and with a deliverability of methane greater than 95% of the storage capacity for use as a transportation fuel under standard operating conditions. As per DOE targets, the adsorbent should be able to adsorb 180 v/v of methane at 35 bars and 25°C with a discharge capacity of 150 v/v methane.

The synthesis of MOF adsorbents was initiated and materials were characterised by XRD, pore size distribution, surface area analysis, TGA and FT-IR .

Single-component adsorption isotherm measurements at various pressures and temperatures using Hiden Isochema IGA Microbalance has continued for both commercially available MOF's as well as in-house synthesised MOF's. Equilibrium isotherms with the tested adsorbents are shown below:



Comparison of volumetric loading capacities with different adsorbents

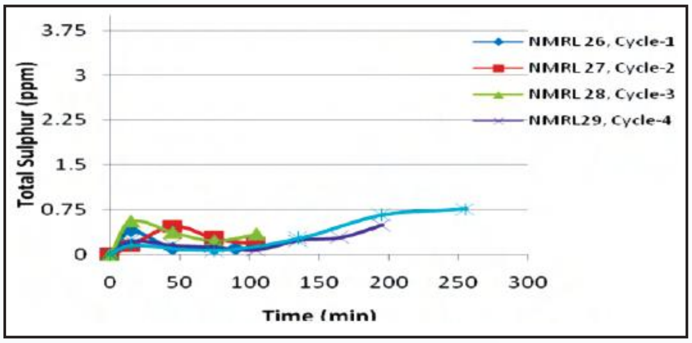
Equilibrium uptake of CH_4 on CuBTC (synthesised at CSIR-IIP) at 298 K

- Adsorbent CP-1 shows high equilibrium capacity of 188 v/v at 25ºC and at 19 bars meeting DOE target
- In-house synthesised CuB IIP also gives >140 v/v methane loading at 25°C and 19 bar

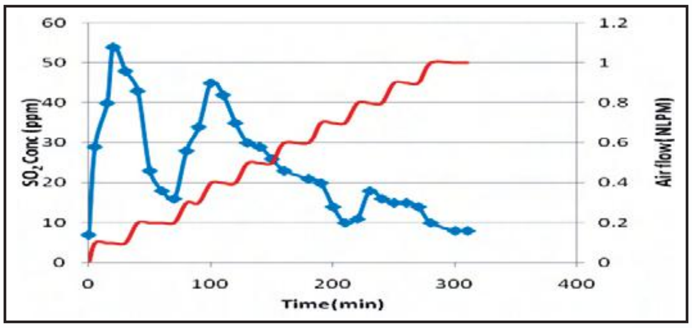
- **Feasibility Study for Production of Ultra-low Sulphur Diesel for On-board Reforming Using Adsorptive Desulphurization**

This work aimed at testing the efficacy of the adsorbents and the process already developed at the CSIR-IIP to bring down sulphur levels from BS-IV diesel [50 ppm] to < 1 ppm. It is also desirable to test the regenerabiltiy and cyclic stability of the adsorbent under repeated adsorption and regeneration cycles. Results shown in **below** indicate that

- The sulphur level of the commercial BS-IV grade diesel (50 ppm'S') procured from the National Capital Territory could be brought down to 1 ppm level
- The desulphurization process is based on fixed-bed vapour phase adsorption
- The adsorbent used was developed in-house
- The adsorbent is regenerable by thermal oxidation means
- The adsorbent shows good adsorption/ regeneration cyclic stability



Cyclic breakthrough curves with commercial BS-IV diesel feed

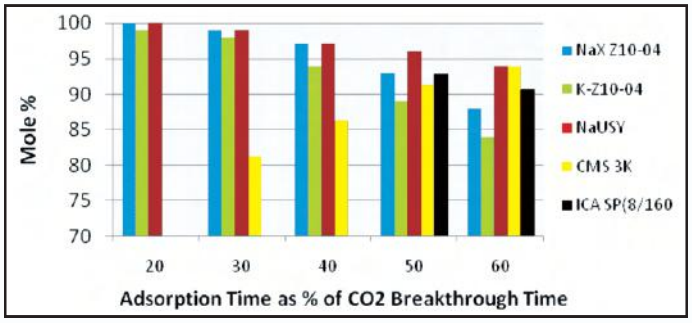


SO_2 evolution curve during adsorbent regeneration

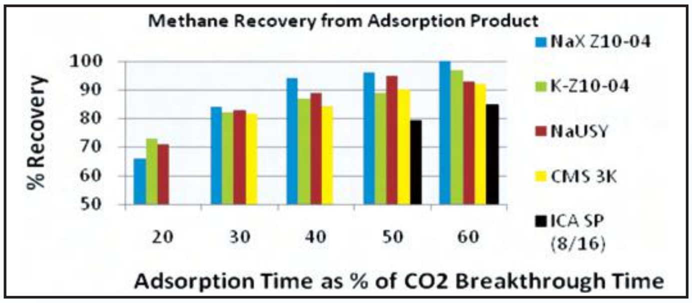
- **Technology Development Renewable Energy from Biogas**

We have developed a pressure vacuum swing adsorption process (PVSA) using a simple cycle to produce pipeline-quality methane from biogas using different classes of adsorbents, which include zeolites, activated carbons and carbon molecular sieves. An exhaustive data base on PVSA studies with these adsorbents was generated.

A comparison of adsorption performance in terms of two important parameters, i.e., methane purity and recovery, is shown in the two following figures:



Comparison of adsorbent performance in terms of methane purity

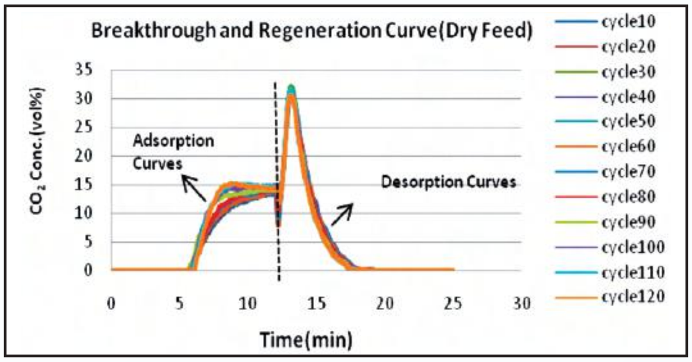


Comparison of adsorbent performance in terms of methane recovery

It is evident from the preceding two figures that even using indigenously available activated carbon and simple four-step PVSA process, methane can be enriched to > 90% level from biogas at a recovery of > 80% , which is comparable with zeolite and carbon molecular sieve adsorbents.

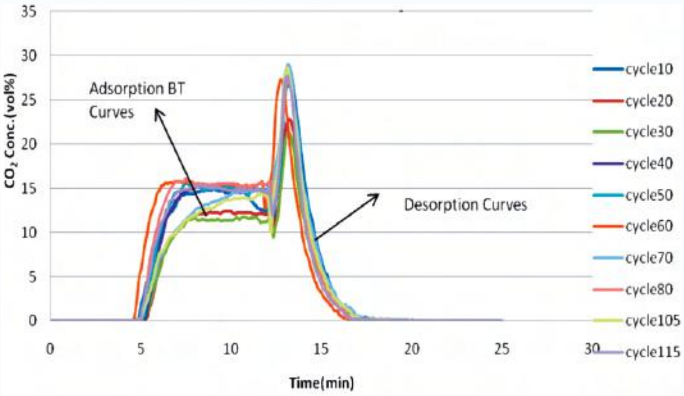
- **Single-column VSA Studies for CO_2 Recovery using Metal Organic Framework Adsorbent**

Metal Organic Frameworks (MOF) are a new class of adsorbents attracting interest for selective CO_2 separation. These are materials in which metal ions or clusters are connected via organic linkers to form highly porous network structures. Several MOF's have been proposed as adsorbents for CO_2 recovery. However, studies reported on CO_2 adsorption on MOF's have been limited mostly to equilibrium isotherm and diffusion measurements with pure components.

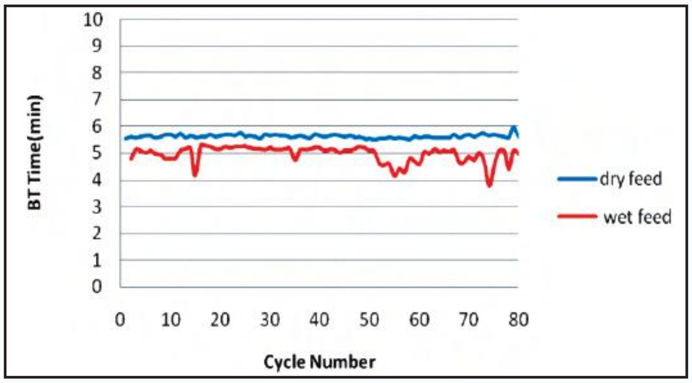


Cyclic breakthrough and regeneration curves with dry feed

We at CSIR-IIP are developing a PVSA process for separation of CO_2 from mixtures with nitrogen-simulating flue gas. Two MOF adsorbents, namely, UiO-66 ($Zr_6O_4(OH)_4$(1,4-dicarboxybenzene), synthesized and formulated into uniform spherical beads by one of our foreign collaborators, are being evaluated for their multicyclic stability with dry and wet feed mixture representing flue gas stream. The cyclic stability results are shown in figures below:



Cyclic breakthrough and regeneration curves with wet feed



Comparison of breakthrough time with dry Vs wet feed

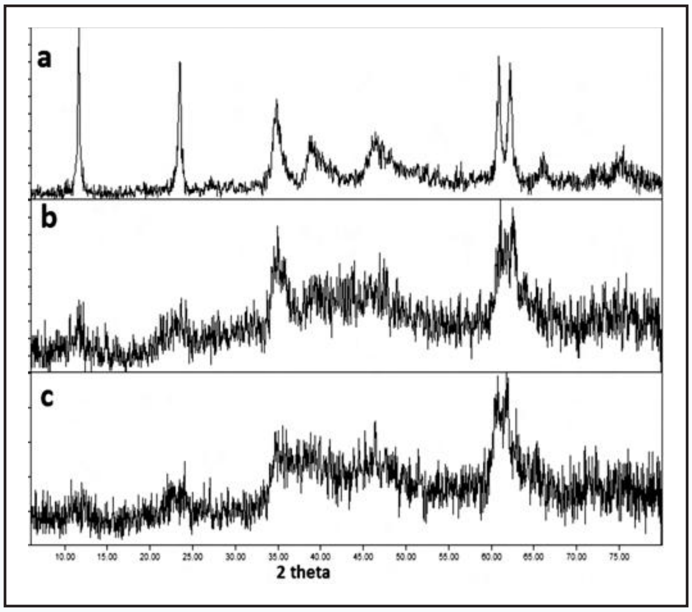
The results indicate about 10% loss in CO_2 breakthrough time occurring with wet feed. However no further deterioration was observed in the adsorption and regeneration performance of the adsorbent in the presence of moisture.

- **Adsorption Technology Development for High-Temperature Acid Gas Removal in Coal Gasification**

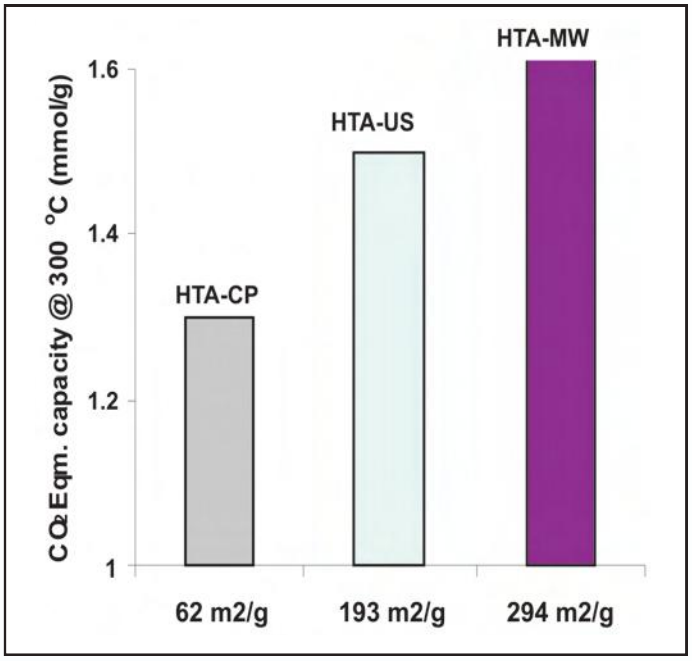
Gas-cleanup technologies presently available for removal of sulphur and CO_2 contaminants in syngas are based on chemical or physical absorption and operate at ambient/sub-ambient temperatures. Implementation of these technologies in the gasification train leads to high thermal efficiency losses both in the case of Sweet Water-Gas-Shift as well as Sour Water-Gas-Shift due to the requirement of cooling and re-heating of the syngas. There are advantages of increased energy efficiency in effecting this cleanup in hot gas conditions and considerable research and development efforts are being made towards this end.

At CSIR-IIP we have been developing a PTSA process-based on hydrotalcite based sorbents for high temperature capture of both CO_2 and H_2S under Sour Water-Gas-Shift reactor conditions .

Different routes for hydrotalcite synthesis route such as Microwave, Ultrasound, and Conventional Co-precipitation, are being explored. Adsorbents were characterized by SEM, XRD and surface area.



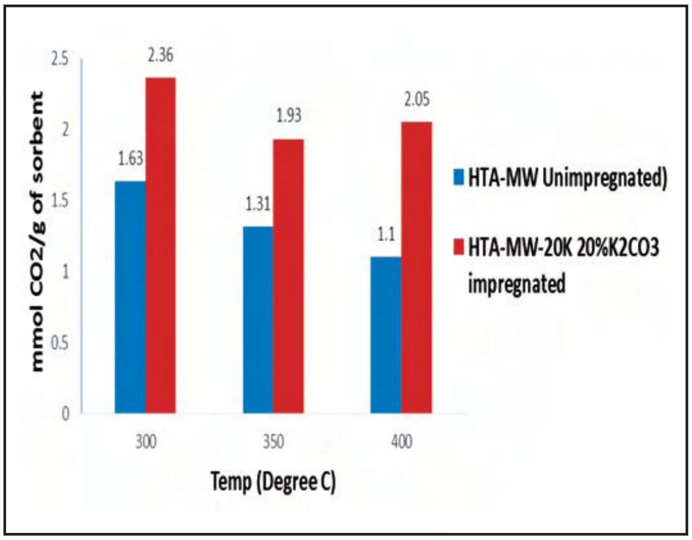
XRD of hydrotalcite synthesized by different routes (a) Co-precipitation, (b) Microwave and (c) Ultrasonic



Comparison of equilibrium capacity of hydrotalcites synthesised by different routes

Results reported in the figure above indicate that a correlation exists between equilibrium CO_2 capacity with the surface area of hydrotalcite-based sorbents. Microwave-synthesized hydrotalcite shows highest surface area compared to other synthesis techniques.

A temperature-dependent promotional effect of K_2CO_3 impregnation on CO_2 uptake was observed (see figure below. No appreciable loss in breakthrough capacity was observed over multiple cycles of adsorption-regeneration.



Promotional effect of K_2CO_3 impregnation on CO_2 capacity improvement

1.9 HEAVY OIL PROCESSING

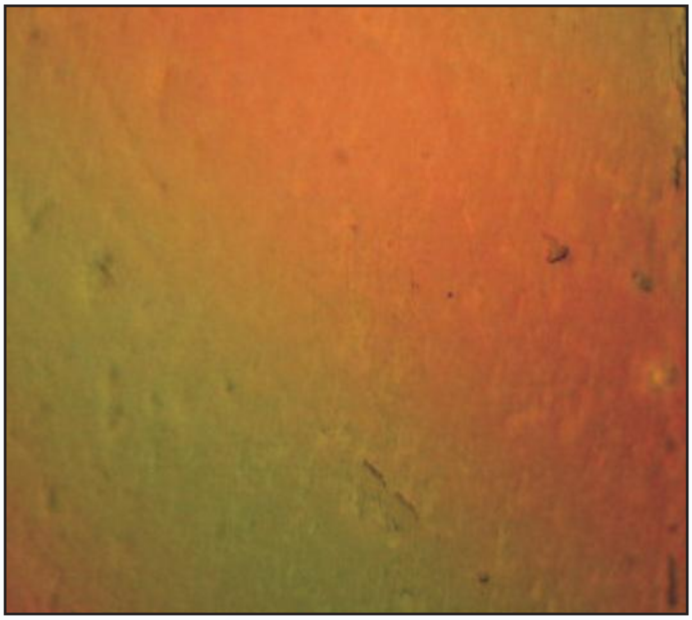
(Lube, Wax, Bitumen and Thermal Conversion Processes)

- **Basic Feasibility Study for Production of Paraffin Wax and Microcrystalline Waxes from VGO**

The objective of this project is to examine the feasibility study for production of paraffin wax and microcrystalline waxes from Vacuum Gas Oil (VGO). The detailed physico-chemical analysis of the VGO sample was completed. The experimental studies indicated that it is possible to produce all grades (Type - I, II, III) of paraffin waxes from VGO by following the solvent extraction route.

- **Development of Petroleum-Derived Carbon Wool and its Carbon Nanotubes Composites**

This project aims at producing 'Carbon Wool' and its 'Carbon Nanotubes Composites' from low-value petroleum feed-stocks. In this project, firstly, isotropic pitch was prepared from pyrolysis tar (naphtha cracker bottom). Several isotropic pitches of different softening points (SPs) and coking values (CVs) from Fluid Catalytic Cracking Bottom and Pyrolysis Tar feed-stocks were prepared and characterized under varied experimental conditions such as Thermal Treatment Temperature, Residence Time, Inert Gas Purge Rate etc. The surface morphology of the pitch having the softening point (SP) of 78.0˚C and coking value (CV) of 47.03 wt% was studied by optical microscopy which clearly indicated that this pitch is purely isotropic in nature. This pitch will be used as a precursor for making the Mesophase Pitch and Carbon Wool.



Isotropic Pitch

- **Upgradation of Petroleum Residues using Unconventional Energy Sources**

The goal of this study was to examine the feasibility of upgradation of petroleum residues using high energy vibrations/radiations such as 'Ultrasonic' and 'Microwaves' as an alternate process to energy-intensive conventional petroleum refining processes. Extensive literature search was done. Physico-chemical characterization of the 2 samples of Vacuum Residues (VR) from different petroleum refineries was also done.

- **Upgradation of Heavy Oils by Hydroprocessing**

The main objective of this study was to upgrade heavy oils by Hydroprocessing. For this project an exclusive laboratory has been set-up. Experimental runs for the slurry-phase hydroprocessing reaction on the Rajasthan heavy crude oil and the RIL vacuum residue are in progress. The activities of these two feeds have been studied at two different temperatures e.g. 400 and 420˚C. So far, the effect of two catalysts (Co-naphthanate and Ni naphthanate) has been studied.

- **Studies on the Use of e-waste for Improving the Properties of Paving-Grade Bitumen**

The main objective of this project was to utilize non-metallic part of electronic waste (e-waste) as an additive to improve the properties of the bituminous binder with improved performance as well as value addition of e-waste. In this project, e-waste was first segregated into metallic and non-metallic portions. The non-metallic portion was pulverized and used for experimental runs. Thermo-gravimetric analysis of e-waste shows that its decomposition temperature is 220°C which is higher than experimental temperature (180 or 190°C). Thus, e-waste material will not react with the feed (short residue) and will work only as a filler. To overcome this problem, a wet approach was tried in which the slurry of e-waste was used with short residue. The slurry prepared in trichloroethylene shows compatibility with the short residue. This is due to the fact that both short residue (SR) as well as e-waste material are soluble in trichloroethylene. The 2.5% wt of e-waste slurry is mixed with the short residue at 190°C; penetration, softening point and ductility at 27°C of the bitumen sample were found to be 40 dmm, 50°C and +70 cm respectively. This bitumen meets the desired properties of VG 40 paving-grade bitumen.

- **Process Simulation and Design of the Soaker Drum Internals for the Visbreaking Unit (VBU)**

The objective of this project is to carry out process design & recommend suitable internals in the existing hollow soaker drum of the VBU. The project also envisages economic analysis to establish the benefits of incorporation of internals in the hollow soaker on the basis of yield and quality improvements. The work was started and the final design package was prepared jointly by the CSIR-IIP & the EIL and submitted to the clients in January 2013. The final report includes, mainly, benefits obtained after incorporation of internals in the existing hollow soaker in terms of enhancement of quantity and quality of products, payback period, energy saving in terms of reduction in temperature and improvement of stability of produced fuel oil. Over all, it is a low-cost revamp as no major hardware change is required with the payback period of less than six months. Presently, fabrication/incorporation of proposed internals is underway.

- **Process Engineering Design Package for Solvent De-oiling Unit**

One of the Indian refineries is setting up a wax deoiling unit using updated IIP-EIL process know-how at a capital outlay of Rs. 753.72 crores including a foreign component of Rs. 86.49 crores for the specialized patent equipment like Scraped Surface DP Chillers and Rotary Vacuum Filters. The wax facility being set-up will have an annual design capacity to produce 50,000 tonnes per annum of food-grade paraffin wax and 4500 tonnes of micro-crystalline wax by processing two waxy streams, namely MVGO & HVGO. The design of the unit is to be based on indigenous technology developed at the Institute for which a joint bid was submitted along with Engineers India Ltd.

- **Detailed Technical Evaluation of Guwahati Refinery – RCO for Production of Paraffin Wax and Microcrystalline Waxes**

In this project, Reduced Crude Oil (RCO) was vacuum-fractionated into LVGO, MVGO, HVGO and residue. The study concluded that it is possible to produce BIS-grade 'Paraffin Wax' with oil content less than 0.1 % from MVGO. From HVGO only, Semi-Microcrystalline Wax can be produced with oil content less than 0.9%. LVGO may be used as a diesel-pool-blending component.

- **Process Design of Soaker Drum Internals for the Revamping of the Visbreaker**

The project was awarded to the CSIR-IIP with the aim of carrying out process design & recommend suitable internals in the existing hollow soaker drum of the Visbreaking Unit (VBU). The final design package prepared jointly by the CSIR-IIP & EIL submitted for implemention. Performance Guarantee Test Run (PGTR) was conducted successfully in January 2013. The CSIR-IIP and the EIL participated in the PGTR. The incorporation of internals in the hollow soaker showed good performance which results in improvement in quality as well as quantity of the products.

- **Feasibility Study for Producing Needle Coke from Residual Fuel Oil from a Client Refinery**

The studies were taken up with an aim to examine the feasibility of making premium grade needle coke froma Residual Fuel Oil (RFO) as well as to optimize the process parameters required to produce the needle coke having low CTE. Delayed coking study was conducted at the CSIR-IIP Coker Plant using the Residual Fuel Oil (RFO) as the feed-stock. The Raw Petroleum Coke (RPC) samples produced with recycle runs at four sets of operating conditions were calcined and characterized in detail. It was found that the Calcined Petroleum Coke (CPC) obtained from recycle runs meet all the needle coke specifications except the CTE. The final report was submitted in January 2013.

- **Study on Clarified Slurry Oil (CSO) and its Conversion into Petroleum Pitch - Precursor for Advanced Carbon Materials**

In this R & D project, Clarified Slurry Oil (CSO) from another cleint Refinery was evaluated for its suitability for use as Carbon Black Feed Stock (CBFS). It was found that CSO is a premium quality CBFS. Further, CSO can also be used as a good-quality feed-stock for making petroleum pitches. Isotropic pitches prepared from CSO are of low softening point (90-95˚C). Mesophase pitch prepared from CSO contains >35% of mesophase content and may be used as a precursor for making carbon fibres and other advanced carbon materials.

2

Achievements

2.1 Papers Published in Journals

1. A comprehensive life cycle assessment (LCA) of *Jatropha* bio-diesel production in India, *Sunil Kumar, Jasvinder Singh, S M Nanoti* and *M O Garg*, *Bio-resource Technology*, 110, 723-729

2. Single-step catalytic liquid-phase hydro-conversion of DCPD into high-energy density fuel exo-THDCPD, *M G Sibi, Bhawan Singh, Rohit Kumar, C Pendem* and *Anil K Sinha*, Green Chemistry, **14**(4), 976-983

3. Alternate feedstock options for petro-chemicals: A Road Map, *M O Garg, S K Ganguly* and *S Sen*, Hydrocarbon Processing, **91**(4), 47-52

4. A temperature- and salt-tolerant L-glutaminase from the Gangotri region of the Uttarakhand Himalayas: enzyme purification and characterization, *Lokendra Kumar, Balvinder Singh, D K Adhikari, Joydeep Mukherjee* and *Debashish Ghosh,* Appl Biochem Biotechnol, **166**(7), 1723–1735

5. A scanning electron microscope-based new method for determining the degree of substitution of sodium carboxymethyl cellulose, *Raj Kumar Singh* and *O P Khatri*, Journal of Microscopy, **246**(1), 43-52, 2012

6. Catalytic performance of nano-crystalline H-ZSM-5 in ethanol to gasoline (ETG), *N Viswanadham, Sandeep K Saxena, Jitendra Kumar, Peta Srinivasulu* and *Devaki Nandan, Fuel*, **95**(1), 298-304

7. Thio-urea dioxide in water as a recyclable catalyst for the synthesis of structurally diverse dihydropyridol [2,3-*d*]pyrimidine-2,4-diones, *Sanny Verma* and *Suman L Jain, Tetrahedron Letters*, **53**(21), 2595-2600

8. Metal acetylacetonates as highly-efficient and cost- effective catalysts for the synthesis of cyclic carbonates from CO_2 and epoxides, *Subodh Kumar, Suman L Jain* and *Bir Sain,* Catalysis Letters, **142**(5), 615-618

9. Comparison of structural properties of pitches prepared from petroleum refinery/petro-chemical residues using NMR spectroscopy, *Manoj Srivastava, Manoj Kumar, U C Agrawal* and *M O Garg,* Open Petroleum Engineering Journal, 5, 14-20

10. Blending optimization of Hempel distilled bio-oil with commercial diesel, *Arakshita Majhi, Y K Sharma* and *D V Naik*, *Fuel*, 96, 264-269

11. 3-D mesoporous titanosilicate support for highly-effective hydrodesulphurization catalysts, *R K Sharma, B S Rana, Deepak Verma, Rohit Kumar, Rashmi Tiwari, M K Jha* and *A K Sinha*, *Microporous and Mesoporous Materials, 155, 177-185*

12. A thermo-alkaliphilic halo-tolerant esterase from *Rhodococcus* sp. LKE-028 (MTCC 5562): enzyme purification and characterization, *Lokendra Kumar, Balvinder Singh, D K Adhikari, Joydeep Mukherjee* and *Debashish Ghosh*, *Process Bio-chemistry*, **47**(6), 983-991

13. High surface area sol-gel nano-silica as a novel drug carrier substrate for sustained drug release, *Padmaja Parameswaran Nampi, Vinitha Sudha Mohan, A K Sinha* and *Harikrishna Varma*, *Materials Research Bulletin*, **47**(6), 1379-1384

14. The kinetics of hydro-desulphurization of diesel: pore diffusion aspects, *S K Ganguly*, Pet. Sci. Technol., **30**(12), 1187-1194

15. A novel thermo-stable xylanase of *Paenibacillus macerans* IIPSP3 isolated from termite gut, *Pratibha Dheeran, N Nandhagopal, Sachin Kumar, Y K Jaiswal* and *D K Adhikari*, J of Ind Microbiology & Biotec, **39**(6), 851-860

16. Self-alignment of gold nano-particles through the control of particle-substrate and particle-particle interactions, *Hiroyuki Sugimura, Jeong-Hyeon Yang, Shou Uchida, Takahiro Higashino, Om Prakash Khatri, Takashi Ichii* and *Kuniaki Murase*, *Procedia Engineering*, Open Access Journal (Proc. of IUMRS Int.l Conf in Asia 2011), *36*, 374-381, 2012

17. A search for eco-friendly detergent/dispersant additives for vegetable oil-based lubricants, *A K Singh* and *Raj Kumar Singh,* Journal of Surfactants and Detergents, **15**(4), 399-409

18. Evaluation of *Chlorella minutissima* oil for biodiesel production, *Savita Kaul, Rahul Jain, L N Sivakumar Konthala, Dinesh Bangwal, Neeraj Atray* and *Basant Kumar,* Journal of ASTM International, **9**(5), JAI104322, 6 pp

19. Optimization of biodiesel production by response surface methodology and genetic algorithm,

Richa Singhal, Prateek Seth, Dinesh Bangwal and *Savita Kaul*, Journal of ASTM International, **9**(5), JAI104328, 7 pp

20. Synthesis and electro-chemical, optical, and thermal properties of polycarbosilanes with silylene–vinylene–phenylene–vinylene backbones and triphenylamine or carbazole unit-containing side chains, *Hiroshi Yamashita, Yoshitada Suzuki, Tumula Venkateshwar Rao* and *Yuko Uchimaru, Journal of Organo-metallic Chemistry, 710, 59-60*

21. UV-induced covalent assembly of gold nanoparticles in linear patterns on oxide-free silicon surface, *O P Khatri, T Ichii, K Murase* and *Sugimura, Journal of Material Chemistry*, 22, 16546-16551

22. Copper (II) trans-bis-(glycinato): an efficient heterogeneous catalyst for cross-coupling of phenols with aryl halides, *Sanny Verma, Neeraj Kumar* and *Suman L Jain, Tetrahedron Letters*, **53**(35), 4665-4668

23. Multiple Oxo-Vanadium Schiff base containing cyclotriphosphazene as a robust heterogeneous catalyst for regioselective oxidation of naphthols and phenols to quinines, *Praveen K Khatri* and *Suman L Jain*, Catalysis Letters, **142**(8), 1020-1025

24. Biopolymer templated porous TiO_2: an efficient catalyst for conversion of unutilized sugars derived from hemicelluloses, *Sudipta De, Saikat Dutta, Astam K Patra, Bharat S Rana, Anil K Sinha, Basudeb Saha* and *Asim Bhaumik*, *Applied Catalysis A: General*, 435-436, 197-203

25. The instability of storage of middle distillate fuels: a review, *Y K Sharma*, Petroleum Science and Technology, **30**(17), 1839-1850

26. Covalent assembly of silver nanoparticles on hydrogen terminated silicon surface, *O P Khatri, Takashi Ichii, Kuniaki Murase, Masayuki Kanehara, Toshiharu Teranishi* and *Hiroyuki Sugimura*, *Journal of Colloid and Interface Science*, 382, 22–27

27. Effective catalytic conversion of cellulose into high yields of methyl glucosides over sulphonated carbon-based catalyst, *Sambha Dora, Thallada Bhaskar, Rawel Singh, D V Naik* and *D K Adhikari*, *Bioresource Technology,* 120, 318-321

28. Room-temperature selective oxidation of cyclohexane over Cu-nanoclusters supported on nanocrystalline Cr_2O_3, *Bipul Sarkar, Pragati Prajapati, Rahul Tiwari, Ritesh Tiwari, Shilpi Ghosh, Shankha Shubhra Acharyya, Chandrashekar Pendem, Rajib Kumar Singha, L N Sivakumar Konthala, Jagdish Kumar, Takehiko Sasaki* and *Rajaram Bal*, Green Chemistry, **14**(9), 2600-2606

29. Combined thiourea dioxide-water: an effective reusable catalyst for the synthesis of polyhydroquinolines via Hantzsch multicomponent coupling, *Neeraj Kumar, Sanny Verma* and *Suman L Jain*, Chemistry Letters, 41(9), 920-922

30. TiO_2-ZrO_2 binary oxides for effective hydrodesulphurization catalysts, *Rahul Tiwari, B S Rana, R Kumar* and *A K Sinha*, Open Catalysis Journal(Bentham Science Publishers Ltd), 5, 39-49

31. Effect of heating rate on the pyrolysis of high-impact polystyrene containing brominated flame retardants: Fate of brominated flame retardants, *Guido Grause, Daiki Karakita, Tomohito Kameda, Thallada Bhaskar* and *Toshiaki Yoshioka*, J of Material Cycles and Waste Management, **14**(3), 259-265, 2012

32. Pt nanoparticles supported on mesoporous ZSM-5: a potential catalyst for reforming of methane with carbon dioxide, *Bipul Sarkar, Shashank Suman, Ritesh Tiwari, Rajib Kumar Singha, Shilpi Ghosh, Shankha, Shubhra Acharyya, L N Sivakumar Konthala, Chandrashekar Pendem, Kshudiram Mantri* and *Rajaram Bal, Indian Journal of Chemistry, Section A: Inorganic, Bio-inorganic, Physical, Theoretical & Analytical Chemistry,* ***51A*** *(9-10), 1348-1353*

33. Dispersion of alkylated graphene in organic solvents and its potential for lubrication applications, *Shivani Choudhary, Harshal P Mungse* and *O P Khatri*, Journal of Materials Chemistry, **22**(39), 21032-21039

34. Reappraisal of the Skarstrom Cycle for CO_2 recovery from flue gas streams: new results with potassium-exchanged zeolite adsorbent, *Anshu Nanoti, Soumen Dasgupta, Arti, Nabanita Biswas, A N Goswami, M O Garg, Swapnil Divekar* and

Chandrasekhar Pendem, Ind & Engineering Chem Res., **51**(42), 13765-13772

35. Thiourea dioxide catalyzed multi-component coupling reaction for one-step synthesis of naphthopyran derivatives, *Sanny Verma* and *Suman L Jain, Tetrahedron Letters*, **53**(45), 6055-6058

36. Aqueous phase reforming of glycerol to 1, 2-propanediol over Pt-nanoparticles supported on hydrotalcite in the absence of hydrogen. *Chandrashekar Pendem, Piyush Gupta, Nisha Chaudhary, Sarvajit Singh, Jagdish Kumar,Takehiko Sasaki, Arunabha Datta* and *Rajaram Bal,* Green Chemistry, **14**(11), 3107-3113

37. Oxidation of sulphides to sulphones with hydrogen peroxide in the presence of acetic acid and Amberlyst 15, *T V Rao, Sapna Bondwal, Priyanka Bisht, Chandrashekar Pendem* and *Jagdish Kumar*, Reaction Kinetics, Mechanisms and Catalysis, **107(**2), 449-466

38. Predicting the performance of an LPG extractor: a nomographic approach, *A Jain, N Rathi* and *S K Ganguly*, Petroleum Science and Technology, **30**(23), 2494-2503

39. Temperature-dependent reaction pathways for anomalous hydrocracking of triglycerides in the presence of sulphided Co-Mo-catalyst, *Mohit Anand* and *Anil K Sinha*, *Bioresource Technology*, 126, 148-155

40. Mechanistic kinetics of catalytic oxidation of 1-butanethiol in light oil sweetening, *Sudip K Ganguly, Gautam Das, Sunil Kumar, Bir Sain* and *M O Garg*, *Catalysis Today*, **198**(1), 246-251

41. Reforming of methane with CO_2 over Ni-nanoparticle supported on mesoporous ZSM-5, *Bipul Sarkar, Ritesh Tiwari, Rajib Kumar Singha, Shashank Suman, Shilpi Ghosh, Shankha Shubhra Acharyya, Kshudiram Mantri* and *Rajaram Bal*, *Catalysis Today*, **198**(1), 209-214

42. Synthesis, characterization and catalytic activity of cobalt phthalocyanine dichloride in sweetening of heavier petroleum fractions, *Gautam Das, Bir Sain* and *Sunil Kumar*, *Catalysis Today*, **198**(1), 228-232

43. Catalytic functionalities of FSM-16 ordered mesoporus silica-supported molybdenum hydroprocessing catalysts, *Shelu Garg, Kapil Soni, Manoj Kumar, Thallada Bhaskar, J K Gupta, K S Rama Rao* and G Murali Dhar, *Catalysis Today*, **198**(1), 263-269

44. *Jatropha* oil conversion to liquid hydrocarbon fuels using mesoporous titanosilicate-supported sulphide catalysts, *R K Sharma, Mohit Anand, B S Rana, Rohit Kumar, Saleem Farooqui, M G Sibi* and *Anil K Sinha*, *Catalysis Today*, **198**(1), 314-320

45. Chemically-modified expended starch grafted Ni-acetylacetonate/TBAB: an effective reusable catalytic combination for cycloaddition of carbon dioxide to epoxides, *Subodh Kumar, Suman L Jain* and *Bir Sain*, *Catalysis Today*, **198**(1), 204-208

46. Reactive-extraction of *Pongamia* seeds for biodiesel production, *Jyoti Porwal, Dinesh Bangwal, M O Garg, Savita Kaul, A P Harvey, J G Lee, F H Kasim* and *E J Eterigh*, Journal of Scientific & Industrial Research, **71**(12), 822-828

47. Etherification of glycerol for improved production of oxygenates, *N Viswanadham* and *Sandeep K Saxena, Fuel,* 103, 980-986

48. Analytical approaches to characterizing pyrolysis oil from biomass, *Pankaj K Kannaujia, Y K Sharma, U C Agrawal* and *M O Garg*, *TrAC Trends in Analytical Chemistry*, *42*, 125-136

49. Impact of brominated flame retardants on the thermal degradation of high-impact polystyrene, *Guido Grause, Daiki Karakita, Jun Ishibashi, Tomohito Kameda, Thallada Bhaskar* and *Toshiaki Yoshioka, Polymer Degradation and Stability*, ***98****(1),*306-315

50. Renewable hydrocarbons through biomass hydropyrolysis process: challenges and opportunities, *Bhavya Balagurumurthy, Twinkle S Oza, Thallada Bhaskar* and *D K Adhikari, Journal of Material Cycles and Waste Management,* **15**(1) 9-15

51. Synthesis and catalytic applications of amine-interacted $Cu_2(OH)PO_4$ nanoplates (copper NPs) and tubes (copper NTs), *Peta Sreenivasulu, N Viswanadham, Devaki Nandan, L N Sivakumar Konthala* and *B Sreedhar,* RSC Advances (Open Access Journal), **3**(3),729-732

52. Predicting de-mercaptanization in an LPG Extractor: A Parametric Approach, *S K Ganguly, A Jain* and *N Rathi,* Petroleum Science and Technology, 31:4, 428-437

53. Enhanced performance of nano-crystalline ZSM-5 in acetone to gasoline (ATG) reaction, *N Viswanadham, Sandeep K Saxena*, Fuel, 105, 490-495

54. Synthesis and catalytic applications of hierarchical mesoporous $AlPO_4$/$ZnAlPO_4$ for direct hydroxylation of benzene to phenol using hydrogen peroxide, *Peta Sreenivasulu, Devaki Nandan, Manoj Kumar, N Viswanadham,* J Material Chem: Materials for Energy & Sustainability, **1**(10), 3268-3271

55. Development of hydroprocessing route to transportation fuels from non-edible plant-oils, *A K Sinha, Mohit Anand, B S Rana, Rohit Kumar, S A Farooqui, M G Sibi, R Kumar* and *R K Joshi,* Catalysis Surveys from Asia, **17**(1), 1-13

56. Optimization of Reaction Conditions for Preparing Carboxymethyl Cellulose from Corn Cobic Agricultural Waste, *Raj Kumar Singh* and *A K Singh,* Waste and Biomass Valorization, **4**(1) 129-137

57. Synthesized and modified zeolite materials as catalysts for isomerization reaction in petroleum refining, *N Viswanadham, Sandeep K Saxena* and *Lalji Dixit,* Asian Materials Science Letters, **2**(1),15-38

58. Effect of fuel choice on nanoparticle emission factors in LPG-gasoline BI-fuel vehicle, *A Momenimovahed, J S Olfert, M D Checkel, S Pathak, V Sood, L, Robindro, S K Singal, A K Jain* and *M O Garg*, International Journal of Automotive Technology, 14, 1-11

59. On the development of Vacuum Swing adsorption (VSA) technology for post-combustion CO_2 capture, *Anne Andersen, Swapnil Divekar, Soumen Dasgupta, Jasmina Hafizovic Cavka, Aarti, Anshu Nanoti, Aud Spjelkavik, Amar N Goswami, M O Garg* and *Richard Blom*, Energy Procedia (Proceeding of International conference on Greenhouse Gas Technologies GHGT-11 held at Kyoto, 37, 33-39

2.2 Papers Presented in Conferences/ Seminars

Graphene 2012, Brussels, Belgium, April 10-13, 2012

1. De-oxygenation of graphene oxide in water: green and elegant approach, *O P Khatri, Shivani Choudhary* and *Harshal P Mungse*

The 24th Biennial Organic Reactions Catalysis Society Conference, Westin Annapolis, MD, USA, April 15-19, 2012

2. Starch immobilized Ni-acetylacetonate catalyzed dimethyl carbonate promoted synthesis of cyclic carbonates via cycloaddition of epoxides with carbon dioxide, *Suman L Jain, Subodh Kumar* and *Bir Sain*

103 AOCS Annual Meeting & Expo, California, USA, April 29 - May 2, 2012

3. Reactive Extraction for bio-diesel production using solid green catalyst, *Savita Kaul, Jyoti Porwal, Dinesh Bangwal, Rajaram Bal* and *M O Garg*

4. Development of bio-grease for girth gears, *Savita Kaul, Ponnekanti Nagendramma, R P S Bisht* and *M R Tyagi*

STLE 2012, 67th Annual Meeting & Exhibition of the Society of Tribologists and Lubrication Engineers, St. Louis, Missouri, USA, May 6-10, 2012

5. Environment-friendly/bio-degradable fluids, *Savita Kaul, Ponnekanti Nagendramma* and *G D Thakre*

6. Performance evaluation of journal bearings used in sugar mills applying the Taguchi method, *S M Muzakkir, Harsh Hirani* and *G D Thakre*

International Mexican Congress on Chemical Reaction Engineering (IMCCRE 2012), Ixtapa-Zihuatanejo, Guerrero, Mexico, June 10-15, 2012

7. Chemo-selective catalytic conversion of glycerol as a bio-renewable source for oxygenated additive for the diesel fuel, *N Viswanadham, Sandeep K Saxena, Devaki Nandan, P Sreenivasulu, Basant Kumar* and *M O Garg*

International Refining and Petro-chemical Conference (IRPC), Mico – Milano Congressi , Milan, Italy, June 12-14, 2012

8. Transportation fuels and petro-chemicals from waste polyolefins, *Sanat Kumar, H U Khan, Manisha Sahai, Ajay Kumar, S M Nanoti and M O Garg*

9. Production of virgin oil from used oil—an innovative eco-friendly technology, *U C Agarwal, Manoj Kumar, Manoj Srivastava, S M Nanoti* and *M O Garg*

CAT4BIO International Conference on Advances in Catalysis for Biomass Valorization, Thessalonki, Greece, July 8-11, 2012

10. Energy-efficient process for algae valorization, *Richa Singhal, Dinesh Bangwal, Manan Dave, Jani Jagat M, Shraddha Singhal, Savita Kaul* and *D K Adhikari*

2nd Indo-French Symposium on Catalysis for Sustainable and Environmental Chemistry, Lille University, France, July 11 - 13, 2012

11. Process for *Jatropha* oil conversion to diesel and kerosene, *Rohit Kumar, B S Rana, R Kumar, R K Joshi* and *A K Sinha*

17th Refinery Technology Meet (RTM), Bangalore, July 18-20, 2012

12. Design of a solvent recovery section of a grassroots deoiling unit based on physical insights, *Sunil Kumar, S M Nanoti* and *M O Garg*

13. Commercialization of indigenously developed "Advanced Soaker Visbreaking Technology" at HPCL Vizag Refinery, *M O Garg, U C Agarwal, Deepak Tandon, Satya Niketan Yadav, Y K Sharma, Sunil Kumar, S M Nanoti, S Handa, Suma Mathew, S Bharathan, M Jagannadha Rao* and *Iman Ghosh Dastidar*

14. Use of low-level heat to increase crude preheat: an application of advanced pinch concepts, *M O Garg, Sunil Kumar* and *S M Nanoti*

15. Process optimization of a conventional Lube Extraction Unit, *M O Garg, U C Agarwal, S M Nanoti, Manoj Srivastava* and *Manoj Kumar (CSIR-IIP), M Konde, D S Laud, M Joshi & Garima Singh* (HPCL-Mumbai Refinery)

16. Renewable aviation fuels using hierarchical nanostructured catalysts, *R Kumar, B S Rana, R Kumar, R K Joshi* and *A K Sinha*

17. Renewable Energy from Biogas, *Anshu Nanoti, Soumen Dasgupta, Aarti Arya, Swapnil Divekar, Nilesh Gode, Amar N Goswami* and *M O Garg*

18. Successful international collaboration leading to development of green technologies, *Anshu Nanoti, Soumen Dasgupta, Aarti Arya, Swapnil Divekar, A N Goswami* and *M O Garg*

19. Collaborative research and commercialization, *M O Garg*

Sixteenth National Congress on Corrosion Control, organized by the National Corrosion Council of India (NCCI), Kolkata, August 23-25, 2012

20. Petroleum Naphthenic acidic corrosion, *R C Saxena* and *A K Chatterjee*

39th Leeds-Lyon Symposium on Tribology, Leeds, UK, September 4-7, 2012

21. Mathematical modelling of piston ring linear tribosystem, *G D Thakre* and *M R Tyagi*

International Conference on Chemical Constellation: Cheminar-2012 (CCC-2012), Dr B R Ambedkar NIT, Jalandhar, September 10-12, 2012

22. Converting corn cobic waste biomass into methylcellulose: a thickener, *Raj Kumar Singh*

Oil Spill India 2012-International Conference & Exhibition, organized by iTEN Media Pvt. Ltd, Goa, September 13-15, 2012

23. Microbial oil spill management in sea, *D K Adhikari*

Third International Symposium on Green Chemistry for Environment, Health and Development at Skiathos Island, Greece, October 3-5, 2012

24. Thiol-yne mediated synthesis of nanostarch grafted oxo-vanadium Schiff base for oxidation of alcohols, *Sanny Verma* and *Suman L Jain*

ASME/STLE 2012 International Joint Tribology Conference at Denver, Colorado, October 7-10, 2012

25. Performance evaluation of journal bearings used in sugar mills using Taguchi methods, *S M Muzzakir, Harin Hirani* and *G D Thakre*

10th International Oil & Gas Conference and Exhibition, PETROTECH-2012, New Delhi, October 14-17, 2012

26. *Jatropha* oil conversion to liquid hydrocarbon fuels using mesoporous titanosilicate supported sulphide catalysts, *R K Sharma, N Naidu, M Anand, B S Rana, R Kumar, S A Farooqui, M G Sibi, R K Joshi, R Kumar* and *A K Sinha*

27. Optimization of process parameters for CO_2 absorption/regeneration by loading with aqueous solutions of 2-amino-2-methyl-1-propanol (AMP) and AMP with piperazine, *S K Biswas, S Halavath, P Kumar, S M Nanoti* and *M O Garg*

28. Studies on the compositional analysis of liquid and gaseous hydrocarbons-obtained from waste polyethylene, *H U Khan, Manisha Sahai, Sanat Kumar* and *Jagdish Kumar*

29. CFD Studies on hydrodynamics of an internal loop airlift reactor, *Madhavi Gera, Jasvinder Singh, D K Adhikari,* and *M O Garg*

30. Investigation into vehicular performance and emission from isomers of butanol blended in gasoline, *Mritunjay Kumar Shukla, Yograj Singh, L Robindro, A K Jain,* and *S K Singal*

31. Tribological behaviour of lubricating greases and their analytical perspectives, *G D Thakre, P Nagendramma, Savita Kaul, R P S Bisht* and *M R Tyagi*

32. Feedstock options for petrochemicals, *Sudip K Ganguly, Shounak Sen* and *M O Garg*

4th International Conference on Advanced Nano Materials (ANM 2012), IIT-Madras, Chennai, October 17-19, 2012

33. Synthesis of copper oxide nanorods in ionic liquids and its potential for lubricant applications, *Rashi Gusain* and *O P Khatri*

2012 hE Annual Meeting at Pittsburgh, USA, October 28 – November 2, 2012

34. Single-column VSA studies for CO_2 recovery using metal organic frame work adsorbent: comparison with commercial zeolite, *Arti Arya, Soumen Dasgupta, Swapnil Divekar, Anshu Nanoti, A N Goswami, M O Garg, Anne Anderson, Jasmina Hafizovic Cavka* and *Richard Blom*

35. 1,3-dimethylimidazolium-2-carboxylate derived from dimethyl carbonate: a recyclable green catalyst for the chemical activation of CO_2, *Suman L Jain* and *Subodh Kumar*

National Conference on Carbon Materials 2012 (CCM 2012), BARC, Mumbai, November 1-3, 2012

36. Hydrothermal deoxygenation of graphene oxide, *Shivani Choudhary* and *Harshal P Mungse*

37. Synthesis and characterization of graphene oxide/ polymer composites for lubricating applications, *Arvind Kumar, Babita Behera, Ankushi Bansal, A K Chatterjee* and *S S Ray*

38. Optical microscopic imaging of mesophase pitches and petroleum semicoke catalyzed by transition metals, *Subhash Kumar* and *Manoj Srivastava*

39. Preparation of petroleum pitches for different applications from refinery/petrochemical residues, *Manoj Srivastava, Manoj Kumar, U C Agarwal* and M O Garg

International conference on Industrial Biotechnology (ICIB-2012) at Punjabi University, Patiala, November 21-23, 2012

40. Catalytic hydrothermal liquefaction of wheat husk, *Rawel Singh, Thallada Bhaskar* and *Bhavya Balagurumurthy*

7th Uttarakhand State Science & Technology Congress, November 21-23, 2012

41. Synthesis and characterization of cellulose palmate esters for biolubricant application, *Raj K Singh, Anshul Verma, Raghuvir Singh, G M Bahuguna, L N Shivakumar* and Sandeep Saran

Winter school on Frontiers in Material Science, International Centre for Material Science, JNCASR, Bangalore, December 3-8, 2012

42. Spectroscopic studies on deoxygenation of graphene oxide in water, *Harshal P Mungse, Shivani Choudhary* and *O P Khatri*

One-day Workshop on Understanding Real-world Indian Driving Cycle and its Impact, CRRI, New Delhi, December 4, 2012

43. Development of a driving cycle for passenger cars in a Tier-II city, *Sunil Pathak* and *S K Singal*

TAPSUN Conference 2012 on Advances in Futuristic Solar Energy Technology, organized by CSIR-NPL, New Delhi, December 4- 5, 2012

44. Protein-based solar photovoltaics: Bioprospecting photosynthetic micro-organisms and purification of its photosynthetic protein, *Neelima Shah, Deepti Agarwal, Rashmi, Sunil K Suman, Debashish Ghosh, Diptarka Dasgupta, Sheetal Bandhu* and *D K Adhikari*

8th International Conference on Industrial Tribology (ICIT-2012), organized by TSI, Pune, December 7-9, 2012

45. Copper oxide nanorods as potential additives for reduction in friction and wear, *Rashi Gusain* and *O P Khatri*

46. Investigation into fatigue life of elastohydrodynamic lubricant point contacts, *G D Thakre, M R Tyagi, Satish C Sharma* and *S P Harsha, Indian Institute of Technology-Roorkee (IITR)*

47. Study of lubricant performance in elastohydrodynamic lubricant point contacts, *G D Thakre, M R Tyagi, Satish C Sharma* and *S P Harsha (IITR)*

Biofest-2012, organized by the Bright International Conferences & Events, Hyderabad, December 12-13, 2012

48. Biorefinery approach for production of lignocellulosic ethanol and other byproducts from the waste of sugar mills and the pulp & paper industry, *D K Adhikari, R K Jain, Deepti Agrawal, Diwakar Pandey, Diptarka Dasgupta, Debashish Ghosh, Rashmi, Vasanta V Thakur* and *Sunil K Suman*

FICCI's Roving Seminar on Industrial Lubricants and Management, New Delhi, December 18-19, 2012

49. Types of lubricants and grease and their applicability in industries, *G D Thakre, Pankaj Arya* and *B M Shukla*

International Conference on Solar Energy Photovoltaic (ICSEP-2012), School of Electronics Engg, KIT University, Bhubaneswar, December 19-21, 2012

50. High surface area mesoporous titania for dye sensitized solar cell, *A K Sinha* and *Vipin Amoli*

CHEMCON-2012, Dr B R Ambedkar NIT, Jalandhar, December 27-30, 2012

51. Catalytic cracking of pyrolytic oil model compound with gas oil: a case study of acetic acid, *D V Naik, Vimal Kumar, B Prasad, M O Garg, Neeraj Atheya, K K Singh* and *D K Adhikari*

9th International Colloquium: Fuels-Conventional and Future Energy for Automobiles, Stuttgart, Germany, January 15- 17, 2013

52. Butanol/diesel blends as SI engine fuels: physico-chemical and performance characteristics evaluation, *M K Shukla, G D Thakre, R C Saxena, Y K Shrama, A K Jain* and *S K Singal*

15th CRSI National Symposium in Chemistry (NDS-2013), BHU, Varanasi, February 1-3, 2013

53. Synthesis, characterization & lubrication aspects of halogen-free ionic liquids, *Rashi Gusain* and *O P Khatri*

54. Designing and synthesis of raft chain transfer agents for polymerization, *Ankushi Bansal, P Padmalatha, Piyush Gupta, S S Ray* and *A K Chatterjee*

21st National Symposium on Catalysis (Catsymp-21), IICT, Hyderabad, February 10-13, 2013

55. Graphene oxide and chemically-functionalized graphene oxide as solid acid catalyst for esterification reactions, *Harshal P Mungse, Niharika Bhakuni, Aruna Kukreti* and *O P Khatri*

56. A novel method for synthesis of hierarchical ZSM-5 for catalytic applications, *Devaki Nandan, Peta Sreenivasulu, L N Sivakumar Kanthala, Raghubir Singh* and *N Viswanadham*

57. Synthesis and catalytic applications of copper hydroxyl phosphate nano plates (CuNP) and tubes (CuNT), *Peta Sreenivasulu, Devaki Nandan, Sandeep Saran, G M Bahuguna* and *N Viswanadham*

58. Catalytic conversion of biomass-derived intermediates into gasoline and olefins, *Sandeep K Saxena, Jagdish Kumar* and *N Viswanadham*

59. A novel synthesis method for creation of strong acidity along with bi-/tri-modal mesoporosity in boehmite alumina, *Manoj Kumar, A K Saxena, Babu Lal, S K Saxena* and *N Viswanadham*

60. Effective catalytic conversion of cellulose into high yields of methyl glucosides over sulphonated carbon based catalyst, *Rawel Singh, Sambha Dora, Thallada Bhaskar, Bhavya Balagurumurthy, D V Naik* and *D K Adhikari*

61. Pt-nanoparticles with tuneable size supported on nanocrystalline ceria for low temperature water-gas shift (WGS) reaction, *Bipul Sarkar, Ritesh Tiwari, Reena Goyal, Ankur Bordoloi* and *Rajaram Bal*

62. Low-temperature partial oxidation of methane to syn-gas over Ni-supported ceria catalysts, *Rajib kumar Singha, Chandrasekhar Pendem* and *Rajaram Bal*

63. Selective oxidation of benzene to phenol over $CuCr_2O_4$ spinel nanoparticle catalyst, *Shankha Shubhra Acharyya, Chandrasekhar Pendem* and *Rajaram Bal*

64. One-step selective oxidation of propylene to propylene oxide over Ag-nanoparticles supported on WO_3 nanorods, *Shilpi Ghosh, Chandrasekhar Pendem* and *Rajaram Bal*

65. Temperature-dependent reaction pathways for anomalous hydrocracking of triglycerides over Co-Mo-catalyst, *Anand Mohit* and *Anil K Sinha*

International Conference on Advances in Chemical Engineering, organized by IIT-Roorkee, Roorkee, February 22-24, 2013

66. Trouble-shooting, energy-efficiency and quality improvement in food grade hexane (FGH) unit by changeover of solvent, *Sunil Kumar, S M Nanoti, BR Nautiyal, P Ghosh* and *M O Garg*

67. Studies on production of L-lactic acid from lignocellulosic biomass using consolidated bio-processing, *Jayati Trivedi, Deepti Agrawal* and *D K Adhikari*

68. Hydropyrolysis of lignocellulosic biomass for production of hydrocarbons, *Bhavya Balagurumurthy, Thallada Bhaskar* and *D K Adhikari*

International Conference on Emerging Technologies: Micro to Nano-ETMN, BITS Goa Campus, Goa, February 23-24, 2013

69. Thin film lubrication of micro-machine elements, *G D Thakre, V K Meena, Pankaj K Arya* and *B M Shukla*

2.3 Patents Sealed

2.3.1 Patents Sealed Abroad

1. A composition and process for lubricating oils for two-stroke gasoline engine, *Arun Kumar Singh, Naval Kishore Pandey* and *Ashok Kumar Gupta*, China, Patent No. CN101437925, dt. 25.04.2012

2. A process for production of ethanol from starch, *D K Adhikari, Tsering Stobdan, Ravindra Pal Singh* and *Ashok Kumar Gupta*, UK, Patent No. GB2460983, dt. 02.05.2012

3. A process for preparation of P-toulic acid by liquid phase oxidation of P-xylene in water, Japan, *M P Saxena, A K Gupta, S K Sharma, D P Bangwal* and *Krishan Kumar*, Patent No. JP5055262, dt. 24.10.2012

4. A composition and process for insulating fluid, *A K Singh, N K Pandey* and *A K Gupta*, China, Patent No. CN101326592B, dt. 04.07.2012

5. A process for preparation of P-toluic acid by liquid phase oxidation of P-xylene in water, *M P Saxena, A K Gupta, S K Sharma, D P Bangwal* and *Krishan Kumar*, China, Patent No. ZL200580049287.6, dt. 11.07.2012

6. A process for preparation of P-toluic acid by liquid phase oxidation of P-xylene in water, *M P Saxena, A K Gupta, S K Sharma, D P Bangwal* and *Krishan Kumar*, Taiwan, Patent No. I 368607, dt. 21.07.02012

7. Process for preparation of ethanol from starch, *D K Adhikari, Tsering Stobdan, R P Singh* and *A K Gupta*, USA, Patent No. 8227220 B2, dt. 24.07.2012

8. Strain and a novel process for ethanol production from lignocellulosic biomass at high *temperature, D K Adhikari, Sachin Kumar, C D Sharma* and *Deep Chand,* USA, Patent No. 8,268,600 B2, dt. 18.09.2012

9. A Process for metal working fluid from heavy aklylate, *A K Singh, O N Anand* and *A K Gupta*, Australia, Patent No. 2011201929, dt. 27.9.2012

10. A composition of lubricating oil for two-stroke gasoline engine and process for the preparation thereof, *A K Singh, N K Pandey* and *A K Gupta*, Japan, Patent No. 5097710, Dt. 28.9.2012

11. A composition and process for hydraulic fluid, *A K Singh, N K Pandey* and *A K Gupta*, China, Patent No. ZL200580052250.9, dt. 10.10.2012

12. A process for production of ethanol from starch, *D K Adhikari, Tsering Stobdan, R P Singh* and *A K Gupta,* China, Patent No. ZL200880017851.X, dt. 12.12.1012

13. Modified zeolite catalyst useful for conversion of paraffins, olefins and aromatics in a mixed feedstock into isoparaffins and a process thereof, *N Viswanadham, Raviraj Kamble, Amit Sharma, Jagdish Kumar, B S Negi, G Murali Dhar* and *M O Garg*, USA, Patent No. 8,349,754, dt. 08.01.2013

14. A composition and process for insulating fluid, *A K Singh, N K Pandey* and *A K Gupta*, Canada, Patent No. 2632225, dt.19.02.2013

2.3.2 Patents Sealed in India

1. A process for metal-working fluid from heavy aklylate, *A K Singh, O N Anand* and *A K Gupta*, Patent No. 251864, dt. 12.04.2012

2. A composition of insulating fluid and process for the preparation thereof, *A K Singh, Naval Kishore Pandey* and *A K Gupta*, Patent No. 253025, dt. 15.06.2012

3. Process for oxidative desulphurization of liquid hydrocarbon fuels by using carboxylic acid-alkali metal peroxoborate as oxidation system, *Bir Sain, T V Rao, B R Nautiyal, S M Nanoti, Y K Sharma, M O Garg* and *A K Gupta,* Application No. 253487, dt. 25.07.2012

4. A process for preparation of lubricants based on hydrogenated vegetable oils, *V K Chhibber, A K Gupta, O N Anand, Jaideep Mehta, Mahendra Pal* and *Anju Sharma*, Patent No. 255026, dt. 16.01.3013 *(Jointly with the CHT)*

2.4 Patents Filed

2.4.1 Patents Filed Abroad

1. A process for conversion of low cost and high FFA oils to biodiesel, *Savita Kaul, Neeraj Atray* and *A K Bhatnagar*, USA, Application No. 13/395871, dt. 20.06.2012

2. A process for conversion of bioethanol into gasoline, *N Viswanadham* and *Sandeep K Saxena*, USA, Application No. 13/619608, dt. 14.09.2012

3. Sulphonated carbon silica composite material and a process for the preparation thereof**,** *N Viswanadham* and *Devaki Nandan*, USA, Application No. 13/623775, 20.09.2012

4. An improved process for selective hydroxylation of benzene to phenol with molecular oxygen (air) over solid catalysts, *Rajaram Bal, Shankha Shubhra Acharyya, Shilpi Ghosh, Bipul Sarkar, K S Rawat* and *Chandrashekar Pendem*, USA, Application No. 13/623653, dt. 20.09.2012

5. An improved process for preparation of Cu-Cr oxides for selective oxidation reactions, *Rajaram Bal, Bipul Sarkar, Shankha Shubhra Acharyya, Shilpi Ghosh, Chandrashekar Pendem* and *Jagdish Kumar*, USA, Application No. 13/623618, dt. 20.09.2012

6. A process for preparation of Ag-W oxide catalyst for the selective conversion of propylene to propylene oxide with molecular oxygen, *Rajaram Bal, Shilpi Ghosh, Shankha Shubhra Acharyya, Bipul Sarkar, Chandrashekar Pendem* and *Rajib Kumar Singha*, PCT, Appliction No. PCT/IN2012/000836, dt. 21.12.0212

7. Modified zeolite catalyst useful for conversion of paraffins, olefins and aromatics in a mixed feedstocks into isoparaffins and a process thereof, *N Viswanadham, Ravirjaj Kamble, Amit Sharma, Jagdish Kumar, B S Negi, G Murali Dhar* and *M O Garg*, USA, Application No. 13/729,962, dt. 28.12.2012

8. A process for separating aromatics and removal of suphur compounds from the heart cut of catalytically cracked gasoline, *M O Garg, S M Nanoti, B R Nautiyal, Sunil Kumar, Prasenjit Ghosh, Nisha, Pooja Yadav, Jagdish Kumar, Manish Tiwari, M R G Rao* and *N S Murthy*, WO, Application No, PCT.IN2013/000154, dt. 14.3.2013 ***(****Jointly with M/s Reliance Industries Limited)*

9. A process for production of benzene lean gasoline by recovery of high purity benzene from unprocessed cracked gasoline fraction containing organic peroxides, *M O Garg, S M Nanoti, B R Nautiyal, Sunil Kumar, Prasenjit Ghosh, Nisha, Pooja Yadav, Jagdish Kumar, Manish Tiwari, M R G Rao* and *N S Murthy*, USA, Application No. 13/843286, dt. 15.3.3013

2.4.2 Patents Filed in India

1. Consolidated bio-processing of lignocellulosic biomass for L-lactic acid production, *D K Adhikari, Jayati Trivedi* and *Deepti Agrawal*, Application No. 223Del2012, dt. 19.07.2012

2. A process for production of benzene lean gasoline by recovery of high purity benzene from unprocessed cracked gasoline fractions containing organic peroxides, *M O Garg, S M Nanoti, B R Nautiyal, Sunil Kumar, Prasenjit Ghosh, Nisha, Pooja Yadav, Jagdish Kumar, Manish Tiwari, M R G Rao* and *N S Murthy*, Application No. 2502 Del2012, dt. 9.8.2012, *(Jointly with M/s Reliance Industries Limited)*

3. A novel process for synthesis of hierarchical mesoporous silica, *N Viswanadham* and *Devaki Nandan*, Application No. 259Del2012, dt. 22.08.2012

4. A catalytic process to convert renewable feedstock into aromatics-rich aviation fuel, *A K Sinha, Mohit Anand, Saleem Akthar Farooqui, Rakesh Kumar, R K Joshi, Rohit Kumar, B S Rana* and *Deepak Verma*, Application No. 3039Del2012, dt. 28.09.2012

5. A process for preparation of high performance lube base oils from spent lubricating oil, *M O Garg, Manoj Kumar, Manoj Srivastava, Sunil Kumar* and *S M Nanoti*, Application No, 3040Del2012, dt. 28.09.2012

6. Magnetically separable functionalized acidic carbon nano-sheets for biomass processing, A K Sinha and Deepak Verma, Application No. 3141Del2012, dt. 8.10.2012

7. A process for value-addition of residual oil for girth gear lubricating grease, *Savita Kaul, P Nagendramma, R P S Bisht* and *M R Tyagi*, Application No. 3142Del2012, dt. 8.10.2012

8. Catalytic process to convert renewable feedstocks directly into aromatics-rich feedstock pool, *A K Sinha, Mohit Anand, Saleem Akthar Farooqui, Rakesh Kumar, R K Joshi, Rohit Kumar, B S Rana, Deepak Verma* and *Malayil Sibi*, Application No. 3144Del2012, dt. 8.10.2012

9. A single-step catalyst and process to convert triglycerides and free fatty acids directly into isomerized hydrocarbons, *A K Sinha, B S Rana, Rohit Kumar* and *Deepak Verma*, Application No. 3196Del2012, dt. 12.10.2012

10. An improved process for selective separation of linear terminal olefins and n-paraffins from a coker distillate, *Indrajit K Ghosh, Suman Lata Jain, Jagdish Kumar, A K Chatterjee* and *Bir Sain*, Application No. 3192Del 2012, dt. 12.10.2012

11. Process for production of renewable fuels and chemicals in a bio-refinery from baggasse pith, *D K Adhikari, Savita Kaul, Debashish Ghosh, Deepti Agarwal, Rashmi, Diptarka Dasgupta, Sunil K Suman, Dinesh Bangwal, M S Negi, U K Jaiswal, Pankaj K Arya, R K Jain, Vasantha V Thakur, R M Mathur, Diwaker Pandey* and *Dharmendra Kumar* (CPPRI), Application No. 3444Del 2012, dt. 07.11.2012, *Jointly with the Central Pulp & Paper Research Institute (Dept. of Industrial Policy & Promotion, Ministry of Commerce & Industries, Govt. of India, Saharanpur)*

12. An improved process and catalyst for selective dehydrogenation / oxidative dehydrogenation of ethane to ethylene, *Rajaram Bal, Bipul Sarkar, Rajib Kumar Singha, Chandrashekar Pendem, Shankha Shubhra Acharyya* and *Shilpi Ghosh*, Application No. 3443Del2012, dt. 07.11.2012

13. An improved process and catalyst for single-step conversion of glycerol to acrylic acid, *Rajaram Bal, Bipul Sarkar, Rajib Kumar Singha, Chandrashekar Pendem, Shankha Shubhra Acharyya* and *Shilpi Ghosh*, Application No. 3442Del2012, dt. 07.11.2012

14. A catalytic process to convert microbial lipids, bio-crude and lignin directly into aromatics-rich feedstock, *A K Sinha, Mohit Anand, D K Adhikari, Saleem Akthar Farooqui, Debashish Ghosh, Rashmi, Rakesh Kumar, R K Joshi, Rohit Kumar, Jagdish Kumar, Deep Chand, Tasleem Khan* and *Parvez Alam*, Application No. 3441Del2012, dt. 07.11.2012

15. A single-step catalytic process for conversion of naphtha to diesel-range hydrocarbons, *N Viswanadham, Peta Sreenivasulu, Sandeep K Saxena, Rajiv Panwar, Devaki Nandan* and *Jagdish Kumar*, Application No. 3485Del2012, dt. 08.11-2012.

16. Biodegradable base stock as neat cutting oil, *Savita Kaul, P Nagendramma, G D Thakre, R P S Bisht* and *M R Tyagi*, Application No. 3483Del2012, dt. 08.11.2012

17. An improved process for biodiesel production, *M O Garg, Adam Harvey, Jyoti Porwal, Dinesh Bangwal, Richa Singhal* and Savita Kaul, Application No. 3616Del2012, dt. 26.11.2012

18. An improved coke-resistant solid catalyst and process for methane reforming reaction with carbon dioxide, *Rajaram Bal, Bipul Sarkar, Chandrashekar Pendem, Rajib Kumar Singha, Shankha Shubhra Acharyya* and *Shilpi Ghosh*, Application No. 3614Del2012, dt. 26.11.2012

19. An improved process for production of gamma-butyrolactone, *P Padmalatha, Parveen Kumar*

Khatri, Suman Lata Jain, A K Chatterjee and *Bir Sain*, Application No. 0248Del2013, dt. 30.01.2013

20. Second-stage selective hydrogenation of pyrolysis gasoline to produce quality solvents, *A K Sinha, Mohit Anand, Saleem Akthar Farooqui, Rakesh Kumar, R K Joshi, Rohit Kumar, Tasleem Khan* and *Parvez Alam*, Application No. 865Del2013, dt. 22.03.2013

21. Method for the synthesis of magnetically separable and silica-decorated metal nanostructures, *A K Sinha* and *Bhawan Singh*, Application No. 864Del2013, dt. 22.03.2013

2.5 D.Litt./D.Phil. Degrees Awarded

- Ms Pratibha Dhiran was awarded Ph.D. for her thesis on *'Molecular Chararctrization of Thermozymes'*, by the Jiwaji University, Gwalior under the supervision of Dr D K Adhikari, Chief Scientist, CSIR-IIP.

2.6 Honours, Awards & Recognitions

2.6.1 Institutional/Group Awards

राजभाषा नीति के श्रेष्ठ कार्यान्वयन हेतु प्रथम पुरस्कार

नगर राजभाषा कार्यान्वयन समिति (नराकास), देहरादून की ओर से देहरादून नगर में केंद्र सरकार के शताधिक कार्यालयों में से भारतीय पेट्रोलियम संस्थान, देहरादून को राजभाषा हिंदी के श्रेष्ठ कार्यान्वयन हेतु वर्ष 2010–11 का **'प्रथम पुरस्कार'** प्राप्त हुआ। यह पुरस्कार संस्थान की ओर से संस्थान के राजभाषा अनुभाग के प्रभारी डॉ० दिनेश चंद्र चमोला ने डॉ० स्वर्ण सुब्बा राव, भारत के महासर्वेक्षक एवं अध्यक्ष, 'नराकास', देहरादून से प्राप्त किया।

संस्थान की ओर से 'नराकास' देहरादून द्वारा प्रदत्त प्रथम पुरस्कार ग्रहण करते डॉ दिनेश चंद्र चमोला। अन्य (बाएँ से दाएँ) श्री राकेश कुमार, उप निदेशक, क्षेत्रीय कार्यान्वयन कार्यालय (उ.क्षे.), राजभाषा विभाग, भारत सरकार; डॉ स्वर्ण सुब्बा राव एवं श्री एल एन् शीतल, सम्पादक 'राष्ट्रीय सहारा' (मुख्य अतिथि)

2.6.2 Individual Awards

- Dr Y K Sharma, Chief Scientist, was awarded the D.Sc. degree by the Dr B R Ambedkar University, Agra, on his thesis entitled *'Studies on the mechanism of degradation behaviour of distillate fuels'*.

  The problem of degradation can be studied in terms of stability in storage, when fuel is stored for a period longer than usual. This study involves a new approach for understanding the mechanism of degradation occurring in distillate fuels by concentrating the hydrocarbon sediment precursors from cracked stocks and doping them with stable fuel. The real composition of sediment-forming compounds of cracked stocks provides a more realistic picture of degradation. The main emphasis has been on the separation of those classes of compounds responsible for the stability of cracked stocks such as light cycle oil and visbreaker gas oil. This work has elucidated the characterization of such fuels.

- Dr Thallada Bhaskar, Senior Scientist, was selected as a Distinguished Researcher by the *National Advanced Institute of Science and Technology (AIST)*, Japan for the year 2012 for his work on *'Recovery of useful resources from e-waste'*.

- Dr Thallada Bhaskar was also selected for the Raman Research Fellowship 2013-14 under the guidance of Dr Duncan Akporiaye, Research Director, SINTEF Materials and Chemistry, Oslo, Norway.

2.7 MoU's MoC's / Agreements Signed

2.7.1 With Indian Concerns

- With the Kendriya Vidyalaya Sangathan *for transfer of 5 acres of the CSIR-IIP's land to the Kendriya Vidyalaya, CSIR-IIP for construction of a new building for the Kendriya Vidyalaya.*

MoU with the KVS : Dr Garg exchanges documents with Mr R B Singh, Deputy Commissioner of the KVS. Others present are (L-R) : Dr Charu Sharma, Principal, KV-IIP & Mr V K Kaushika, CoA, CSIR-IIP

- With M/s BPCL, Mumbai *for developmental activity on characterization scale-up and commercialization of new ammonical water-soluble fixed-bed sweetening catalyst for gasoline/ kerosene/ATF*

MoU with M/s BPCL. Mr P S Viswanthan, Dy GM (R&D), BPCL & Mr B M Shukla, Head, RPBD, CSIR-IIP exchange documents.

- With M/s IOCL, Faridabad *for promotion of education, research and innovation and to provide a model for academia-industry partnership for directing Research & Development on projects relevant to the industry, having high prospects of commercialization*

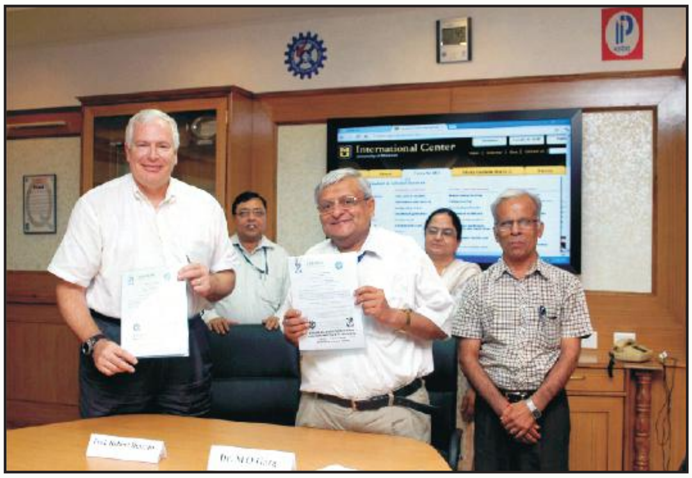
MoU with M/s IOCL. Dr Garg exchanges documents with Dr R K Malhotra, Director (R&D), IOCL

- With the University of Petroleum & Energy Studies (UPES), Dehradun
- Non-disclosure agreement with the Hyundai Oil Bank R&D Institute, Gyeonggi-do, Korea on *'Conversion of Naphtha to a Heavier Distillate, i.e. Diesel'*
- With M/s Premas Biotech Pvt. Ltd., Haryana for *'Production of glycolipids in batch & fed-batch operation'*.
- With M/s Tata Motors Ltd., Mumbai for component and vehicles testing of passenger and commercial vehicles as well as provision of hired test facilities.
- With M/s Jaypee Institute of Information Technology (JIIT), NOIDA to utilize mutual R&D facilities and expertise for collaborative R&D work and training of scientific manpower of the JIIT and the CSIR-IIP in the area of biorefinery.
- With M/s Lubrizol India Pvt. Ltd., Mumbai on '*Field trials on a four-stroke motorcycle for performance evaluation of engine lubricants'*.
- With M/s Technip KT India, NOIDA on '*Process technology including catalysts for conversion of waste plastics to value-added products e.g. gasoline, diesel and aromatics'*.
- With M/s Trash Energy India Pvt. Ltd. (TEIPL), Motihari, Bihar on *'An integrated biochemical process for lignocellulosic ethanol & value-addition'*.

2.7.2 With Foreign Concerns

- With the University of Alicante at Alicante, Spain *scientific collaboration for mutual benefit in carrying out Research & Development work.*

- With the Institute of Materials and Environmental Chemistry (IMEC), CRC, Hungarian Academy of Sciences, Hungary, *to utilize mutual R&D facilities and expertise for scientific, collaborative R&D work and training of scientific manpower amongst researchers of CSIR/CSIR-IIP and IMEC in the area of renewable energy and bio-fuels.*
- With the University of Missouri, USA for academic collaboration



Prof Robert Duncan of the University of Missouri, USA, exchanges Documents with Dr M O Garg

- With Royal Melbourne Institute of Technology (RMIT), Melbourne, Victoria, Austraila *'To co-operate in establishing closer links that may involve: staff and student exchange, research opportunities and MSc and PhD research opportunities'*.

Prof Peter Coloe, Vice-President, Science, Engineering and Health and Vice-President, RMIT, exchanges documents with Dr M O Garg

3

Human Resource Development

3.1 Training the Personnel from the Oil Industry & Related Fields

The CSIR-IIP imparts, as a part of its mandate, training to the personnel from the oil industry & related fields like the automobile industry and the transport sector etc.

3.1.1 Programmes on *'Petroleum Refining Technology'*

- Programme for the Chemical Engineers of the IOCL, New Delhi, March 19 – May 4, 2012
- Programme for the Chemical Engineers of BPCL-Kochi Refinery, May 14 – June 1, 2012

Faculty & trainees at the training programme during May 14 – June 1, 2012

- Programme for Chemical Engineers of the the IOCL, New Delhi, August 13 – September 28, 2012
- Programme for the Chemical Engineers of different refineries viz., CPCL, Chennai, India; KPRL, Mombasa, Kenya; NRL, Numaligarh, India and IOCL, Panipat, India, October 1-19, 2012
- Programme for the Chemical Engineers of HPCL, Bangalore, November 26 – December 14, 2012
- Programme for the Chemical Engineers of IOCL, New Delhi and CPCL, Chennai, November 26, 2012 - January 11, 2013

Faculty and participants of the training Programme, during November 26, 2012 - January 11, 2013

3.1.2 Other Programmes

- Workshop-cum-Training Programme on '*Vehicular Pollution'* for the Officers of the MRTH, New Delhi, October 19 - November 2, 2012
- Programme on '*Laboratory Practicals*' for the Chemists of NTPC, NOIDA, December 24 – January 4, 2013
- Training programme on *'Laboratory Practicals'* for the Assistant Chemists of the NTPC, NOIDA, December 12, 2012 - January 4, 2013
- Workshop-cum-training programme on *'Vehicular Emissions and Control'* for the Officers of the Ministry of Road Transport & Highways (MRTH), New Delhi, February 4-8, 2013
- Training programme on *'Operation and Maintenance of CFR Engines'* for the Executives of different refineries, July 23- August 3, 2012

Faculty and trainees of the programme dated July 23-August 3, 2012

3.2 HRD Programmes for the Employees

3.2.1 Programmes Organized by the HRDC (CSIR), Ghaziabad

- Mr G C Bahuguna, Sr Technical Officer; Mr M S Negi & Mr Rajeev Panwar, Technicians, *Training Programme on Competency Development of Group-II Personnel*, April 11-14, 2012
- Rohit Kumar and Ms Rashmi, Technical Assistants, *Orientation Training Programme for Technical Group III Personnel*, June 25 - 29, 2012
- Mrs Geeta Chhetri and Ms Kusum, Sr Stenographers, '*Professional Skills Development Programme for PS's/ PA's/ Stenographers*,' July 11-13, 2012
- Mr M S Mehra, F&AO, a workshop on *'Modified Accounting Software',* October 18-19, 2012
- Mr Prasoon Kumar, SO and Mr Vishvendra Dogra, Assistant, *'CSIR Enterprise Transformation Project: CSIR-Administration; Breaking Barriers Conference-cum-Hands-on Training for ERP-HR Portal Related Processes and Configuration of HR Processes for ESS, PMS and Assessment Modules',* November 5-6, 2012

- Mr Saleem Akhtar Farooqui and Subham Paul, Scientists, *Induction Training Programme for Newly Recruited Scientists,* January 27 to February 5, 2013
- Mr G P Sharma, PS, *'Orientation–cum-Training Programme for PS's/ PA's/ Sr Stenographers*,' February 18-22, 2013
- Dr Atul Ranjan, Scientist and Mr C S Bisht, SO(F&A), *'Training Programme on Direct & Indirect Taxes'*, February 25-26, 2013
- Mr M K Gairola and Mr Prasoon Kumar, Section Officers, *'Training Programme on Capacity Building for SO's/ Assistants Recruited Through CASE 2009'*, February 25 – March 6, 2013

3.2.2 Attendance in Programmes Organized by Different Organizations /Institutions etc.

- Mr Deeptarka Dasgupta, Scientist, *Introduction to Systems and Synthetic Biology for Scientists and Engineer*s, IIT-Bombay, April 30 - May 3, 2012
- Mr Umesh Kumar, Mr Subham Paul, Scientists and Ms Pooja Yadav, Technical Assistant, *7th Summer School on Petroleum Refining & Petro-chemicals,* organized by the Petrotech Society, IIPM, Gurgaon, June 4-8, 2012
- Mrs Poonam Gupta, Principal Scientist and Mr R K Chauhan, Senior Technical Officer, *'ISO 9001 : 2008 Series QMS Auditor/ Lead Auditor Training Course'*, organized by the DNV, New Delhi, August 27-31, 2012
- Mr Devendra Singh, Senior Scientist, *Workshop on Design and Analysis of Experiments* organized by the Indian Statistical Institute, , ISI, Kolkata Campus, Kolkata, November 19-23, 2012
- Mr Pankaj Kumar and Mr S P Saklani, Assistants, *Workshop on Policies & Procedures on Finance & Accounting,* CSIR-IMT Chandigrah, November 26-27, 2012
- Mr Harshal P Mungse, TA, '*Winter School on Frontiers in Material Science',* International Center for Material Science, JNCASR, Bangalore, December 3-8, 2012

3.3 Colloquia

- Mr Sandip Biswas, Scientist, '*Development of Regenerative Process for SO_2 Removal from SRU Tail Gas Streams'*, April 4, 2012
- Dr Y K Sharma, Senior Principal Scientist, Dr Dr Manoj Srivastava, Principal Scientist, Dr P Nagendramma, Technician, Mr Manoj Thapliyal, Technical Officer, Mr Anand Singh, Sr Technical Officer, '*Proceedings of the 9th International Symposium on Fuels & Lubricants (ISFL)'* (held at New Delhi on March 5 - 7, 2012), April 19, 2012
- Mr L Robindro, Senior Scientist, *'Sustainable E-mobility using Renewable Energies – A Concept Towards Hybrid Electric Vehicle (HEV) Technology'*, May 10, 2012
- Dr M O Garg, Director, 'What does technology mean!' – May 11, 2012
- Dr Anshu Nanoti, Senior Principal Scientist, Dr Manoj Srivastava, Principal Scientist, Dr Deepti Agrawal, Scientist and Mr Deeptarka Dasgupta, Scientist, *'Proceedings of the International Conference on Refining Challenges – Way Forward*' (April 16-17, 2012) and '*Proceedings of the 3rd International Symposium on Bio-fuels and Bio-energy* (April 19-20, 2012)', May 17, 2012
- Mr Ajit Soundankar, Application Engineer, *'Introduction to Gas Chromatography and Applications'*, May 29, 2012
- Dr Savita Kaul, Prinicipal Scientist, visited the USA to attend :
  - o *'the 103 AOCS Annual Meeting & Expo',*
  - o *'67th Annual Meeting of the Society of Tribologists and Lubrication Engineers (STLE)',*

She also visited the Illinois and Missouri Universities.

- Mr Vipin Amoli, JRF, CSIR-IIP, *'Solid-State Dye-Sensitized Solar Cell'*, August 3, 2012
- Mr Wolfgang Betz, Marketing Director, M/s Physical Electronics, USA, *'New XPS Techniques'*, August 6, 2012
- Dr Ramani Sankaranarayan and Dr Geeta Vaidyanathan, CTx Green, Odisha, '*Village-level Biodiesel (VLB) Boot-Strapping Village Development'*, August 8, 2012
- Mr Angus Tsang, Asia Pacific Channel Manager, Bruker AXS Pte Ltd., Singapore, *'Latest Development in AFM Technologies for Nanoscale Characterization'*, August 22, 2012

- Dr Swaminathan Sivaram, Bhatnagar Fellow & Ex-Director, CSIR-NCL, Pune, *Polymer Membranes for Fuel Cells: Structure, Property, Performance and Challenges*, November 1, 2012
- Dr Mukesh Saxena, Head, AutoChem & Government Business (Lab), Mettler-Toledo India Private Limited, *Technical Presentation on React IR:* in-situ *FTIR Used for Real-Time Reaction Monitoring Easymax: A Parallel Reactor System*, November 8, 2012
- Prof Dr Peter Stryzhak, Head, Institute of Physical Chemistry of the National Academy of Sciences of Ukraine, Ukraine, *Nanomaterials in Heterogeneous Catalysis,* December 3, 2012
- Dr Dudnyk Oleksii Mykolaiovych, Senior Researcher, Coal Energy Technology Institute, National Academy of Sciences of Ukraine, *Conversion of Solid Organic Wastes to Fuels and Chemicals*, December 4, 2012
- Prof Dr Peter Stryzhak, Head, Institute of Physical Chemistry of National Academy of Sciences of Ukraine, Ukraine, *Fischer Tropsch Reactions*, December 4, 2012
- Dr M Shiraj, Project Leader, the National Institute of Advanced Industrial Science & Technology (AIST), Japan, *Development of Sustainable Catalytic Reaction System Using Carbon Dioxide and Water*, December 13, 2012
- Prof Michael T Klein of the University of Delaware, USA, through video-conferencing on *'Structure-oriented modelling of reaction systems'*, March 12, 2013
- Video–conferencing with the Global Educational Consultancy (GEC), Russia on *collaboration between them and the CSIR-IIP*

3.4 Deputations Abroad

- Dr Savita Kaul, Senior Scientist, visited the USA to present papers at the *103 AOCS Annual Meeting & Expo* and *67^{th} Annual Meeting of Society of Tribologists and Lubrication Engineers* at Long Beach, California. She held discussions at the University of Missouri and the Illinois University, April 29 – May 9, 2012
- Dr M O Garg, Director and Dr Sanat Kumar, Senior Scientist, visited Milan, Italy to attend the *Third Annual International Refining and Petro-chemical Conference (IRPC – 2012*), June 12-14, 2012. Dr Sanat Kumar presented a paper while Dr M O Garg, Director, chaired a session at the conference.
- Dr Suman L Jain, Senior Scientist, visited the Pukyong National University, S Korea for discussions and carrying out experimental work under an Indo-Korean project funded by the NRF, Korea and DST, July 9-18, 2012.
- Dr A K Sinha, Principal Scientist, visited France to present an invited paper at the *'Second Bilateral Indo-French Symposium on Catalysis for Sustainable and Environmental Chemistry'* in Lille, France under the auspices of the CSIR-NCL and the UCCS, France, July 11-14, 2012.
- Mr Swapnil Divekar, Scientist, visited SINTEF, Norway, under the *'Indo-Norway Project on CO_2 Recovery from Power Plants,'* sponsored by the MFA, Norway, September 1-30, 2012.
- Dr M O Garg, Director, Dr S M Nanoti, Chief Scientist, Dr B R Nautiyal, Sr Technical Officer and Mr Prasenjit Ghosh, Scientist, visited SABIC Petrochemical, UK for demonstration and installation of BTX Model and to conduct a 3-day training course, October 8-12, 2012.
- Dr Anshu Nanoti, Senior Principal Scientist, visited USA to attend and present a research paper at the *'2012 AIChE Annual Meeting'* at Pittsburgh, USA, October 28 – November 2, 2012.
- Mr Saleem Akhtar Farooqui, Scientist, visited Russia as a team member of a delegation led by the Indian Navy and the Naval Materials Research Laboratory (NMRL) to discuss possible co-operation for the *Indo-Russia Joint Development of Fuel Cell-Based AIP Module*, October 31 - November 2, 2012.
- Dr A K Sinha, Principal Scientist and Mr Saleem Akhtar Farooqui, Scientist, visited the Coal Energy Technology Institute, National Academy of Sciences, Ukraine, under the *Joint Collaborative Indo-Ukraine Project*, November 3-16, 2012.
- Dr Thallada Bhaskar, Senior Scientist, was invited as the Distinguished Researcher to work on the project *'Recovery of Useful Resources from E-waste'* at the Research Institute for Environmental

Management Technology (EMTech) by AIST, Japan, January 7 – February 22, 2013.

- Mr M K Shukla, Scientist, visited Germany to present a research paper at the *'9th International Colloquium on Fuels-Conventional and Future Energy for Automobiles'*, Stuttgart, Germany, January 15-17, 2013
- Dr Soumen Dasgupta, Scientist, visited the University of Melbourne to participate in the experimental work under a joint research project with Prof Paul A Webley, entitled *'Renewable Energy from Biogas: Technology Development'* awarded under the Australia-India Strategic Research Fund (AISRF) scheme, February 1-28, 2013
- Dr Anil K Sinha, Principal Scientist and Mr Deepak Verma, SRF, visited Taiwan on an invitation by Dr Dennis W Hwang of the Department of Chemistry & Biochemistry at the National Chung Cheng University, Taiwan, in connection with an on-going collaborative research project entitled *'Supermagnetic Porous Iron-Oxide Nanostructures for Magnetically Separable Catalysts and MRI Contrast Agent'* under the Indo-Taiwan Programme of Cooperation (POC) in Science & Technology, February 16-25, 2013
- Dr M O Garg, Director, and Dr N Viswanadham, Principal Scientist, visited the CSIRO Earth Sciences & Engineering, Clayton, Victoria, Melbourne, Australia, to attend the kick-off meeting under a joint research project approved by the DST-AISRF besides the CSIRO centre at Perth, February 18-22, 2013

4

Research Activities : Ongoing, Initiated & Completed

4.1 Projects Initiated

4.1.1 Sponsored

- Desulphurization of residual fuel oil (RFO) using solvent extraction route
- Studies on value-addition of NGL through production of rubber solvent
- Technology development for adsorbed natural gas
- Development and commercialization of new ammonical water soluble fixed-bed sweetening catalyst
- Supportive laboratory data generation on CSIR-IIP-EIL-NRL SO_2 recovery process to prepare BDEP for Numaligarh refinery limited
- Crude preheat maximisation study for CDU-I & II
- Generation of technology information package (TIP) for the project on simultaneous production of pure benzene and US grade gasoline from FCC C6 heart cut (deisohexaniser side cut)
- Feasibility study for value-addition to low-polymer wax
- Feasibility study for dearomatization and desulphurization of heavy kerosene stream
- Training module of principles of solvent extraction and applications in production of pure aroamtics and butadiene
- Carrying out revamp study of sour water stripper unit at Refinery-II in the Manali Refinery at CPCL, Chennai: (Phase-II: providing the basic design package for the most suitable solution of Phase-I)
- Simultaneous production of pure benzene and US-grade gasoline from FCC C6 heart cut : support during development of the BDEP
- Process simulation and design of soaker drum internals for visbreaking unit at IOCL-Mathura Refinery
- Detailed technical evaluation of RCO for production of paraffin & micro-crystalline waxes at Guwahati Refinery : Phase-I studies
- Basic feasibility study for production of paraffin & microcrystalline waxes from VGO at Essar Oil Limited
- Development of catalyst for production of syngas from CO_2 and methane
- Research on the new process of motor fuel production from waste; hydrogen and synthesis gas generation from solid biomass and domestic wastes; conversion of biomass-derived gases (syn-gas) to second & third generation liquid biofuel using nanocatalysts
- Functionalized hierarchical nano composite materials for synthetic and renewable fuels production
- Quick explorative study for conversion of naphtha feed on CSIR-IIP's catalyst for the possible production of diesel range hydrocarbons
- Corrosion inhibitor performance evaluation studies
- Oxidation and thermal stability of hydraulic oil
- Oxidation stability of fire-resistant hydraulic fluid "LUB-SYNTHOL HFDU-68"
- Evaluation of engine as per IS-7347-1974
- Evaluation of fire-resistant hydraulic fluid samples
- Study of deposit characteristics on two motor cycle engine components
- Evaluation of fuel economy and emissions on diesel and gasoline passenger cars using a special lubricant formulation and fuel additive
- Study of deposit characteristics on two Honda Activa scooter engine components
- Comparative testing and analysis of fresh and degraded engine oil used in MI-17 helicopter
- Testing of ISO HV-68 AND VG-32 OILS
- Studies on fresh and used oil samples SU30-MKI
- Comparative testing and analysis of Russian and Indian hypoid oil used IN MI-8 / MI-17 / MI-17 IV helicopter
- Evaluation studies on crude oil sample from M/s Cairn Energy India Pvt. Ltd.
- Studies on a gasoline sample as per BIS specifications from M/s Honda SIEL Car India Ltd., NOIDA

- Studies on reformate samples for M/s BPCL, Mumbai
- Studies on creosote samples from M/s Koromandal Refractories (P) Ltd., Karnataka
- Studies on gasoline samples for selected properties from the Chandigarh Police
- Studies on naphtha samples from M/s GAIL
- Evaluation study of the *Mangala* crude oil from M/s HPCL, Mumbai
- Studies on wash oil samples (hydrocarbons) from M/s GAIL
- Studies on fuel sample derived from waste plastics
- Studies on diesel samples from M/s Hyundai India Ltd.
- Studies on the effect of fuel stick on the characteristics of high-speed diesel (HSD)
- Preparation of narrow fraction from VGO cut of Essar Oil Ltd

4.1.2 In-House

- Extraction, characterization, upgradation and rheological behaviour of bitumen extracted from Canadian tar sands
- Upgradation of heavy oils by hydroprocessing
- Studies on relationship between feedstock composition & mesophase / semicoke formation and their surface morphology
- Utilization of biofeed (glycerol) in the FCCU for fuels and chemicals
- Functionalized micro-/meso-carbon composites and hierarchical materials for hydrocarbon conversion
- Hydrogenation of CO_2 over nanocatalysts
- Variable vacuum fractional distillation and studies on fractions for the hydrocracked plant-derived oil
- Process for production of butadiene from n-butane using microchannel reactor system
- Steam reforming of pyrolysis oil for hydrogen production
- Development of new-generation lubricants for micro-electro-mechanical system (MEMS)
- Production of village-level biodiesel from non-edible oils (locally available)
- Alternative fuels combustion studies under controlled engine operating parameters
- Development and integration of an electronic control unit (ECU) for the electric Maruti 800 car
- Development of technology for upgradation of biogas to transportation and cooking fuels
- Graphene polymer composites for high-end uses : preparation, characterization & evaluation

4.1.3 XII Five-Year Plan Projects Taken up as the Nodal Laboratory (CSIR-IIP Part Only)

Energy Efficient Technologies (E2++)

- Development of adsorption-based technology for separation of propane and propylene
- Metal organic framework (MOF)-based materials for practical storage and delivery of natural gas as transportation fuel
- Upgradation of petroleum residues using unconventional energy sources
- Valorization of difficult-to-process low-value feedstocks from petroleum streams using non-HDS route
- Process intensification using microchannel reactors for future transportation fuels : PIFF (Process Intensification for Future Fuels)
- Membrane technology for hydrogen recovery from low hydrogen-bearing refinery off
- Production of high-value alpha-olefins from low-value feed-stocks
- Development of membrane separation technology for gasoline vapour recovery from hydrocarbon air mixtures

Biomass-to-Energy (Bio-En)

- Advanced biofuels/energy products from algae
- Conversion of lignocellulosic biomass to renewable jet fuel
- Hydrothermal upgradation of lignocellulosic biomass to bio-crude/value-added hydrocarbons
- Technology development for fast pyrolysis of biomass to liquid hydrocarbons

- Integrated hydropyrolysis of lignocellulosic biomass to value-added hydrocarbons
- Microwave-assisted catalytic pyrolysis of biomass and characterization of bio-oil

Catalyst for Sustainable Energy (ECat)

- Photo-assisted conversion of carbon dioxide to hydrocarbon fuels
- Utilization of isobutylene obtained from refinery C4 stream for production of p-xylene
- Hydroprocessing route to new generation, future transportation fuels
- Electro-active nanoporous oxide films with improved ionic and electrnoic conductivities for development of energy storage devices (EANO)
- Catalyst development for conversion of naphtha to diesel and branched paraffin-rich gasoline
- Synthesis of efficient catalysts from economic and renewable sources useful for fuel production
- Efficient use of hydrocarbons in refining of gases through alkylation
- Development of a new-generation solid basic oxide or hydrotalcyte-supported catalyst and its kinetic model for fixed-bed sweetening of heavier petroleum fractions
- Development of nano-catalysts for conversion of methane to lower olefins
- Studies on mechanistic kinetics of conversion of non-refinery/refinery feedstock to basic petrochemicals
- Catalyst development for hydroprocessing of residues
- Carbon-free hydrogen production using H_2S in a petroleum refinery

New Generation Lubricants & Additives (GenLube) (11)

- Strategic initiative to develop economical, eco-friendly lubricants from low-cost feedstocks
- Lubrication Capabilities of graphene and its inorganic analogues
- Potential metal phosphorus and sulphur free additives for lubricating oils as substitute of ZDDP
- New-generation multifunctional lubricating oil additives
- New-generation multifunctional additives for biofuels and blended fuels
- Study on compatibility behaviour of new-generation lubricants with engineering materials
- Development of novel additives to improve pipeline flow of blends of high- and low-pour crude oils
- Development of thin layer activation (TLA) technique for studying corrosion behaviour of high-tan crude oils
- Study of the molecular-level interactions of bio-lubes and bio-additives

Research Initiative for Low Emissions (RILE)

- Assessment of real-world and ultrafine particle emissions from vehicles
- Preparation and evaluation of new catalysts for direct decomposition
- Development of nano-structured fuel-born catalyst for PM emission reduction in engine exhaust and for fuel economy improvement
- Development of bio-lubricants and additives for non-edible vegetable oil for engine applications

Waste to Wealth : Waste Plastics (W2W)

- Research initiative for an environment-friendly thermo-chemical conversion process for e-waste plastics
- Development of an environment-friendly process for conversion of waste plastics (production, process, and municipal waste) to value-added products
- Biodiesel and thermoplastics from wastes : poultry chicken feather (Keratin)

Advanced Carbon Materials (AdCarbMate)

- Coordination among project leaders to meet the objectives of the project and compilation of the 6-monthly progress reports received from each project leader
- Synthesis of 'Carbon Nanotubes' and 'Carbon Fiber Analogue' utilizing asphaltene and resins from heavy ends of crude oil
- Development of lab process for production, extraction and utilization of 'Graphene' from heavy petroleum ends

- Development of petroleum derived carbon wool and its carbon nanotubes composite
- Compilation of final reports received from each project leader and preparation of final report on the project

4.1.4 XII Five-Year Plan Projects Taken up as a Participating Lab (CSIR-IIP Part Only)

- Biocatalysts for industrial application & green organic synthesis (BIAGOS)
- Development of sustainable processes for edible oils with health benefits from traditional and new resources (PEOPLE HOPE)
- Centre for bio-therapeutic molecule discovery (BIODISCOVERY)
- Catalysts for Specialty Chemicals
- Novel hierarchical porous, nano-structured inorganic oxides for application to catalysis
- A multi-scale simulation and modelling approach to designing smart functional materials for use in energy, electro-chemistry and bio-mimetics (MSM)
- New-generation materials design for hydrocarbon science and technology using molecular modelling and simulation
- CFD modelling of conversion routes of biomass to value-added products and development of an integrated bio-refinery concept
- Natural products as affordable healthcare agents (NaPAHA)
- Specialty materials based on engineered clays (SPECS)
- Sustainable technologies for utilization of rare earths (SURE)

4.2 On-going Projects

4.2.1 Sponsored

- Development of adsorption technology for recovery of CO_2 from power plant flue gas
- Renewable energy from biogas technology development
- Feasibility study for production of Ultra-Low Sulphur Diesel for on-board reforming using adsorptive desulphurisation
- Study of developing process and providing technology information for simultaneous production of US-grade gasoline and pure benzene from FCC C6 heart cut
- Comparative study of diesel reforming processes (SDR, POX and ATR) using process simulator
- Carrying out revamp study of sour water stripper unit at Refinery-II in the Manali Refinery at CPCL, Chennai (Phase-I carrying out the adequacy study)
- Study on processing light vacuum gas oil from Mumbai high and Nile crude to produce paraffin wax at M/s MRPL
- Processing of light neutral distillate in NMP lube extraction unit at M/s CPCL
- Study for processing of LVGO & HVGO stocks for production of paraffin & microcrystalline wax at NRL
- Process engineering design package for solvent deoiling unit at NRL
- Basic design engineering package (BDEP) for solvent refining of base oil
- Development of new nano-structured mesoporous materials like SBA-15 for catalytic application in hydrotreatment
- Application of biofuels for aviation : green jet fuel from *Jatropha* oil (biojet) and bioethanol
- Nanostructured porous inorganic oxide materials with tailored pore size and their coatings for application to catalysis, environment and for inclusion of biomolecules
- Process design of soaker drum internals for revamp of visbreaker at the HPCL, Vizag Refinery
- Feasibility study for producing needle coke from residual fuel oil ex-Numaligarh Refinery
- Production of second- and third-generation biofuels (biomass-to-liquid)
- Installation of IIP-BTX model at the sulpholane extraction plant in M/s SABIC, UK Petrochemicals, UK

- Dye-sensitized Solar Cell (DSSC)/ Quantum Dot Dye Sensitized Solar Cell
- Hydropyrolysis of lignocellulosic biomass to value-added hydrocarbons
- Utilization of CO_2 feedstocks for production of value-added chemicals
- Development of process for normal dodecane fraction from straight-run kerosene obtained from a petroleum refinery
- Utilization of carbon dioxide for production of fuels and chemicals
- Valorization of glycerol for biodegradable base fluids and new biofuel formulations
- Production of biodiesel from low-cost feedstocks using heterogeneous catalyst
- Eco-friendly emulsion breaker for drill-cutting waste
- An integrated approach for utilization of bagasse pith for production of biethanol and value-added lignin production
- Boundary lubrication capabilities of ionic liquids and their futuristic applications to lubricant development
- Study on tribo-chemical events of ionic liquids
- Field trials on four-stroke motorcycles for performance evaluation of engine oils
- Operation of the Fuel Testing Laboratory at NOIDA
- Study of the effect of ionizing radiation on biomass for its conversion to ethanol
- Development of graphene-metal oxide nano-composites as potential candidates for photovolatic applications

4.2.2 In-House

- Studies on the flow behaviour of diesel matrix at different temperatures : wax additive interaction in relation to composition and properties of waxes
- Feasibility study for recovery of butanol from fermentation broths
- Feasibility study for upgradation of residual fuel oil (RFO) using non-HDS route
- Degradation/depolymerization of commingled plastic to produce value added products
- Feasibility study for production of pure benzene from light FCC gasoline
- Molecular modelling and simulation application for development of adsorbents for methane storage
- Studies on the use of e-waste for improving the properties of paving-grade bitumen
- Development of new fixed-bed sweetening catalyst
- Catalyst development for conversion of light naphtha to diesel
- Transformation of CO_2 to syngas ($CO+H_2$) over supported nano-structured mixed-metal catalytic systems
- Hydroprocessing of biomass derived oil : fractional distillation and detailed studies on fractions
- Selective oxidation of propylene to propylene oxide with molecular oxygen over nanocatalysts
- Making the Xytel unit into functioning one for catalyst evaluation
- Development of novel green catalytic methodologies for oxidation and acid-base catalyzed reactions
- Development of process for detergent-grade alpha-olefin sulphonates by using linear alpha olefins (C14-C18 range) from coker distillate of an Indian Refinery
- Development of an indigenous process for synthesis of N-Methyl-2-Pyrrolidone (NMP)
- Co-processing studies of biomass-derived fast pyrolysis bio-oil with vacuum gas oil in the fluid catalytic cracking (FCC) unit
- Synthesis, characterization and tribo-evaluation of cellulose fatty esters for biolubricant applications
- Conversion of lignocellulosic biomass to middle distillate hydrocarbons (C_{12}-C_{18}) and solvents (butanol) through biotechnology route
- Biocatalytic upgradation of crude oil
- Screening of thermophilic butanologen
- Genetic modification of oleaginous micro-organisms to enhance biofuel production

- Isolation, purification and characterization of photosensitive protein from anoxygenic photosynthetic bacteria
- To investigate the oxidation stability of a biolubricants for IC engine applications
- Combustion study of CI and SI engines
- Design and development of novel-type maintenance-free bearings
- µ-EHL & failure investigation in line contacts
- Study on the effect of fuel sensitivity on performance and emissions of modern spark ignition engines
- In-use particulate emission comparison of diesel and natural gas vehicles for Indian road conditions
- Development of a test method for evaluation of fuel oil additives for combustion performance
- Blending effect of bio-oil with conventional fuels and its performance
- Synthesis, development, characterization and evaluation of graphene-TiO_2 hybrid material for enhancement of photovoltaic cell efficiency

4.2.3 Network Projects (NWP)

- Adsorption technology development for high temperature acid gas removal in coal gasification
- Advanced solvents and blended formulations for CO_2 capture
- Metrology in chemistry (MiC) in petroleum-related area : standardization of biodiesel on at Indian level (Activity-1)
- Development of reference materials for lubricity, viscosity and trace metal analysis
- Organic and polymers (including protein)-based photovoltaics (OPV) (Novel approaches for solar energy conversion; technologies and products for solar energy utilization through networking)

4.3 Projects Completed

4.3.1 Sponsored

- Synthesis of room-temperature ionic liquids and study of their applications for extraction of sulphur, nitrogen & aromatic compounds from petroleum feedstocks
- Scale-up studies for conversion of waste plastic & low-polymer wax to value-added hydrocarbons
- Pinch technology study at AVU and DCU of the Digboi Refinery
- Study of crude oil analysis of IC complex
- Techno-economic feasibility of open-loop thermal-chemical S-I cycle of H_2S split for carbon-free hydrogen production in petroleum refinery
- Upgradation of clarified slurry oil (CSO) Ex-RIL by converting it into petroleum pitches (isotropic and mesophase)-precursors for advanced carbon materials
- Novel doped 3-D nanoporous oxides for dye-sensitized solar cells (DSSC)
- MAT testing of catalyst samples from HPCL, Vishakhapattanam
- Commercial development of reprocessing of pyrolysis gasoline
- Direct production of biodiesel from non-edible oil seeds by reactive extraction
- FZG gear scuffing performance evaluation of lubricating oils
- Evaluation of Servofyres HFDU 68 ES for GZG test
- Setting up of Modernized Emission Measurement Facility at IIP, Dehradun (Phase-I)
- Preliminary evaluation of Py-oil of M/s UOP
- Evaluation of fire-resistant hydraulic fluid samples
- Overhauling of CFR octane engines at M/s Reliance Industries Limited (RIL), Jamnagar, Gujarat
- Investigation of oil blackening of AI-20 aero engine
- Short evaluation studies on crude oil samples from ONGCL
- Evaluation of crude oil sample from the Mangala field of Rajasthan besides flash point and BS&W of crude oil from Viramgam and AGI 33 terminals

4.3.2 In-House

- Systematic studies on kinetics of CO_2 absorption in chemical and / or physical solvents and blends
- Novel solvent for CO_2 capture

- Development of carbon wool from petroleum pitches/residues
- Exploratory studies of hydrodenitrogenation (HDN) catalyst for refinery streams
- Single-step catalytic process to bio-jet fuels from triglycerides (Empower Project-1)
- Selective oxidation of methane to methanol with molecular oxygen over supported nanoclusters (Empower Project-2)
- Development of new-generation metal and phosphorus-free lubricant additives as substitutes for ZDDP
- Screening of algae oil for biodiesel production
- Chemically-derived graphene nanosheets as new-generation lubricant additives
- Conversion of Maruti-800 car into a solar-electric hybrid vehicle
- Optimization of domestic gas stove burner design (LPG/NG) for enhanced performance by mathematical modelling and an experimental method

4.3.3 CSIR-NIF Scheme Projects

Improvement of / value-addition to grassroots innovations :

- kero gas stove with lighting fixture
- *dosa* burner
- wood-fired stove
- jute match-stick
- modified auto engine for increasing mileage

4.3.4 Supra-Institutional Projects (SIP)

Development of Know-How and Technology for Environment-friendly Conversion And Utilization of Biomass to Fuels, Lubricants and Additives

- Development and improvement of heterogeneous catalyst for biofuels
- Pilot plant, scale-up and commercialization of biodiesel process
- Hydrotreating of vegetable oil for green diesel production
- Hydrogen production from glycerol
- Important chemical intermediates from glycerol
- Modified alkyd resin development for value-addition to glycerol
- Development of catalyst for production of ethers from glycerol
- Development of process know-how for bio-ethanol production from cellulosic and starchy biomass using thermophilic micro-organisms
- Process & technology for production of liquid and gaseous fuels by fast pyrolysis of biomass
- Upgradation of bio-oils to future fuels
- Gasification technology development for production of synthesis gas from carbonaceous feedstocks for downstream utilization
- Development of eco-friendly additives and lubricants: (1) saccharide-based bio-degradable lubricants and (2) additives for bio-degradable lubricants
- PSA process for CO_2 recovery from biomass pyrolysis / gasification off gas
- Development of absorption-based technologies for CO_2 capture from biomass-gasification flue gases
- Development of life-cycle analysis model for bio-mass conversion to fuels and lubricants
- Development of methods for compositional analysis of biofuels, biolubricants & additives
- Engine performance studies on bio-fuels, bio-lubricants and additives
- Tribological studies of bio-lubricants and fuels
- Corrosion behaviour studies on bio-fuels, bio-lubricants and additives
- Additive development and oxidative stability studies on biofuels and biolubricants

4.3.5 Network Project (NWP)

- Development of specialty inorganic materials for diverse applications

5

Enhancing R & D Infrastructure

5.1 New Facilities Created

5.1.1 Transient Test Bed Facility

This facility is equipped with transient AC dynamometer, CVS, partial and full-flow dilution tunnel, and pre- and post-cat emission analyzers. It was created to measure the performance and mass emission of engines in transient cycle. The dynamometer is capable of testing engines up to 400 kW. This fully instrumented facility enables performance mapping and emission measurement on transient test cycles.It consists of :

- 440 kW Transient Dynamometer
- CVS with Full Flow Dilution Tunnel
- Pre-Cat & Post-Cat Raw Gas Analyzers
- Diluted Exhaust Gas Analyzers
- Partial Flow Dilution Tunnel
- Conditioned Particulate Weighing Chamber
- Opacimeter
- Fuel Conditioning & Measurement
- Oil Conditioning & Measurement
- Coolant Conditioning and Intake Air Conditioning & Measurement

Transient Test Bed Facility

5.1.2 Research Engine Test Bench

A fully-instrumented research engine with variable compression ratios (indigenous make) was installed and commissioned. In this, the engine head can be changed to operate on both SI & CI fuels. Besides, all the combustion parameters can be studied.

RE Test Bench

5.1.3 CFR Octane Unit

A CFR octane engine was installed and commissioned for measuring octane rating of various fuels. This is a combination unit requiring only minor equipment adjustments to switch between the research and motor methods. Variable compression cylinder allows compression ratios to be changed during engine operation for a wide range of fuel tests.

CFR-O Unit

5.1.4 Anaerobic workstation

The anaerobic workstation, suitable for anaerobic and microaerophilic applications, provides with a generous working area and large incubation capacity in the smallest possible footprint. The workstation is fitted with unique 'rapid lock' manually-operated portholes that allow both access for the operator's arms and the simultaneous transfer of up to 20 x 90mm Petri dishes using high-comfort latex-free sleeves and cuffs. An automatic gas refill system for sleeves ensures that the internal atmosphere is not compromised by the transfer of oxygen through the ports. Sleeves can be operated with nitrogen as a cost-saving option if desired. The novel 'lift-off' facility – the whole top can be disengaged easily from the base – allows the addition and/or removal of bulk samples and equipment. Internal surfaces can be cleaned very easily as the floor will contain any spillage and there are no gaps through which loops or bottle caps can fall.

5.1.5 2D Gel Electrophoresis System

Two-dimensional polyacrylamide gel electrophoresis (2D-PAGE) is a form of gel electrophoresis in which proteins are separated and identified in two dimensions oriented at right angles to each other. In this technique, proteins are separated by two different physical properties. The first dimension, isoelectric focussing, separates proteins on the basis of their net charge. The second dimension, SDS-PAGE, further separates the proteins by their mass. Small changes in charge and mass can easily be detected by this method, because it is rare that two different proteins will resolve to the same place in both dimensions.

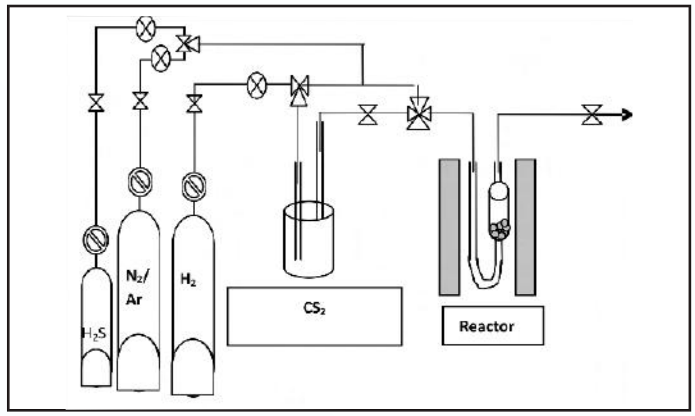
5.1.6 Total Organic Carbon (TOC)

Total Organic Carbon (TOC) analyzer adopts the combustion catalytic oxidation method which provides an ultra-wide range of 4 µg/L to 30,000 mg/L through co-ordination with NDIR. This is the highest level of detection sensitivity available with the combustion catalytic oxidation method. In addition, the combustion catalytic oxidation method makes it possible to efficiently oxidize not only easily-decomposed, low-molecular-weight organic compounds, but also hard-to-decompose insoluble and macromolecular organic compounds. The automatic dilution function enables measurements up to 30,000 mg/L. It is capable of TC, IC, TOC, and even TN (total nitrogen) measurements. Simultaneous measurement of TOC and TN (total nitrogen), and the measurement of gas samples and solid samples is also possible with this unit.

TOC instrument (Model: TOC-L CSH with TNML and SSM-5000A)

5.1.7 Atmospheric Activation and Regeneration Unit

Hydroprocessing catalysts are prepared in oxide form in general. This oxide form is not an active phase for hydroprocessing reactions. The catalysts used in these reactions are activated before reactions. The activation can be done *in-situ* and *ex-situ*. Generally, for continuous flow reactor, the activation is carried out *in-situ,* i.e., the catalysts are loaded once inside the reactor and activation is done prior to reaction without taking out the catalysts. But in *ex-situ* process, the catalysts are activated outside the reactor and these activated catalysts are then transferred to the reactor for reaction. *Ex-situ* activation is used to study hydroprocessing activities in the batch reactor. Therefore, for our requirement, one activation unit was designed and fabricated. This unit can also be used for multiple purposes like activation, regeneration, study of catalyst acidity, activity determination of catalyst by using model compounds, etc.



Simplified Flow Diagram for Catalyst Activation

Catalyst Activation and Regeneration Reactor System

5.1.8 Sulphur Analyzer

A Sulphur Analyzer from M/s Oxford Instruments provides for measurement of a wide range of sulphur concentrations from ppm levels to 9 wt%.

Oxford-XRF Sulphur Analyzer

6

Important Events

6.1 Foundation Days

6.1.1 70th CSIR Foundation Day (celebrated belatedly on November 1, 2011) Celebrations

The CSIR Foundation Day function was held in the Dr Lovraj Kumar Auditorium. Mr R S Butola, Chairman & Managing Director, IOCL, was the Chief Guest while Dr R K Malhotra, Director (R&D), IOCL, was the Guest of Honour. Dr M O Garg, Director, CSIR-IIP, welcomed the guests and said that the pace of industrialization had found a boost through the 38 laboratories and 39 field stations of the CSIR. He spoke about the ro le played by the CSIR and the CSIR-IIP in the development of the country.

Mr R S Butola initiating the Foundation Day proceedings. Others on the podium: Dr Y K Sharma, Dr R K Malhotra, Mr V K Kaushika, Dr M O Garg and Ms Sheetal Bandhu

Mr Butola stressed on the need to implement long-term strategies to ensure fuel supply in the future. Energy is important for the development of the nation, especially cheap and sustainable energy. Research on alternate sources of energy, e.g. solar, bio-, non-conventional and nuclear, is the need of the hour to ensure energy supply equal to its demand. Fuel supply in the future is a constant global concern. Traditional sources of energy have been reduced to a limit. The main reason behind this is the insufficiency of the storage of crude oil. It is necessary to develop alternative sources of energy and the CSIR-Indian Institute of Petroleum can take effective action in this direction by developing new technologies, he said.

Dr R K Malhotra, in his address, underlined the need to speed up research activities for technological development. He pointed out that India ranks third as a carbon-emitting nation after the USA and China. In this light, long-term strategies for future supply need to be worked upon. He also suggested that the experts from the IOCL and the CSIR-IIP could team up to conduct research in petro sector. Technologies addressing the need to deal with heavy, acidic and high sulphur content crude oil need to be developed, he said.

The Chief Guest flanked by the other dignitaries

Green Operation

'CSIR@70' also envisioned a 'Green Operation' for the CSIR's national laboratories and institutes beginning on its 70th Foundation Day. This was observed with a plantation drive at the CSIR-IIP. The CSIR has now adopted the maintenance & sustenance of the eco-system along with the maintenance of greenery as its target along with science & technology.

Sports Event

A carrom competition was also organized in view of the 70th CSIR Foundation Day celebrations. Details can be found in this chapter at 6.7.2.

Inauguration of the Modernized Knowledge Resource Centre (KRC)

The Chief Guest also inaugurated the newly refurbished and modernized Knowledge Resource Centre (KRC) of the Institute on this occasion.

Mr Butola unveils the inaugural plaque of the Knowledge Resource Centre

6.1.2 CSIR-IIP Foundation Day & Dr Bhimrao Ambedkar Jayanti, April 14, 2012

The Institute celebrated its 52nd Foundation Day on April 14, 2012. On this occasion, the foundation stone for a new building of the Kendriya Vidyalaya, CSIR-IIP, Dehradun, was laid by Dr M O Garg, Director. The main attraction of the function was the CSIR-IIP Foundation Day Lecture delivered by Mr Sudhir Vasudeva, Chairman & Managing Director, ONGC. Mr Vasudeva later inaugurated the Modernized Emission Measurement Facility Laboratory in the campus, too.

Mr Sudhir Vasudeva lights the inaugural lamp

Delivering the lecture, he said that the need of the day is to develop energy-efficient and environment-friendly technologies which are globally competitive. He stressed on the need to develop bio-chemical processes as these are known to be less energy-intensive and to adopt simulation and modelling techniques effectively.

Talking about the phenomenon of 'Brain-Drain', Mr Vasudeva said that we could have prevented it. This trend, born in the fifties and sixties, is alive and kicking even

Dr Garg lays the foundation stone for a new KV-IIP building as the KVS & KV-IIP officials felicitate

today. As many as 12% scientists & 38% doctors in the USA are Indians, and in NASA alone, 36% or almost 4 out of 10 scientists are Indians. Further, 34% employees at Microsoft, 28% at IBM, 17% at Intel and 13% at Xerox are Indians. Even today, Indians comprise the second highest batch of foreign students in the US universities, most of whom prefer to stay back. There is a need to reverse the process.

Dr Garg & Mr Vasudeva paying respects to Dr Ambedkar

Mr Vasudeva said that at present India's R & D spend is merely 0.9% of its GDP. In terms of numbers in US dollars adjusted for PPP, it amounts to 36.1 billion. Compared to the top three nations, i.e., USA, China and Japan with figures of US $ 405.3, 153.7 and 144.1 respectively, the contrast becomes very stark. While this investment has to increase, it is important to determine where these additional investments have to be made to place us in a global leadership role. His message to the scientists was : *"Dream —Envision —Realize".*

Earlier Mr Vasudeva, Dr Garg & others paid their tributes to Dr Bhim Rao Ambedkar on his *Jayanti* which falls on 14th April every year coinciding with the CSIR-IIP Foundation Day.

6.2 National Days

6.2.1 National Technology Day, May 11, 2012

"Technology focus is sharper today as it goes on changing continuously. Hence innovation is essential to keep pace with R&D. Many organizations have been seen to have perished due to lack of innovation. As this has been declared as a 'Decade of Innovation' by our Hon'ble Prime Minster, we have to focus on innovation in our R&D organizations." Such were the thoughts expressed by Dr R K Malhotra, Director (R&D), Indian Oil Corporation Limited

(IOCL), speaking as the Chief Guest on the occasion of the National Technology Day at the Institute.

Dr R K Malhotra initiating the National Technology Day programme

Dr Malhotra stressed upon the need to have visionary leaders for R&D. *"We have to pick up from the threads of basic research and make it a marketable product,"* he said. Innovation in his opinion included, in its ambit, innovation in the way of thinking & working also. Dr Malhotra stressed upon the pursuit of alternative sources of energy as oil & gas will still continue to supply a major part of it. These alternative sources include bio-mass, agro-based, solar, gasification-, thermal, algaes & gas hydrates which need more focus.

6.2.2 Independence Day, August 15, 2012

The 66th Independence Day of the country was celebrated on August 15, 2012. Dr M O Garg, Director hoisted the Tricolour on this occasion. Essay and Drawing Competitions were organized for the children of the staff members on this occasion.

Dr Garg accepts the salute on the Independence Day

6.2.3 गणतंत्र दिवस समारोह, 26 जनवरी, 2013

गणतंत्र दिवस समारोह का आयोजन मुख्य भवन के प्रांगण में किया गया जिसमें निदेशक महोदय ने बीते वर्ष की उपलब्धियों की चर्चा की। पारंपरिक रूप से केंद्रीय विद्यालय, भापेसं के बच्चों द्वारा प्रस्तुत उत्तम सांस्कृतिक प्रस्तुतियों ने समाँ बांध दिया।

विविधताओं का देश भारतः गणतंत्र दिवस पर स्कूली बच्चों की सांस्कृतिक प्रस्तुति

6.2.4. National Science Day, February 28, 2012

National Science Day was celebrated on February 28, 2013. It may be recalled that it was on this day in 1928 that Sir Chandrasekhar Venkat Raman had discovered the radiation effect involving the inelastic scattering of light later known as "Raman Effect". Sir Raman was awarded the Nobel Prize on December 11, 1930 for this discovery. He was the first Asian to get the Nobel prize in any disciple of science. His discovery is now a powerful technique in physical and chemical research, particularly for characterization of materials. February 28 is celebrated as the National Science Day by all the scientific organizations throughout the country.

Dr Y V N Krishnamurthy initiates the National Science Day proceedings

The programme was inaugurated by the Chief Guest Dr Y V N Krishnamurthy, Director, Indian Institute of Remote Sensing, Dehradun. He gave a presentation in which he discussed Uttarakhand's water resources. He cautioned that water sources in Uttarakhand are disappearing. He said that the Indian Space Research Organization (ISRO) is working on a technology through which they will try to find the path of water resources which will help in finding the ways to recharge them.

The Chief Guest director also said that his institute would hold discussions with CSIR-IIP to explore common areas of interest. Speaking on remote sensing, he said that this technology can play a significant role in mineral exploration. He cited examples of remote sensing being used in India for exploration of diamonds, copper, iron ore and manganese. Dr Krishnamurthy said that work in science has its frustrating moments but one should focus on the light at the end of the tunnel.

Dr Garg said: *"India has the third largest technical manpower in the world and all the developments in the country are due to the advancements in science and technology in the last 80 years,"* he said. *"But it is regrettable that no other Indian after Sir C V Raman has won the Nobel Prize in science since then,"* he added. He called upon the younger generation to *"take an oath to dedicate themselves and win the Nobel Prize".*

6.3 State-wide Missions

6.3.1 Oil & Gas Conservation Fortnight, January 15-31, 2013

The third week of January 2013 saw the Oil and Gas Conservation Fortnight, jointly organized by the CSIR-Indian Institute of Petroleum, IOC, BPCL and Petroleum Conservation Research Association getting kicked off with its inauguration by Mr Pritam Singh, Hon'ble Minister of Food & Civil Supplies, Minor Irrigation, Rural Development & Panchayati Raj, Government of Uttarakhand, as the Chief Guest.

Present on the occasion besides Mr Pritam singh were Dr M O Garg, Director, CSIR-IIP; Mr Ashwani Dua, State Coordinator, Oil Companies; Mr Mayank Bhatnagar, Chief Regional Manager, HPCL and Dr S K Sharma, Scientist, CSIR-IIP.

Welcoming the Chief Guest, Dr M O Garg said that in the present context energy and environment play an important role, and with the increase in Green House Gases there has been a great environmental imbalance.

Inaugural moments of the fortnight

The need of the hour is to come forward with energy-efficient technologies for cutting down its usage.

Speaking on the occasion, the Chief Guest, Mr Pritam Singh, said that the increasing use of oil is a matter of grave concern for the country and the world. *"Each and every drop of oil is precious and it must be conserved and its preservation should become part of everyone's life"*, he said.

Human chain formation on 'Save Oil'

Mr Ashwani Dua said that in our country, energy is used in various fields such as industry, transport, agriculture and for domestic use. He said that the oil industry would organize awareness workshops during the fortnight in all the districts of Uttarakhand. The programme ended with a human chain formation by the students of the KV, CSIR-IIP and Guru Ram Rai Public School, Dehradun. The Chief Guest flagged off a van carrying publicity material for the Fortnight.

6.4 Exposure Events

6.4.1 Scientific Advisory Committee (SAC) Meet, June 28-29, 2012

The 71st Meeting of the Scientific Advisory Committee (SAC) of the Ministry of Petroleum & Natural Gas (MoP&NG) on Hydrocarbons was organized in the CSIR-IIP during June 28-29, 2012.

Mr Arun Balakrishnan, Chairman, SAC (centre), presides over the SAC meeting

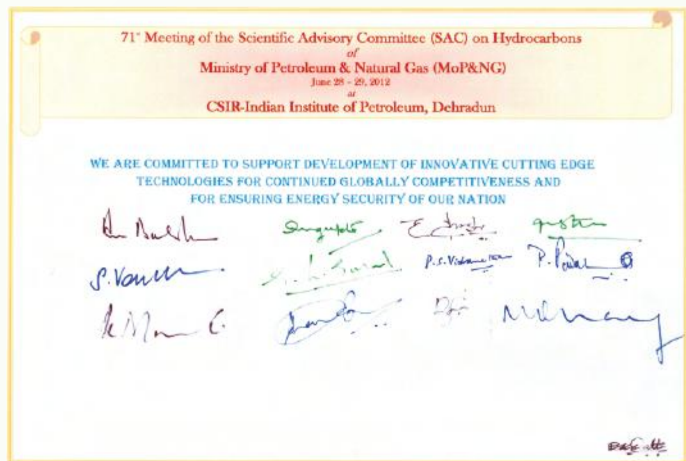
The deliberations included discussions on, and approval of, the revised SAC Charter; areas of R&D, new technologies for continuous improvement of the hydrocarbon sector and '*Indian innovations*'.

The meeting was attended by Mr Arun Balakrishnan, Chairman, SAC; Mr L N Gupta, JS, MoP&NG; Dr R K Malhotra, Director, IOCL (R&D); Mr B Basu; Mr R K Ghosh, Director (Ref), IOCL; Mr B K Datta, Director (Ref), BPCL; Mr K Murali, Director (Ref), HPCL; Mr S Venkaratamana, MD, CPCL; Mr B D Ghosh, ED, CHT; Prof Shantanu Roy, IIT-Delhi; Mr P S Viswanathan, Head (R&D), BPCL; Mr G Sri Ganesh, ED (R&D), HPCL; Dr S Banik, Mr Jagdish Singh & Mr A S Pathak from the CHT; Mr R P Verma & Dr N V Choudhary from the HPCL; Mr Shantanu Das, Mr Bharat Newalkar, Mr V Ravi Kumar & Mr Padmanabhan from the BPCL; Dr R N Maity, EIL; Dr Sriniwas, BITS; Dr Ponnani & Prof M S Babu, Gitam University; Mr B N Prabhu and Mr Anil Bhardwaj, ONGC; Dr A S K Sinha, IT, Bhubaneshwar; Dr Sanjukta Subudhi, TERI, Delhi; Mr M V Lall, Chief Geologist, DGH & Mr S K Nema, Plazma.

Showcasing the Institute's activities

The SAC members also affirmed their endorsement to support and develop indigenous technologies for inclusive growth of the nation and the oil industry by signing a pledge.

The on-going activities of the Institute were showcased in a poster presentation by various research groups working in the Institute. A newly built facility for bio-jet fuels (Pilot Plant) was inaugurated by Mr L N Gupta, Joint Secretary, MoP&NG.



71st Meeting of the Scientific Advisory Committee (SAC) on Hydrocarbons
of
Ministry of Petroleum & Natural Gas (MoP&NG)
June 28 - 29, 2012
at
CSIR-Indian Institute of Petroleum, Dehradun

WE ARE COMMITTED TO SUPPORT DEVELOPMENT OF INNOVATIVE CUTTING EDGE TECHNOLOGIES FOR CONTINUED GLOBALLY COMPETITIVENESS AND FOR ENSURING ENERGY SECURITY OF OUR NATION

An image of the pledge

6.5 Policy-related Events

6.5.1 SCOE and CMVR-TSC Meetings

CSIR-IIP hosted meetings of the Standing Committee on Implementation Emission Legislation (SCOE) and meeting of the Central Motor Vehicle Rules–Technical Standing Committee (CMVR-TSC) on July 9, 2012.

Around 60 participants from various Ministries, ARAI, Members of the Society of Indian Automobile Manufacturers (SIAM), Emissions Control Manufacturers' Association (ECMA) and other industry experts attended both the meetings. These meetings were convened by Mr Srinivas and Mrs Rashmi Urdhwareshe, Automotive Research Assocaition of India (ARAI), Pune. Some of the agenda points deliberated upon in the meeting of the Standing Committee on Emission Legislations (SCOE) were: rules for replacement of catalytic converters, introduction of audit systems for PUC centres, hydrogen

Members of SCOE and CMVR-TSC pose together

and hydrogen CNG (HCNG) as an automotive fuel, discussion on consultation documents for Fuel Efficiency Norms to be prepared by the Bureau of Energy Efficiency (BEE), applicability of diesel engine emission norms for engines not covered under the CMVR/MoEF certification, updating of Indian Driving Cycle (IDC) for two- and three-wheelers, etc.

6.6 Research Management Events

6.6.1 CSIR-IIP Research Council Meeting, September 6, 2011

The 38th Research Council Meeting on August 30-31, 2012 was chaired by Prof D V Khakhar, IIT-Mumbai, and attended by Mr Anand Kumar, PETROTECH, New Delhi; Prof I M Mishra, IIT-Roorkee; Mr P Padmanabhan, BPCL, Mumbai and Mr Pramod Kumbhar, VP, Praj Industries.

Prof D V Khakhar (second from right) presides over the RC meeting; Dr M O Garg sits next to him

6.7 हमारा क्रीड़ा पक्ष

6.7.1 44वीं शांति स्वरूप भटनागर स्मृति खेल–प्रतियोगिता (मैदान –खेल : आंचलिक), 1–3 फरवरी, 2012

सीएसआइआर–भापेसं स्टाफ क्लब के तत्वावधान में सीएसआइआर–राष्ट्रीय पर्यावरण इंजीनियरी अनुसंधान संस्थान (CSIR-NEERI), नागपुर में आयोजित 44वें शांति स्वरूप भटनागर स्मृति टूर्नामेंट–इनडोअर (SSBMT-Indoor) (फरवरी 1–3, 2013) में सीएसआइआर–भापेसं से कुल 13 खिलाड़ियों ने विभिन्न प्रतियोगिताओं यथा – बैडमिंटन, टेबल टेनिस, ब्रिज, शतरंज एवं कैरम बोर्ड – में भाग लिया। इनमें से 5 खिलाड़ियों ने फाइनल में जगह बनाई । फाइनल के लिए स्थान बनाने वाले खिलाड़ियों के नाम इस प्रकार हैं :–

बैडमिंटन (टीम) : श्री देवेन्द्र राय, श्री बी बी डिमरी एवं श्री टीकाराम भट्ट।

टेबल टेनिस (टीम) : श्री एस सी भट्ट एवं श्री एन के रावत।

डॉए मअ ेग र्गक ैरमप्र तियोगिताक ाउ द्घाटनक रतेह ुए

6.7.2 जिला–स्तर की दो–दिवसीय कैरम प्रतियोगिता का आयोजन

70वें **सी एस आइ आर** स्थापना–दिवस के उपलक्ष्य में संस्थान के स्टाफ क्लब द्वारा आयोजित दो–दिवसीय **'द्वितीय जिला–स्तरीय कैरम प्रतियोगिता'** का आयोजन 22 व 23 सितंबर, 2012 को आइ आइ पी समुदाय केंद्र में किया गया।

6.8 Employee Awareness Drives

6.8.1 Vigilance Awareness Week, October 29 - November 3, 2012

As per the directives of the Central Vigilance Commission, New Delhi, received through the CSIR-Hqrs., New Delhi, a Vigilance Awareness Week (October 29-November 3, 2012) was organized which commenced with a pledge on 29th October, 2012.

On this occasion, a debate competition was organized on 02.11.2012 on the topic *"Corruption and Public Servants".*

6.9 सामाजिक एवं सांस्कृतिक गतिविधियाँ

6.9.1 सांस्कृतिक संध्या

सीएसआइआर–भापेसं स्टाफ क्लब की ओर से सांस्कृतिक संध्या *'एकश ामस ंस्थानक ेन म'* का आयोजन दिनांक 8.11.2012 को किया गया।

सांस्कृतिकस ंध्याक ाए कझ लक

6.9.2 लोहड़ी व मकर संक्रांति

13 जनवरी, 2013 को मकर संक्रांति तथा लोहड़ी पर्व के शुभावसर पर स्टाफ क्लब कार्यकारिणी द्वारा लोहड़ी उत्सव का आयोजन किया गया, जिसमें एक अलाव जलाकर ऋतु–परिवर्तन का स्वागत किया गया और गीत–संगीत के साथ पारंपरिक प्रसाद–वितरण हुआ।

6.9.3 मीना बाजार

26 जनवरी 2013 को एक वार्षिक मेले (मीना बाजार) का आयोजन भी स्टाफ क्लब के माध्यम से कर एक परंपरा स्थापित की गई। मेले का उद्घाटन श्रीमती अलका गर्ग द्वारा किया गया।

श्रीमतीअ लकाग र्गद्व ाराव ार्षिकम`लेक ाउ द्घाटन

6.10 COMMUNITY HEALTH DRIVES

6.10.1 Voluntary Blood Donation Camp

A Blood Donation Camp was organized on December 13, 2012 in which 70 units of blood were collected. Blood camp is a regular feature in the CSIR-IIP community. The practice has as its basis the philosophy of saving lives.

Mrs Alka Garg, inaugurating the Blood Donation Camp, felicitate by Dr Lalita Bakaya, Sr RMO

6.10.2 Typhoid Vaccination Drive

A camp for Vaccination Against Typhoid was organized by the CSIR-IIP Medical and Health-Care Centre on April 23, 2012.

6.10.3 Hepatitis 'B' Vaccination Drive

Screening Camp for Hepatitis-B & Hepatitis-C was organized on February 27, 2013.

6.10.4 Blood Sugar Camp

- A Free Blood Sugar Camp was organized to assess glycosylated haemoglobin in diabetic patients at the CSIR-IIP Healthcare Centre on August 29, 2012
- Another Blood Sugar Camp was witnessed on February 6, 2013

7

Research & Management Bodies

7.1 THE CSIR-IIP RESEARCH COUNCIL

Chairman
Prof Devang V Khakhar
Director
Indian Institute of Technology, Bombay
P.O.-IIT, Powai, Mumbai – 400 076

External Members

Mr P K Kapil
Executive Director
Reliance Industries Ltd.
Village Meghpar/Padana, Taluka-Lapur
Dist Jamnagar – 361280

Mr K Murali
Director
Hindustan Petroleum Corporation Ltd.
17, Jamshedji Tata Road, Church Gate
Mumbai – 400020

Dr D M Kale
Advisor & Ex-DG
Chief Engineer Centre
Oil and Natural Gas Commission
5th to 15th Floor, South Tower
Scope Minar, Laxmi Nagar
New Delhi – 110092

Mr K Balachandran
Managing Director
Chennai Petroleum Corporation Limited
536, Anna Salai, Teynampet,
Chennai – 600018

Mr P Padmanabhan
General Manager (Technical)
Bharat Petroleum Corporation Ltd.
Refinery, Mahul
Mumbai – 400074

Mr A S Basu
Executive Director
Indian Oil Corporation Ltd.
Scope Complex, Core – 2
7, Institutional Area, Lodhi Road
New Delhi – 110003

Dr Balu Sarma
President & Chief Technology Officer
PRAJ MATRIX-The Innovative Center
(A Division of Praj Industries Ltd.)
Gate No. 1098, 402 & 403, Urawade
Taluka-Mulshi
Pune- 411042

Prof I M Mishra
Professor
Deptt of Chemical Engineering
Indian Institute of Technology, Roorkee
Saharanpur Campus, Paper Mill Road
Saharanpur – 247001

Mr Anand Kumar
Former Director (R&D)
Indian Oil Corporationn Ltd &
Director, Petrotech-India
602, Tolstoy Bhavan, Tolstoy Marg
Rajiv Gandhi Chowk
New Delhi – 110001

Mr S K Srivastava
Director-General
Directorate-General of Hydrocarbons
C-139, Sector-63
NOIDA – 201301

D-G's Nominee(s)

Dr B D Kulkarni
Dy Director & Head
Chemical Engineering &
Process Development Division
National Chemical Laboratory
Pashan Road, Pune – 411008

Dr Amalendu Sinha
Director
Central Institute of Mining & Fuel Research
Barwa Road
Dhanbad – 826015

Cluster Director

Dr S Sivaram
CSIR Bhatnagar Fellow
A 201, Polymers & Advanced
Materials Laboratory
National Chemical Laboratory
Dr. Homi Bhabha Raod
Pune – 411008

Director

Dr M O Garg
Director
Indian Institute of Petroleum
PO-IIP, Mohkampur
Dehradun – 248005

Permanent Invitee

Head or His Nominee
Planning & Performance Division
Council of Scientific & Industrial Research
Anusandhan Bhawan, 2-Rafi Marg
New Delhi – 110001

Secretary

Mr B M Shukla
Head, RPBD
Indian Institute of Petroleum
PO-IIP Mohkampur
Dehradun – 248005

7.2 THE CSIR-IIP MANAGEMENT COUNCIL

Chairman
Dr M O Garg
Director

Internal Members

Dr S S Ray
Senior Principal Scientist

Mr S K Ganguly
Principal Scientist

Dr Suman Lata Jain
Senior Scientist

Dr O P Khatri
Senior Scientist

Dr Lalita Bakaya
Principal Technical Officer (3)

Mr B M Shukla
Chief Scientist
Head, RPBD

Mr M S Mehra
F&AO

Mr V K Kaushika
CoA (Secretary)

External Member

Prof S K Bhattacharya
Director
CBRI, Roorkee

8

राजभाषा

8.1 'राजभाषा हिंदी विशिष्ट व्याख्यानमाला'

8.1.1 '12वाँ पुष्प', 29 जून, 2012

'राजभाषा हिंदी विशिष्ट व्याख्यानमाला' के 12वें व्याख्यान का उद्‌घाटन करते हुए श्री विजय कुमार कौशिक, प्रशासन नियंत्रक ने कहा कि इन व्याख्यानों के आयोजन से संस्थान ने राजभाषा कार्यान्वयन के क्षेत्र में अपनी विशिष्ट पहचान बनाई है । आज हम अधिकांश पत्राचार, टिप्पण लेखन आदि कार्य खुलकर हिंदी में करने लगे हैं।

कार्यक्रम का संचालन करते हुए डॉ0 दिनेश चंद्र चमोला, वरिष्ठ हिंदी अधिकारी ने कहा कि अनुवाद ज्ञान–विज्ञान का सेतु और ज्ञान की अभिव्यक्ति का माध्यम है। भारतीय भाषाओं में एक–दूसरे से नैकट्य पाने के लिए भी अनुवाद प्रासंगिक है।

मुख्य अतिथि प्रो0 कृष्ण कुमार गोस्वामी, प्रख्यात भाषा–वैज्ञानिक, दिल्ली ने 'अनुवाद और भाषा–विज्ञान' विषय पर अपना विद्वत्तापूर्ण और सारगर्भित व्याख्यान दिया। प्रो0 गोस्वामी ने हिंदी के संदर्भ में सांविधानिक उपबंधों (धारा 343–351) की चर्चा करते हुए बताया कि हिंदी के तीन विशिष्ट संदर्भ हैं––जनपदीय, राष्ट्रीय और अंतर्राष्ट्रीय। जनपदीय संदर्भों में हिंदी देश के दस हिंदी–भाषी राज्यों में प्रयुक्त है। राष्ट्रीय संदर्भ में हिंदी के दो स्वरूप हैं––राष्ट्रभाषा व राजभाषा। जहां राष्ट्रभाषा सांस्कृतिक चेतना, सामाजिक–सांस्कृतिक पहचान और संपर्क भाषा के रूप में देश के विभिन्न हिस्सों में अपने विशिष्ट स्वरूपों में, जैसे दक्खनी हिंदी के रूप में प्रयुक्त है, वहीं राजभाषा के रूप में यह सरकार व जनता के बीच संपर्क–भाषा के रूप में प्रयुक्त है। अंतर्राष्ट्रीय संदर्भों में जहाँ एक ओर हिंदी मॉरिशस, फिजी, सुरीनाम आदि देशों में भारतवंशी लोगों की भाषा के रूप में 50–70 प्रतिशत लोगों द्वारा अपनी सामाजिक–सांस्कृतिक पहचान के रूप में प्रयोग की जाती है, वहीं दूसरी ओर हिंदी अपने अंतर्राष्ट्रीय संदर्भों में अन्य देशों में अध्ययन की भाषा के रूप में है और 150 देशों में पढ़ाई जाती है। प्रो0 गोस्वामी ने प्रशासनिक, वैज्ञानिक, संचार, वाणिज्य जैसे क्षेत्रों में प्रयुक्त होने वाली हिंदी के विशिष्ट स्वरूपों की चर्चा करते हुए कहा कि यह भाषा का 'प्रयुक्ति' (register) पक्ष है कि एक शब्द के अलग–अलग संदर्भों में अलग–अलग अर्थ होते हैं। 'प्रयुक्ति' भाषा की एक विशेष शैली होती है, जैसे सामाजिक शैली, संरचनात्मक शैली आदि। प्रो0 गोस्वामी ने रेखांकित किया कि पहले अनुवाद मात्र धार्मिक पुस्तकों आदि के होते थे, उसके बाद कला क्षेत्र अर्थात् कविता, कहानी, उपन्यास आदि के अनुवाद हुए और अब वैज्ञानिक पुस्तकों आदि के भी अनुवाद हो रहे हैं जिसके लिए विशिष्ट शब्दावली का विकास किया जाता है।

8.1.2 '13वाँ पुष्प', 21 सितंबर, 2012

'राजभाषा हिंदी विशिष्ट व्याख्यानमाला' के 13वें व्याख्यान मे अपने उद्‌गार व्यक्त करते हुए प्रो० दुर्गा प्रसाद गुप्त, जामिया मिलिया इस्लामिया विश्वविद्यालय, दिल्ली ने संस्थान में आयोजित किए जाने वाले हिंदी कार्यक्रमों की चर्चा करते हुए यहां हिंदी के प्रति विद्यमान प्रेम की सराहना की। प्रो० गुप्त ने अन्य भाषाओं की तुलना में हिंदी की अपेक्षया कम उम्र के होते हुए भी इसकी श्रेष्ठ उपलब्धियों

व्याख्यानद`तेह्‌,एप्‌्र१०ड ीप ीग्‌ुप्त

की बात कही । इसके बावजूद हम पर औपनिवेशिक अतीत की छाया होने के कारण ही हिंदी की वर्तमान शोचनीय स्थिति है। 60 करोड़ से अधिक लोगों की इस भाषा के अनेक रूप हैं। यह भाषा भारत की भाषिक और सांस्कृतिक विविधता का प्रतीक है। हिंदी किसी एक विशेष राज्य अथवा जाति की भाषा नहीं है। अपने उदार चरित्र के कारण हिंदी विश्व के श्रेष्ठतम साहित्य एवं भारतीय भाषाओं के साहित्य की अभिव्यक्ति बनी है। किंतु राजनीति के कारण हिंदी जैसी भाषा का विरोध होता है। भाषा संस्कृति की वाहक है और इसे विस्मृत करने के कारण संस्कृति के विभिन्न वाहक जैसे नृत्य, रंगमंच आदि हिंदी प्रदेश से लुप्त हो रहे हैं। हम दूसरों की भाषा, संस्कृति, खान–पान, पहनावे को अपने देश की भाषा आदि से श्रेष्ठतर मानते हैं। प्रो० गुप्त ने आश्चर्य प्रकट किया कि भारत को छोड़कर विश्व में अन्य कहीं भी प्राथमिक शिक्षा मातृभाषा से इतर भाषाओं में नहीं दी जाती । कठिन शब्दावली का आरोप हिंदी पर ही लगता है, अंग्रेजी पर नहीं । प्रो० गुप्त ने सरकारी व अन्य संस्थानों द्वारा किए जाने वाले भाषा प्रयत्नों की आलोचना एवं रचनात्मक सहयोग के अभाव को एक विडंबना बताया। यद्यपि अनुवाद की चुनौतियां तो रहेंगी ही । हम बहुत–सारी गुलामियों में जी रहे हैं, जिनका प्रारंभ भाषा से होता है। हमें अपनी भाषा में ज्ञान–विज्ञान लिखना व सीखना चाहिए तथा सृजनात्मकता को अपनाना चाहिए, नहीं तो एक राष्ट्र के रूप में हमारा अस्तित्व समाप्त हो जाएगा।

इससे पूर्व डॉ० दिनेश चमोला, वरिष्ठ हिंदी अधिकारी ने मुख्य अतिथि का परिचय दिया और कहा कि हिंदी बाजार, एकता व अखंडता की भाषा है। अन्य सभी भाषाएं भी ज्ञान की सरिताएं हैं। पर अपनी भाषा का सम्मान आवश्यक है। मीडिया भी सफलता के लिए हिंदी का माध्यम अपना रहा है। हिंदी में विज्ञान भी मूल रूप से लिखा जाना चाहिए।

मुख्य अतिथि का स्वागत करते हुए श्री विजय कुमार कौशिक, प्रशासन नियंत्रक ने आशा व्यक्त की कि इस व्याख्यान से संस्थान में एक नई चेतना का उदय होगा। अंततः श्री सुरेन्द्र कुमार, प्रशासन अधिकारी ने सभी का धन्यवाद ज्ञापित किया।

8.1.3 '14वाँ पुष्प', 27 फरवरी, 2013

'कार्यालयीन अनुवाद : वैज्ञानिक संस्थानों के संदर्भ में' विषय पर 'उत्तराखंड भाषा संस्थान' व 'डॉ0 पी0 द0 बड़थ्वाल हिंदी अकादमी,

उत्तराखंड', देहरादून के सचिव डॉ० एम् आर सकलानी ने एक सारगर्भित और धाराप्रवाह व्याख्यान दिया। डॉ० सकलानी ने विषय के विभिन्न पक्षों पर प्रकाश डालते हुए श्रोताओं का ज्ञानवर्द्धन किया।

कार्यक्रम का संचालन करते एवं डॉ० सकलानी का परिचय देते हुए संस्थान के वरिष्ठ हिंदी अधिकारी डॉ० दिनेश चंद्र चमोला ने अनुवाद की आवश्यकता, महत्व व कार्यालयीन पद्धति में उसके स्थान पर दो शब्द कहे।

धन्यवाद प्रस्ताव देते हुए प्रशासन नियंत्रक श्री विजय कुमार कौशिक ने श्रोताओं से आग्रह किया कि हमें विशय के महत्व को आत्मसात् करना चाहिए।

8.2 हिंदी समारोह

8.2.1 हिंदी माह समापन समारोह, 30 सितंबर, 2012

विभिन्न प्रतियोगिताओं व अन्य आयोजनों से परिपूर्ण 'हिंदी माह–2012' का समापन प्रो0 रतन कुमार पांडेय, अध्यक्ष हिंदी विभाग, मुंबई विश्वविद्यालय, मुंबई के मुख्य अतिथित्व में आयोजित एक भव्य समारोह के साथ हुआ।

प्रो० पांडेय ने कहा कि हम एक स्वतंत्र व संप्रभु लोकतंत्र के रूप में 64 वर्ष राजभाषा के साथ बिता चुके हैं। यह दुःख की बात है कि हम हिंदी को कुछ विशेष दिनों तक ही सीमित रखते हैं। प्रो० पांडेय ने हिंदी की राजभाषा के रूप में सांविधानिक स्थिति और इस संबंध में दक्षिण भारत में हिंदी विरोधी आंदोलन की चर्चा करते हुए आश्चर्य–मिश्रित दुख प्रकट किया कि अपनी क्षेत्रीय भाषा अर्थात तमिल को बचाए जाने की अपेक्षा वहां गुलाम बनाने वाली विदेशी भाषा अर्थात अंग्रेजी को ही बचाने का आंदोलन हुआ। यह समझा ही नहीं गया कि हमारे देश के नायकों ने विभिन्न भाषा–भाषी क्षेत्रों के होते हुए भी यदि हिंदी का ही संपर्क भाषा, राष्ट्रभाषा या राजभाषा के रूप में चयन किया था, तो आखिर क्यों ? उदारीकरण का सूत्रपात होने के बाद देश में आए विदेशी टी वी चैनलों ने भी प्रारंभिक वर्षों के तुरंत बाद यहां की आवश्यकता समझते हुए यह जान लिया था कि भारत में हिंदी चैनल ही चल सकते हैं। अंग्रेजी भाषा इंग्लैंड में भी 100 वर्षों के संघर्ष के बाद ही राजभाषा का दर्जा पा सकी थी। हिंदी को भी समय लग सकता है, पर वह आएगी अवश्य। प्रो. पांडेय ने

हिंदीम ाहस मापनस मारोहक`ेउ द्घाटनक`ेक्ष ण

जनभाषा की महत्ता पर और भी अधिक प्रकाश डालते हुए कहा कि अपने काल में संस्कृत के होते हुए भी बुद्ध व महावीर ने अपनी बात जन–जन तक पहुंचाने के लिए पालि और प्राकृत का प्रयोग किया। गोस्वामी तुलसीदास ने संस्कृत का विद्वान होते हुए भी 'रामचरित मानस' जनता की भाषा में लिखा। प्रो. पांडेय ने संस्थान के संदर्भ में वैज्ञानिकों को संबोधित करते हुए कहा कि अंग्रेजी की अपेक्षा अपनी भाषा को अपनाते हुए वैज्ञानिक जो साहित्य देंगे, वह जनता का बड़ा हित करने वाला है। प्रौद्योगिकी वही भाषा अपनाती है, जहां उसका विकास होता है। अनुवाद संबंधी भ्रांतियों और उसके महत्व की चर्चा करते हुए प्रो. पांडेय ने कहा कि अनुवाद ने हमें बहुत कुछ दिया है, अन्य भाषाओं के ज्ञान, विज्ञान व साहित्य को हम तक पहुंचाया है। प्रो. पांडेय ने वैज्ञानिकों का आह्वान किया कि वे शब्दावली बनाएं, इस हेतु अध्यापन–क्षेत्र से सहायता लें, व्यावहारिक प्रयोग से सीखें। विज्ञान व प्रौद्योगिकी के संस्थान भाषा का रास्ता दिखा सकते हैं।

मुख्य अतिथि ने हिंदी माह के अवसर पर आयोजित विभिन्न प्रतियोगिताओं के विजेताओं तथा सरकारी कामकाज में मूलरूप से सर्वाधिक हिंदी प्रयोग करने वाले कर्मचारियों को पुरस्कृत भी किया।

8.3 संगोष्ठियाँ / कार्यशालाएँ

8.3.1 आंतरिक हिंदी वैज्ञानिक संगोष्ठियाँ

- 37वीं आंतरिक हिंदी वैज्ञानिक संगोष्ठी, 20 जून, 2012

इस त्रैमासिक संगोष्ठी में डॉ0 राजकुमार सिंह ने **'सोडियम कार्बोक्सी मेथिल सेलुलोज में SEM EDX पर आधारित प्रतिस्थापन डिग्री के निर्धारण की एक नई विधि'**; डॉ0 उमेश कुमार ने **'फोटो उत्प्रेरकः मौलिक गुण एवं अनुप्रयोग'**; सुश्री पूजा यादव ने **'अपशिष्ट जल से बेन्जाइल एल्कोहॉल की पुनःप्राप्ति'**; डॉ० दीप्ति अग्रवाल ने **'जैव सक्सेनिक अम्ल उत्पादन'** तथा श्री मृत्युंजय कुमार शुक्ल ने **'सरस्वती नदीः एक भू–वैज्ञानिक सर्वेक्षण'** विषयों पर प्रस्तुतियां दीं।

- **38वीं आंतरिक हिंदी वैज्ञानिक संगोष्ठी, 13 सितंबर, 2012**

इस त्रैमासिक संगोष्ठी में श्री ओम प्रकाश शर्मा ने **'वसीय अम्ल एक उत्तम सल्फर रहित एवं पर्यावरण अनुकूल स्नेहकतावर्धक योजक'**; श्री सन्नी वर्मा ने **'नैनौ स्टार्च उत्प्रेरक अनुप्रयोगों के लिए नई सामग्री'**; श्री अरविंद सिंह ने **'उत्तम स्वास्थ्य का मूल स्रोतः शहद'**; श्री दीपक टंडन ने **'स्वदेशी विकसित उच्च सोकर श्यानता भंजन तकनीक का एचपीसीएल (विशाखापटट्नम) में व्यवसायीकरण'** तथा श्री गौरव मिश्र ने **'सिन गैस बनाने के लिए कृष्ण द्रव का गैसीकरण'** विषयों पर अपनी–अपनी प्रस्तुतियां दीं।

- **39वीं आंतरिक हिंदी वैज्ञानिक संगोष्ठी, 28 मार्च, 2013**

इस त्रैमासिक संगोष्ठी में डॉ० डी के अधिकारी ने **'भारत का सौर ऊर्जा मिशन'**; श्री प्रसेनजित घोष ने **'भूतापीय ऊर्जा'**; श्री हरिचंद सिंह ने **'उद्यान का महत्व'**; श्री हाकिम सिंह ने **'अंतर्दहन इंजनः अनुरक्षण एवं ईंधन मितव्ययिता'**; डॉ एच यू खान ने **'वैकिल्पक ईंधन परिचर्चा'** एवं श्री अजय पाल ने **'भविष्य के ईंधन'** विषयों पर प्रस्तुतियां दीं।

9

The Institute as an Academic Body under the AcSIR*

*Academy of Scientific & Innovative Research

9.1 CSIR-PGRPE Programme at the CSIR-IIP

9.1.1 Interface with the Prospective PGRPE Students through a live Q&A Session on the *'Sahara Samay'* TV Channel

Mr Sudip K Ganguly, Principal Scientist & Co-ordinator, PGRPE, telephonically replied to questions on petroleum engineering studies posed by prospective students during a live TV programme on the *'Sahara Samay'* TV Channel on July 27, 2012 at 3:30 p.m.

- **Award of M Tech Degree**

The dissertations of the M Tech course in respect of the following students of the PGRPE 2010 batch were evaluated by the Thesis Committee consisting of Dr Raja Ram Bal, Dr Anil K Sinha, Dr D K Adhikari, Dr S K Singal, Mr S K Ganguly (PGRPE Co-ordinator), Dr S Tripathi (Thesis Coordinator) and Dr M O Garg, Director, CSIR-IIP:

- Mr Shashank Suman
- Mr Neelam Naidu
- Ms Jayati Trivedi
- Ms Madhvi Gera

These students were awarded M Tech Degree by the AcSIR on 26th September, 2012 during a Convocation Ceremony held at the Vigyan Bhavan, New Delhi.

9.1.2 PGRPE (Integrated M.Tech-Ph.D) in Advanced Automotive Technology-AAT

To infuse in younger persons a spirit of R&D and with a background of paucity of skilled/trained manpower for automotive sector within the country, it was decided to initiate a 2-year post-graduate research programme in Advance Automotive Technologies (AAT). This PG research programme aims to provide in-depth exposure to the engineering concepts, scientific principles, research methodology and hands-on experience on advanced R&D concepts. The first batch of the programme was initiated in September 2012.

10

The CSIR-IIP Family

Staff List as on March 31, 2013

10.1 SCIENTISTS GROUP-IV

Name of employee	Designation
Dr M O Garg	Director
Dr A N Goswami	Chief Scientist
Mr U C Agarwal	Chief Scientist
Dr S M Nanoti	Chief Scientist
Mr B M Shukla	Chief Scientist
Dr S K Singhal	Chief Scientist
Dr D K Adhikari	Chief Scientist
Mr Nishan Singh	Chief Scientist
Mr A K Jain	Chief Scientist
Dr A K Chatterjee	Chief Scientist
Dr Mahendra Pal	Chief Scientist
Mr A K Aigal	Sr Principal Scientist
Dr Y K Sharma	Sr Principal Scientist
Dr S K Sharma	Sr Principal Scientist
Dr Gautam Dass	Sr Principal Scientist
Mr U K Jaiswal	Sr Principal Scientist
Mr N K Pandey	Sr Principal Scientist
Mr Sudhanshu Gupta	Sr Principal Scientist
Dr S S Ray	Sr Principal Scientist
Dr (Mrs) Anshu Nanoti	Sr Principal Scientist
Dr Neeraj Athaiya	Sr Principal Scientist
Mr S K Ganguli	Principal Scientist
Mrs Poonam Gupta	Principal Scientist
Dr (Mrs) Savita Kaul	Principal Scientist
Mr A K Saxena	Principal Scientist
Dr N Vishwanadham	Principal Scientist
Mr Rajesh Kumar	Principal Scientist
Mr P Vijayanand	Principal Scientist
Dr Manoj Srivastava	Principal Scientist
Dr Samir Kumar Maiti	Principal Scientist
Mr V S Dangwal	Senior Scientist
Mr P C Joshi	Senior Scientist
Dr V V D N Prasad	Senior Scientist
Dr T Venkateshwar Rao	Senior Scientist
Dr P S Verma	Senior Scientist
Dr Anil Kumar Sinha	Senior Scientist
Dr Anil Kumar Jain	Senior Scientist
Dr Thallada Bhaskar	Senior Scientist
Mr Sunil Pathak	Senior Scientist
Dr Sanat Kumar	Senior Scientist
Dr Neeraj Atrey	Senior Scientist
Dr Suman Lata Jain	Senior Scientist
Dr O P Khatri	Senior Scientist
Dr Shailendra Tripathi	Scientist
Mr L Robindro	Scientist
Mr Devender Singh	Scientist
Mr Suryadev Kumar	Scientist
Mr Wittison Kamei	Scientist
Dr Soumen Dasgupta	Scientist
Dr Rajaram Bal	Scientist
Dr Atul Ranjan	Scientist
Mr G D Thakre	Scientist
Mr Arakshita Mazhi	Scientist
Mr D V Naik	Scientist
Dr Ajay Kumar	Scientist
Mr Mritunjay Kumar Shukla	Scientist
Mr Sunil Kumar	Scientist
Mr Prasanjit Ghosh	Scientist
Mr Salim Akhtar Faruqi	Scientist
Ms Richa Singhal	Scientist
Ms Aarti	Scientist
Dr Babita Behera	Scientist
Dr Debashish Ghosh	Scientist
Mr Pankaj Kumar Kannaujia	Scientist
Mr Deeptarka Dasgupta	Scientist
Ms Bhavya B	Scientist
Ms Dipti Agarwal	Scientist
Mr Anand Mohit	Scientist
Mr Sunil Kumar Suman	Scientist
Mr Indrajeet Kumar Ghosh	Scientist
Dr Subham Paul	Scietnist
Dr Umesh Kumar	Scientist
Mr Swapnil Divekar	Jr. Scientist
Mr Sandip Kumar Biswas	Jr. Scientist
Mr Pankaj Kumar Arya	Jr. Scientist
Dr Rashmi	Jr. Scientist
Dr Raj Kumar Singh	Jr. Scientist

10.2 TECHNICAL STAFF GROUP-III

Name of employee	Designation
Dr (Mrs) Lalita Bakaya	Principal Technical Officer (RMO)
Mr Babu Lal	Sr Technical Officer (3)
Dr D C Pandey	Sr Technical Officer (3)
Dr R K Chauhan	Sr Technical Officer (3)
Mr Anand Singh	Sr Technical Officer (3)
Mr D P Bangwal	Sr Technical Officer (3)
Dr Jasvinder Singh	Sr Technical Officer (3)
Dr Ajay Kumar Gupta	Sr Technical Officer (3)
Dr K S Rawat	Sr Technical Officer (3)
Mr M L Sharma II	Sr Technical Officer (3)
Mr Manoj Kumar	Sr Technical Officer (3)
Mr Laxmi Narayan	Sr Technical Officer (3)
Mr C R Srivastava	Sr Technical Officer (3))
Dr B R Nautiyal	Sr Technical Officer (3)
Mr R C Saxena	Sr Technical Officer (3)
Mr Servjeet Singh	Sr Technical Officer (3)
Mr Mahipal	Sr Technical Officer (3)
Mr Hakim Singh	Sr Technical Officer (3)
Mrs Pushpa Gupta	Sr Technical Officer (3)
Mr K K Singh	Sr Technical Officer (3)
Mr Girender Singh	Sr Technical Officer (3)
Mr Siya Ram	Sr Technical Officer (3)
Mr G M Bahuguna	Sr Technical Officer (2)
Mr Yog Raj	Sr Technical Officer (2)
Mr V S Kukreti	Sr Technical Officer (2)
Mr K P Bhatt	Sr Technical Officer (2)
Mr Ravi Khanna	Sr Technical Officer (2)
Mr Yograj Singh	Sr Technical Officer (2)
Dr Ghanshyam Thakkar	Sr Technical Officer (2)
Mr Kalyan Singh	Sr Technical Officer (2)
Mr Deependra Kumar Pandey	Sr Technical Officer (1)
Mr M K S Aloopwan	Sr Technical Officer (1)
Mr Hari Chand Singh	Sr Technical Officer (1)
Mr C D Sharma	Sr Technical Officer (1))
Mr Sath Pal Singh	Sr Technical Officer (1)
Mr Sunil Kumar	Sr Technical Officer (1)
Mr Rakesh Kumar	Sr Technical Officer (1)
Mr Mukesh Sharma	Sr Technical Officer (1)
Mr Sandeep Saran	Sr Technical Officer (1)
Mr Satish Kumar	Sr Technical Officer (1)
Mr Jagdish Kumar	Sr Technical Officer (1)
Mr Manoj Kumar	Sr Technical Officer (1)
Mr Sajid Ahmad Sharif	Sr Technical Officer (1)
Mr Rakesh Kumar Joshi	Technical Officer
Mr Vineet Sood	Technical Officer
Mr Satya Niketan Yadav	Technical Officer
Mr Rajendra Badola	Technical Officer
Mr Sarvanad Tiwari	Technical Assistant
Mr Amit Sharma	Technical Assistant
Mr Om Prakash Sharma	Technical Assistant
Mrs Nisha	Technical Assistant
Ms Rekha Chanuhan	Technical Assistant
Mr Sund Ram Sharma	Technical Assistant
Mr Kamal Kumar	Technical Assistant
Ms Pooja Yadav	Technical Assistant
Ms Jyoti Porwal	Technical Assistant
Mrs Sandhya Jain	Technical Assistant
Mr Yashveer Singh Meena	Technical Assistant
Mr Chandrashekar Pendem	Technical Assistant
Mr Praveen Kumar Khatri	Technical Assistant
Mrs Kamla Yadav	Technical Assistant
Ms Manisha Sahai	Technical Assistant
Mr K L N Konthala	Technical Assistant
Mr Srinivas Halavath	Technical Assistant
Mr Piyush Gupta,	Technical Assistant
Mr Rohit Kumar	Technical Assistant
Ms Rashmi	Technical Assistant
Mr Pradeep Kumar	Technical Assistant
Mr Raguvir Singh	Technical Assistant
Mr Deependra Tripathi	Technical Assistant
Mr V Bhanu Prasad	Technical Assistant
Ms P Padma Latha	Technical Assistant
Mr Mukesh Kumar Poddar	Technical Assistant
Mr Amit Kumar	Technical Assistant
Mr Appala Naidu Chokappu	Technical Assistant
Mr Manjo Kumar	Technical Assistant
Mr Akhilesh Kumar Kurmi	Technical Assistant
Mr Jitendra Kumar	Technical Assistant
Mr K D P Lakshmi Kumar	Technical Assistant

10.3 TECHNICAL STAFF GROUP-II

Name of employee	Designation
Mr P B Pant	Sr Technician (2)
Mr P S Lal	Sr Technician (2)
Mr Triloki Prasad	Sr Technician (2)
Mr Mohkam Singh	Sr Technician (2)
Mr Ram Pal Singh	Sr Technician (2)
Mr Paramjeet Singh I	Sr Technician (2)
Mr G C Bahuguna	Sr Technician (2)
Mr V P Mamgain	Sr Technician (1)
Mr Madan Gopal	Sr Technician (1)
Mr T C Sharma	Sr Technician (1)
Mr N N Bahuguna	Sr Technician (1)
Mr Deep Chand	Sr Technician (1)
Mr Harbhajan Singh	Sr Technician (1)
Mr H K Sahi	Sr Technician (1)
Mr Paramjeet Singh II	Sr. Technician (1)
Mr Rajeev Sharma	Technician (2)
Mr Rajnish Bhatnagar	Technician (2)
Mrs Anjali Bhatnagar	Technician (2)
Mr Anil Kumar	Technician (2)
Mr Rajpal Singh	Technician (2)
Mr N K Rawat	Technician (2)
Mr Prem Chand Verma	Technician (2)
Mr Sanjeev Kumar	Technician (1)
Mr Mayank Mishra	Technician (1)
Mr Pradeep Singh Negi	Technician (1)
Mr Devender Singh Batola	Technician (1)
Mr Binod Kumar	Technician (1)
Mr Puran Singh Aswal	Technician (1)
Mr Pradeep Singh Panwar	Technician (1)
Mr Rituraj Negi	Technician (1)
Mr Parvej Alam	Technician (1)
Mr Vivek Kumar Sharma	Technician (1)
Mr Rajendra Kumar	Technician (1)
Mr Naseem Ahmed	Technician (1)
Mr Ashok Kumar Thakur	Technician (1)
Mr Gembbir Singh	Technician (1)
Mr Ashok Kumar	Technician (1)
Mr Mahendra Singh Negi	Technician (1)
Mr Shiv Prasad Nautiyal	Technician (1)
Mr Manmohan S. Gosain	Technician (1)
Mr Daniel Shah	Technician (1)
Mr Rajeev Panwar	Technician (1)
Mr Indu Shekhar	Technician (1)
Mr Sandeep Kumar Saxena	Technician (1)
Dr (Mrs) Aruna Kukreti	Technician (1)
Mr Satish Mani	Technician (1)
Mr Khem Singh	Technician (1)
Mr Abbal Singh	Technician (1)
Mr Girish Chand Tiwari	Technician (1)
Mr Rajesh Sharma	Technician (1)
Mr Naveen Kr. Maurya	Technician (1)
Mr Pushp Raj Sharma	Technician (1)
Dr (Mrs) P Nagendramma	Technician (1)
Mr Tasleem Khan	Technician (1)
Mrs Ritu Mourya	Nursing Sister (ANM) Non-Tech
Mr Hari Prakash	Pharmacist (Non-FCS)
Mr Ombir Singh	Technician (1)
Mr Jitendra Singh	Technician (1)
Mr V Silambarsan	Technician (1)
Mr V V Magan Bahi	Technician (1)
Mr Guru Jothi G	Technician (1)
Mr Ashwani Kuamr	Technician (1)
Mr Amardeep Kumar	Technician (1)
Mr Kawle R Koluram	Technician (1)

10.4 LABORATORY STAFF GROUP I

Mr Daniel Shah	Technician (1)
Mr Vijay Singh	Laboratory Attendant
Mr Ranjeet Singh	Laboratory Assistant
Mr Budh Singh	Laboratory Assistant
Mr D B Shukla	Laboratory Assistant
Mr Jagdish Singh	Laboratory Assistant
Mr Hari Kishan	Laboratory Assistant
Mr Sukhbir	Laboratory Assistant
Mr Ashok Kumar	Laboratory Assistant
Mrs Maya Gusain	Laboratory Assistant
Mr Balbir Singh II (GB)	Laboratory Assistant
Mr Raj Kumar	Laboratory Assistant
Mr S P Mani	Laboratory Assistant
Mr Balbir Singh I	Laboratory Assistant

Mr Mohd Parvej	Laboratory Assistant
Mr Shyam Singh	Laboratory Attendant (2)
Mr Surat Ram	Laboratory Attendant (2)
Mr Mahesh Pal	Laboratory Attendant (2)
Mr Ranbir Singh	Laboratory Attendant (2)
Mrs Shyam Lata	Laboratory Attendant (2)
Mr Sanjay Kumar	Laboratory Attendant (2)
Mrs Ganga Devi	Laboratory Attendant (2)
Mr Jai Prakash	Laboratory Attendant (2)
Mr Bharat Singh	Laboratory Attendant (2)
Mr S K Verma	Laboratory Attendant (2)
Mrs Kanta Devi	Laboratory Attendant (2)
Mr Dinesh Chandra	Laboratory Attendant (1)
Mr Sunil Kumar	Laboratory Attendant (1)
Mr Naveen Bhatt	Laboratory Attendant (1)
Mr Burhanudeen	Laboratory Attendant (1)
Mr Hari Singh	Laboratory Attendant (1)
Mr Narendra Singh Negi	Laboratory Attendant (1)
Mr Harold Gladwyn	Laboratory Attendant (1)
Mr Mohan Singh	Laboratory Attendant (1)
Mr Jyoti Prasad	Laboratory Attendant (1)
Mr Sanjay Kumar	Laboratory Attendant (1)
Mr Shivram Singh	Laboratory Attendant (1)
Mr Rakesh Kumar	Laboratory Attendant (1)
Mr Pradeep Singh Pundir	Laboratory Attendant (1)
Mr Ram Kishore Maurya	Laboratory Attendant (1)

10.5 ADMINISTRATIVE STAFF

10.5.1 COMMON CADRE OFFICERS

Mr V K Kaushika	Controller of Administration
Mr Surender Kumar	Administrative Officer
Mr Suresh Pant	Stores & Purchase Officer
Mr M S Mehra	Finance & Accounts Officer
Mr Parvesh Chand	Section Officer (General)
Mr Rajeev Kumar Verma	Section Officer (General))
Mr Prasoon Kumar	Section Officer (General)
Mr Mukesh Kumar Gairola	Section Officer (General)
Mr Shivraj Singh Kushwaha	Section Officer(Stores & Purchase)
Mr C S Bisht	Section Officer(Finance & Accounts)
Mr. R.K. Kapoor	Private Secretary

10.5.2 ASSISTANTS GRADE I

Mr Ramesh Kumar Joshi	Assistant (General) Grade-I
Mr D S Negi	Assistant (General) Grade-I
Mr R S Chauhan	Assistant (General) Grade-I
Mr Manbar Singh Negi	Assistant (General) Grade-I
Mr Vijay Kumar Kataria	Assistant (General) Grade-I
Mrs Vineeta Walia	Assistant (General) Grade-I
Mr Manoj Tiwari	Assistant (General) Grade-I
Mr Arvind Arora	Assistant (General) Grade-I
Mrs Kanak Kuchhal	Assistant (General) Grade-I
Mohd Javed	Assistant (General) Grade-I
Mrs Abha Dhyani	Assistant (General) Grade-I
Ms Neha Nautiyal	Assistant (General) Grade-I
Mr B B Dimri	Assistant (General) Grade-I
Mr Vishvendra K Dogra	Jr. Steno
Mrs Shobha Panwar	Assistant (Finance & Accounts) Grade-I
Mr Satish Chand	Assistant (Finance & Accounts) Grade-I
Mr L R Kaushik	Assistant (Stores & Purchase) Grade-I
Mr V K Kapoor	Assistant (Stores & Purchase) Grade-I
Ms Meena Kumari	Assistant (Stores & Purchase) Grade-I
Mr R N Sharma	Assistant (Stores & Purchase) Grade-I
Mr R K Bhattacharya	Assistant (Stores & Purchase) Grade-I
Mr Pramod Joshi	Assistant (Stores & Purchase) Grade-I
Mrs Seema Sharma	Assistant (Finance & Accounts) Grade-I
Mr Jitendra Singh Negi	Assistant (Finance & Accounts) Grade-I
Mr Pankaj Mourya	Assistant (Finance & Accounts) Grade-I
Mr Mahesh Kumar Jatav	Assistant (Finance & Accounts) Grade-I
Mr Shiv Prasad Saklani	Assistant (Finance & Accounts) Grade-I
Mrs Kiran Lata	Assistant (General) Grade-I

10.5.3 ASSISTANTS GRADE II

Name of employee	Designation
Mr Adesh Seth	Assistant (General) Grade-II
Ms Pratima Bagga	Assistant (General) Grade-II
Mr Jassu Kumar Sharma	Assistant (General) Grade-II
Mrs Anju Sharma	Assistant (General) Grade-II
Mr Rakesh Pant	Assistant (General) Grade-II
Mrs Anita Devi	Assistant (General) Grade-II)
Mr Sanjay Pokhriyal	Assistant (General) Grade-II
Mr Harjeet Singh	Assistant (General) Grade-II
Mr Kulwant Singh	Assistant (General) Grade-II)
Mrs Harvinder Kaur	Assistant (General) Grade-II
Mr M. Pal Singh Arora	Assistant (Stores & Purchase) Grade-II
Mr Vikram Singh	Assistant (Stores & Purchase) Grade-II
Ms Asha Joshi	Assistant (Stores & Purchase) Grade-II
Mr Himmat Singh	Assistant (Stores & Purchase) Grade-II

10.5.4 ASSISTANTS GRADE III

Name of employee	Designation
Mr Ashish Raturi	Assistant (Finance & Accounts) Grade-III
Mr Jitendra Singh Rawat	Assistant (General) Grade-III
Mrs Kiran Bala	Assistant (General) Grade-III
Mr Sunil Rawat	Assistant (Stores & Purchase) Grade-III
Mohd. Furkan Saifi	Assistant (Finance & Accounts) Grade-III

10.5.5 STENOGRAPHIC GADRE

Name of employee	Designation
Mr G S Sharma	PS
Mrs Geeta Chhetri	Sr Stenographer (Assured Career Progression)
Mr Suresh Kothari	Sr Stenographer (Assured Career Progression)
Mr S C Bhatt	Sr Stenographer
Mr G P Sharma	Sr Stenographer
Mr P S Chauhan	PS
Mrs Saroj Kushwaha	Sr Stenographer
Mr Devendra Rai	Sr Stenographer
Ms Reena Sharma	Sr Stenographer
Ms Kusum	Sr Stenographer
Mrs Bhawana Rawat	Jr Stenographer
Mr Rajendra Kumar	Jr Stenographer
Mrs Shaloo Vinodhia	Jr Stenographer
Mr Navneet Singh Rana	Jr Stenographer

10.5.6 ISOLATED POSTS

Name of employee	Designation
Dr D C Chamola	Sr Hindi Officer
Mr M C Ratori	Hindi Officer
Capt R J Simon	Sr Security Officer
Mr Mohar Singh Nirala	Driver
Mr Tajender Singh	Driver
Mr G S Mehta	Driver
Mr Rajender Prasad	Driver
Mr Mukesh Kumar	Driver
Mr Govind Singh Rawat	Driver

10.5.7 CANTEEN STAFF

Name of employee	Designation
Mr Bharat Singh Bisht	Assistant Halwai-cum-Cook
Mr Lok Bahadur	Tea/Coffee Maker (Assured Career Progression)
Mr Gopal Singh	Bearer (Assured Career Progression)
Mr Sudama Singh	Bearer (Assured Career Progression)
Mr Matbar Singh I	Bearer (Assured Career Progression)
Mr Matbar Singh II	Bearer (Assured Career Progression)
Mr Asha Ram	Bearer (Assured Career Progression)
Mr Munish Kumar	Safai Karmachari (Assured Career Progression)

10.5.8 MULTI-TASKING GROUP (MTS)

Name of employee	Designation
Mr Mandev Singh	Junior Security Guard (Assured Career Progression)
Mr Deepak Kumar	Group C (Assured Career Progression)
Mr K N Sharma	Junior Security Guard (Assured Career Progression)
Mr B B Ekka	Junior Security Guard (Assured Career Progression)
Mr Raja Ram	Junior Security Guard (Assured Career Progression)
Mr Gopal Singh	Junior Security Guard
Mr Ghanshyam	Group C
Mr Mukesh Kumar	Group C
Mr Ram Pal	Group C
Mr Chandra Sekhar	Group C
Mr Rajesh Kumar	Group C
Mr Dalip Kumar	Safai Karamachari
Mr Naresh Kumar	Group C
Mr Surjeet Thapa	Group C
Mr Kamal Kumar	Group C
Mr Ajay Pal	Group C
Mr Dev Singh Adhikari	Group C
Mrs Bharti Payal	Group C
Mr Hemant Kumar Tiwari	Group C
Mr Brijender Singh Bisht	Group C
Mr Sudama Singh	Group C
Mr Laxman Singh Rawat	Group C
Mr Rajbeer Singh	Group C
Mr Amit Upadhyay	Group C
Mr Ramesh Chandra	Group C
Mr Shiv Singh Rawat	Group C
Mr Ajay Paul	Group C
Mr Pankaj Bhaskar	Group C
Mr Murlidhar Chandna	Group C
Mr Tika Ram Bhatt	Group C
Mr Vikram Singh Kandari	Group C
Mr Vishwas Kumar	Group C
Mr Rajesh Kumar	Group C
Mr Manoj Kumar	Group C
Mr Sanjay Kumar	Group C
Mrs Yashoda	Group C
Mr Rajendra Prasad	Group C
Mr Kalu Ram	Group C
Mr Rajendra Prasad Dabral	Group C
Mr Mannu Ram	Group C
Mr Irshad Khan	Group C
Mr Suresh Kumar	Farash
Mr Kedar Dutt Pandey	Group C
Mr Gokul Prasad	Group C
Mr Vivek Singh	Group C
Mr Harish Kumar	Group C
Mr Bijendra Dutt	Group C
Mr Ghanshyam	Group C
Mr Rajesh	Farash
Mr Tanveer Ahmad	Group C
Mr Vijay Kumar Verma	Group C
Mr Sanjay	Group C
Mr Tilak Kumar	Farash
Ms Sarveshvari Devi	Group-C (Non-Technical)
Mr Kamal Singh	Group-C (Non-Technical)
Smt Shyamkali	Group-C (Non-Technical)
Mr Mukesh Kumar	Group-C (Non-Technical)
Mr Chander Singh	Group-C (Non-Technical)
Mr Kishore Kumar	Group-C (Non-Technical)
Mr Surender Kumar	Group-C (Non-Technical)
Mr Rajesh Kumar	Group-C (Non-Technical)
Mr Arvind Khandoori	Group-C (Non-Technical)
Mrs Sureshi Rawat	Chair Caner(Non Technical)
Mr Ramchander	Group C (Non-Technical)
Mr Suresh Chand	Group-C (Non-Technical)
Mr G B Khatri	Group-C (Non-Technical)
Mr Mukul Sharma	Group-C (Non-Technical)
Mr D S Pundir	Group-C (Non-Technical)
Mrs Uma Devi	Trainee

सीएसआइआर – भारतीय पेट्रोलियम संस्थान, देहरादून

CSIR-Indian Institute of Petroleum, Dehradun

पोस्ट–आइ आइ पी, मोहकमपुर
देहरादून–248 005
उत्तराखण्ड, भारत
टेलीफोन : 0135-2660205
फैक्स : 0135-2660202/2660098
ई–मेल : director@iip.res.in
वेब : www.iip.res.in

P.O. IIP, Mohkampur
Dehradun-248 005
Uttarakhand, India
Telephone : 0135-2660205
Fax : 0135-2660202/2660098
E-mail : director@iip.res.in
Web : www.iip.res.in