

द्विवार्षिक प्रतिवेदन

BIENNIAL REPORT

2002 - 2004



केन्द्रीय नमक व समुद्री रसायन अनुसंधान संस्थान

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इस कार्य में संस्थान के सभी विभागाध्यक्षों से प्राप्त सहयोग के लिये आभारी हैं ।



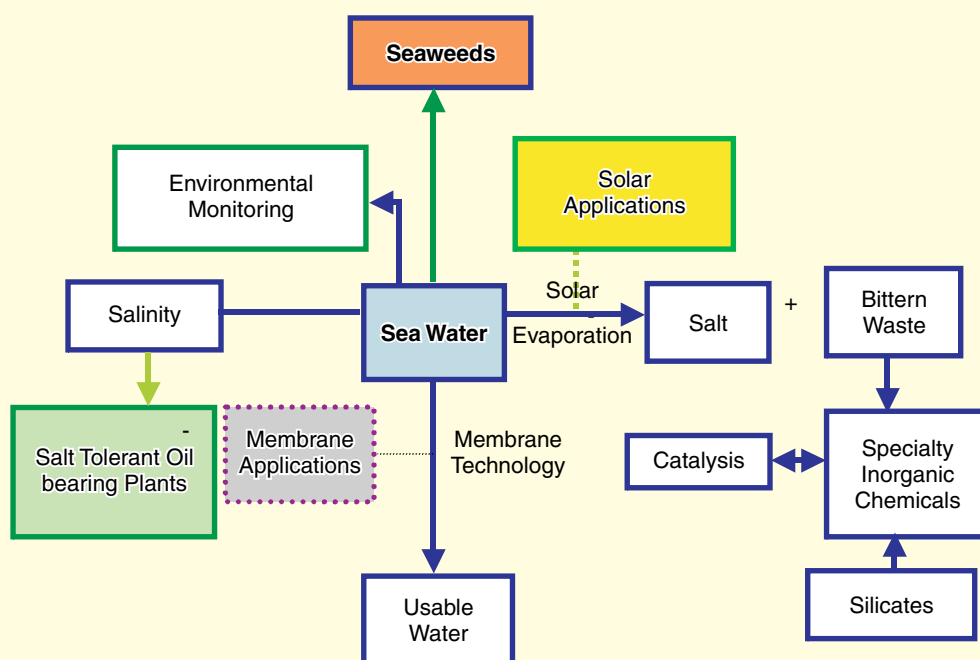
*The Mahatma who rocked the British Empire
&
galvanised the people
by defiantly gathering salt at the Dandi seashore.
6th April, 1930*



"I do not wish any worker to come to these laboratories merely with the aim of earning his living. What I wish is that our young men and women who come here should have a zeal for working out problems which would have great consequence. That would give vitality to these Institutes. They should realize that service to science is real service to India - no, even to the whole world; science has no frontiers".

*Pandit Jawaharlal Nehru
Extract from the Inaugural address on 10th April, 1954*

CSMCRI AT A GLANCE



Schematic depiction of the activities of
CENTRAL SALT & MARINE CHEMICALS RESEARCH INSTITUTE
with seawater as the central theme



प्राक्कथन

मुझे 2002-2004 का प्रतिवेदन प्रस्तुत करने में अपार हर्ष होता है। संस्थान की स्वर्णजयंती मनाना एक ऐतिहासिक मील का पत्थर था। इस दौरान वनस्पति लवण तथा बैल-शक्ति से विलवणन के पारवेधन अन्वेषणों से संस्थान को उच्च प्रत्यक्षता प्राप्त हुई। औरिस्सा के दामनजोडी में स्थित नाल्को के 10,000 टन प्रतिवर्ष जिओलाईट के संयंत्र का कार्यसम्पादन गारंटी अन्वीक्षा, सफलतापूर्वक सम्पन्न हुआ तथा संघट झिल्ली आधारित स्वदेशी पतली फिल्म का उपयोग करके चैन्नई पेट्रोकेमिकल्स कार्पोरेशन में, 10 लाख लीटर प्रति दिन क्षमतावाला प्रतिवर्ती रसाकर्षण संयंत्र, तृतीय उपचरित मल-जल के उपचार हेतु लगाया गया। चैन्नई में लगाये गये प्रतिवर्ती रसाकर्षण संयंत्र के कार्य के लिये वर्ष 2004 के सी. एस. आई. आर. टेकनोलोजी पुरस्कार प्राप्त हुआ। मन्नार की खाड़ी में कप्पाफाइकस अल्वारेज़ी की बेडा खेती आरम्भ की गई, तथा देश के इतिहास में प्रथमबार 200 टन खेती उत्पादित समुद्री शैवाल निर्यात किया गया। बिटर्न से अल्प सोडियम लवण के सस्ते उत्पादन की। नवल प्रौद्योगिकी स्थानान्तरण के लिये संस्थान ने हिन्दुस्तान लिवर लिमिटेड के साथ करार पर हस्ताक्षर किया। इस अन्वेषण के लिये यु. एस. एवम् पी. सी. टी. पेटन्ट भी किये गये। अन्य महत्वपूर्ण उपलब्धियों में; ब्रोमीन रहित बिटर्न उच्छिष्ट से, पारदर्शी ग्रेड मैग्नेशिया तथा पोटाश के सल्फेट उर्वरक बनाने की योग्य प्रविधि का विकास हुआ है। ग्रेटर रन ओफ कच्छ में हरसाल 2500 टन उर्वरक बनाने का प्लान्ट स्थापन की औपचारिकतायें पूरी की जा रही हैं। अपरदित भूमि में बायोडीज़ल के विकास के लिये संस्थान ने जर्मन स्थित डायमलर क्रिस्टल तथा होहेनहीम विश्वविद्यालय से हाथ मिलाये और हमारे लिए यह आनंद की बात है कि इसी जेट्रोफा करकस बीज के तेल से उत्पादित शुद्ध बायोडीज़ल से दो सी-क्लास मर्सिडीज कारें 12,000 कि मी सफलतापूर्वक चलीं। इस योजना के प्रारम्भिक स्तर की इन उपलब्धियों ने, आर्थिक वृद्धि के लिये व्यर्थ भूमि के उपयोग की अवधारणा में आत्मविश्वास पैदा किया है और संस्थान ने सी एस आई आर के औषधि अनुसंधान कार्यक्रम में भी योगदान किया है और संस्थान सी. एस. आई. आर. के अनेक नेटवर्क परियोजनाओं में भी प्रतिभागी है।

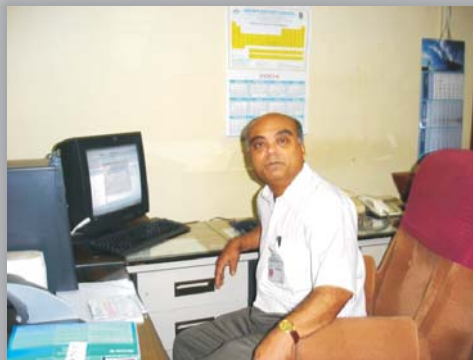


हमारा संस्थान सामाजिक मिशनों पर भी केन्द्रित रहा है; इसके अंतर्गत पीने के पानी के लिए राजस्थान एवम् तमिलनाडु के कई गाँवों में विलवणन संयंत्र सफलतापूर्वक लगाये गये। गाँवों में पीने के पानी में से फ्लोराइड दूर करने की प्रौद्योगिकी का प्रदर्शन भी किया गया। कच्छ के विशाल मरुभूमि के सीमित नमक उत्पादकों के आय में तकनीकी मध्यस्थता द्वारा गुणात्मक सुधार करने के लिये, संस्थान ने औपचारिक रूप से स्वरोजगार महिला संगठन (SEWA) की प्रतिभागिता में भी प्रवेश किया। यह संतुष्टिप्रद है कि इस ध्येय के लिये ग्राह्य तकनीकी की नवलता की पहचान यु. एस. पेटन्ट स्वीकृति से हुई। शिक्षा में अमूल्य योगदान हेतु अन्वेषण में, उत्तमतर लिखने के चॉक का विकास किया गया।

यह सराहनीय रहा कि मौलिक अनुसंधान तथा प्रौद्योगिकी विकास के बीच उत्तम सामंजस्य बनाया गया। वर्ष 2004 में एक तरफ जहाँ 10 यु. एस. पेटन्ट ग्रांट के लिये स्वीकृत हुए, संस्थान ने सी. एस. आई. आर. के अन्तर्गत, शोध पत्रों के प्रकाशन में औसत इंपैक्ट फैक्टर (सी ए 2.0) की दृष्टि से, अपना उच्च स्थान बनाये रखा। संस्थान के अनुसंधानों पर आधारित, कई शोध छात्रों को पी. एच. डी. उपाधि भी मिली। अब हमारा प्रयास तकनीकी चुनौतियों से उत्पन्न रोचक व्यवहारिक तथा मौलिक अनुसंधान समस्याओं के सृजन पर है, जिससे हमारे अनुसंधान एवम् विकास के सभी अवयव पूर्णतः संगठित दिखें। नई प्रतिभाओं के प्रवेश द्वारा संस्थान के अद्यतन साधनों में महत्वपूर्ण सुधार किये गये तथा काम करने के लिये एक नई प्रयोगशाला तैयार की गई।

जी के घोष

पुष्पितो कुमार घोष



FOREWORD

*I have great pleasure in presenting the Report for the period 2002-2004. A historic milestone was the celebration of our Golden Jubilee. The Institute gained high visibility during this period with the breakthrough inventions of vegetable salt and oxen-powered desalination. Performance guarantee trials of the 10,000 TPA zeolite-A plant at NALCO, Damanjodi were successfully concluded and a 1 million liters per day reverse osmosis plant based on indigenous thin film composite membrane was commissioned at Chennai Petrochemicals Corporation for treatment of tertiary treated sewage water. These achievements were recognized through the award of CSIR Technology Prizes in 2002 and 2004. Raft cultivation of *Kappaphycus alvarezii* was successfully introduced in the Gulf of Mannar and, for the first time in the country's history, 200 tons of cultivated seaweed was exported. The Institute signed an MoU with M/s Hindustan Lever Limited for transfer of its novel technology for cost-effective production of low sodium salt from bittern. U.S. and PCT patents were also secured for the invention. Another important achievement was the development of a viable process for production of sulphate of potash (SOP) fertilizer and refractory grade magnesia from debrominated bittern waste; formalities are being completed for installation of a 2500 TPA SOP demonstration plant in the Greater Rann of Kutch. The Institute also joined hands with DaimlerChrysler AG and the University of Hohenheim to develop biodiesel from eroded soils and it is indeed heartening that two C-class Mercedes Benz cars covered over 6000 km with the neat biodiesel produced from the oil of *Jatropha curcas* seeds. This important achievement in the initial phase of the project has created confidence in the concept of wasteland utilization for economic gains. Useful contributions were also made towards CSIR's drug discovery programme. The Institute is also a participant in several CSIR networked projects. Close interactions were also forged with the Global Research Alliance, particularly in the area of water.*

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The Institute continued to focus on societal missions and successfully set up a number of desalination plants in villages of Rajasthan and Tamil Nadu. Its defluoridation technologies were also demonstrated in villages. The Institute also formally entered into a partnership with the Self Employed Women's Association (SEWA) to bring about qualitative improvements in the incomes of marginal salt producers in the Little Rann of Kutch through technological intervention. It is gratifying that the novelty of the technology adopted for this purpose was recognized through award of a U.S. patent. In its quest for making a valuable contribution to education, a superior writing chalk and duster were developed.

It is creditable that a good balance was maintained between basic research and technology development. One of our scientists was awarded the CSIR Young Scientist award and another scientist the Raman Fellowship. 10 U.S. patents were granted/cleared for grant in 2004 and the Institute continued to maintain its standing within CSIR in terms of average impact factor (ca. 2.0) of publications. Several students were also granted the Ph. D. degree based on the research work carried out in the Institute. It is now our endeavour to generate interesting applied and basic research problems that emanate from technological challenges so that all components of our R&D are seen to be fully integrated. The competency base of the laboratory is also being strengthened through induction of new talent. Simultaneously, the infrastructure has been greatly improved and a new laboratory is now ready for occupation.

CSMCRI expresses its profound gratitude to all those who have lent their support to the Institute and looks forward to improving its performance with each passing year.

Pushpito K. Ghosh

Pushpito K. Ghosh



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INORGANIC CHEMICALS

Salt & Marine Chemicals

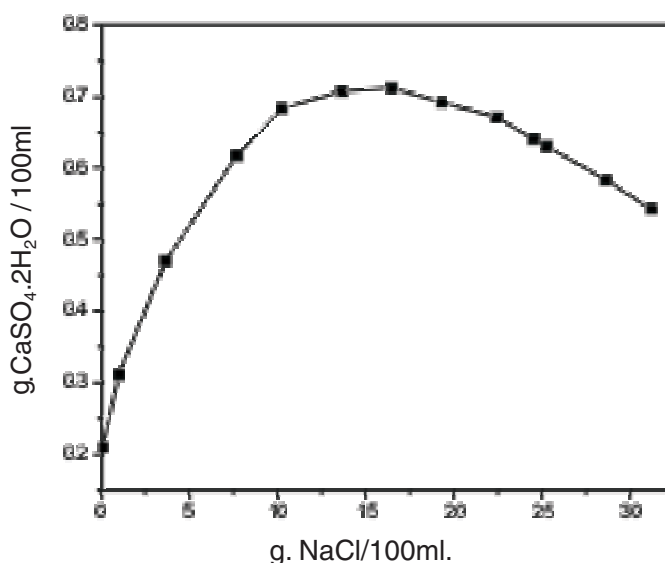
Low sodium salt from Bitterns: A new process for the recovery of low sodium salt (mixture of NaCl and KCl) has been developed. Hitherto, such salt was being produced by mixing NaCl and KCl which led to higher than desirable cost of the product, particularly when the KCl content was $\geq 30\%$. In the new process, low sodium salt of desired composition is obtained directly by desulphating bittern and manipulating the composition of crude carnallite ($\text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}$) obtained from such bittern (US Patent Appln. No. 10/062,583 dated 31 Jan, 2002; approved for issuance of patent on 5 May, 2004). The new route is most cost-effective when integrated with production of other marine chemicals or when inexpensive sources of calcium chloride are available. The technology has been licensed.

Low sodium salt of Botanic Origin: Following the enthusiastic response nationally and internationally to the invention of vegetable salt, the Institute has produced low sodium salt of botanic origin (US and PCT Patent applications filed). The invention exploits the ability of *Salicornia brachiata* to accumulate NaCl and that of the *Eucheuma* seaweed to accumulate KCl. Test marketing of these salts (Saloni and Saloni K) has begun both in India and overseas.

The logo for SciDev Net, featuring the text "SciDev Net" in white on a red rectangular background.

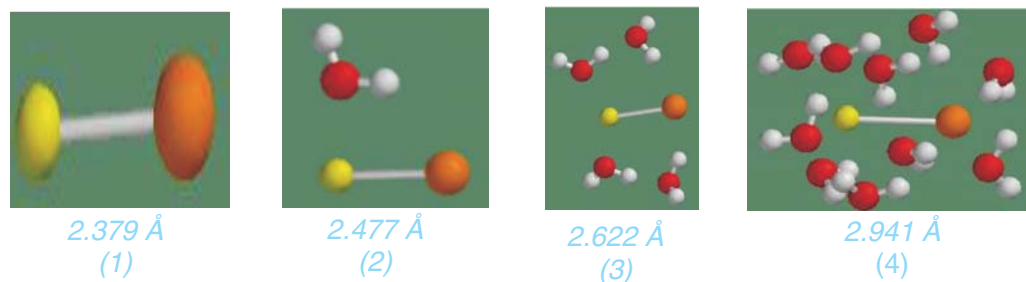
[NEW DELHI] An Indian research team has produced salt from a leafless shrub that grows in salty soil on the Indian coast. The researchers hope that their research will lead to a market for plant-derived salt&&. (15 May 2003)

Ionic interactions of CaSO_4 in aqueous sodium chloride and calcium chloride solutions in the temperature range 30-35° C: Thermodynamic, volumetric, transport and surface properties such as solubility, density, viscosity, electrical conductivity and surface tension of $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ in an aqueous system of NaCl and CaCl_2 have been measured in the temperature range of 30-35° C with a view to determine the ionic interactions existing in the system. Based on the change in the solubility pattern of CaSO_4 in the brine system it has been possible to predict the increase in solubility of CaSO_4 in presence of NaCl, which contributes to the contamination of impurities in salt during the process of salt manufacture. On the other hand, addition of CaCl_2 reduces the solubility of CaSO_4 in the system facilitating early separation of CaSO_4 . The latter invention is the subject of a recent patent.



Solubility of CaSO₄·2H₂O as a function of NaCl concentration (T=35°C)

Solvation of Sodium Chloride: *Ab initio* study of NaCl(H₂O)_n:



Sodium chloride solvated with water molecules: (yellow=Na, orange=Cl, red=oxygen) The values indicated are the Na⁺--Cl interionic distances.

Although it is clear that salt dissociates into ions in bulk solution, it is not clear how the process occurs when water molecules are added. It has been found through *ab initio* studies that the addition of relatively small number of water molecules (ca. 10) results in significantly enhanced separation of the ions (from 2.37 Å to 2.94 Å) as shown in the figures. Although bond distances are greatly enhanced for NaCl(H₂O)₁₀ (4), it is still a contact ion pair. It is likely that a second sphere of hydration is necessary to attain complete separation. It is emphasized, however, that the results obtained are not for NaCl in a solid lattice (which is the normal state) but of a single NaCl molecule assumed to be initially in a gas phase. We are exploring the possibility of conducting similar studies on an NaCl solid cluster. It is anticipated that such studies will eventually shed light on fundamental questions such as the difference in solubility behaviour of NaCl and KCl, for example.

Pebble shaped salt: Certain crystal habits are disliked in common salt because they give the crystalline mass a poor appearance; others make the product prone to caking, induce poor flow characteristics or give rise to difficulties in the handling or packaging of the material. Whereas NaCl generally crystallizes in the face centered cubic structure, modification of the cubic morphology of common salt to spherical shape is a much sought after goal for superior flow. Till date, the approaches followed to achieve this goal have been limited to the use of additives for crystal habit modification. In one such approach, dodecahedral shaped salt could be produced in presence of glycine, and a means of recycling the excess glycine in subsequent batches was developed (*US Patent Application No: 10/ 745,758 ; PCT Application No: PCT /IB 03/ 06237*). It has now been possible to transform the cubic morphology into pebble-like shape without use of additives. This was achieved through the conjugate effect of induced strain and controlled crystallization conditions, which led to an assembly of cubic crystals in the overall shape of a pebble.



Near spherical NaCl crystals through new process that does not involve use of any additive

Pure salt through desulphatation of brine: About 30 percent of the salt produced in the country is from subsoil brines. Such brines are used where access to seawater is poor. Although sub-soil brine improves the efficiency of production in view of its higher NaCl content (ca. 4-5 fold higher than seawater), the salt obtained is of inferior quality with higher than acceptable levels of calcium, magnesium and sulphate impurities. Recognising that sulphate is the key culprit in brine that leads to build up of the impurities, an innovative route was developed to produce superior quality salt in the field from sub-soil brine, through use of distiller waste liquor of soda ash industries. (*US Patent Application No 10/ 003,213 and PCT Patent Application No. PCT /IN01/ 00185 (both applications cleared for grant)*). The salt, after mechanical washing, analysed for >99.5 percent NaCl, 0.03% calcium, 0.02% magnesium and 0.1% sulphate. The improved methodology was utilised by several agarias in the Dehgam area of Little Rann of Kutch (LRK) which is in the vicinity of the distiller waste discharge point of a soda ash industry and where the salt quality is particularly poor. Three selected salt works were able to obtain salt with Ca = 0.10-0.12%, Mg = 0.05-0.08%, SO₄ = 0.20-0.25% compared to 0.40-0.45% Ca, 0.3-0.35% Mg and 1.0-1.5% SO₄ for conventionally produced salt. The value and marketability of the salt was greatly enhanced as a result and it is believed that the quality of salt will further improve when the process is adhered to more strictly. The technology is also being demonstrated in the premises of some major salt producers both for sea and sub-soil brines.

A noteworthy feature of the desulphatation technology developed by us is that the bittern, being free of sulphate, is suitable for production of carnallite ($\text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}$) which, in turn, can be utilised for manufacture of KCl. Through



Salt production through desulphatation of brine in the salt farm of Kodabhai at Dehgam, LRK

a modification of the general methodology, it was possible to produce carnallite of two grades in 60:40 ratio, wherein the former is of ultra-high purity and gives >98% pure KCl through simple decomposition and washing of the carnallite. The other carnallite is more contaminated with NaCl and ideally suited for production of low sodium salt of desired composition (*US Patent Application No : 10/814,779 dated March 30,2004*).

We are simultaneously investigating cost-effective methods of generating calcium chloride *in situ*, for locations that do not have access to distiller waste or other sources of waste calcium chloride. One such approach involves the generation of calcium chloride from MgCl_2 -rich bittern and lime. The by-product $\text{Mg}(\text{OH})_2$ is of adequate purity for refractory grade magnesia application. A still superior product (CSMCRI Sample 3 in the Table below) can be obtained by using carnallite decomposed liquor, proper upgradation of lime, and efficient processing. A spin off from the work is that it has been proved possible in the laboratory to obtain bromide concentrations as high as 8.4 gpl in the end bittern with excellent bromide recovery. This would be a major advantage for bromine recovery with higher plant capacity utilisation and energy efficiency.

Comparison of CSMCRI MgO with Typical Properties of Magnesite Refractories for Different Applications^a

Constituents	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7	CSMCRI Samples		
								1	2	3
MgO (%)	92.0	94.0	95.0	96.0	97.0	98.0	98.5	94.2	95.3	97.4
CaO (%)	2.0	1.5	-	2.0	1.0	1.5	0.74	3.0	3.6	2.11
SiO ₂ (%)	4.0	2.0	2.0	1.0	0.5	0.5	0.12	1.7	0.2	trace
Fe ₂ O ₃ (%)	-	1.0	1.0	0.5	0.5	0.2	0.44	0.25	0.12	0.14
Al ₂ O ₃ (%)	0.8	-	-	0.3	-	0.1	0.07	0.23	0.21	0.17
B ₂ O ₃ (%)	-	-	-	-	-	-	0.01	0.05	0.05	trace
A.P. (%)	18	20	18	17	17	17	-	17.3	18	-
RUL, °C	1600	1650	1700	1700	1700	1720	-	>1650	>1650	-
Applications	Hot Metal Mixer	Glass Tank wall & checker	Electric arc furnace	Glass tank regenerat- or checkers	Hot metal mixer	Glass tank regenerat- or checkers	LD converter for steel making	-	-	-

^aAnalysis and Data courtesy Central Glass & Ceramics Research Institute, Kolkata

Sulphate of potash (SOP) fertilizer and refractory grade MgO from marine bitterns:

The entire requirement (2-3 M tons) of potash (K_2O) in the country is met through imports. Sulphate of Potash (SOP) is preferred to Muriate of Potash (MOP) as potassic fertilizer due to its double nutrient value and low salt index. A scheme was evolved whereby SOP can be produced from pristine or debrominated bittern in Greater Rann of Kutch. In the strategy initially adopted by us, kainite ($KCl \cdot MgSO_4 \cdot 3H_2O$)-type mixed salt would be produced from bittern and converted into schoenite ($K_2SO_4 \cdot MgSO_4 \cdot 2H_2O$). It would then be treated with imported Muriate of Potash (MOP) for production of K_2SO_4 . In the new approach adopted by us, MOP is generated from effluent streams that contain as much as 80 g/L of KCl. As a result, the process of obtaining pure schoenite is greatly

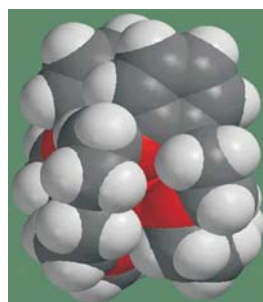


View of bench scale unit for recovery of SOP and MgO from bittern at Experimental Salt Farm of CSMCRI

simplified while at the same time eliminating the need for MOP import except for the purpose of initializing the process. Lime and bittern are the only raw materials required in the process (US Patent Application No : 10/ 814,778 dated March 30,2004). In partnership with TIFAC and an industry, plans are afoot for erection of a 2500 TPA SOP demonstration plant in the Greater Rann of Kutch.

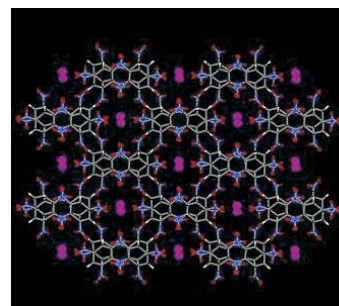
Competitive binding of mixed alkali and alkaline earth metal ions with selective ligands:

The recovery of potassium ion from bittern using several crown ligands has been investigated experimentally as well as by high level computational methods. The high selectivity (ca. 88 %) of dibenzo-30-crown-10 could be rationalized. The calculated results suggest that the preferential selectivity of potassium ion is a delicate balance between crown-cation interaction and hydration of metal ions present in bittern.



K⁺-complexed DB30C10

Dipicryl-amine anion extracts K^+ from bittern with >98% purity. However, with an equimolar mixture of K^+ , Rb^+ and Cs^+ , the same ligand shows 91% selectivity towards Cs^+ , 6.5% selectivity towards Rb^+ , and only 2.5% selectivity towards K^+ . Our detailed study suggested that the ionic radii, structural



Single crystal structure of the Cs⁺ salt of dipicryl-amine. The Cs⁺ ion (purple sphere) are encapsulated in the cavities

organization, and enthalpy of hydration of the cations are the key factors that govern selective precipitation. This observation is also supported by ^{23}Na , ^{87}Rb and ^{133}Cs NMR study. Meanwhile, it has been possible to develop a practical process of preparing Dipicrylamine. This has enabled us to explore the utility of the ligand in selective extraction processes pertaining to potash recovery. A scheme has been devised where such a methodology would be especially beneficial over the conventional methodology of fractional crystallization.

Membrane based removal of calcium, magnesium and sulphate from Brine: Following the preliminary results on application of nanofiltration membranes for selective removal of divalent ions from seawater, reported in the previous biennial report, a trial was conducted on pilot scale and 4000 liter of membrane-processed seawater was prepared with greatly reduced (>90%) concentrations of calcium, magnesium and sulphate. The utility of such brine for a variety of applications, including washing of raw salt, use for preparation of industrial brines, etc., is being investigated. Simultaneously, efforts are underway to carry out similar studies with sub-soil brine although this poses a formidable challenge in view of the high density of such brines.

Gypsum encrustation on template: Production of solar salt is preceded by the precipitation of gypsum which occurs in the brine density range of 17-20°Be'. This gypsum is normally used for manufacture of Plaster of Paris and



The picture depicts the innovation of encrustation of gypsum crystallites on a template. This innovation has its origin in the solar salt production process.

cement. With the growing appreciation within the Institute that gypsum crystallites can take up unusually attractive forms, efforts were made to explore the possible aesthetic applications of slow gypsum crystallization. It was found that certain metal templates can be used for encrustation of gypsum crystallites. Efforts will be made to promote a new cottage industry in our country based on the innovation.

Improving quality and yield of salt recovered from sea/inland brines by the marginal salt producers in Gujarat: As reported in Biennial Report 2000-02, CSMCRI along with SEWA adopted about 35 salt works in Little Rann of Kutch (Surendranagar District) for quality improvement resulting in 25 to 30 percent increase in yield with an increased income of Rs.50/- per ton of salt. During the current reporting period the endeavour to help marginal salt producers continued and 109 salt works at LRK region were adopted for

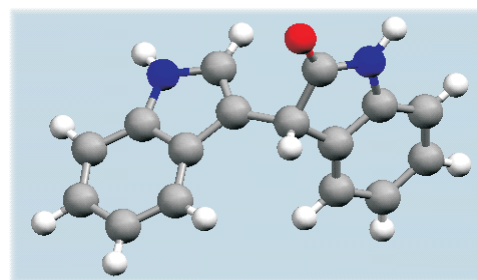
quality upgradation in collaboration with SEWA. As part of the overall objective, modified design and lay out of all the salt works suiting to the brine density and location of salt works were prepared by the Agarias under CSMCRI supervision.

Training in salt production: As part of our collaboration with SEWA, three training programs were organized at LRK. 150 Agarias were trained to design and operate their salt works on scientific lines to improve the yield and quality of salt. Similarly, ANANDI Sansthan, an NGO working for the upliftment of women, sponsored two training programs for the salt producers at Malia region (Morbi-Gujarat) in October-November, 2003. In all, 30 salt producers participated in the 2-day programs and they were trained in the production of industrial grade salt from sea/subsoil brines of the region.

Establishment of Model salt works: Two model salt works each of 5-acre area were set up in Dehgam and Kuda villages in LRK. The model salt works are already in operation. A QC laboratory is also being set up. Simultaneously, infrastructural facilities for the recovery of value added marine chemicals by down stream processing of bittern at LRK are being created. The development will help in pollution abatement as the distiller waste liquor is utilized in the process. Another salt works is being established at Rajasthan to improve the salt quality from lake brine. This work is supported by the Salt Department, State Government and Sambhar Salt Limited.

Organic Chemistry and Catalysis

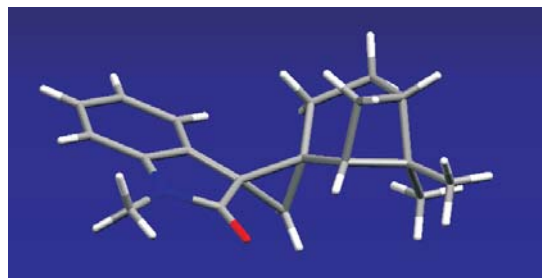
Rhodium(II)acetate-catalysed transformations: Transition metal complexes orchestrated a variety of C-C bond forming processes that are important to create the basic skeleton of the organic structure. We have been involved in the area of catalytic metal-carbene transformations to synthesize a variety of new molecules in an efficient manner with an advantage over classical synthetic methods. Diazo carbonyl compounds are versatile chemical intermediates that undergo an array of transformations and find a wide range of applications in organic synthesis. Apparently, the intermolecular C-H insertions are believed to be synthetically not useful because of the low selectivity and competitive intramolecular reactions. We have achieved the first facile regiospecific intermolecular C-H



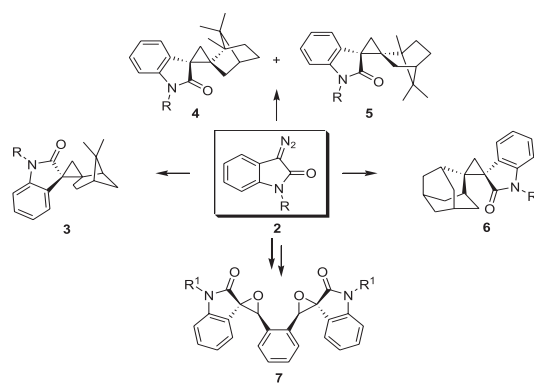
X-ray crystal structure of compound 1

insertion reactions of cyclic diazo carbonyl compounds with substituted indoles and pyrroles in the presence of rhodium(II) acetate catalyst to afford 1,3-dihydro-1'-H-[3,3']biindolyl-2-ones (**1**) and 2-pyrrol-3'-yloxindoles in excellent yields (*Chem. Commun.*, 2002, 824).

Rhodium(II) acetate catalyzed intermolecular *mono-* as well as *bis-* cyclopropanation reactions of cyclic diazoamides were shown to furnish an assortment of stable strained di- and tetraspirocyclic cyclopropane compounds in good yield with brevity. The cyclic diazoamides **2** were reacted with several *exo*-methylene compounds at room temperature to afford the stable strained spirocyclic cyclopropyloxindole systems **3-6**. The resultant products exhibit good functional group content, cyclic connectivity and stereocenter content (*Synlett*, 2003, 1599). The reaction of cyclic diazoamides **2** with aryl aldehydes catalysed by rhodium(II) acetate led to the intermolecular stereoselective epoxide ring formation. An assortment of spiro-indolooxiranes has been synthesized in a facile manner. The use of aryl dialdehydes in the course of reaction of cyclic diazoamide resulted in the formation of bis-spiro-indolooxiranes **7**. This process forms an interesting example in which the bis-epoxide ring system is synthesized from the diazo carbonyl compound. In this process, polycyclic compounds with specific stereochemistry are quickly and efficiently generated from simple starting materials (*Synlett*, 2004, 639).

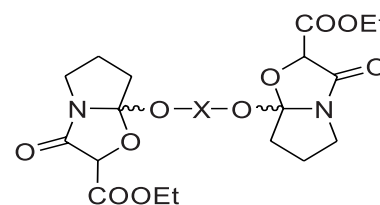


X-ray crystal structure of compound 3



The unstable isomünchnones generated from the α -diazoimides have efficiently been trapped using oxygen nucleophiles in the presence of rhodium(II) acetate catalyst. This forms a facile tandem cyclization-nucleophilic addition route to the 2,3-fused perhydrooxazol-4-one and bis (2,3-fused perhydrooxazol-4-one) **8** skeletons with the option to vary

substituents and ring sizes. Formation of up to two cyclic rings, four CO bonds is achieved in a single step in good yield. This synthetic process forms a facile entry into the new family of 2,3-fused perhydrooxazol-4-one and bis (2,3-fused perhydrooxazol-4-one) **8** systems, with excellent atom economy. It is anticipated that this technique of multiple bond formation will be useful for the syntheses of dendrimers (*Chem. Commun.*, 2003, 440).



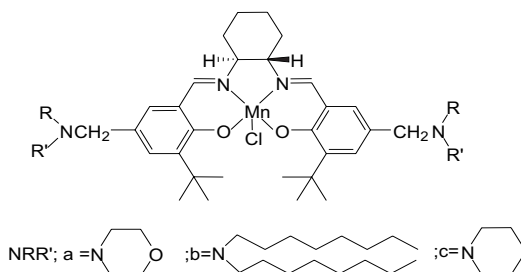
8; X = alkyl, aryl, alkynyl

Single synthetic step:
 2 rings
 4 C-O bonds
 2 quaternary carbons
 4 stereocentres

Metal-complex catalysed chiral epoxidation

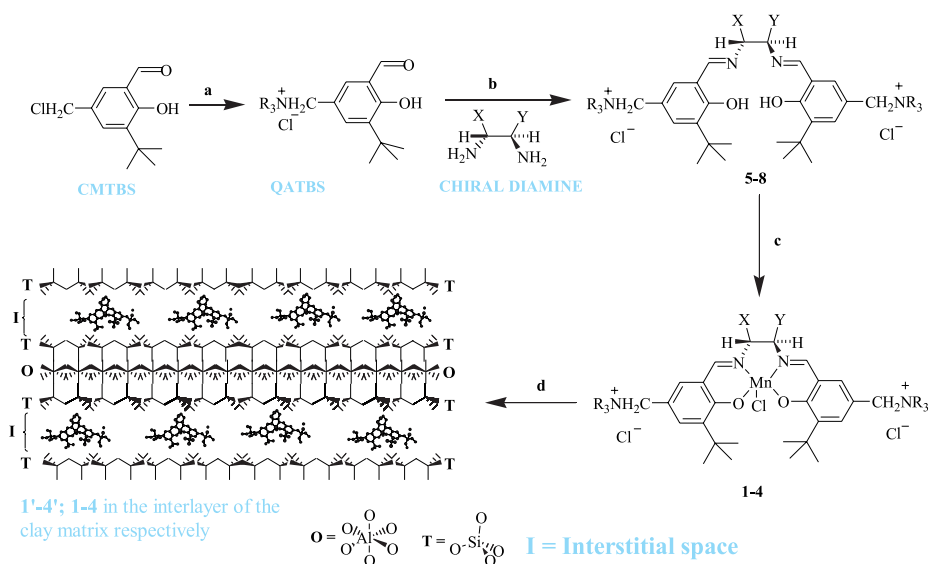
Chiral epoxidation catalysts with in-built phase transfer capability

capability: A series of Mn(III)Salen based catalysts having in-built phase transfer capability were synthesized. These catalysts showed enhanced activity and selectivity for alkene epoxidation even with the use of inexpensive pyridine N-oxide as an axial base (*J. Catal.*, 2002, 209, 99). Spectroscopic and magnetic study established that, Mn(IV)oxo, acts as active catalytic species rather than generally believed Mn(V)oxo.



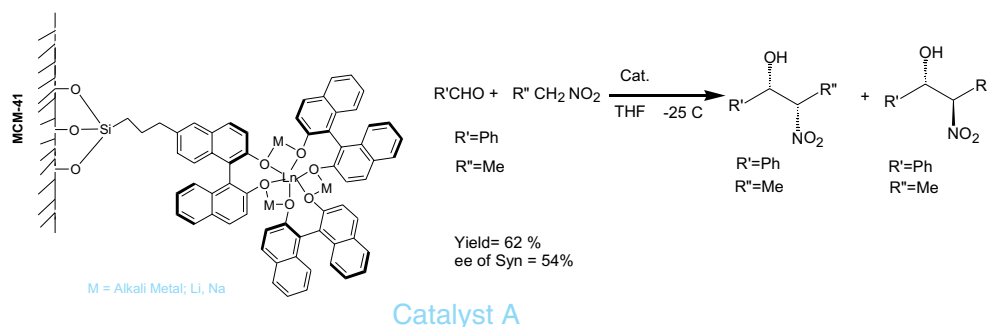
Clay based heterogeneous enantioselective epoxidation catalysts

Dicationic chiral Mn(III) Salen complexes were heterogenized in the interlayers of Montmorillonite clay by simple cation exchange technique. The supported catalysts were found to be effective for the epoxidation of alkenes under heterogeneous conditions (*J. Catal.*, 2004, 221, 234). High chiral induction, as determined by ¹H NMR/ HPLC using the chiral shift reagent Eu(hfc)₃, was obtained in case of cyclo, nitro and cyano chromene with catalyst loading of 0.4 mol % up to five cycles.



1 and **5**; X = Y = Ph, R = *isooctyl*; **2** and **6** = X = Y = -(CH₂)₄, R = *isooctyl* **3** and **7**; X = Y = Ph, R = ethyl, **4** and **8**; X = Y = -(CH₂)₄, R = ethyl,

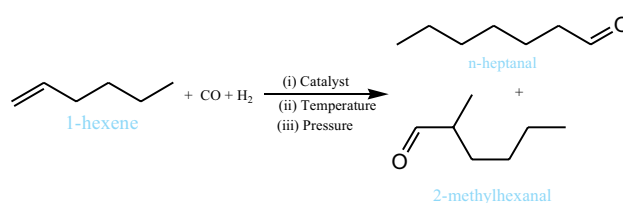
Chiral ligands covalently bound on mesoporous silica: Chiral BINOL ligand was synthesized and covalently bonded to silanol groups of ordered mesoporous MCM-41. Characterization of the catalyst was done using XRD, TGA, N₂ BET, FT-IR and elemental analysis. The catalyst A was then used for nitro aldol reaction using benzaldehyde and nitroethane as the reactants. The initial results showed that the activity of the supported catalyst is equivalent to its homogeneous counterpart.



Metal-complex based other catalytic reactions

Hydroformylation of alkenes catalysed by phosphene complexes:

A rhodium metal complex, RhCl(AsPh₃)₃, was used as a catalyst for hydroformylation of 1-hexene in homogeneous conditions. The catalytic activity of RhCl(AsPh₃)₃ was observed to be similar and associated with less



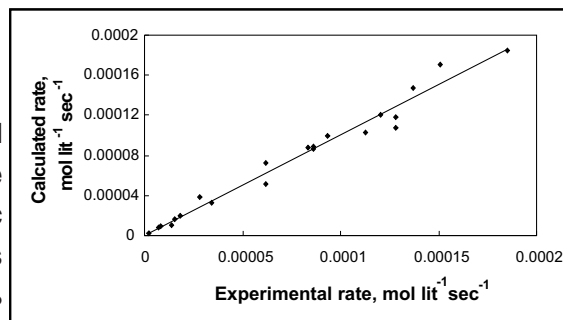
activation energy with respect to its analogue, RhCl(PPh₃)₃.

Effect of various parameters on the rate of hydroformylation have been investigated in wide range of conditions in

order to study the kinetic, thermodynamic and mass transfer of the reaction. The rate of hydroformylation increased on increasing catalyst concentration up to 20.00×10^{-5} mol/L followed by a decrease and then saturation, and highly active species was identified as RhH(CO)(AsPh₃)₂. Dependence of H₂ pressure showed first order kinetics confirming oxidative addition of hydrogen to acyl complex (RCO)Rh(CO)(AsPh₃)₂ as rate determining step. Rates were increased with increasing CO pressure up to a certain limit and after that followed inhibition due to formation of hydroformylation inactive acyl species, (RCO)Rh(CO)₂(AsPh₃)₂ and/or (RCO)Rh(CO)₃(AsPh₃). Agitation speed dependence indicated that a moderate speed of 100 rpm is sufficient for the reaction and RhCl(AsPh₃)₃ catalyst system is observed to be more susceptible than RhCl(PPh₃)₃ towards the temperature of heat-treatment. The determined activation energy is 10.2 kcal/mol and low value of entropy of activation (-48.5 ± 1 cal/(K mol)) is highly

$$\text{rate} = \frac{4008.22 * [A]^{0.75} * [B] * C^{0.35} * D}{((1 + 102.0 * [B] + 10.99 * D)^3 * D)}$$

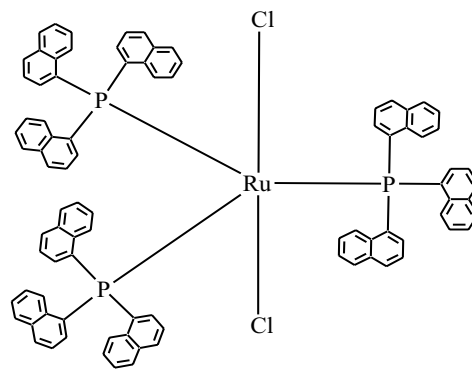
favorable for studied hydroformylation catalyst. The nonlinear semi-empirical kinetic model representing the data was found to be the best with 11.6 % error between experimental and calculated rates.



Comparison of reaction rates calculated from the empirical model with experimental data

RuCl₂(TNP)₃, a new catalyst for regio-selective hydrogenation of alkenes:

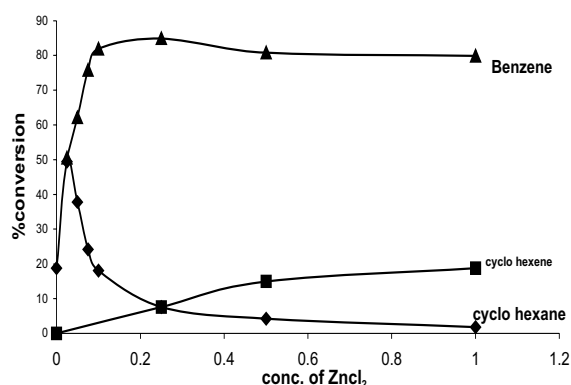
A new ruthenium complex, RuCl₂(TNP)₃, (TNP = Tri Naphthyl phosphine) was synthesized and found to be an effective catalyst for selective homogeneous hydrogenation of various alkenes having terminal, internal, steric hindered C=C bonds. A comparative study with analogue, RuCl₂(PPh₃)₃ Wilkinson's catalyst, performed under identical conditions indicated that the modified catalyst RuCl₂(TNP)₃, is highly efficient for regio-selective hydrogenation. The catalyst was found to be more effective for hydrogenation of terminal olefins.



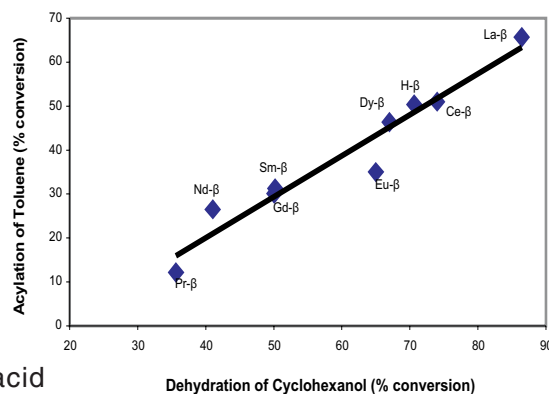
RuCl₂(TNP)₃ complex

Water soluble metal complex catalysts for hydrogenation of benzene and alkenes:

Water soluble catalyst, RuCl₂(TPPTS)₃, was synthesized and used for hydrogenation of various unsaturated hydrocarbons such as 1-hexene, 1-heptene, styrene, cyclooctene, cyclooctadiene and benzene. Use of such a biphasic catalytic system is observed to be more effective for separation of product and also for the recovery of catalyst. The catalysts were very effective for partial hydrogenation of benzene with 19% conversion and 91% cyclohexene selectivity in the presence of zinc salts (*J. Mol. Cat. A*, 2003, 202, 9).



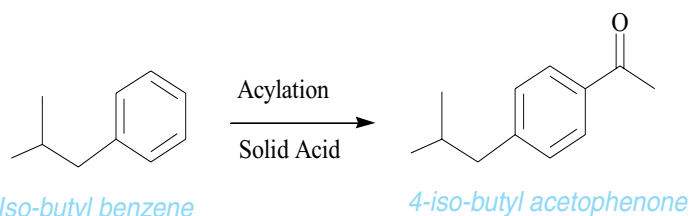
Acylation of aromatics with solid acids: Acylation of toluene was studied with rare earth cation exchanged zeolite β using acetic anhydride as an acylating agent and nitrobenzene, o-dichlorobenzene and dichloroethane as the solvent in liquid phase in the temperature range of 368 to 408 K. The rare earth cation exchanged zeolites were observed to have the catalytic activity in the following order $\text{La-}\beta > \text{Ce-}\beta > \text{H-}\beta > \text{Dy-}\beta > \text{Eu-}\beta > \text{Sm-}\beta > \text{Gd-}\beta > \text{Nd-}\beta > \text{Pr-}\beta$ with more than 95% selectivity towards the para isomer. Among the solvents studied, nitrobenzene is the most favored for toluene acylation reaction. The correlation of catalytic activities of the different catalysts with the cyclohexanol dehydration as well as DRIFT spectroscopy showed that the toluene acylation is a Brönsted acid catalyzed reaction (*J. Mol. Cat. A*, 2004, 215,201).



Correlation of toluene acylation activity with Bronsted acidity of zeolite

Solid acid catalysts for acylation of isobutylbenzene: Acylation of isobutyl benzene presently done using HF or AlCl_3 catalysts was studied with an objective to develop eco-friendly catalysts. Zeolite based catalysts giving 32% conversion with 92% selectivity for 4-isobutyl acetophenone has been developed.

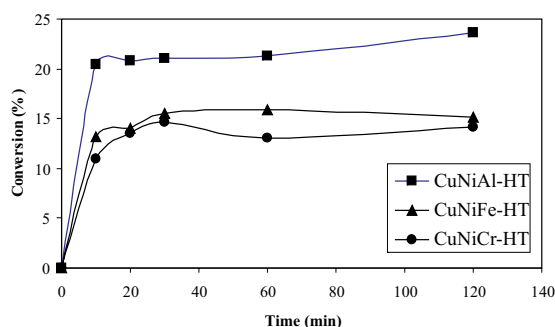
This is the highest conversion and selectivity reported so far with any zeolite catalysts. The catalyst developed has been



extensively studied under varied process parameters and regeneration conditions. An international patent application (*US Patent application No. 10/678,902, PCT/IN 03/00439*) has been submitted for this work.

Solid base catalysts for hydroxylation of phenol and isomerization of eugenol: Hydrotalcite type compounds have been used as solid base catalyst for selective hydroxylation of phenol to dihydroxybenzene and isomerization of eugenol and safrole to isoeugenol and isosafrole. Copper containing hydrotalcites with different trivalent metal ions were used as catalyst for hydroxylation of phenol to dihydroxybenzene using H_2O_2 as oxidant. Among the catalysts studied, Al-containing samples showed maximum activity (CuNiAl-

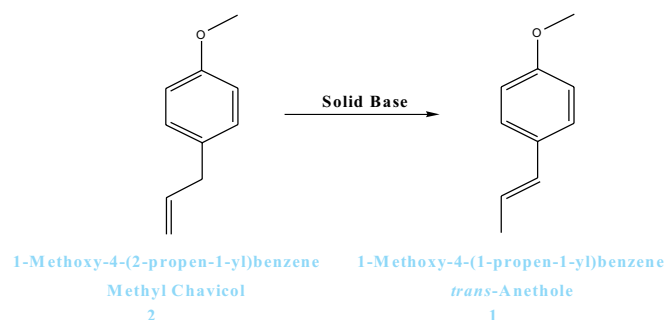
HT, 23.7%; CuCoAl-HT, 21.5% at 65°C ; substrate:catalyst 100:1; substrate:oxidant 2:1; water as solvent) followed by iron and chromium systems (*J. Cat.*, 2003, 220, 161).



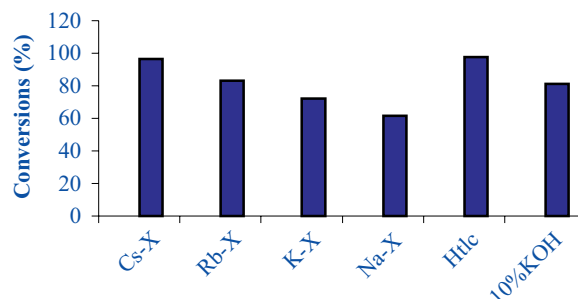
Variation in the reaction time for hydroxylation of phenol over CuNiM(III)-HTs

Isomerization of eugenol and safrole to iso-eugenol and isosafrole is an important reaction, involving double bond migration, catalyzed by bases. Hydrotalcites, were used as eco-friendly catalysts for this double bond migration. Among the catalysts studied, MgAl-hydrotalcite with Mg/Al atomic ratio 6.0 showed maximum conversion of around 98% with a cis/trans isosafrole ratio of 1:9 at 200°C using DMSO as solvent. Among various binary hydrotalcites investigated, Mg and Ni offered maximum activity, wherein MgAl-4HT showed nearly 73% conversion and NiAl-4HT showed 75% conversion with 15:85 *cis:trans* ratio at 200°C with a substrate:catalyst mass ratio of 2:1. Bronsted basic hydroxyl groups of hydrotalcite are presumed to be the active centers.

Solvent-free isomerization of methyl chavicol to anethole: *Trans*-anethole is an important perfumery chemical and intermediate for the synthesis of other perfumery chemicals. Currently, *trans*-anethole is commercially synthesized by isomerization of methyl chavicol using liquid base, KOH. However, this synthetic strategy has drawbacks in terms of use of reagents in large amount, post synthesis work-up in separation of spent KOH from reactants/products, effluent problem, in disposal of KOH. Potential of solid base catalysts namely the zeolites, basic alumina, and hydrotalcite was studied for solvent free, single pot isomerisation of methyl chavicol to *trans*-anethole.



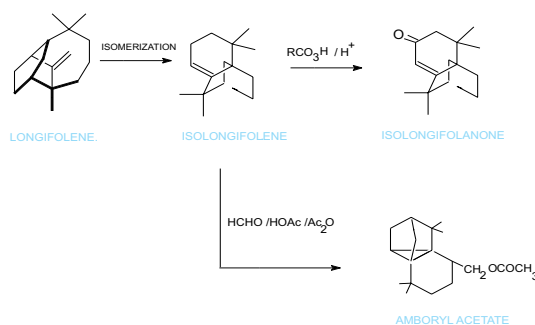
Hydrotalcite, cesium cation exchanged zeolite X and KOH impregnated alumina showed more than 90% conversion of methyl chavicol and 76 to 100% selectivity for trans-anethole and are found to be potential alternatives to presently used liquid base KOH (*Cat. Commun.*, 2003, 4, 543).



Conversions data obtained with various solid bases for isomerization of Methyl Chavicol to trans-anethole

Solid acid catalysts for isomerization of longifolene:

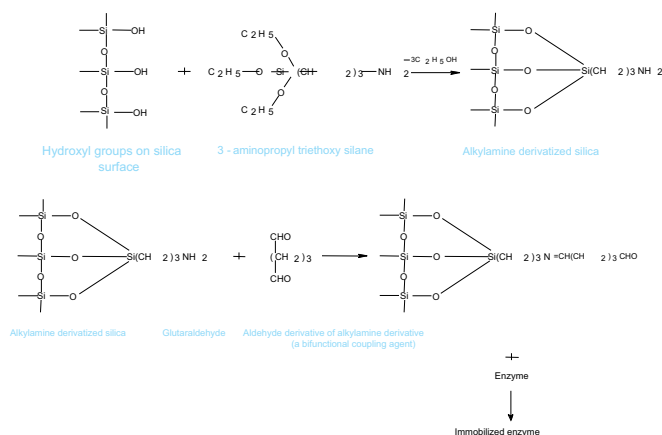
Longifolene, $C_{15}H_{24}$, (decahydro-4,8,8-trimethyl-9-methylene-1-4-methanoazulene), present in the Indian turpentine oil obtained from Chirpine (*Pinus longifolia*) to the extent of 5-7% is the largest tonnage sesqui-terpene hydrocarbon available anywhere in the world. The economical utilization of this terpene hydrocarbon involves its transformation into isomeric product iso-



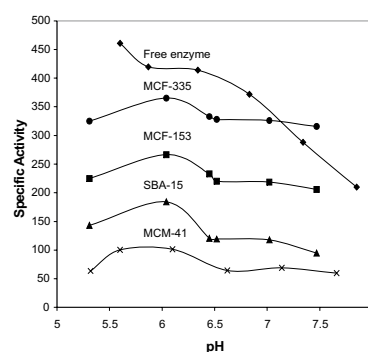
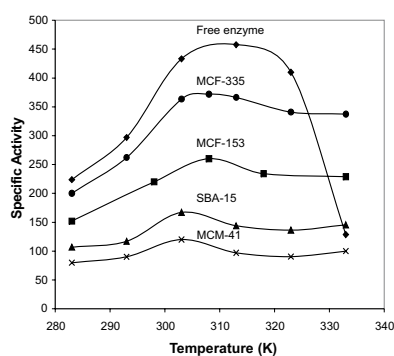
longifolene and its derivatives are extensively used due to their woody and floral odor in perfumery and pharmaceutical industries. Currently used processes using sulphuric acid results in a large quantity of unwanted waste chemicals as by-products that require further treatment before disposal.

Zeolites and sulfated zirconia based solid acid catalysts were developed for solvent free, single stage process for the isomerization of longifolene to isolongifolene with 90% conversion and 100% selectivity. An international patent (*US Appl. No. 10/448,457; PCT Appl. No. PCT/IN 03/00200*) has been filed for this development.

Immobilized α -amylase on mesoporous silica: Immobilization of amylase in different mesoporous silica (MCM-41, SBA-15, MCF-153 and MCF-355) was carried out by covalent binding and the enzyme then used for hydrolysis of starch. Immobilisation was found to enhance the tolerance to pH and temperature for all of the mesoporous silica studied.



Steps for immobilization of enzyme on mesoporous silicas

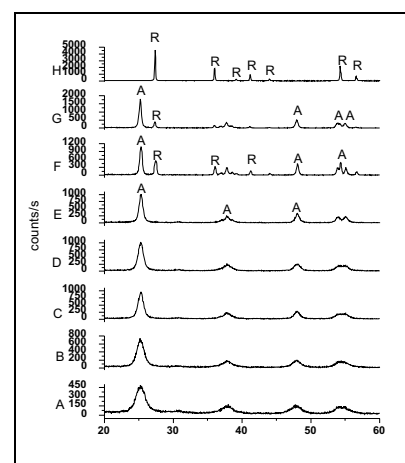


Effect of reaction temperature and pH on the specific activity of immobilized amylase on mesoporous silica for the hydrolysis of starch

The specific activity was highest for MCF-355, it being up to 80% of free enzyme. This is attributed to the larger pore size of the silica, which would allow for easier diffusion of substrate.

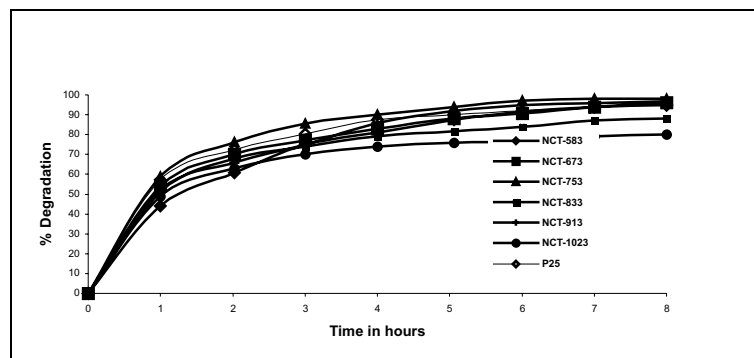
Photocatalytic degradation of nitrobenzene using nanocrystalline TiO₂

Nanocrystalline TiO₂ prepared by sol-gel method was calcined at various temperatures under airflow. The crystalline structure, bandgap, and morphology of the nanocrystalline TiO₂ have been characterised by X-ray diffraction (XRD), Diffuse Reflectance Spectroscopy (DRS), and BET technique. In this work it is found that the bandgap of the nanocrystalline TiO₂ decreases from 3.29 to 3.01 eV with increase in calcination temperature.



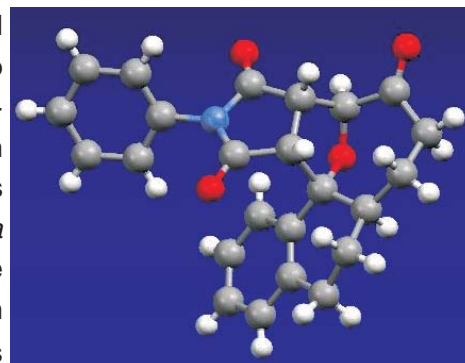
XRD pattern of nanocrystalline TiO₂ calcined at different temperature
 NCT-393 B) NCT-583 C) NCT-673 D) NCT-753 E) NCT-833
 F) NCT-913 G)P25 H) NCT-1023

It was found that due to the nanocrystal structure of TiO_2 there was increase in stability of anatase phase up to 833K. The lowest bandgap was obtained at 1023K for rutile phase. The photocatalytic degradation of nitrobenzene was studied with nanocrystalline TiO_2 of various bandgap and compared with standard P25 Degussa samples.



Degradation of nitrobenzene with various catalysts

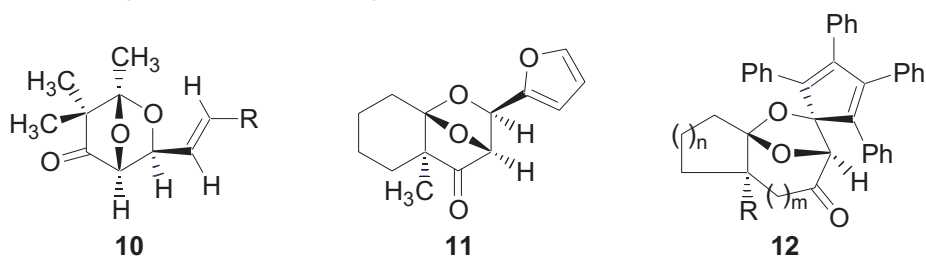
New molecules toward terpenoids: The cyclooctane structural units present in a wide range of natural terpenoids exist either as isolated rings, or form parts of bicyclic or tricyclic frameworks, for example, tremulenediol A, dumortinol, and roseadione. To synthesize these naturally existing compounds, a series of α -diazo carbonyl compounds tethered to cyclopentanone/cyclohexanone/1-tetralone units were synthesized in diazomethane solution to construct various fused cyclooctane ring systems *via* rhodium-generated carbonyl ylides. The reaction of rhodium(II) acetate dimer with various α -diazo carbonyl compounds generated transient cyclic seven-membered ring carbonyl ylides, which



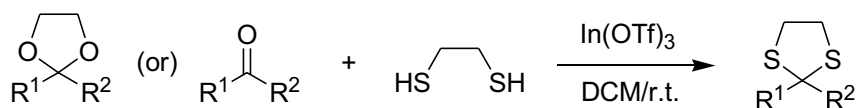
X-ray structure of compound 9

underwent facile 1,3-dipolar cycloadditions with dipolarophiles, like *N*-phenylmaleimide, *p*-benzoquinone, and dimethylacetylene dicarboxylate to furnish a variety of fused epoxy-bridged cyclooctane ring systems in a tandem manner. Interestingly, an oxepine ring system was generated *via* an intramolecular proton transfer of a seven-membered ring carbonyl ylide. A tri-oxa polycyclic compound was obtained in the case of *p*-benzoquinone as dipolarophile. Single-crystal X-ray analysis of a fused cyclooctanoid derivative 9 is reported to decisively establish the structure and stereochemistry of the fused epoxy-bridged cyclooctane ring systems; further analysis revealed the existence of a unique intermolecular CH interaction motif in the solid-state architecture (*Bull. Chem. Soc. Jpn.*, 2002, 75, 801).

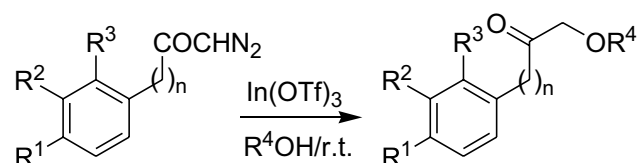
Stereoselective studies on the tandem reactions of carbonyl ylides generated from α -diazo ketones in the presence of various carbonyl compounds have been performed. Intramolecular cyclization of rhodium(II) carbenoids generated the transient five- or six-membered-ring carbonyl ylide dipoles, which efficiently underwent 1,3-dipolar cycloaddition reactions with various dipolarophiles such as aromatic aldehydes, α,β -unsaturated aldehydes, α,β -unsaturated ketones and dienone in a regio- and stereoselective manner. These reactions were found to be highly chemo-, regio- and stereoselective, giving the *exo*-cycloadducts 10-12 in good yields with the formation of three bonds in a single step. These highly functionalized polycyclic products could serve as flexible building blocks for complex target synthesis (*J. Org. Chem.*, 2002, 67, 8019).



New synthetic methods: Protection of a variety of carbonyl compounds as thioacetals using indium triflate, a mild Lewis acid catalyst, was achieved at ambient temperature in very good yield. Trans thioacetalization of oxyacetals into thioacetals was also achieved in excellent yield. A mixture of carbonyl compound and its respective oxyacetal was also completely converted into thioacetal in the presence of indium triflate (*Tetrahedron*, 2002, 58, 7897).

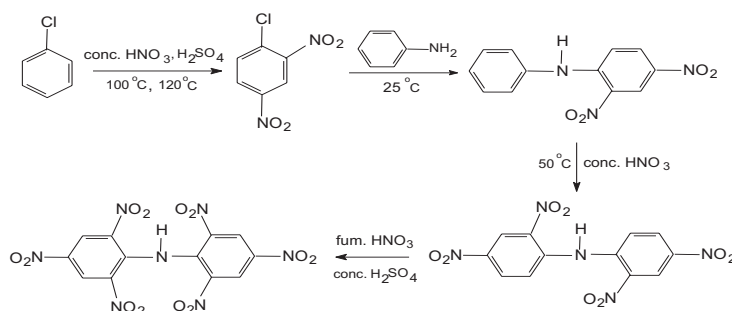


Facile O-H insertion reactions of α -diazo ketones with aliphatic/aromatic alcohols or benzenethiol have been developed in the presence of indium triflate as a catalyst. These reactions provided good yields of α -alkoxy ketones. A comparative study with other Lewis acids establishes the excellent reactivity of indium triflate in O-H insertion reactions of α -diazo ketones (*Tetrahedron Lett.*, 2003, 43, 3133).

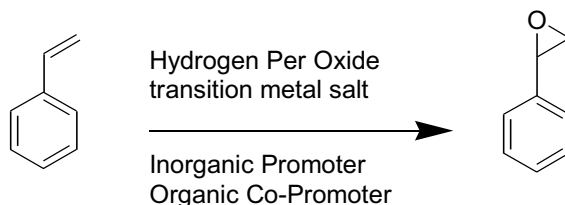


The Michael addition reaction of 1,3-dicarbonyl compounds and enones was carried out in the presence of a catalytic amount of 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU) in ethanol under the mild reaction condition furnished Michael adducts in excellent yields.

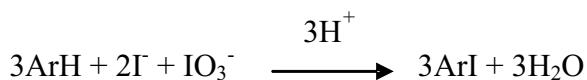
Synthesis of dipicryl-amine: Dipicryl-amine (DPA) has been synthesized at 100 g scale following a modified literature procedure as shown below. The modified procedure produced highly pure DPA, which has been used for extraction of potassium from the effluent generated in the process of converting crude kainite into pure schoenite. The scale up of DPA will enable us to undertake bench scale extraction studies.



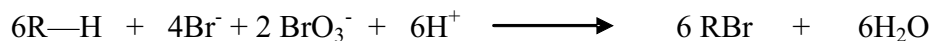
Eco-friendly synthesis of styrene epoxide: An new process for the synthesis of styrene oxide from styrene has been developed. This process is an eco-friendly alternative to the conventional route used for the synthesis of styrene epoxide from benzene using chlorine as it employs H_2O_2 , a cleaner oxidant, and is carried out under mild conditions. Furthermore, commercial grade chemicals can be used, and the catalyst comprises of an inexpensive transition metal salt with easily available inorganic /organic additives used as promoters. The conversion efficiency of 99% with 97% selectivity for epoxide was observed at 1 kg scale. *The modified route constitutes an important development, as it may be useful for other epoxidation reactions as well. Discussions are underway for the transfer of know-how to an industry.*



A new environment friendly protocol for iodination of electron-rich aromatic compounds: A new environment friendly procedure has been developed for aromatic iodination with a mixture of potassium iodide and potassium iodate. The reagent, which can be simply prepared from iodine, is introduced along with the aromatic reactant and acid is added gradually in stoichiometric quantity to achieve *in situ* iodination at room temperature without any catalyst. The inspiration behind development of the reagent was the quality control test that is used to monitor iodine content in iodized salt. Phenol, aniline and anisole could be converted into 2,4,6-triiodophenol, 4-iodo-aniline and 4-iodo-anisole in 98%, 65% and 81% isolated yield, respectively (*Tetrahedron Lett.*, 2003, 44, 5099).



Eco-friendly brominating agent: We have previously shown that a mixture of bromide/bromate in appropriate proportions can function as a useful brominating agent for the preparation of tetrabromobisphenol-A while eliminating the drawbacks of liquid bromine (*US Patent No. 6,365,786*).

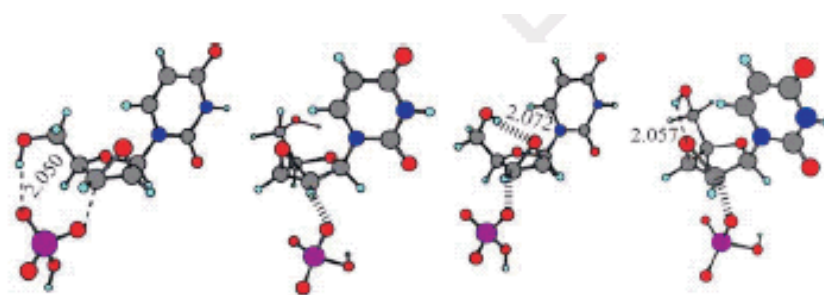


We have now been successful in developing a cost-effective method for the preparation of this brominating agent. The invention utilizes our knowledge of the cold process of bromine manufacture, wherein bromine liberated from bittern is initially absorbed in an alkaline solution which is subsequently acidified to obtain liquid bromine in pure form. It has been possible to modify the stoichiometry of bromide/bromate in the alkaline mixture to enable us to perform bromination reactions with high yield and bromine atom efficiency. The reagent is useful for bromination of water-tolerant organic substrates without the need for any catalyst. Bromobenzene, tetrabromobisphenol-A, N-bromosuccinimide and 2,4,4,6 tetrabromo-2,5-cyclohexadienone are among several useful compounds that were prepared through this route (*US patent No. 6,740,253 dated 25 May, 2004*).

Computational studies on organic reactions

A semi-empirical and density functional study on the origin of regioselective epoxy-ring opening of 2' 3'-lyxoanhydrothymidine:

The importance of antisense oligo-nucleotides is well recognized in therapeutic applications, to inhibit and to activate gene expression and for many mechanistic studies. With the advancement of antisense technology, attempts have been made to synthesize the oligoarabino-nucleotides as oligoribonucleotide mimics. Synthetic strategies adopted for synthesizing such nucleotides are the



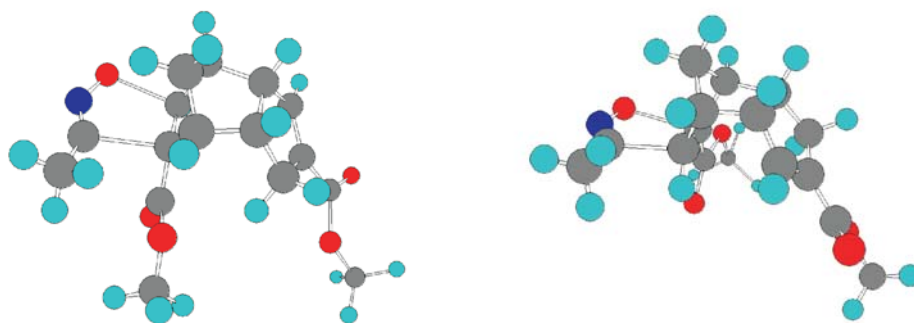
Transition states for the attack of phosphate anion at C2 and C3 centers of 2,3-epoxynucleosides

regioselective phosphorylation of 2,3-epoxynucleosides of lyxo configuration. While regioselectivities observed in such reactions are excellent, the reason for the preferential approach of a nucleophile (phosphate dianion) on a particular reactive site of epoxy ring was obscure. We have now unraveled the factors

responsible for the regioselective epoxy ring opening of 2,3 lyxoanhydrothymidine 1 with phosphate dianion at semi-empirical AM1 and at DFT levels. The relative importance of hydrogen bonding of the leaving oxygen with axial hydroxymethyl group in the transition states of lyxouridine epoxide was analyzed and suggested that this was not an important factor, which control the regioselectivity as speculated (*J. Mol. Struct., Theochem*, 2004, 673, 127).

Selectivities in the 1,3-dipolar cycloaddition of nitrile oxides to dicyclopentadiene and its derivatives:

The 1,3-dipolar cycloaddition of nitrile oxides, generated from aldoximes and nitroalkanes, to dicyclopentadiene proceeds with complete chemo- and stereoselectivity. The approach of the dipole takes place exclusively from the exo-face of the bicycloheptane moiety providing a mixture of regioisomers in the approximate ratio of 55:45. On the other hand, nitrile oxide cycloaddition to dimethyldicyclopentadiene dicarboxylate (Thiele's ester), besides exhibiting chemo- and stereo-selectivity as in the case of dicyclopentadiene, exhibits complete regio-selectivity as well providing a single isomer in good yield. The Influence of remote substituents, including sterically 'sterile' ones, on the regioselectivity has also been investigated using 8-hydroxy and 1-keto derivatives of dicyclopentadiene. These experimental observations have been investigated through gas phase and solvent model MO calculations on the transition state geometries at semi-empirical (PM3) and hybrid *ab initio*-DFT levels of theory. By performing model calculations on well-established experimental observations the computational methods employed in this study were rigorously tested.



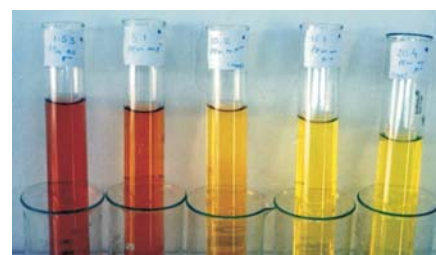
Exo- transition states for the addition of nitrile oxide to Thiele's ester.

The combination of semi-empirical (PM3) and hybrid *ab initio*/DFT (B3LYP) methods predicted the chemo-, stereo- and regio-selectivity of dicyclopentadienes and its derivatives. These more economical methods have successfully predicted the selectivity in the 1,3-dipolar cycloadditions of nitrile oxide to model systems as well as complex real systems. Regioselectivities observed in these cases were rationalized on the basis of Mulliken population analysis. The commonly used frontier molecular orbital analysis failed to predict the regio-selectivity in these cases at the levels of theory employed (*Tetrahedron*, 2004, 60, 1453). Furthermore, tandem cyclization-1,3-

cycloaddition behaviour of various carbonyl compounds was studied computationally to assess the relative importances of steric and electronic effects in controlling the stereoselection in these reactions (*J. Org. Chem.* 2002, 8019).

Analytical method development and Sensor research

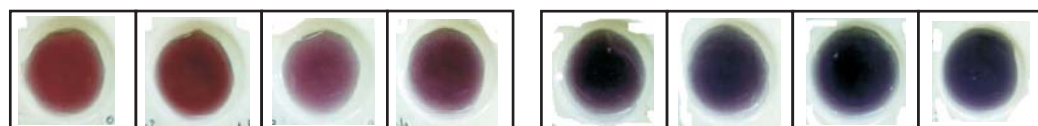
Estimation of fluoride in water by colour and spot tests: Quick estimation of fluoride in natural water by colour and spot tests methods are developed. These methods are based on the reaction between metals like zirconium (Zr^{3+}) and cerium (Ce^{3+}) with suitable dyes like Alizarine-Red-S and Alizarine complexone. In the first method, into a series of aqueous solutions containing NaF of concentrations 0.0-20.5 ppm a mixed acid reagent, which is prepared by standard aqueous solution of Alizarine Red-S, Zirconium oxychloride octahydrate and dilute H_2SO_4 , was added, followed by a standard



Quick estimation of fluoride in natural water by colour test method

solution of sodium arsenite. The mixture was kept for 1 h. In the blank experiment (0.0 ppm fluoride), a dark reddish brown colour develops and as the concentration of fluoride increases, the colour becomes progressively lighter. The colour is light yellow when fluoride concentration is around 20 ppm. The change of colour is due to the progressive formation of $[ZrF_6]^{2-}$ complex as a function of concentration of the fluoride ion. About 30 unknown samples were accurately analysed by this optimized colour-visual method.

In the second method, spot tests were carried out on China-clay spot plate, on each spot of which 3 drops of a standard fluoride solution were added. Then a fixed amount of buffered alizarine complexone was added followed by addition of cerous nitrate solution. After few minutes, the colour that developed on the spot ranged from scarlet red to lilac blue, depending upon the fluoride concentration. The fluoride concentration of a number of “unknown” samples were successfully guessed through naked eye observation. Although semi-quantitative in nature, the test is useful in view of its simplicity.

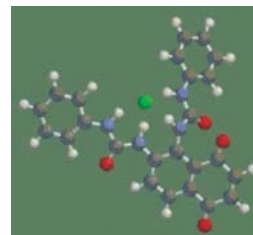


0.0 ppm 0.42 ppm 1.53 ppm 2.04 ppm 5.10 ppm 10.20 ppm 15.30 ppm 20.40 ppm

Quick estimation of fluoride in natural water by spot test method

Estimation of fluoride in non-aqueous media:

Two new receptor molecules based on urea and thiourea derivatives have been designed and synthesized. These receptors showed highly selective binding towards fluoride ion as compared to other corresponding halide ions. Both these receptors are found to be sensitive for naked eye colorimetric detection of fluoride ion in non-aqueous medium.



Sensor for fluoride ion in non-aqueous medium

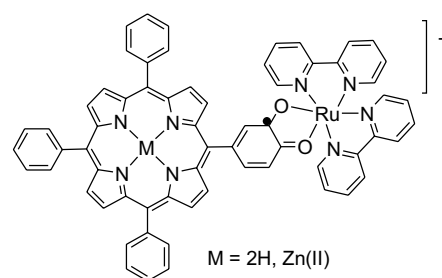
Purity of the bulk precipitated microcrystalline new materials:

A method has been developed to check the structures of bulk-precipitated complexes of DPA anion with alkali metal ions. Powder XRD patterns were simulated from single crystal structures and compared with the experimental powder XRD profiles of the bulk materials. The agreement was excellent suggesting that bulk precipitates have high purities and similar structures as the single crystals.

Quantitative estimation of carbon atoms in a molecule using carbon-13 NMR:

A simplified method for the quantification of carbon atoms of some organic compounds, such as amino acids, was investigated using proton decoupled ^{13}C NMR spectroscopy. The spectra were recorded as a function of pulse delay between successive scans, and at a particular time interval the intensity of the signals corresponding to the same number of carbon atoms became almost equal. The integral area of ^{13}C signals recorded under such condition yielded quantitative estimates that were accurate to within 90-95% for a large number of molecules.

Photo-active sensors: As a part of our sensor development programme, a new series of redox/photo-active bi/tri-chromophoric complexes have been synthesized, which show a very intense MLCT band in the near infrared region of the spectrum. Further, NIR band for all these complexes bleaches and recovers with original intensity as function of the redox state of the coordinated dioxolene moiety. The reversible nature and the on-off response provide these molecules a crucial edge for use as a redox active NIR dye (*Chem. Commun.*, 2002, 2648).

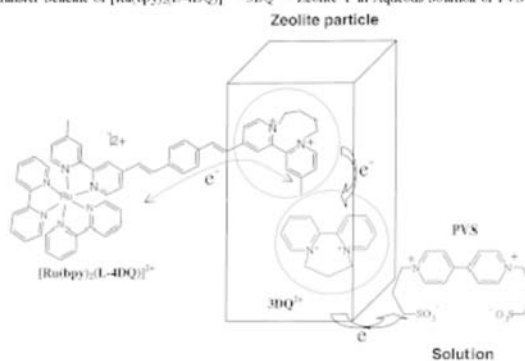


Employing the strategy of quaternization of the 2,2'- α N atoms of the conjugated bipyridine ligand 1,4-bis[2-(4'-methyl-2,2'-bipyrid-4-yl)ethenyl] benzene, a ruthenium(II) complex was tethered on the surface of zeolite Y. Electrochemical and spectroscopic properties of the complex suggest that, upon visible

photoexcitation of the MLCT band, the electron is localized on the conjugated ligand rather than the bipyridines. Electron transfer from the surface complex to bipyridinium ions (methyl viologen) within the zeolite was observed. Visible light photolysis of the ruthenium-zeolite solid ion-exchanged with diquat and suspended in a propyl viologen sulfonate solution led to permanent formation of the blue propyl viologen sulfonate radical ion in solution. The model that is proposed involves intrazeolitic charge transfer to ion-exchanged diquat followed by interfacial (zeolite to solution) electron transfer to propyl viologen sulfonate in solution. Because of the slow intramolecular back-electron-transfer reaction and the forward electron propagation via the ion-exchanged diquat, Ru(III) is formed. This Ru(III) complex formed on the zeolite is proposed to react rapidly with water in the presence of light, followed by reaction with the propyl viologen sulfonate, to form pyridones and regeneration of Ru(II), which then continues the photochemical process (*Inorg. Chem.* 2003, 42, 4215).

Under sensor development programme, we have also synthesized a series of homo and hetero di- and trinuclear complexes using *cis*-M(bpy)₂ (M = Ru(II) and Os(II), bpy = 2,2'-bipyridine) as building blocks and 2,4,6-Tris(2-pyridyl)-1,3,5-triazine (tptz) as spacer. During synthesis, metal-induced unusual hydroxylation

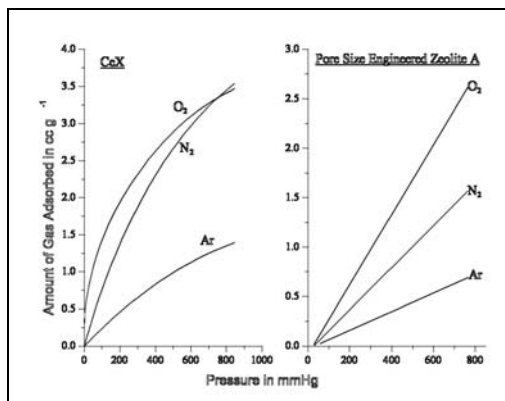
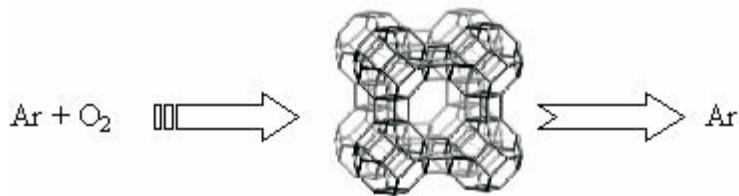
Photoelectron-Transfer Scheme of [Ru(bpy)₃(L-4DQ)]²⁺-3DQ²⁺-Zeolite Y in Aqueous Solution of PVS



of the triazine ring is noted and electrochemical studies of these complexes showed strong intermetallic electronic communication. Mixed-valence species of these complexes, which have been generated by partial chemical oxidation, exhibited strong intervalence transition (IT) in the NIR region.

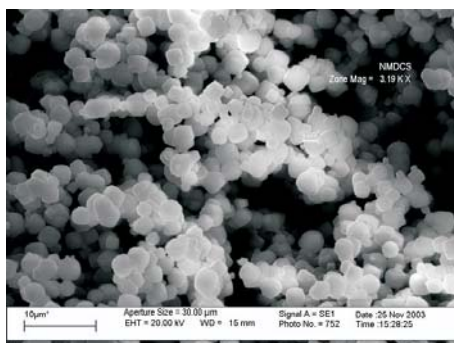
Specialty Inorganic and Organic Materials

Novel Adsorbents for selective adsorption of oxygen from oxygen-argon mixture: New approaches involving *in situ* cluster and oxide formation of transition/rare earth metals inside zeolite A cavities has been used for preparing two new O₂ selective adsorbents. Oxygen selective adsorbents hold potential for argon purification as it shows selectivity over argon and limited selectivity over nitrogen. Two international patents have been filed (*US Patent application No. 10/403,475, 2003; US Patent application No. 10/726,748, 2003. PCT International Application No. PCT/IB03/05324*) for these developments.



Flow sheet of the preparation of Sodium silicates, zeolite-A and precipitated silica from kimberlite

Sodium silicate, precipitated silica and zeolite-A from Kimberlite waste generated during diamond mining:

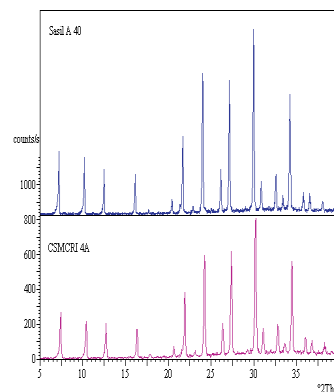
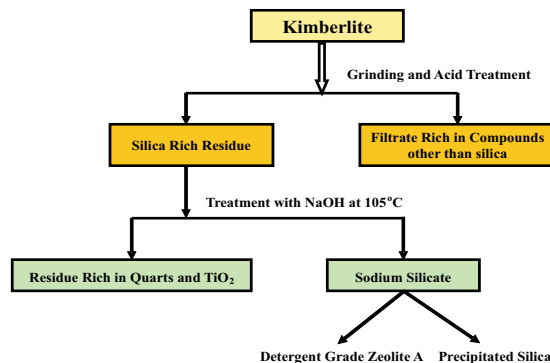


SEM of detergent grade zeolite A from Kimberlite



Artist's impression of diamond mining in Panaa

Schematic of the process Developed



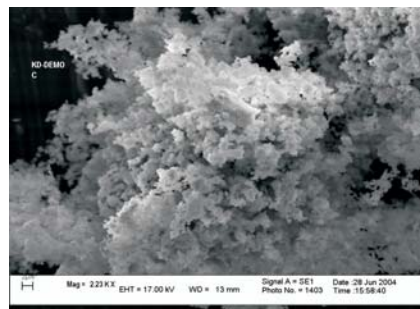
X-Ray diffraction of the zeolite A prepared using sodium silicate prepared from kimberlite. The X-Ray diffraction of the standard zeolite-A of SASIL

A huge quantity of solid Kimberlite waste (10 tons per carat) is generated during diamond mining. In Panna mines itself, which is mining about 83,000 carat of diamond, >0.8 million tons of this solid is produced every year.

A process has been developed for the preparation of sodium silicate at 100kg scale with $\text{SiO}_2/\text{Na}_2\text{O}$ ratio of 3.2, detergent grade zeolite-A (10kg scale) and precipitated silica (10kg scale) using sodium silicate from silica rich Kimberlite waste in collaboration with National Mineral Development Corporation Limited (NMDC) Hyderabad.

Polymer grade precipitated silica for transparent PP film. A process for the production of polymer grade silica with particle size ≤ 10 microns for making transparent PP film was developed and know-how transferred to M/s Kadvani Chemicals Private Ltd., Jamnagar. Evaluation of the sample of polypropylene having film thickness of 40 microns showed excellent performance for haze, gloss and other properties.

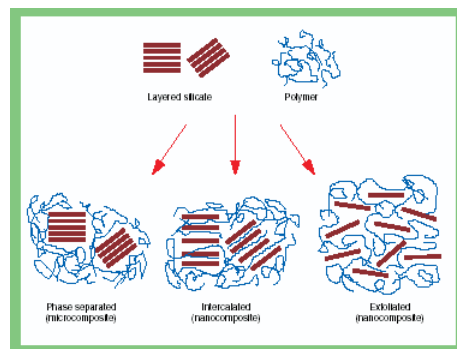
Nanoclays for polymer composites: Development of nanoclays based on Indian natural clays for polymer nanocomposites is in progress. Detailed survey of Indian clays in terms of their availability, chemicals composition, cation exchange capacity, montmorillonite content was carried out and two clay



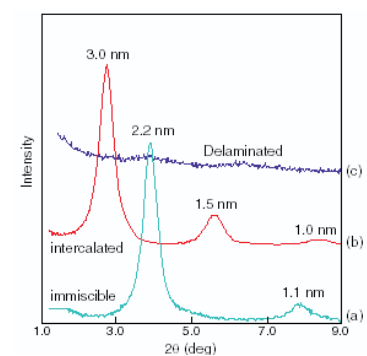
SEM of Polymer grade precipitated silica



Transparent PP film using silica



Intercalated & Exfoliated Polymer



samples of Indian origin were chosen for preparing nanoclays. Around 15 samples were prepared using different organic moieties and evaluated for PP Nanocomposites at NCL, Pune. A few nanoclay samples have shown improvement in the mechanical and modulus properties of PP nanocomposites.

Ion-exchange membranes by sol-gel technique: Organic-inorganic polymer hybrids constitute an emerging research field, which has opened the possibility of tailoring new materials. These hybrid materials have a great potential for the design of innovative membranes. For membrane applications the use of hybrids is an open and promising strategy. Efforts were made to develop organic-inorganic nano-composite material by aqueous sol-gel process, in which cation- and anion-exchange groups were introduced separately by oxidizing SH group to SO_3H using H_2O_2 or $\text{K}_2\text{Cr}_2\text{O}_7$ as oxidizing agent and by chemical grafting of 4 vinyl pyridine, respectively. These membranes exhibited excellent flexibility, dimensional, thermal and chemical stability and electrochemical properties. Route for the preparation of these membranes is completely eco-friendly in nature because it avoids use of solvents and hazardous chemicals like chloro methyl ether and chloro sulfonic acid.

Precipitated calcium carbonate from inorganic waste: CSMCRI has earlier demonstrated at pilot plant scale that the calcium carbonate rich inorganic solid generated in a nitrophosphate plant of a fertilizer industry can be converted to precipitated calcium carbonate (PCC) for various applications. The Institute has recently been granted a US patent (US patent No; 6,671, 864 dated July 13, 2004) for this development. Further evaluation of the PCC product is being done by end-user industries. Discussions are also in progress for commercialization of this process.

Low dust writing chalk sticks: The chalk had been a traditional teaching aid in school, colleges and institutions. It is likely to continue to play critical role in education in our country, notwithstanding developments around information technology and erasable inks for white boards. It is typically manufactured by small-scale industries with little quality control or formal product specifications. Available writing chalk sticks in India has number of demerits on usage. These



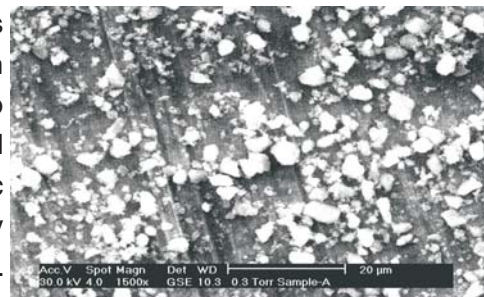
Indigenous extruded chalk sticks



Hydraulic machine for extrude chalk

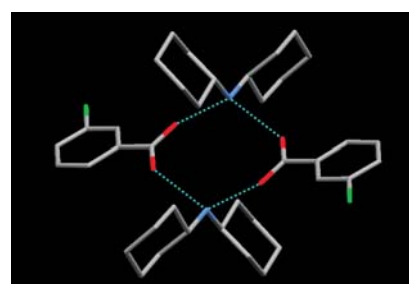
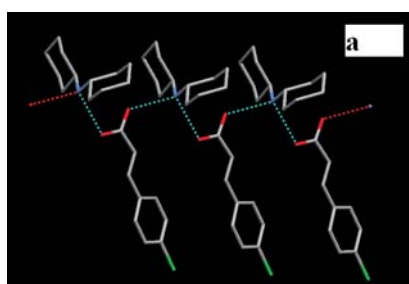
are: (i) sticks break easily (ii) poor clarity and non homogeneity of the marks on writing, (iii) high dust release and screeching sound while writing (iv) moisture sensitivity and poor performance in wet weather. These problems persist, as it had not been scientifically addressed before.

A superior quality extruded chalk has been made with high bulk density, smooth finish, dust-free nature, ability to withstand easy breakage, easy and improved resolution of writing on ceramic board, good visibility of writing, and easy wiping with a specially designed duster. Relatively soft variety chalk samples have also been developed with medium bulk density for more general application on existing boards. This variety of chalk has very good visibility of writing, and very easy wiping even in ordinary black board. The raw material cost for a 6 cm long x 1 cm diameter chalk has been worked out at 15 paisa, and a selling price of chalk of around 30 paisa seems possible. One such chalk piece can write as much as 2 to 3 regular chalk pieces.



The photograph represents the SEM images of the chalk dust particles transferred from the writing board to a cello tape

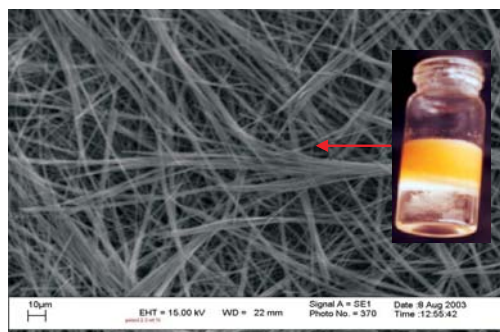
Gelators and their structure-property correlation: Gels are viscoelastic materials comprised of a gelator molecule and solvent wherein the gelator molecules form intriguing 3-D intertwining network of 1-D fibers and the solvent molecules are immobilized in such network leading to solid like gel materials. The driving force for 1-D fibrous growth, at molecular level, must be coming from 1-D nonbonded network such as hydrogen bonding. A series of organic salts derived from variously substituted cinnamic acid, benzoic acid and dicyclohexylamine have been prepared (*Chem Mater*, 2003, 15, 3971). Since these salts are between mono-carboxylic acid and secondary amine, only two types of hydrogen bonded networks are possible; 1-D and 0-D. Therefore, it was



Gelator: 1-D hydrogen bonded network Nongelator: 0-D hydrogen bonded network

expected that at least some of these salts should be capable of gelation. Out of eighteen salts prepared, six of them showed excellent gelation ability including selective gelation of oil from oil/water mixtures, the second such report in the literature. Single crystal structure determination of fourteen of such salts including four gelators and ten nongelators, indicate that 1-D hydrogen bonded networks always promote gelation whereas 0-D network did not produce gelators without any exception. This is the first such straightforward structure-property correlation ever shown in gel literature. Another series of salts prepared from cyclobutane dicarboxylic acid and various imidazole derivatives resulted in

one efficient gelation namely the 1:1 salt of the acid and unsubstituted imidazole (*Chem Mater.* 2003, 15, 2136). Any substitution on imidazole moiety or 1:2 (acid:base) salts resulted into nongelator. Single crystal structure of the gelator and few nongelators, and subsequent XRPD studies on xerogel and gel indicate that 1-D hydrogen bonded network promotes gelation where as 2-D network does not encourage gelation process. We also found a new class of low molecular weight organic gel (LMOG), derived from pyridyl amides of trimesic acids (*Chem Mater.* 2004, 16, 2332)



Selective gelation of petrol from petrol /water mixture and SEM image of gelator (Dicyclohexylammonium-4-chlorocinnamate salt) fibers inside the petrol layer

BIENNIAL REPORT : 2002-2004

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POLYMER & MEMBRANE SCIENCE

Membrane Science & Technology

Chronopotentiometric studies on dialytic properties of glycine across ion-exchange membrane:

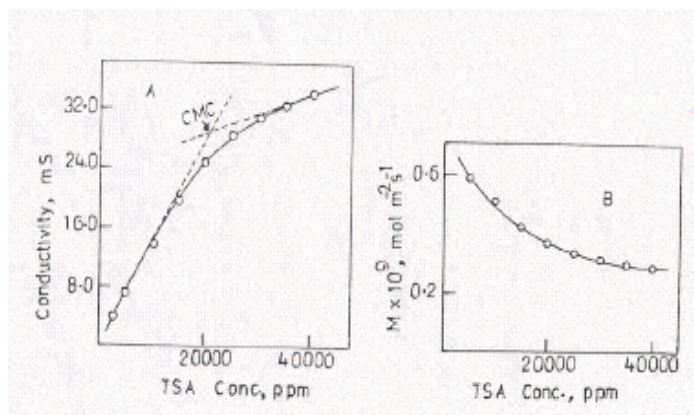
Separation of different amino acids or their desalination is often achieved by precipitation process, but membrane separation technology can also solve this problem efficiently. Electro-transport properties of glycine across ion-exchange membranes were studied as a function of pH by chronopotentiometry. The study was undertaken to probe the effect of variations in the nature of the glycine moiety at different pH; specifically, the different nature of neutral, cationic, anionic and zwitterionic forms. Sand's equation of the chronopotentiometry was modified for the estimation of number of ionic sites at ion-exchange membrane masked or absorbed by glycine ions (ΔC_{div}).

$$\Delta C_{div} = I \tau^{1/2} \frac{2 (t_i^m - t_i)}{z_i F D}^{1/2}$$

Where τ is the transition time at applied current I , and t_i^m and t_i are the counter-ion transport numbers in membrane and solution phases, respectively. Results indicated that glycine in cationic or anionic forms can efficiently electro-transport through ion-exchange membrane, while it is difficult for glycine in zwitterionic form to do so (*Journal of Membrane Science, 203 (2002) 43-51*).

Separation of sodium sulfate and p-toluene sulfonic acid (pTSA) by electrodialysis (ED):

Separation of 12% (w/v) Na_2SO_4 from 2% (w/v) pTSA was carried out under different experimental conditions by batch wise ED



Variation of: (A) solution conductivity; (B) dialytic rate of Na_2SO_4 with pTSA concentration.

in four stages. Energy consumption and current efficiency of the process was found to depend on the Na_2SO_4 and pTSA concentrations because of enhanced back diffusion from concentrate to treated compartments. Dialytic rates of Na_2SO_4 were estimated and it was found that that pTSA adsorbed or masked the surface of anion exchange membranes, which is responsible for the reduction in the ionic transportation. Adsorption/masking was completed up to its critical micelle concentration, and beyond this concentration; further increase in pTSA

concentration had no more effect on ionic transportation. The results point to the need to identify means of suppressing the masking of exchange sites of the membrane by pTSA (*Separation Science and Technology*, 37(14) (2002) 3273-3289).

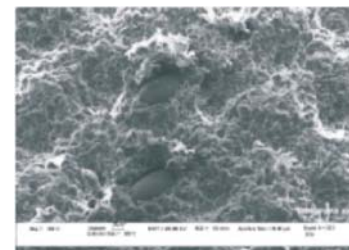
Electrical conductance of heterogeneous cation-exchange membranes in electrolyte solutions: Heterogeneous ion-exchange membranes have been prepared and their conductance measured in different electrolyte solutions. The volume fractions of joint gel phase and integral phase in the membrane have been evaluated. With the help of iso-conductance points, the electro-conductivities of the joint-gel phase and counter-ion diffusion coefficient through that phase of the membrane in equilibrium with different electrolyte solutions were estimated (*Journal of Physical Chemistry B*, 106 (2002) 11910-11915).

International evaluation of CSMCRI interpolymer ion-exchange membranes: Interpolymer ion-exchange membranes developed by CSMCRI were evaluated in the laboratory of Prof. S. H. Moon, KJIST, Kwanju, South Korea against commercial membranes supplied by M/s Tokyoma Soda Co., Japan. The cation-exchange membrane of CSMCRI is comparable in all respects with that of Tokyoma whereas the anion-exchange membrane exhibits a higher electrical resistance, which may affect overall ED performance.

Properties	Cation-exchange membrane		Anion-exchange membrane	
	Tokyoma, Japan	CSMCRI	Tokyoma, Japan	CSMCRI
Thickness (m)	160-200	156	140-180	132
Electrical resistance(m ²) (By Impedance measurement)	3.22	2.92	2.90	6.96
Transport number (By EMF method)	0.980	0.985	0.980	0.970
Fraction of conducting phase (By Chropotentiometry)	0.882	0.892	0.655	0.620

Following the encouraging findings in Korea, 10 m² of interpolymer cation-exchange membrane was supplied to Prof. Yu. Lixin, Tsinghua University, China and its performance was reproduced.

ED stack with hybrid cell pair of interpolymer cation exchange and heterogeneous anion exchange membrane: CSMCRI's cation exchange membrane has been found to be of international class, which would justify its use in ED stacks. Moreover, such membranes are less difficult to make whereas the anion exchange interpolymer membrane preparation involves use of hazardous chloromethyl ether and trimethyl amine. Moreover, the electrical resistance of the latter



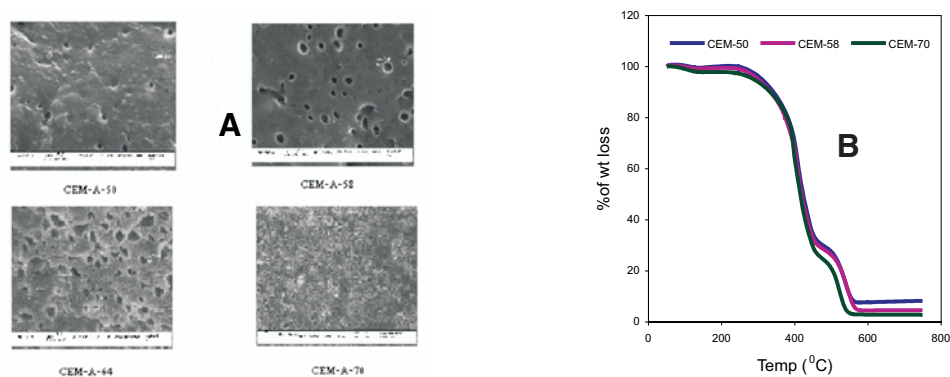
SEM image of HGA

membrane is also high. To avoid the problem with the latter, a heterogeneous anion exchange membrane (HGA) was prepared through the simple technique of casting a pre-formed anion exchange resin on a fabric. The electro-dialytic property of the hybrid cell was evaluated and current efficiency was found to be comparable whereas the rate of salt transport was marginally lower (*Journal of Membrane Science*, 240 (2004) 211-219; *Desalination* (2004) In press).

Novel twin electro-dialyzer for the production of demineralized water: In an ED stack, anode is a costly component. By using a common anode, one can make significant cost reduction in the ED process for versatile industrial applications. A novel twin electro-dialyzer with common anode, in which the first ED stack was packed with non-conducting spacers and second ED stack was packed with ion-conducting spacers, was developed and tested under various experimental conditions. Both stacks separately performed well and in combination produced demineralized water with conductivity $15\text{-}20\text{ S cm}^{-1}$ from brackish water with TDS 500-800 PPM. By extending the number of common stacks it is, in principle, possible to reduce the anode and other associated costs quite significantly (*Desalination* 151 (2002) 33-42).

Device to make high purity water: A simplified EDI unit with conventional interpolymer ion-exchange membranes along with same type of punched membranes suitably interposed to augment electrical conductivity was designed to produce water with conductivity $2.3\text{ }\mu\text{S}$ from 30 PPM NaCl solution.

Ion exchange Membranes by sol-gel technique: Nano-structured organic-inorganic composite membranes combine in a single film the attractive thermo-mechanical properties of the inorganic backbone and the specific chemical reactivity of the functional groups in the organic polymer. Efforts were made to develop organic-inorganic nano-composites by aqueous sol-gel process, in which cation- and anion-exchange groups were introduced separately by oxidizing SH group to SO_3H using H_2O_2 or $\text{K}_2\text{Cr}_2\text{O}_7$ as oxidizing agent and by chemical grafting of 4-vinyl pyridine, respectively.



(A) SEM images and (B) TGA plots of acid catalyzed nano-composite cation-exchange membranes having different silica contents.

These membranes exhibited excellent flexibility and electrochemical properties in addition to high dimensional, thermal, and chemical stabilities. These developments open up new avenues for tailoring the pore design and charge density of membranes for different applications as solid polymer electrolyte and utility in fuel cell design.

Electrodialysis-ultrafiltration hybrid process for desalting and dewatering of iron-dextran solutions: Iron dextran is a valuable pharmaceutical product. During manufacture, it is initially obtained as a solution having 1.5% (w/v) Fe and 6.1% (w/v) NaCl whereas the desired composition for further processing is 5-6% (w/v) Fe and 1% (w/v) NaCl content. The twin task of desalting and concentration posed a difficult challenge, particularly in view of the high viscosity of the solution. The problem was circumvented by a novel ED-UF hybrid process, which resulted in easy desalting and dewatering to required concentration (*PCT Patent submitted, 2002*).

Data for ED-UF hybrid membrane process. Composition of feed iron dextran solution is: [Fe] 1.5%(w/v); [NaCl] 6.1%(w/v); pH 6.9; viscosity 20.13 m poise.

Data of ED experiments					Data of UF experiments				
Potential (V/CP)	Current Efficiency (%)	Power consum. (kWhr/kg)	Desalted stream		P (Bar)	Flux x 10 ¹² (m ³ N ⁻¹ s ⁻¹)	Concentrated Fe dextran		
			[NaCl] (%)	pH			[Fe] (%)	[NaCl] (%)	Viscosity (m poise)
1.25	82.4	0.837	0.90	7.1	4.0	3.409	4.7	0.91	273.5
1.50	75.7	0.912	0.91	7.1	5.0	4.995	4.8	0.91	275.4

Separation and concentration of NaOH from fusion mass: Electrodialysis has enabled us to recover a clear solution of alkali from a fusion mass containing naphthalene sulphonic acid, sodium hydroxide and sodium acetate. This important achievement opens up the possibility of recycling acid/alkali at the end of a reaction instead of neutralizing the same and discarding as effluent.

Concentration of ammonium sulfate: In collaboration with RRL, Bhubaneswar, ammonium sulfate could be recovered and concentrated from 110 to 250 g/l.

Polyaniline composite ion-exchange membranes: Polyaniline (PANI) has good affinity for ion-exchange membranes and can also polymerize in the membrane matrix by chemical oxidation resulting in an electrically conducting polymer. PANI modifies the hydrophobic and hydrophilic nature of ion-exchange membrane as well as its charge density. Thus it can be useful for the separation of ions with similar charges. Composite membranes were prepared by chemical polymerization of a thin layer of PANI in the presence of high oxidant concentration on a single face of cation- or anion-exchange membranes. These composite membranes were electrochemically characterized and evaluated for the electrodialytic separation of NaCl from its equimolar mixture with one of the

following salts: Na_2SO_4 , CaCl_2 and CuCl_2 . Under optimum experimental conditions up to 30% of the NaCl in solution could be cleanly separated without any contamination of Na_2SO_4 whereas for mixtures of NaCl/ CaCl_2 and NaCl/ CuCl_2 as much as 50-60% of the NaCl was recovered cleanly (*Journal of Colloid and Interface Science*, 277(2004) 162-171).

Development of brine purification resin. Electrolysis of brine solution in a membrane cell is the most environmentally friendly technology known for production of caustic soda and chlorine. However, a stringent requirement is brine of extremely high purity, with hardness not exceeding 20 ppb to minimize membrane damage and, consequently, deterioration of electrochemical performance. Chemical treatment of brine brings down the hardness to only around 1 ppm; hence further purification with the help of a suitable chelating ion-exchange resin is necessary. The institute has endeavored to synthesise such resins.

Brine purification resins were mostly synthesized by co-polymerizing acrylic monomers and acrylic cross-linkers and in certain cases partly by aromatic cross-linkers. These were then functionalized to obtain amino methyl phosphonic acid groups. The resins were exhaustively studied for various physico-chemical and hydrodynamic properties at GACL, Vadodara. A pilot plant containing 50 liters of this resin was run at GACL, Vadodara for brine purification performance. The resin treated 325 m^3 of brine (70°C , pH10 brine) over 29 days @ 500 liters/h flow rate. The leakage of Ca^{2+} in treated brine was <20 ppb through out the run. The values compared well with Lewatit -TP 208, an iminocarboxylic acid type resin. To increase the thermal as well as chemical stability of resin, terpolymer based resins were synthesized and tested twice at GACL for a period of 30 and 40 days with success.

Resin	Volume of resin in H^+ form, ml.	Volume of resin in Na^+ form, ml.	% expansion		Total capacity, meq/g.	Ca^{++} eluted out, g/lit.
			H^+	Na^+		
Lewatit TP 208	530 I cycle II cycle	830	56.2	7.37	17.5	
			56.6	7.06	17.46	
			40	6.95	16.5	
TP-2-0.7-nH	680 I cycle II cycle	941	40.0	7.14	13.5	
			38.33	7.43	13.94	
			28.57	7.51		
*TP-3-0.7-nH	770 I cycle II cycle	995	28.0	6.95	15.5	
			29.22	6.87	14.97	
			23.81	6.44		
AMP**	-	-	85.2	8.2	10.0	
			67.0	8.0		

* Optimized resin; ** Resin that showed less stability

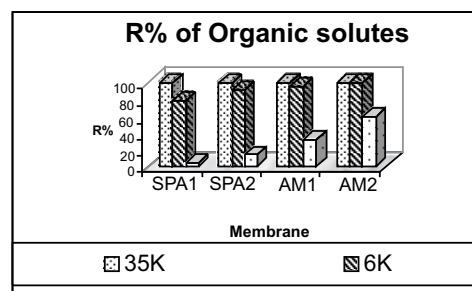
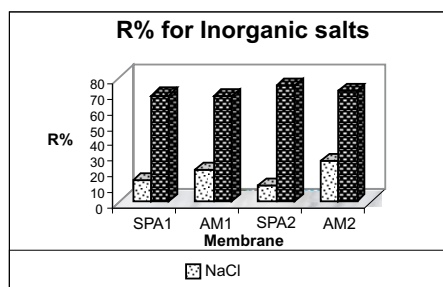
Review of the mechanism of transport of water and salt across a semi-permeable membrane.

A review was prepared of state-of-the-art techniques to separate electrolytes from aqueous solution using the nanofiltration and reverse osmosis membranes (*Review in chem. Engg. 2002(1-2) 111-180*). The extended Nernst-Planck equation, solution diffusion theory, irreversible thermodynamics model, Donnan equilibrium and Kimura-Sourirajan theory were analysed and the following conclusions obtained:

1. Charged nanofiltration membranes are much more suitable for separation of electrolyte mixtures in aqueous solution having multivalent ions than conventional reverse osmosis membranes commonly used for desalination of brackish and seawater.
2. The most elaborate theoretical treatment to describe transport of salt and water through nanofiltration membranes is the extended Nernst-Planck model. The thickness of the rejection layer of the membrane and charge density can be estimated using this model. Other models having analytical solutions are applicable to specific systems with varying degrees of success.
3. The equilibrium of the salt at the solution-membrane interface is described by the Donnan equilibrium. In the case of charged membranes, this equilibrium preferentially allows monovalent ions to permeate through the membrane, while rejecting the divalent ions. Steric effect has been included in the Donnan equilibrium model to allow for the size effect of ions.
4. Extensively computational models like the space charge model provide a more informative picture of the charge distribution inside the membrane pores. However, this effect can be small for pores of small diameter, which is the case for many commercial nanofiltration membranes, as revealed by atomic force microscopy (AFM). The pore size estimated by fitting the experimental flux-rejection data with the extended Nernst-Planck equation is in good agreement with the values measured by AFM.

Surface modification of ultrafiltration membranes. Surface modification of ultrafiltration membranes with a thin layer of cross-linked polymer having negatively charged functional group such as SO_3H was carried out by *in situ* redox polymerization of suitable monomers to obtain membranes having fouling resistance characteristics. The surface chemistry of the membranes was characterized by infrared spectroscopy. Further, the performances of the membranes were measured using aqueous feed solutions of various inorganic and organic solutes. These membranes exhibit inorganic solute separations that are characteristic of NF membranes even though their MW cut off values are

higher, implying that the charged surface exerts profound effect on the performance of the membranes. Apart from bestowing antifouling property, the membranes can be exploited for low pressure separations of multivalent ionic salts from monovalent ionic salts, and for processing of relevant biotechnological product streams.



Development of nanofiltration (NF) membrane for selective fluoride removal. Loose negatively charged thin film composite polypiperazine amide-based NF membrane was prepared in the laboratory and defluoridation experiments conducted on a test kit with pure water, tap water, saline water and hard water into which 5-20 ppm sodium fluoride (NaF) was added. Our studies indicated that the membrane can be used quite effectively to reduce up to 50-85% of the fluoride impurity in water, depending on feed water quality. Experiments conducted with 1000-2000 ppm TDS brackish water showed that salinity is also reduced by 30-35% and hardness up to 80-85%.

Treatment of seawater with nanofiltration membrane. It has been mentioned in the previous biennial report that seawater can be treated with an appropriate nanofiltration membrane to remove divalent ions selectively with minimum loss of sodium chloride. Such a separation would be of considerable interest for use of seawater in place of fresh water in industrial applications like preparation of brine for soda ash and caustic soda industries. Nanofiltration membranes could also be used for RO pretreatment to minimize fouling of the RO membranes. We have carried out two sets of experiments: (i) wherein seawater was purified in two stages of nanofiltration, with 50% recovery in each stage giving overall 25% recovery and (ii) wherein seawater was treated in a single pass with 75% permeate recovery. The latter experiment took approximately 8 hours. Each set of experiments was carried out with 4000 liters of seawater using a 4" diameter module.

Feed and permeate analysis after 2-stage NF with overall 25% recovery

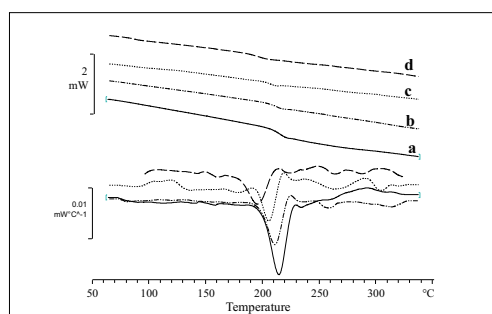
Water	Calcium (mg/L)	Magnesium (mg/L)	Total hardness as CaCO ₃ (mg/L)
Feed	441	1131	5750
Permeate	62	38	310
% Rejection	86	97	95

Feed and permeate analysis after single stage NF with overall 75% recovery

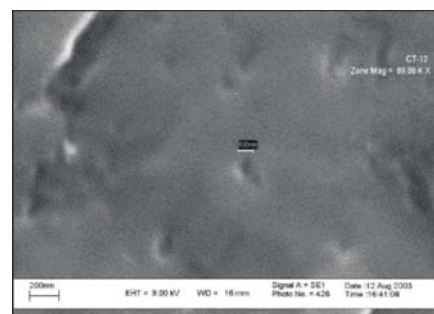
Water	Sp. Gr./(^o Be)	Calcium (mg/L)	Magnesium (mg/L)	Sulphate (mg/L)	Total hardness as CaCO ₃ (mg/L)
Feed		461	1325	3036	6600
Permeate		241	328	30	1950
% Rejection		48	75	99	71

Structure-property relationships of novel thin film composite (TFC) membranes.

Thin film composite (TFC) membrane was prepared from the interfacial polymerization of meta-phenylenediamine (MPD) and trimesoyl chloride (TMC). The TFC membrane based on MPD and TMC components has been successfully employed in the brackish and seawater desalination. Some studies on TFC membrane prepared by different monomers have also been studied in detail. (Indian Patent No. 169550; Indian Patent No. 1216/DEL/2004; J. Membr. Sci., 211, 2003, pp. 13-24). Understanding the relationship between the preparative conditions and the properties of composite membranes is the key to the successful development of membranes for various separation applications. Novel composite membranes containing polyamide skin layer of the reaction product of trimesoyl chloride and 1,3-cyclohexanebis(methylamine) (CHMA), 2,3-diaminopyridine (DAP) were prepared by *in situ* interfacial polycondensation under different conditions on a reinforced microporous polyethersulfone support. The polyamide skin layers were isolated by dissolving the PES support in dichloromethane and the free skin layers were characterized by IR, TGA and DSC techniques to obtain information on the chemical nature as well as physical properties of the skin. The glass transition temperatures (T_g , 195-210^oC) of polyamide skins are dependent on the concentration of the monomers (TMC/diamine) used for skin layer formation. Increasing trend in the T_g values was observed with increase in concentration of TMC/diamine. TGA thermograms show that the initial decomposition temperatures of the polyamide skins are in the range of 330-400^oC which is about 20-90^oC lower than that of polyethersulfone (420^oC). Scanning electron microscopy studies of the



DSC thermograms of: a) PES, and b-d) poly (CHMA-TMC) skins; CHMA = 2%, TMC = 0.01, 0.1 and 0.2% in b, c, and d respectively.



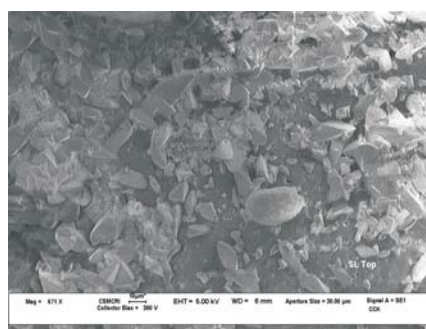
SEM microphotograph of top poly(CHMA-TMC) skin layer

membranes indicate that the top polyamide skin surface appears like a honeycomb like structure. SEM cross sections of the membranes clearly show the presence of nodular structure which arise from the dense polyamide skin. In between the nodules, there are pore channels that traverse up to the polyester support. The equilibrium water uptake of the membranes increases with the increase of TMC concentration in the reaction solution due to the formation of more amount of carboxylic acid group (J. Membr. Sci., 214 (2003) 211-221).

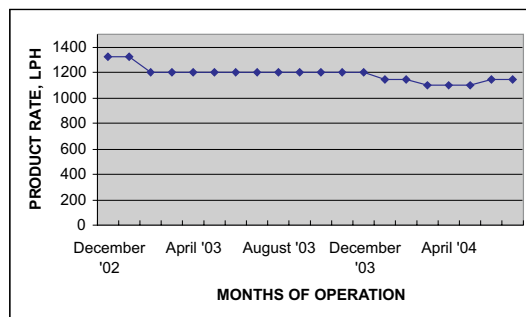
Fouling and flux decline in TFC membrane. Flux decline and fouling are important parameters to be observed during RO operation and maintenance as the economics of the technology depends much on the membrane life and product water output. The lifetime of the membrane is related to the chemical nature of feed water, pretreatments, operation condition, frequency of cleaning and membrane fouling. As we use only sand-filter and micron-filter in our plants to clear the incoming feed and no other chemical treatment is given before passing the feed into membrane module, a significant fouling was expected. It was therefore felt important to conduct performance monitoring to accumulate real operation data for future implementation. Figure shows SEM picture of one fouled membrane surface showing deposition of inorganic salt foulants. The foulant is found to be calcium carbonate based on FT-IR (presence of strong band at $\sim 1420\text{ cm}^{-1}$ and sharper band at $\sim 710\text{ cm}^{-1}$ and $\sim 880\text{ cm}^{-1}$). The figures shows membrane performance profile for 18 months operation.



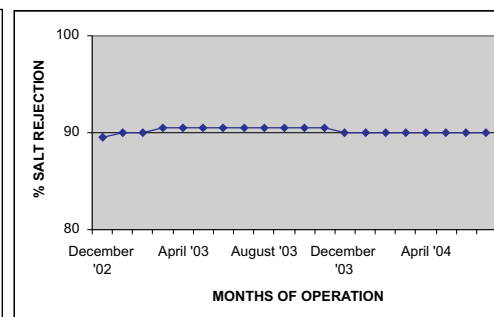
Fouled TFC membrane module



SEM examination of the fouled surface



Foulant on top surface of membrane



Membrane performance Vs operation time

Novel film forming polyimides for non-aqueous membrane applications. Novel film forming polyimides which are soluble in polar aprotic organic solvents like DMF, DMAc, NMP and DMSO but insoluble in other organic solvents were synthesized using appropriate diamines and dianhydrides. The synthesis involves their polycondensation to obtain polyamic acids, followed by cycloimidization to polyimides. The polymers are being utilized for the development of suitable membranes for non-aqueous applications such as separation of solvents from dewaxed lube oil and solvent recovery from vegetable oil extracts. (*Current Science, 2003, vol. 85 (6), 761-771*)

Commissioning of 1 Million liters/day RO plant at CPCL, Chennai. CSMCRI had earlier shown the suitability of the TFC RO membrane developed in-house for desalination of tertiary treated sewage water at CPCL, Chennai. Demonstration of the technology at a much higher scale was sought as a prelude to commercial exploitation and a Rs 60 lakhs project was funded by the Centre for High Technology to install a 1 MLD plant at CPCL based on indigenous membrane. CSMCRI produced nearly 2000 sq. m. of the TFC membrane for this purpose that gave, on average, 35-40 gfd flux and 93-96 % salt rejection under standard conditions of testing at coupon level. The membrane was then rolled into modules. The plant that was installed at CPCL in November 2003 comprises 42 spiral modules of 200 mm (8”) dia x 1 m size. The plant is operating at 200-psi pressure with 75% recovery of product water. The quality of the product water is about 150 ppm from 1500-1700 ppm feed water. The commissioning report states that the performance of the indigenous membrane elements is “almost at par with the imported CEPA 40 membrane modules from Hydranautics in terms of salt rejection, product rate and recovery.”

Commissioning of 1 MLD Demonstration RO plant 25-11-2003

1. Commissioning of the 1 MLD Demonstration RO plant using indigenous RO membranes was completed on 24.11.03.
2. It was operated overnight and after stabilization, its performance was assessed. Results are as follows:

Trains	Two (A and B)
Feed flow per train	24KL/Hr. (400 lpm)
Array	22(4 elements in each pressure vessel)
Feed pressure	16 – 17 kg/cm ²
Pressure drop	3 kg/ cm ²
Product flow	18 KL/Hr
Feed conductance	2310 S/cm
Product conductance	227 S/cm
Product recovery	75 %
Salt rejection	86-90% (expected to improve after 2 days of continuous operation)
Time of continuous operation	16 hours



1 MLD Indigenous RO Plant at CPCL, Chennai

The performance of indigenous RO membranes in 22 array is nearly matching the projections for imported RO membranes (ESPA -3 of Hydranautics Inc., USA) except for the higher feed pressure needed for indigenous membranes (copy of Hydranautics projections enclosed)

Installation of Prototype RO plant in Rajasthan for long-term field study. Under a DST sponsored project, we have installed an RO plant of 2000 liters/hour capacity, at Kisari village of Jhunjunu district, Rajasthan in August 2002. The plant consists of sand filter, cartridge filter, booster pump, high-pressure pump, membrane housing and control panel. The plant has six spiral elements each of 4" dia x 1m size made from our TFC membrane. The RO plant was installed in a location where plant room, well-water supply, electric supply and storage tanks are available. The pilot plant installed in Rajasthan is treating brackish water with 90% selectivity to yield potable water. A noteworthy point is that the feed water is contaminated with excessive amounts of fluoride and nitrate and these harmful components too are eliminated through the RO treatment. The Institute received generous acclaim from the villagers of Kisari village, Rajasthan, local NGOs and the Public Health Engineer on completion of one year of successful operation of the plant. Feedback was captured on a CD and the plant was featured in Doordarshan's *Turning Point* show to commemorate two years of successful operation and the benefits that have accrued to villagers. (*Desalination* 161 (2004) 137-144; *Desalination*, 165 (2004) 202-208



“No more illness or fever among children” (Kisari village school teacher responding to a question on benefits that have accrued to children from purified water)

Parameter	Feed water	Permeate water
Total dissolved solids (ppm)	1907	148
Fluoride (ppm)	1.74	0.169
Total hardness (as CaCO ₃) (ppm)	261	9
Nitrate (ppm)	151	23.4

Feed & Product Water Data for Kisari (Rajasthan) brackish water RO plant after 1 year of operation

Field installation of brackish water RO plant at Air Force Station, Utarlai, Barmer (Rajasthan). The Indian Air Force centre at Utarlai, Barmer, with a population of 8,000, faced acute water shortage supply and the water from the bore-well was also brackish water besides containing fluoride. The feed water quality is about 3000 ppm with presence of excess fluoride (2.2

ppm). To help the centre in its potable water requirement a brackish water RO plant (1800 LPH) was installed at the Air Force Station for converting the brackish water into safe drinking water. The plant (named Ganga by the Air Force) is operating at 225 psi pressure and providing fluoride free (0.278 ppm) potable drinking water of 250 ppm TDS and 90-92% rejection of fluoride. The water is being bottled and distributed to the station staff. In view of the growing demand for the water, it has been decided to install a second plant of 2500 LPH capacity.



RO plant (named Ganga) at Airforce Base, Utarlai, Rajasthan

Distribution of bottled water.

Installation of low cost RO unit at Ervadi village, Ramanathapuram District, TN.

While our previous village level desalination plants have been based on 4" diameter modules, the successful development of 8" modules under the programme supported by Centre for High Technology, prompted us to explore the possibility of simplifying our village level plants and, at the same time, reducing the cost of the plant. The first such unit of 1000 LPH capacity was installed in Ervadi village in May 2004. The infrastructure for housing the plant was set up by the District Collectorate. The plant is presently treating water having around 11000 ppm TDS and producing around 5000 liters product water within a total duration of 6-7 hours. The fabrication cost of the prototype unit was around Rs 3.5 lakhs excluding manpower charges.



Picture of 1000 LPH brackish water RO plant installed in Ervadi village, Ramanathapuram District in May 2004

Demonstration of Fluoride removal in Nalgonda District with mobile RO unit.

In view of the success obtained at Kisari village, Rajasthan in eliminating the problems of fluoride and nitrate in addition to TDS, a 500 L/hour RO unit was mounted on a mobile van and used for treating fluoride-contaminated water in six villages falling under the Wailapally watershed (~15,000 population) of Nalgonda district, A. P. At present the requirement of drinking water in these villages is met from Hyderabad city, as the water available

in the six villages contains 3.0-6.0 ppm of fluoride and is therefore not potable. The demonstration RO plant was operated for 2 hours in each of the villages and the TDS and fluoride rejections in all the cases were in the range of 85-90% (*on the spot analysis courtesy CGWB scientists*). The product water rate was 8 L/min with 2 modules of 4" size. Response of villagers to the water was overwhelming. A proposal is being prepared for installation of a larger unit under the CSIR Network Programme on Ground Water.

Fluoride removal by CSMCRI's TFC membrane in Nalgonda District, A.P.

Location (Villages)	Electrical Conductivity, μ S/cm		Fluoride, ppm	
	Feed	Permeate	Feed	Permeate
Wailapally	2500	500	6.50	0.88
Gattuppal	670	75	4.50	0.44
Puttapaka	2300	330	0.90	0.10
Yelamakanna	4800	527	3.00	0.45
Kalvakuntla	1875	241	4.00	0.53

Reverse Osmosis driven by animal power: Since many villages have oxen with insufficient work during non-agricultural periods such as summer months, when the need for water is especially acute, an oxen-powered reverse osmosis (RO) unit was considered to be an attractive option for desalination of brackish water. The idea appeared all the more attractive in view of the perennially short supply of electricity, especially three-phase power in rural areas. Such a unit was designed, developed and patented (PCT Patent Application No. PCT/IB02/05606 dated 23 December, 2002).

A pair of sturdy oxen is connected to one side of a 4 meter long mechanical link while the other side of the link is coupled to the input shaft of a gear box, comprising three sets of bevel helical gears. The gear box is designed to convert animal power in the form of low rpm (ca. 2 rpm) and high torque at the inlet shaft into mechanical power (~ 1.2 hp) of high rpm (200 rpm) and low torque at the output shaft. The output shaft is coupled to the crankshaft of the reciprocating high pressure pump, which discharges 20 LPM feed water with hydraulic pressure in the range of 15-22 kg depending on the physique of the animals. This hydraulic pressure is adequate to carry out desalination (any brackish water RO membrane element would be suitable but the Institute uses its indigenously developed 4" diameter thin film composite spiral RO membrane elements) of feed



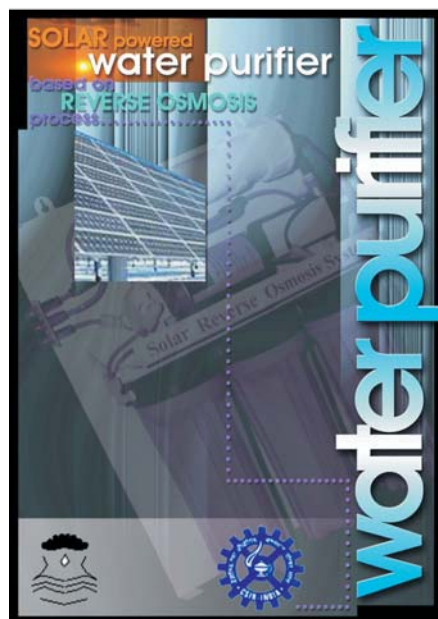
Camel powered unit in action near Jaisalmer, Rajasthan



Oxen powered RO unit in Hasnabad, W. B

water with up to 5000 mg/L TDS (total dissolved solids). In the initial prototype system developed the product water output was around 400-500 LPH. By replacing the wooden roller attached to the mechanical arm with a scooter wheel, frictional losses have been greatly reduced and the operation has become more silent. Output has also increased to 600-700 LPH. The oxen also appear to be able to carry out their job with less effort. The permeate water contains < 500 mg/L TDS and is free of harmful impurities. One oxen-powered unit has been installed in an island (Maachranga Deep) in the North 24 Parganas District of West Bengal. Besides being utilized to cater to the drinking water requirement in the island which has no electricity, the unit has been found to be very useful for simultaneous reduction of arsenic, salinity and iron from water in this arsenic-infested district. The unit has recently been adapted to run with camel power through a collaboration with the Rajasthan State Mines & Minerals Limited and is presently housed in Nagaraja village near Jaisalmer. The novel device would also be useful for purification of different types of water through use of appropriate membrane modules. For example, it can be used as an ultrafiltration device to eliminate germs from water while nanofiltration modules can be employed to remove hardness or other toxic multivalent impurity ions besides germs.

Development of Solar Powered R.O. unit. Two solar powered RO units of 8 liters/h and 15 liters/h capacity were designed and fabricated on behalf of Rajiv Gandhi National Drinking Water Mission (RGNDWM). One unit was installed at Science Park, Jaipur for publicizing and promoting the concept while the second unit was installed for conducting field trials in Bahadurvas village of Jhunjunu district, Rajasthan. Both the units are operating with the help of two solar photovoltaic(PV)panels.



Concentration of coconut water. Pepsico India Holding Ltd., sponsored a project for concentration of coconut water by RO. The purpose of the work was to achieve a concentration of 15° Brix from the initial 4° Brix. Several initial experiments were carried out with the available coconut water using one particular type of TFC membrane on RO test kit for optimization of conditions. Following this, the concentration of coconut water was carried out with 4" diameter spiral elements using two types of membranes. (Values of the salt rejection properties of the two modules used were 94% and 98%, respectively, as per conventional testing with 0.2% NaCl at 250 psig.) 50 liter feed volume was used in each experiment, for which 300-350 coconuts were required. To avoid deterioration in the quality of coconut water, the above experiments were undertaken at a temperature of 10-15 °C. Experimental details for both modules are given in the table below. With one membrane module we could concentrate the coconut water up to 8° Brix with a CF of about 2.0. At higher concentrations, there was slight leakage into the permeate. With the other membrane module, it was possible to concentrate the coconut water from 4° Brix to 12° Brix with a concentration factor (CF) of 2.5. It took approximately 30-40 minutes to carry out the experiment with 50 L of coconut water and a single 4" element. The operating pressure was 250 psig which increased gradually to 450 psig with increasing concentration. With both modules, there was a gradual deterioration in the flux with progress of the experiment, indicating that there is some fouling of the membrane surface. However, the membrane could be cleaned easily and the original flux was restored. The concentrated coconut water was stored under refrigerated condition in a metallized plastic pouch. The pouched coconut water retained its original taste for over a month when stored in the refrigerator.

Performance evaluation of TFC R.O. membrane for concentration of coconut water.

Characteristics	Membrane module 1	Membrane module 2
Feed Volume (Litres)	50	50
Permeate volume (Litres)	26	32
Concentrated volume (Litres)	24	18
Feed conductivity (Micromhos)	1.2×10^4	1.1×10^4
Processing Temperature	10-15 °C	10-15 °C
Permeate conductivity (Micromhos)	5×10^3	0.9×10^3
Feed (initial) °Brix	4.0	4.0

2-stage seawater desalination. Although seawater desalination is conventionally done the world over with seawater membrane modules at high pressure and in a single step, it was felt that lower pressure operation with brackish membrane modules in two stages may be a better option for villages. Such a plant would have the advantage of using less expensive hardware and, consequently, lower capital cost. Moreover, lower pressure operation would be a

safer option in a village environment. The idea was mooted to the Collectorate of Ramanathpuram District, where there is an acute drinking water shortage and general unhappiness with the state of some of the RO plants installed by others for seawater desalination. A prototype unit was installed at Nelmadur village, and is producing 3000-4000 liters of water over a 7-8 hour period. An improved version of the plant with synchronized two stage operation so as to produce 1000 LPH product water is being designed. An additional feature of the design is utilization of wasted energy in first and second stage reject water for driving useful processes. In partnership with the Ramanathpuram Collectorate and Department of Science and Technology, New Delhi it is proposed to install four such plants in Ramanathpuram District.



2-Stage 3000-4000 L (7-8 h operation) Seawater Desalination Plant at Nelmadur, Ramanathpuram for Treatment of groundwater having seawater salinity.



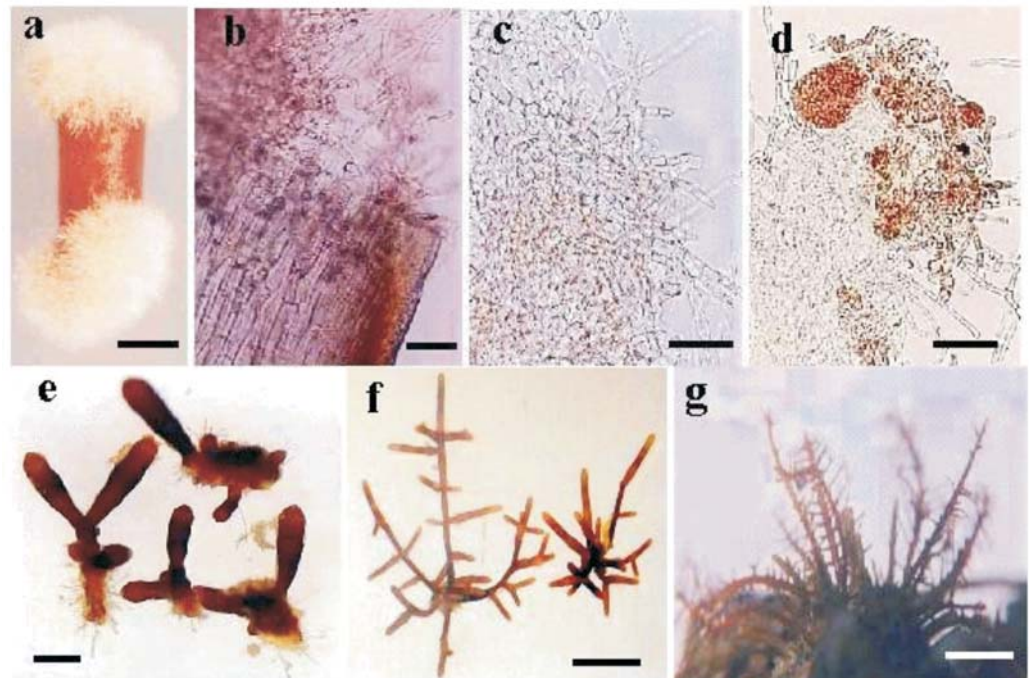
CSMIGRI BIENNIAL REPORT : 2002-2004

3

BIOSALINITY

MARINE ALGAE

Tissue culture studies. In vitro somatic embryogenesis and regeneration of somatic embryos to whole plants through micropropagules was successfully demonstrated from pigmented uniseriate filamentous callus of *Kappaphycus alvarezii* (*Eucheuma cottonii*). More than 80% of the explants cultured in Provasoli enriched seawater (PES) medium (solidified with 1.5% Difco bacto agar) showed callus development. Some sub-cultured calli produced densely pigmented spherical or oval-shaped micropropagules that subsequently developed into young plantlets in liquid PES medium. The micropropagule production was further improved through somatic embryogenesis by a novel method of culturing thin slices of pigmented callus with naphthaleneacetic acid (NAA) or a mixture of NAA and 6-benzylaminopurine. Transfer of embryogenic callus to liquid medium facilitated rapid morphogenesis of somatic embryos into micropropagules that grew into whole plants in subsequent cultivation in the sea. The prolific somatic embryogenesis observed in this study offers a promising tool for rapid and mass clonal production of seed stock for commercial farming (J. Phycol. 39(3):610-616.2003).

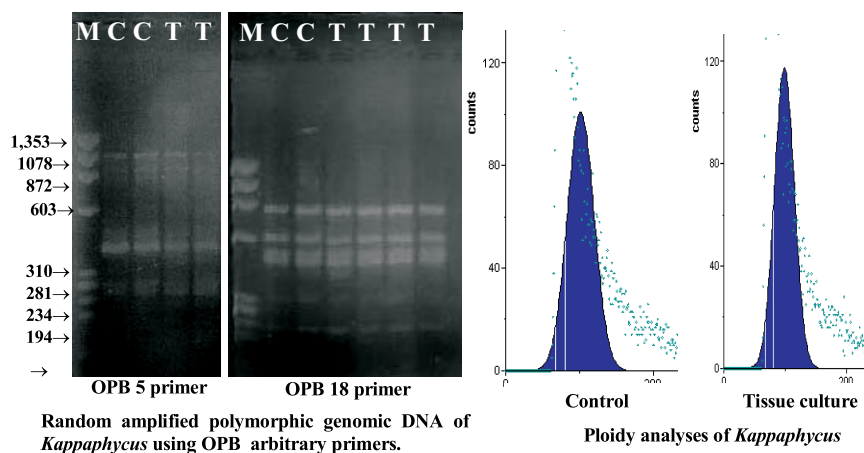


Callus induction and regeneration of de novo plants from pigmented callus of *G. Acerosa*.

Tissue culture of the economically important red alga *Gelidiella acerosa* (Gelidiales, Rhodophyta) was also undertaken. The technique involved preparation of axenic explants and culture of explants and excised callus. Over 90 % of cultured explants were viable and free from microbial contaminants.

Rapid and prolific growth of filamentous callus on explants was observed on cut surfaces during the first month. The highest level of callus induction occurred when explants were cultured in PES medium solidified with 1.5% Difco bacto agar at 20-22°C and 5 $\mu\text{mol photons m}^2 \text{s}^{-1}$ with 12:12 light and dark photoperiod. Up to 90% of the explants cultured at 5 $\mu\text{mol photons m}^2 \text{s}^{-1}$ produced callus, while under 30 and 70 $\mu\text{mol photons m}^2 \text{s}^{-1}$, it was 70 and 9 %, respectively. Similarly, the explant culture medium with 0.5% agar content stimulated bud development in all explants while higher agar content (0.8, 1.0, 1.5, 2.0 and 3.0 %) resulted in a filamentous type of callus growth. Addition of auxins (NAA and IAA), cytokinins (BAP and kinetin) and different carbon supplements (glycerol, sucrose, sorbitol and mannitol) to the culture medium were not effective in terms of callus growth or induction rate. All carbon supplies at 0.5 and 1.0 M concentration showed an inhibitory effect and most of the explants perished after two weeks in culture. The callus mass with bud or shoot developments continued to grow when transferred to semisolid PES medium (0.2% agar w/v) on a rotary shaker. In four months, these shoots gave rise to 2-3 cm long plantlets of *G. acerosa*. The tissue cultured *Gelidiella* germlings adapted well in the field cultivation on coral stones and could be successfully grown into full plants within 6 months (Phycologia. 43(5): 77-83.2004).

Molecular characterization. Since the tissue culture progenies of *Kappaphycus* showed improved growth over wild ones in the earlier studies (U.S. Patent Application No. 09/656,561 dated 09/07,2000; notice of allowance dated 07/29/2004; PCT Patent Application No. WO 02/17707 A1 dated 07/03/2002), an attempt was made to genotype the progeny using RFLP and RAPD markers. The isolated DNA was subjected to restriction endonucleases (Eco R1, Hind III, Bam H1), and RAPD-PCR amplification (20 RAPD primers, 30 ISSR primers and 12 custom made random primers). The preliminary investigations involving RAPD and ploidy analysis did not show any significant differences between control and tissue culture progeny. Thus the reasons for the faster growth of progeny plants remain to be understood.



Isolation of protoplasts from macrophytic green algae. A simple method of mass production of protoplasts, with ability to regenerate into full plants from different species of *Ulva*, *Enteromorpha* and *Monostroma*, was developed. It was found that a mixture comprising 2% cellulase Onozuka R10, 1% NaCl, 0.5% dextran sulphate, and 0.8 M mannitol prepared in deionized water (pH 6.0) facilitated the rapid isolation of a large number of protoplasts from different species of *Ulva*, *Enteromorpha* and *Monostroma*. The protoplast yield data obtained with optimised enzyme mixture was as high as 102.8×10^6 cells g^{-1} f. wt for *Monostroma* while it was in the range of 74.4×10^6 - 88.6×10^6 cells g^{-1} f. wt thallus for different species of *Ulva*, and 82.5×10^6 - 95.4×10^6 cells g^{-1} f. wt for *Enteromorpha*. The overall regeneration rate of protoplast isolated using this method was > 90% and showed normal morphogenesis. This method would allow rapid mass production of viable protoplasts, which could be applied to meet large scale requirements for cells such as seeding material for cultivation, stocks for preservation, isolation of nucleic acids and transformation studies.

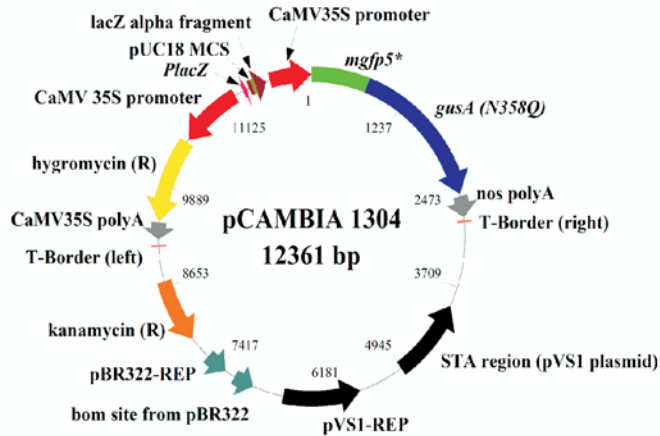
Protoplast yield and regeneration rate for different species of *Ulva*, *Enteromorpha* and *Monostroma* using enzyme mixture-1 and 2.

Species	Mixture-1				Mixture-2			
	Protoplast yield ($\times 10^6$ cells/g f. wt)		Regeneration Rate (%)		Protoplast yield ($\times 10^6$ cells/g f. wt)		Regeneration Rate (%)	
<i>Ulva conglobata</i>	8.9	1.3	91.8	3.5 ^a	85.2	2.9	92.3	6.8 ^a
<i>U. fasciata</i>	14.9	2.4	92.4	5.6	81.4	2.1	90.7	7.3
<i>U. lactuca (wild)</i>	11.2	1.9	87.1	6.6	74.5	1.6	89.4	5.6
<i>U. lactuca (sterile mutant)</i>	15.0	0.9	92.4	3.1	76.6	1.2	91.2	4.5
<i>U. pertusa (sterile mutant)</i>	27.0	1.5	92.6	4.6	74.4	1.9	92.3	6.2
<i>U. reticulata</i>	6.7	2.1	89.5	7.2	88.6	2.3	90.3	6.7
<i>U. rigida</i>	4.5	1.9	89.3	2.9	79.6	1.1	89.5	2.4
<i>Enteromorpha tubulosa</i>	7.8	2.3	92.4	3.7	89.7	1.9	91.4	4.7
<i>E. flexuosa</i>	6.7	1.2	89.6	2.3	95.4	2.2	91.4	4.8
<i>E. compressa</i>	9.5	2.4	88.5	4.5	82.5	1.5	90.5	5.9
<i>Monostroma oxyspermum</i>	31.4	1.3	90.3	4.3	102.8	1.8	90.5	6.5

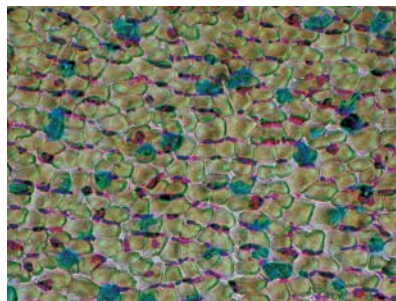
^a - Standard error of mean value of regenerated protoplasts (n = 10 random microscopic bright field (200 cells) counted on 7th day in culture).

Agrobacterium mediated gene transfer in red alga *Porphyra yezoensis*. There has been considerable progress made globally in development of techniques for stable nuclear transformation of unicellular organisms. A new method has been developed for the stable transformation of *Porphyra yezoensis*, an edible red alga, using *Agrobacterium* carrying a plasmid pCAMBIA 1304. This plasmid contains a fused *gfp*--glucuronidase (*gfp-gusA*) and hygromycin (*hpt-II*)-resistant gene, between the T-DNA border sequences. Putative transformed T1 plants were efficiently selected by growing in a selection medium consisting of 50 g.mL⁻¹ hygromycin supplemented with the multidrug

resistant (MDR) pump inhibitor, reserpine, added at the non-lethal concentration of 5 μ M. Transformed plants which recovered in the selection medium tested positive for GUS activity in histochemical analysis. PCR analysis also revealed the presence of both GUS and *hpt-II* genes in the genome of transformed (T1) plants. These results demonstrate that *Porphyra which* is an economically important edible alga, in principle, can be genetically modified to impart improved traits.



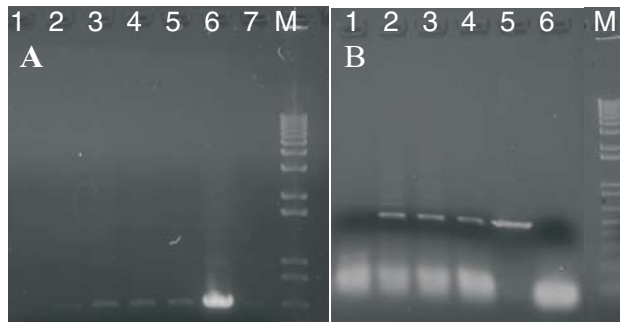
Physical map of pCAMBIA 1304 used for transformation of *Porphyra yezoensis*



Histochemical staining of GUS activity in T1 transformant incubated in X-gluc (blue coloured cells indicate GUS expression).



Histochemical staining of T1 transformants grown under selection with x-gluc for gus gene expression.



Agarose gel showing amplification products of genomic DNA of *Porphyra* for GUS (A) and *hpt-II* (B) primers. 1: *Porphyra* (cultivar #9-13); 2-4 for A and 2-3 for B: Transformants (T1) grown in selection medium; 5 for A and 4 for B: Transformant (T1) grown in normal growth medium, 6 for A and 5 for B: pCAMBIA 1304 plasmid DNA, 7 for A and 6 for B: negative control.

Kappaphycus cultivation: CSMCRI continued its R&D efforts to develop innovative and cost effective technologies for large scale cultivation of *Eucheuma cottonii* (= *Kappaphycus alvarezii*) and *Gelidiella acerosa*. As a result, commercial farming of *Kappaphycus* has been realized and export of cultivated seaweed became possible. Commercial farming of seaweeds has become a promising pursuit of several fishermen families along the Mandapam coast in Tamil Nadu. With a view to expand cultivation to newer localities, farming of *Kappaphycus* was taken up at Thonithurai, Villunditheertham, Manikadu (Palk Bay) and Thonithurai and Krusadai Island (Gulf of Mannar) on Tamil Nadu coast and at Okha and Mithapur (west coast of Gujarat) and Diu. The conducive season is from September to April. The growth rates during 2002 at Diu were found to be 5.0 - 7.8% for polythene bag method, 6.4-8.2% for net bag method and 7.9-9.8% for open culture method. The growth rate at Mithapur ranged from 2.4 - 8.0 % depending on the climatic condition. This alga may be cultivated in 100 hectares at Diu (Gomatimata beach and Opp Airport) and about 3 km stretch along the Mithapur coast. A noteworthy difference between Tamil Nadu and Gujarat is that there is virtually no grazing in the latter, which would account for the higher growth rates. Another factor could be differences in nutrient levels.

Data on world production of *Kappaphycus*.

Kappaphycus production click country to go to GIS	Tons per annum wild harvest	Tons per annum cultivated
China	0	800
Fiji	0	100
India	0	200
Indonesia	formerly ca. 500 mt/yr	48,000
Kiribati	0	100
Madagascar	0	300
Malaysia	formerly small amounts	4,000
Philippines	formerly ca. 500 mt/yr	60,000
Tanzania	0	1,000
Total	114, 700	ca. 200

Source: <http://www.surialink.com>

Data on average yield per plant of *Kappaphycus* obtained by different culture methods

Sl. No.	Cultivation method	Biomass (fresh wt. in grams) after 45 days	
		1 st Cycle	2 nd Cycle
1	Open culture	1820 (6.44)	705 (4.34)
2	Polythene bag method	410.0 (3.13)	551.0 (3.79)
3	Net bag method	800.0 (4.62)	1130.0 (5.38)
4	Net enclosed open culture	1157.5 (5.44)	616.0 (4.04)
5	Raft	1565 (6.01)	--

The technique of *Kappaphycus* cultivation using bamboo rafts (3m x 3m) was evaluated in Indian waters and the method has been found to be vastly superior in terms of yield, cost-effectiveness, and mitigation of the problem of grazing.



Cultivation of *Kappaphycus alvarezii* by raft method in Okha coast, Gujarat



Villagers in Tamil Nadu cultivating seaweed.
Picture accompanying Interview with Dr Manju
Sharma – Swagat April 2004



K. alvarezii by raft cultivation in the Gulf of Mannar: Gaining in popularity and acceptance

Edible seaweeds: The Department of Biotechnology sponsored a project on cultivation of edible seaweeds and their value addition under a mission mode programme on Food and Nutritional Security through biotechnological interventions. CSMCRI is responsible for field cultivation of *Enteromorpha*, *Eucheuma* and *Porphyra* while CFTRI, Mysore will explore their use in processed foods. Field cultivation of *Enteromorpha* was carried out at Okha by seeding the nets with swarmers and subsequently transplanting the same in tide pools and in the open sea. The crop can be cultivated during November-March and attains harvestable size in 40-45 days after seeding of the net. Total crop yield of 152 kg fresh weight of seaweed was obtained from 105 sq. m. net area. A part of this material was sent to CFTRI for further processing. Studies were also initiated on seeding of *Porphyra* on nets. As a first step, laboratory culture studies were

carried out to understand the mode of propagation of *P. okhaensis* collected from Dwarka. Profuse shedding of monospores from young germlings (3-4 weeks old) was observed. Seeding of monospores on cremona nylon filaments obtained from *Porphyra* culture nets was successfully undertaken and subsequently all germlings grew into full plants in laboratory cultures. At present efforts are in progress to understand the factors that control release of monospores and seeding of 1m length of ropes for field trials.



Cremona nylon filament with *Porphyra* germlings raised from monospores: (left) two weeks and (right) 40 days old plants

Large scale cultivation of *Gelidiella* on hollow cylindrical cement blocks

The harvests of *Gelidiella* were continued from 10,000 hollow cylindrical cement blocks (0.5 sq. m. total area) seeded with the seaweed in 2001-2002. The blocks showing good growth initially were harvested in March 2002 and 210 kg dry wt. (i.e., 0.105 kg/block) was obtained from 800 kg of fresh biomass. The crop that was collected in the subsequent harvest from these blocks in September 2002 was used as seed material. Although harvest data was not collected for all the blocks, representative data was taken from some blocks as shown below to calculate yield data. A major weakness of the method at present is that the seaweed is not uniformly attached on the block, as a result of which yields are low. More work will be required to develop a truly cost-effective technology.



Tissue culture progeny of *G. acerosa* being grown on coral stone

Biomass harvested from hollow cylindrical cement blocks^a

Date of harvest	No. of blocks harvested	Total biomass harvested (kg. fresh wt)	Average biomass/block (g. fresh. wt)
March 2002	10	3.60	360
September 2002	10	3.19	320
Feb-March 2003	936	265.44	285
February 2004	672	384.53	572
TOTAL	1628	647.76	398

^a Date of initial plantation done in October 2001

Field cultivation of tissue cultured *Gelidiella* at Krusadai Island.

As reported above, it has been possible to produce whole plants of *Gelidiella acerosa* from the callus. Of the 14 tissue cultured germlings transferred to Mandapam lab, one plant was successfully seeded on a small piece of coral stone which was then put in a fish net bag and transferred to the sea. The initial observations made on morphology showed that the tissue culture plants are healthy and exhibited more profuse branching than the parent plant. Efforts are underway to grow adequate germplasm that is required for agar determination.

***Gracilaria dura*:** Although *Gracilaria dura* was previously considered to yield inferior quality of agar, recent studies have proved that it is a source of high



quality agar and agarose. Unfortunately, the occurrence and distribution of this alga is limited to only certain localities on Saurashtra coast. With a view to increase biomass to make the seaweed attractive for commercial exploitation, cultivation of this alga was undertaken at Okha and Mandapam. Preliminary experiments conducted at Okha during the year 2003-04 showed very promising results with a growth rate of 2.7 %. An initial seed material of 350 grams has yielded 14.79 kg fresh in 137 days. Standardization of cultivation techniques is in progress. Transplantation in Tamil Nadu has also yielded encouraging results except that there can be

Habit of *Gracilaria dura* severe grazing.

Assessment of natural stocks of *Gracilaria edulis* and *Gelidiella acerosa* along the Mandapam coast.

Gracilaria edulis and *Gelidiella acerosa* are the two prime seaweeds for agar production in India. The former is relatively more abundant whereas the latter is in high demand as it yields high gel strength agar suitable for biotechnological applications. In recent times, the growing demand for raw materials by domestic industries has resulted in over harvesting of the natural stocks of these two seaweeds. To understand the current position of natural stocks of agar-yielding seaweeds, a study on density and biomass of the above species was conducted for two consecutive years from 2001 to 2003 in several locations in the Gulf of Mannar, e.g., Ervadi, Kilakkarai, Sethukarai, Rameswaram, Krusadai island and Valinokkam. In highly exploited beds of *Gelidiella acerosa* in Kilakkarai, the biomass was estimated to be 210 g fresh/m² during peak harvest season in July 2003. This is much lower than the value of 425 g dry/m² reported in 1975 from the same area by Thomas *et al.* (*Bot. Mar.* 18: 241-243, 1975). Furthermore, single growth cycle is now noticed in March while two growth cycles were reported earlier, i.e., during January-

February and July-August. Similarly, the biomass of *Gracilaria edulis* has declined at Rameswaram from 216 fresh wt. g/m² in 1996 to 110 gram fresh/m² in August 2003. The biomass values of other agarophytes like *G. crassa*, *G. corticata* and *G. foliifera* showed discontinuous growth pattern without any clear seasonal trend. The overall results of this study reveal that the natural stocks of agarophytes have been decreasing constantly despite declaring the area as Biosphere Reserve by Govt of India in 1989. There is an urgent need, therefore, to revive and conserve natural stocks, and to take recourse to cultivation of these economically important seaweeds for sustainable development.

Seaweed biodiversity on Gujarat coast. Indian coast has been explored for seaweed resources during 70's and there was no systematic study subsequently to assess seaweed biodiversity in the changed environment due to growing anthropogenic pressure and ever increasing coastal industrial pollution. Such a study has now been initiated. In the first phase, 13 localities along the Gujarat coast have been studied for seaweed biodiversity for two years. Samiani Island (22° 29.3' N & 69° 05.2' E) situated at the mouth of Gulf of Kutch is found to contain 28 species belonging to 19 genera of different seaweeds (*Seaweed Res. and Utiln*, 25 (1 & 2): 143-146, 2003). More detailed studies were conducted family-wise and the first family chosen was the monotypic family Caulerpaceae, which comprises 6 species. *Caulerpa racemosa* (Forsskål) J. Agardh var. *occidentalis* (J. Agardh) Børgesen has now been recorded from the Indian coast for the first time while the sighting of *Caulerpa microphysa* (Weber van Bosse) J. Feldmann is the first record for the West Coast of India. *Caulerpa verticillata* J. Agardh, a species of rare distribution, has been collected during the present investigation.



Caulerpa racemosa (Forsskål)
J.A. gardh var. *occidentalis* (J. Agardh)
Børgesen: New Record for India

Natural products and value addition

Screening of seaweed extracts for bioactivity. As part of the continuing programme of work on potential drugs from the ocean funded by the Department of Ocean Development, a total of 240 seaweeds were collected from the Indian coast. Extracts were prepared and forwarded to different participating laboratories for evaluating their biological activity. A small number of extracts have shown low order activity against certain diseases but no promising leads could be developed so far.

Algal products: Cultivation of seaweeds becomes more remunerative if multiple products are obtained. Our novel efforts in this direction, namely utilization of fresh *Kappaphycus* sap as liquid fertilizer, and new applications of carrageenan such as in non-animal gelatin formulations and biodegradable packaging material, have considerable commercial potential. It has also been possible to produce an agarose-like product from *Gracilaria dura* occurring in Indian waters. Seaweeds are also being studied for potential bioactives. Another fertile area of research is development of products from microalgae.

Preparation of biodegradable thin films derived from seaweed polysaccharide:

It has been possible to improve the quality of carrageenan-based films, having thicknesses in the range of 0.05-0.25 mm. Their physical properties (tensile strength, % elongation, water vapour permeability (WVP), hydrophobicity, heat sealing capacity, swelling properties) were measured. The films could also be heat sealed and made into pouches. Various non-aqueous fluids could be stored in the film pouches although improvements in barrier properties will be necessary before practical applications are developed.



Pouch made from seaweed polysaccharide film

Application of *Kappaphycus* sap as liquid fertilizer: An integrated method for simultaneous production of liquid fertilizer and carrageenan rich raw material from fresh seaweed has been developed (*US Patent Application Publication No. 20040031302 A1; February 19, 2004; PCT Patent Application No.: PCT WO 2004/016656 A1; February 26, 2004*). The solid residue is rich in carrageenan whereas the sap contained considerable amounts of both major (K_2O) and minor inorganic nutrients besides growth promoting substances such as auxins and cytokinins. Various concentrations of formulated sap were sprayed on foliage of crops viz. brinjal, okra, onion, black gram and BT cotton cultivated in earthen pots, and grapes and banana on small plots. Depending upon duration of crops 2-5 foliar sprays were applied. The application of 5% sap on crops was found to be quite effective. Work on crop trials is being intensified in partnership with agricultural institutes and industries.



Original (right) and concentrated sap (left) of *Kappaphycus alvarezii*

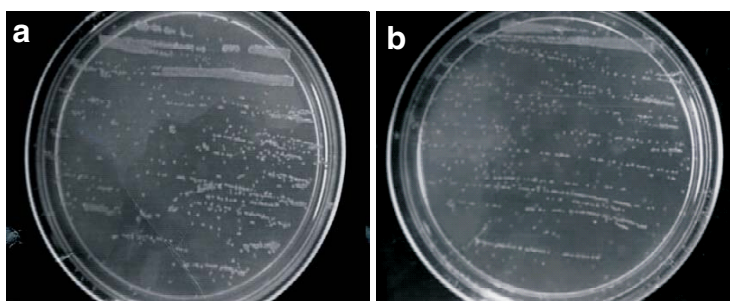
Extrapolated *Kappaphycus* sap cost against yield increase of Onion, BT Cotton and Banana

Crop	Expelled sap conc. applied % (v/v)	Extrapolated yield per hectare (tons)	Extrapolated volume of sap required per hectare (L)	Cost of Sap / hectare @Rs.10/lit. (Rs)
Onion	0	10.23	---	---
	5	12.540	825	8250
Cotton	0	1.650	---	---
	5	2.011	165	1650
Banana	0	26.691	---	---
	5	31.812	225	2250

Low sodium vegetable salt: It has been found that sun-dried *Kappaphycus* sheds significant quantities of salt that has been characterized to be largely KCl. In view of the earlier invention of vegetable salt (Saloni) based on *Salicornia brachiata*, which also contains KCl albeit in small quantity, the idea was conceived to utilize the algal salt to enhance the KCl content in Saloni. The new all-vegetable salt, containing ca. 30% KCl, has been named as Saloni K (US Patent Application No.: 10/819,001).



Low sodium vegetable salt Bacteriological Agar from *Gelidiella acerosa*. An improved process for bacteriological agar (S Agar) from *Gelidiella acerosa* cultivated in our farm in the Gulf of Mannar has been developed. This process has enabled the full potential of the Indian germplasm to be realized. Thus, whereas in the past, yields of ca. 10-15% and gel strength of ca. 300 g/cm² were realized from the same germplasm, it is now possible to obtain agar yield as high as 25%, and with gel strength up to 900 g/cm² (in 1.5% gel at 20°C), for trials conducted at the scale of ca. 0.5 kg agar/batch. The indigenous agar produced at the bench scale was evaluated in IICB, Kolkata, with HiMedia CR 301 agar as standard. The product was certified to be suitable for bacteriological and molecular biology works, and, therefore, its quality may be treated as at least comparable to that of HiMedia CR 301. The indigenous agar was also reported by the Molecular Parasitology Group in IICB to be suitable for culturing the parasite *Leishmania donovani*.



Growth of *E.coli* on (a) S Agar and (b) Himedia CR 301 agar

Agarose from *Gracilaria dura*: A method has been developed to obtain agarose directly from *Gracilaria dura* growing in the Gujarat coast. This seaweed was previously not known to yield such a product. Agarose could be obtained in 20-23% yield with gel strength of 900 g/cm² even at 0.5% application level. The product has the desirable virtue of a low gelling temperature and reasonably low sulphate content. As mentioned above, it has been possible to cultivate the seaweed both in Gujarat and Tamil Nadu and the quality of product obtained from the cultivated seaweed was nearly matching that of the seaweed found in nature. It is proposed to sample out the product to various laboratories once sufficient quantity of seaweed is cultivated.

Comparative data of agarose from *G. dura* and those sold commercially

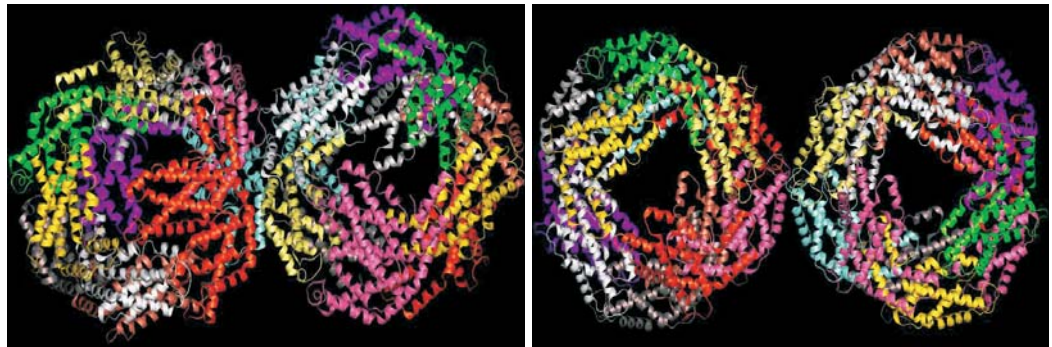
Properties	CSMCRI Agarose	Agarose (Sigma-Aldrich Cat. No. A0576)	Agarose (Sigma-Aldrich Cat. No. A9918)
Gel strength (1% gel)	>1900 g/cm ²	≥ 1800 g/cm ²	≥ 1000 g/cm ²
Gel point	35°C (±1 °C)	36°C (±1.5 °C)	36°C (±1.5 °C)
Sulphate	= 0.25%	=0.12%	=0.25%
Ash content	= 0.9%	= 0.25%	= 0.50%
Price	---	USD 1940 per kg	USD 1015 per kg

Pilot plant at Mandapam: In view of the thrust on seaweed value addition, a need was felt to erect a pilot plant at Mandapam Field Station of CSMCRI. The plant will be commissioned shortly and is expected to produce phycocolloids (agar, carrageenan) at 5kg/day scale. LSF production is also being contemplated.



Pilot Plant shed constructed at Mandapam for processing of Agar and Carrageenan.

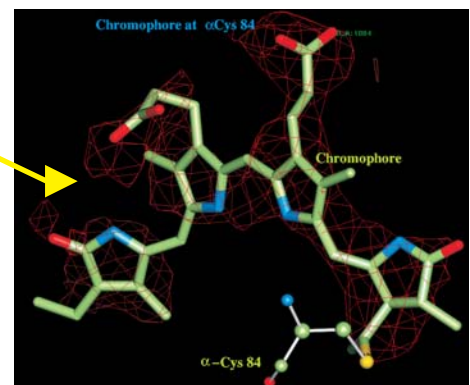
Microbial products: Microorganisms, and in particular bacteria, are known to be a rich source of structurally unique and economically important chemicals like emulsifiers, antifungal agents, biopolymers, antibiotics, enzymes and pigments. We have continued our efforts in this direction, with focus on marine microorganisms.



Ribbon representations of two $(\alpha\beta)_6$ -hexamers without chromophores laterally associated as found in the asymmetric unit of C-PC. (left) *Spirulina* and (right) *Phormidium* C-PC



$(\alpha\beta)$ - monomer of *Phormidium* C-PC along with tetrapyrrole chromophores



Stereo diagram of chromophore a-84 fitted the electron density map ($2F_o - F_c$).

Studies of cyanophyceae and chlorophyceae: The light harvesting pigment has been purified from *Spirulina sp.* (fresh water), *Phormidium sp.* (marine) and *Lyngbya sp.* (marine). C-Phycocyanin from *Spirulina* and *Phormidium* have been crystallized and their structures obtained by X-ray diffraction studies at 3 Å resolution carried out at NCL, Pune . The crystals were found to grow in monoclinic form ($a = 107.33$, $b = 115.64$, $c = 183.26$ Å, $\alpha = \gamma = 90$,

$\beta = 90.03$ for C-PC from *Spirulina*; $a = 107.8$, $b = 115.76$, $c = 183.49 \text{ \AA}$, $\alpha = \gamma = 90$, $\beta = 90.30$ for C-PC from *Phormidium*). The comparison of amino acid sequence between *Phormidium* and *Spirulina* C-PC shows higher percentage of polar and charged residues in α -chain of *Spirulina* C-PC and also a more compact hexameric structure than found with C-PC from *Phormidium*. Interestingly, C-PC from *Spirulina* preserves its structure even at low ionic strength whereas the C-PC from *Phormidium* disaggregates to monomeric units under similar conditions. These differences are possibly on account of gradual adaptation to the environment to which they belong. At the monomeric level, the structures of both C-PC are nearly identical. The structure of the monomer unit of C-PC from *Phormidium*, is shown below. Crystal structure of C-PC from *Lyngbya sp.* remains to be solved.

Studies on the free radical (hydroxyl radical) scavenging activity of purified C-Phycocyanin (Purity ratio >4.0) from *Spirulina sp.* have been carried out. Antioxidant activity against hydroxyl radicals (generated through Fenton's type reaction) was checked by monitoring spectral changes at 620nm. C-PC was found to scavenge the free radicals with concomitant reduction (8-10 %) of the absorption peak at 620 nm. Antioxidant activity against peroxy radicals (generated with thermal decomposition of AAPH) was also checked by monitoring absorption changes at 620 nm and through crocin bleaching assay.

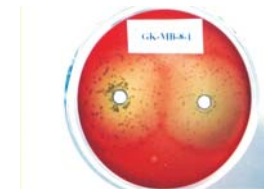
The halotolerant microalgae *Dunaliella salina* is known to contain high quantities of β -carotene (>10 % of the algal dry weight). The carotenes of *D. salina* are a mixture of β -carotene and its isomers, 9-cis and all-trans, while synthetic β -carotene is composed only of all-trans isomer. The high liposolubility of the 9-cis β -carotene permits its high accumulation and storage in animal tissues showing its therapeutic effect through its antioxidant properties. The most efficient strain of *Dunaliella salina* for the production of carotenoids was selected from the salt farm of the Institute. Carotenoid concentrations in the range of 2.61 pg/cell to 5.13 pg/cell were found after optimizing the growth conditions. The crude β -carotene could be further purified.

Exopolysaccharides and enzymes from marine bacteria: An exploratory study was conducted for isolating marine bacteria producing exopolysaccharides. Of the several isolates screened, *Enterobacter cloacae* proved to be the most promising. The chemical investigation of its acidic exopolysaccharide (EPS 71a) revealed that it contained high amount of uronic acid, fucose and sulfate which makes it rare among the bacterial exopolysaccharides reported. High fucose content makes it a suitable candidate for use in biomedical applications such as prevention of tumor cell colonization of the lung (anticancer effect), controlling the formation of WBC (anti-inflammatory effect) and in cosmeceuticals as skin moisturizing agent. Due to high viscosity and emulsifying properties, EPS 71a may also be of interest to food industries.

A study was undertaken to isolate and purify marine bacteria from Gujarat coast capable of producing agarolytic and carrageenolytic enzymes which digest seaweed polysaccharides. The enzymes produced by these bacteria will prove useful in number of biochemical studies, including digestion of raw kelp. Five bacterial cultures each producing agarase and carrageenase were isolated. Two cultures exhibiting maximum activity of carrageenase were selected for further studies. Statistical optimization of medium components by Plackett-Burman Design was carried out. Molecular weight determination of carrageenase was carried out by gel filtration chromatography and found to be 128KD. It could successfully produce protoplasts from *Kappaphycus* in combination with other cell wall degrading enzymes such as cellulase and macerozyme. The enzyme exhibited substrate specificity towards κ -carrageenan only. Similarly, optimization of assay conditions for agarose production was also carried out.



Butyrous colonies of



Hemolytic activity shown by *Pantoea*

Two halo-tolerant isolates, *Pantoea* sp.1 and 2, producing biosurfactants during their growth in mannitol containing Bushnell-Haas medium have been isolated. They were screened for their hemolytic activity which is an indicator of biosurfactant production.

Phytosalinity

Floral biology of *Jatropha curcas*. Phenological aspects of different germplasm of *Jatropha curcas* were studied to understand their growth and reproductive behaviour. The number of male flowers per inflorescence varied in the range of 35-105 while the number of female flowers, which governs productivity, ranged from 1-5. Highest average number of female flowers (4.8 to 5.0) was recorded for CP-9, CP-13 and CP-17, the values being lower (3.6-4.0) for other collections. The former germplasm, which had recorded highest seed yields, were employed in raising a 2 hectare orchard in Mahuda, Orissa. Locational effects, if any, were studied for CP-9, CP-13 and CP-17. Average female flowers per inflorescence were maximum (5.0) at Mohuda while the numbers were less (3-4) in plants raised at Gopalpur and Bhavnagar. The reasons for the variations remain to be understood.

Intraspecific and interspecific hybridization attempts in the elite germplasm revealed that plant species favors successful crossing between male and female flowers borne on different plants (xenogamy) rather than between both types of

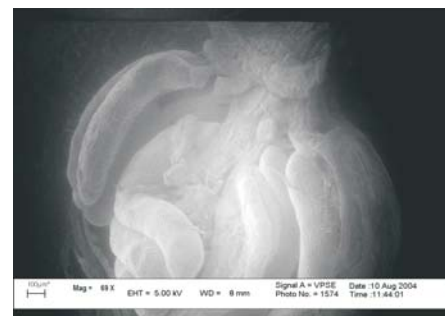
flowers present on the same plant (geitonogamy) as the seed set percentage was more (37-68%) in the former than the latter (11-38%). Seeds obtained from the latter were also comparatively small and thin, and unsuitable for *ex vitro* germination. How to make use of this information in developing suitable hybrids or field layout will be the subject of our future investigation.

Post fertilization studies related to the seed development process were undertaken. Cross sections of immature and mature male and female flowers and from seeds with two different types of seed coats were studied using Scanning Electron Microscopy (SEM). Microphotographs revealed that in ideal genotypes, male flower anthers are arranged in two tiers. In outer whorl anthers are separate while in inner whorl 5 are joined to form a column. In cross section of developing fruit, a trilobulate ovary with properly fertilized ovules could be seen which in turn led to three well grown seeds per capsule in ideal genotype. Two types of seeds, i.e. one with prominent white strips on the seed coat and the other with no such distinguishing feature were observed. The outer membranous layer of cotyledons showed corresponding anatomical features under SEM. Whether these differences lead to other variabilities in characters like seed viability, oil content, etc., remain to be seen. SEM studies were also conducted on the outer membranous layer of cotyledons in underdeveloped seeds and well-grown seeds to note any significant differences at the microscope level. Sections of under developed cotyledons showed desiccated or poorly developed cells whereas cells of well developed cotyledons appeared to contain oil ducts or oil bodies.

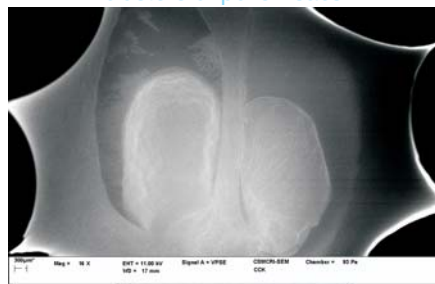
SEM Microphotographs



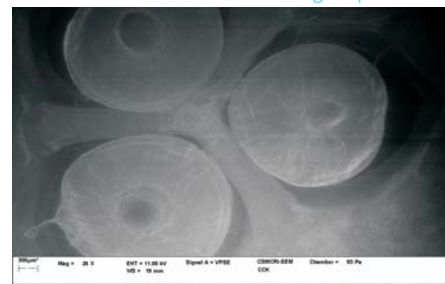
LS of male flower showing 2 tiers of anthers out of two one tire is forming clusters of pollen-sacs.



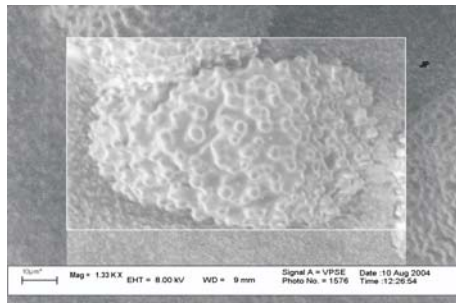
LS of male flower showing 2 tiers of anthers showing lower 5 anthers joining to form clusters and outer 5 anthers becoming separate.



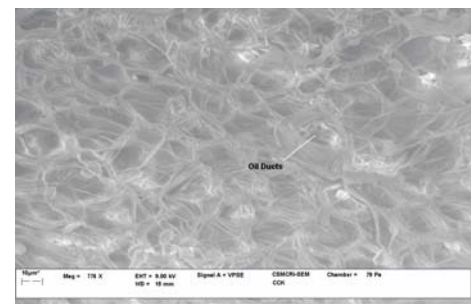
A part of gynoecium showing the initiation of post fertilization process



TS of ovary showing 3 developing ovules after proper fertilization



Cross section of cover of endosperm showing shrunken cells due to loss of moisture



Cross section of a part of proper endosperms development showing oil ducts.

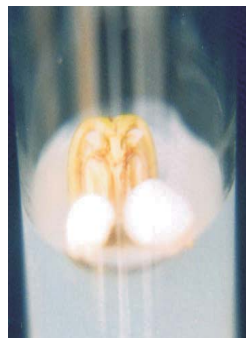


Cross sections of a part of seed cover near caruncle region showing the crushed cells in outer integument layer in a particular seed type.



Cross sections of a part of seed cover near caruncle region showing outer integument becoming columnar in another type of seed.

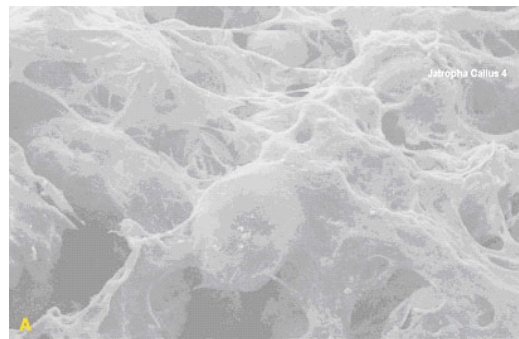
In vitro studies of *Jatropha curcas*: Experiments were undertaken to multiply plants from nodal segments and shoot apices of selected plants of *Jatropha curcas* brought from the field and cultured on MS medium (supplemented with Benzyladenine (BA)). The survival rate of the explants was very poor due to severe inborn fungal infection, which continued even after 2-3 frequent subcultures, thus making the cloning process difficult. The problem was overcome by cleaning explants under running water (2-3h) and subsequently pretreating with a mixture of antibiotics (20 mg/L each of Streptomycin and Cefotaxime). These shoots were later transferred on to MS medium supplemented with 8.88 μ BA. 80-85% success rate was found in obtaining axenic cultures within 7-10 days time.



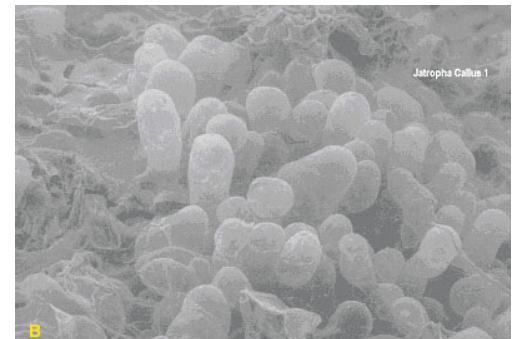
Regeneration of plantlet from zygotic embryos

As part of *in vitro* studies, zygotic embryos of *Jatropha curcas* were separated from the seeds and cultured in MS medium supplemented with various concentrations of BA. Plants germinated through this procedure were transferred to the field. The procedure may be useful for subsequent biotechnological interventions to improve the characteristics of the plant.

In continuation of the earlier studies on induction of somatic embryos from the leaf/petiole segments, callus generated on CLC media supplemented with 9.80 M 2,4-D, and transferred to MS medium containing 0.49 M 2,4-D and 8.88 μ BA, showed formation of nodular structures. SEM studies showed induction of somatic embryos without distinct polar regions. However, these cells showed further growth in the form of shoots. Histological studies showed occurrence of two types of shoot buds, i.e., Type-I cells originating from deep inside the parental callus showing connections with the vascular tissues, and Type-II cells originating from the peripheral layers of the callus without any connections with the parental vascular tissues. Cells of the latter type are of prime importance for future genetic engineering studies.

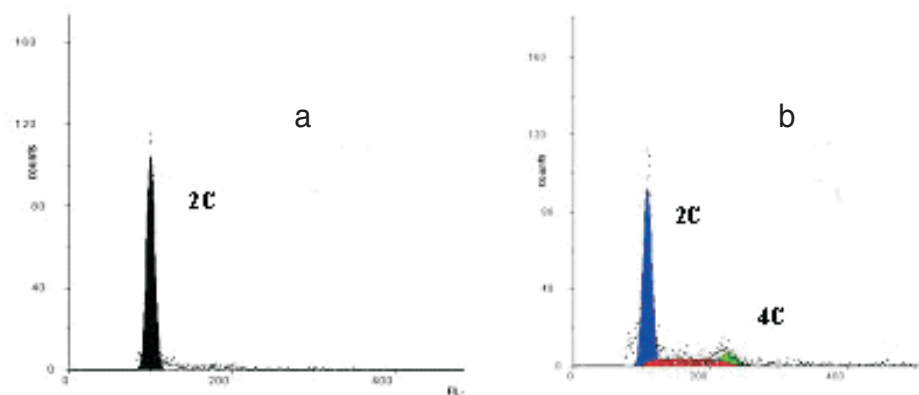


Non Embryogenic tissue



Embryogenic tissue

In a separate study, microshoots obtained through indirect organogenesis were subjected to ploidy level analysis using a Flow Cytometer cell suspensions from the regenerated shoots showed two distinct peaks indicating the possible occurrence of 4C cells as compared to the mother plant



Flow cytometric estimation of ploidy levels in *J. curcas* (a) mother plant showing 2C cells and (b) regenerated shoots showing 2C and 4C cells

Ploidy analysis of some ecotypes collected from different locations was also undertaken including few high yielding genotypes cloned through stem cuttings. Efforts were made to ascertain possible genetic variations through flow cytometry. All plants showed diploid nature (2C), indicating stability at Ploidy level.

Cultivation of *Jatropha curcas* in marginal non-saline lands for Biodiesel:

As part of a project supported by UNDP, the Institute had initiated research on *Jatropha curcas* with focus on popularizing cultivation of the plant. It was recognized that substantial differences exist in the yield of seeds for different germplasm and the project enabled us to identify a handful of plants that gave consistently higher yields. This pioneering effort in India led to a subsequent project sponsored by the Department of Biotechnology to propagate elite germplasm. An international collaborative programme was taken up in August 2003 in partnership with DaimlerChrysler (DC) and University of Hoenheim, Germany to cultivate *Jatropha curcas* on eroded soils and demonstrate preparation of biodiesel of required specification from the oil seed. The Institute is also participating in a project sponsored by the Industries Commissionerate, Government of Gujarat to develop the agrotechnology of *Jatropha* on wasteland. Stem cuttings of elite plants were raised in large numbers and 20 hectares of wasteland have been cultivated in Orissa and 7 hectares in Gujarat. In this endeavour, over 30,000 cuttings were raised from 15 mother plants. The cultivation in Mohuda, Orissa has confirmed that progeny plants retain the superior characteristics of the parent, and most young plants after ca. 1 year have shown profuse flowering and fruiting.



Jatropha orchard at Mahuda, Orissa based on cuttings of elite germplasm. Inset shows fruiting in the 1.5 year old plants

“You have done wonderful progress in development of *Jatropha* plants especially at Mohuda. The plants are full of fruits”

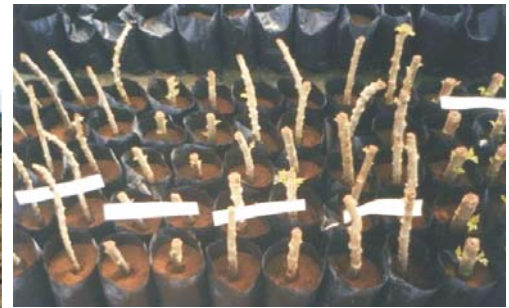
Mr J. N. Dey
Image Vyapar (P) Ltd



(Top) Jatropha cultivation over 5 hectare in Chorvadla, Gujarat on eroded land provided by forest department;



(Bottom) 7.5 hectare wasteland provided by Panchayat in the vicinity to extend cultivation.



Cuttings of elite germplasm for transplantation in the field

The Institute is taking great care to ensure that the project is strictly focused on wasteland to avoid competition for agriculture land. Simultaneously, in partnership with Hohenheim University, efforts are underway to identify viable agronomy practices to maximize yield in wastelands. It is projected that Jatropha cultivation may be a profitable venture if seed yields of 2 tons per hectare per annum are realized and the farmer is able to sell seed at ca. Rs 6000-7000 per ton. Biodiesel can, in principle, be prepared from any triglyceride through transesterification of the oil with lower alcohols. CSMCRI has focused on the stringent EN14214 specification of biodiesel which is currently in vogue in Europe and complies with Euro III emission norms. As can be seen from the table below, these specifications have been matched and the feedback from Germany is that our fuel is “*comparable to any on the EU market.*” Of special note is the high cetane number of the fuel, high ester content, and lower than specified levels of impurities. The fuel has recently been analyzed by a leading Indian petrochemicals company as well and the high quality of the fuel was confirmed. This is a significant achievement given that there is a widely held belief that biodiesel of the above specification cannot be made from oils such as *Jatropha*. The process has additional advantages in as much as most operations are undertaken under ambient conditions and there is little waste generation. Besides biodiesel, oil cake, soap, potassic fertilizer and glycerol are also obtained in the process. On average, it has been found by us that 25-26% oil can be expelled from seed, and ca. 1000 liters of biodiesel is produced from 4 tons of Jatropha seeds. A model of costing of biodiesel that takes into account the value of by-products is currently being developed. Based on the ca. 2500 liters of biodiesel produced till date, a plant design is being prepared that would be suitable for production by rural cooperatives.

DaimlerChrysler undertook tests with our neat biodiesel in view of the high standard of specifications achieved by us. Mercedes Benz C 220 CDI manual transmission vehicles (two numbers) were used for this purpose and these were used without any engine modification. As a precautionary measure, some plastic seals in the fuel system were replaced with inexpensive rubber seals although this may not be necessary in the future. One of the vehicles operating with biodiesel undertook an arduous 6000 km trip covering southern, western and northern cities. No problem was encountered in the trip and an average mileage of 13.5 km/liter was registered, which is in comparable to that with fossil diesel. Also, no visual or audible change in engine characteristics was found. Emission tests were also performed on a chassis dynamometer by the Automobile Research Association of India (ARAI) at the instance of DaimlerChrysler India. During the emission test the following parameters were monitored individually throughout the driving cycle: CO, HC, NOx, CO2, and particulate matter (P.M.). Comparison between the vehicular emission values for a car running on our neat bio-diesel and one running on B.S. II Altermann reference fossil diesel is provided in the figure below. It can be seen that the emissions are well below the Bharat Stage II limits. A most useful result is the very low particulate matter found with biodiesel. These results are, however, considered to be only preliminary and more exhaustive tests will be carried out in the coming months. More recently, tests have been conducted by NSIC Technical Services Centre, Rajkot using CSMCRI's neat biodiesel in a 10 HP stationary diesel engine without any modification and no difficulty was encountered in operation. Tests were conducted for 10 cycles as per BIS norms. Longer duration trials are now planned.

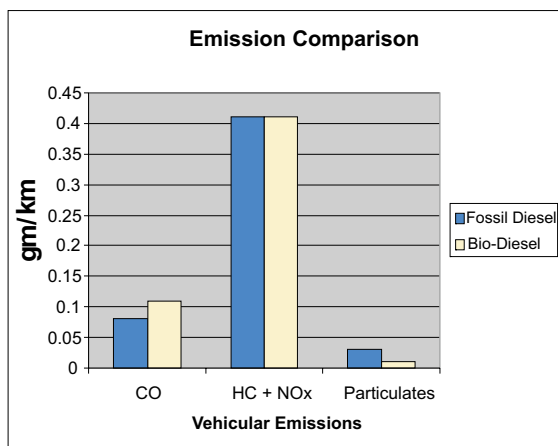
In view of the excellent quality of biodiesel obtained by us from *Jatropha curcas*, farmers will have greater confidence to go in for cultivation of this plant. Moreover, the constant emphasis on utilization of by-products would help in maximizing the value of the farmer's produce. The project has contributed immensely in making biodiesel from *Jatropha curcas* a national priority and the Institute has received numerous inquiries from both within the country and overseas.

Emission Target Limits Currently in Vogue

	CO	HC + NOx	Particulates
Euro 2	1	0.7	0.008
Bharat Stage 2	1	0.7	0.08

The only difference between Euro 2 and Bharat Stage 2 is the maximum speed of in the best cycle. In Euro 2 the maximum speed is 120 km/h and in the case of Bharat Stage 2 the maximum speed is 90 km/h.

C-class Mercedes Benz Car that made a trip across India running on neat biodiesel made by CSMCRI from *Jatropha curcas* seeds.



*Vehicular Emission Comparison between Fossil Diesel (Altermann 11 Reference) and CSMCRI Biodiesel from *Jatropha curcas* oil (Data courtesy Daimlerchrysler India and ARAI, Pune)*



(Top) Oil expeller developed for *Jatropha* seed (right) facility for biodiesel preparation.

Analysis of CSMCRI Methyl Ester of Jatropha Oil^a

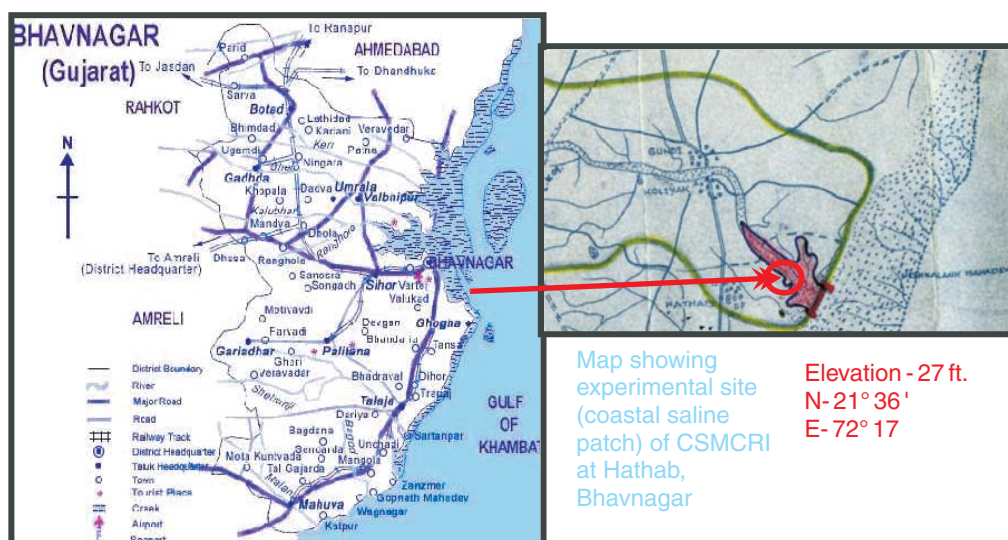
			DIN value ^b	Product prepared by Acid Catalysis	Product prepared by Base Catalysis
Appearance				Clear brownish liquid	Clear brown
Density @ 15°C	ISO 3675	kg/m ³	860-900	881,1	880,0
solid contamination		mg/kg	<24	3	4
Neutralization Number	DIN 51 558-1	mg KOH/g	< 0,5	0,12	0,1
Cooper corrosion	EN ISO 2160	grade	1	NA	NA
Viscosity at 40°C	ISO 3104	mm ² /s	3,5-5,0	4,429	4,34
Iodine number	DIN 53241-1-	gJ ₂ /100g	<120	94	96
Ash	ISO 3987	g/100g	<0,02	<0,01	< 0,01
Verkokungsrückstand aus 10 Vol% - Rückstand	EN ISO 10370	g/100g		NA	<0,01
Water content	EN ISO 12937	mg/kg	<500	600	450
Flash point	DIN EN 22719	°C	> 101	173	160
HFRR		?m		NA	197
Cetan number		-	>51	58 ^c	NA
Monoglyceride	EN 14 105	g/100g	<0,8	0,08	0,15
Diglyceride	EN 14 105	g/100g	<0,2	<0,02	<0,02
Triglyceride	EN 14 105	g/100g	<0,2	<0,02	< 0,02
Free glycerine	EN 14 105	g/100g	<0,2	<0,02	< 0,02
Total glycerine	EN 14 105	g/100g	<0,25	0,02	0,04
Methanol	prEN 14110	g/100g	<0,2	<0,02	< 0,02
Ester-content	prEN 14103	g/100g	-	98,7	98,5
Sodium		mg/kg	<0,5 total	2,6	0,2
Potassium		mg/kg	Na+ Ka	<0,5	0,2
Magnesium		mg/kg	-	<0,5	< 0,5
Calcium		mg/kg	-	<0,5	< 0,5
Phosphorus		mg/kg	<10	<1	<1

^aAnalysis Courtesy Dr. W. Degen, DaimlerChrysler AG, Germany; ^bSpecs. are for Latest EU norm for Biodiesel (EN14214) which would enable compliance with Euro III emission norms; ^cCetane number analysed previously for a separate acid catalysed sample.

Coastal saline agriculture with *Salicornia brachiata*. The research work was accomplished with financial assistance from GSFC-Science Foundation, Vadodara, to explore the feasibility of cultivating *Salicornia brachiata*. This work involved several dimensions, viz. (i) Characterization and evaluation of *Salicornia* (*S. brachiata*) germplasm (ii) Inter-character association and path coefficient analysis, (iii) Genetic diversity (iv) Effect of plant geometry on growth and yield, (v) Response of yield to different levels of nitrogen and phosphorus under highly saline conditions. etc. The final report containing the data on many aspects of saline agriculture development and future scope of the species as salt tolerant crop for coastal salinity ingressed area has been provided to the sponsor.



Natural vegetation of *Salicornia brachiata* on Saurashtra sea-cost



Significant differences in distribution, biomass production, seed yield, oil contents and fatty acids profiles are given below. It has been found feasible to cultivate *Salicornia* although considerable care is required in the initial stages of plant development. In a separate study, the density of natural vegetation is being enhanced with the local germplasm. A significant achievement has been the development of seed pellets by Gujarat Agriculture University, Anand which would prevent the washing away of sown seeds during tides and monsoon water run off. Another important development is the successful expelling of oil from seeds with ca. 18-20% yield (w/w). The oil could be refined to a golden yellow liquid and it is proposed to undertake detailed studies on its suitability for edible and non-edible applications. The Institute has additionally been exploring possible export of tender tips of the plant to be used as salad. The tips were found to be of desired taste, opening up an entirely new avenue for agricultural export, if the logistics of shipment can be evolved.

Seed & Oil Analysis of *S. brachiata* from different locations of Saurashtra coast and comparison with other species

Sr No	Sp. (Location)	1000 seed Wt. (mg.)	Oil content %	Protein content %	Fatty acid composition (%) (GC analysis on Dexil-300)					
					Lauric	Palmitic	Stearic	Oleic	Linoleic	Linolenic
1.	<i>S.brachiata</i> (Diu port)	350	29.30	37.88	1.79	15.48	4.37	--	78.36	--
2.	<i>S.brachiata</i> (Ghogha)	330	31.06	41.75	--	13.53	5.51	--	80.96	--
3.	<i>S.brachiata</i> / (New port)	436	30.96	37.94	--	13.81	1.32	--	84.87	--
4.	<i>S.brachiata</i> (Victor port)	376	34.43	41.68	4.68	20.99	6.64	--	67.52	--
Average value		373	31.44	39.81	3.33	15.95	4.46	--	77.93	--
S.D.		0.040	01.86	01.90	1.33	03.00	1.98	--	06.44	--
C.V. (%)		10.69	05.93	04.78	40.07	18.82	44.39	--	08.26	--
1.	<i>S. bigelovii</i>	1123	28.20 (26-33)	31.20 (30-33)	--	08.10 (7.7-8.7)	02.20 (1.6-2.4)	12.50 (12.0-13.3)	74.00 (73.0-75.2)	02.60 (2.4-2.7)
2	<i>S. europaea</i>	271	28.60	43.50	--	--	--	--	--	--

Preparation of low sodium salt of vegetable origin: The Institute's invention of vegetable salt from *Salicornia brachiata* residue (i.e., after removal of seeds) has been widely hailed as a significant invention. Test marketing of the salt was undertaken by a local dealer and efforts are being intensified to license the technology.



Salicornia brachiata plantation



Tender Tips Mature seed bearing plant



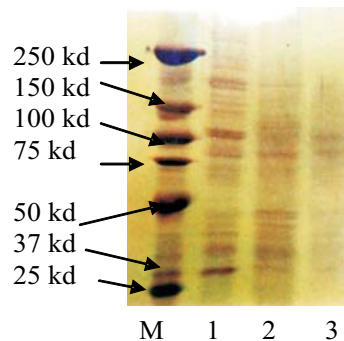
Test marketing of Saloni Vegetable Salt



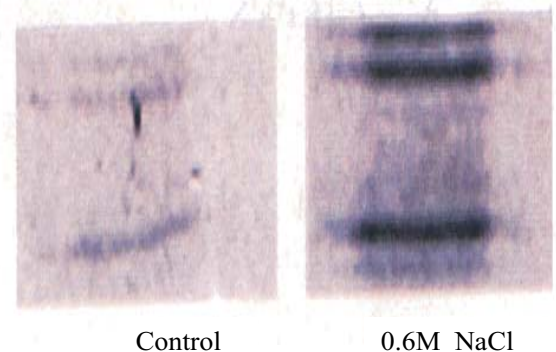
Expelled & refined oil

Salt shock proteins: Tissue specific compartmentalization of ions, metabolites and enzymes in *Salicornia brachiata* has been observed. SDS-PAGE separation of proteins in different tissues revealed that syntheses of salt shock proteins are tissue specific and most of the high molecular weight proteins are localized in vascular tissues. Western blot analysis of plasma membrane ATPase has shown increase in activity with salinity induction.

Root water transport studies indicated that the water transport in *Salicornia* is about 60 times less than that in a glycophyte. Real time RT PCR studies with mRNA showed that the transcriptional regulation of aquaporin genes is down regulated under salinity stress. This, in turn, results in reduced water uptake (as evidenced by root water transport experiments), and movement of water within the cell/plant, that may allow greater cellular conservation of water under saline conditions.



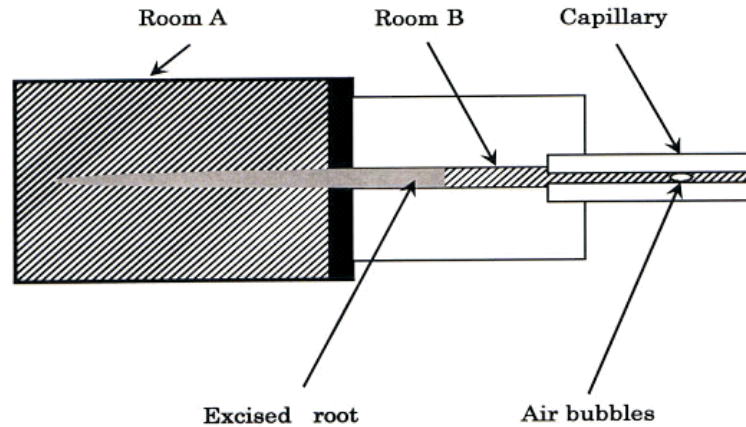
Differential expression of SSPs in *Salicornia*
(M= marker, 1= vascular 2= mesophyll 3= Palisade)



Western blot of plasma membrane ATPase

Functional genomics of plant stress tolerance: Using the activation tagging technique 100,000 T DNA insertion mutants were generated in *Arabidopsis thaliana* and screened for functional sufficiency for salt tolerance. Genes responsible for Na^+/K^+ discrimination and salt tolerance (*AtHKT1*) at root plasma membrane level

were identified. Similarly, terminal domain phosphatase (AtCPLs) genes responsible for abiotic stress tolerance and growth and development were isolated and characterized (*Proc. Natl. Acad. Sci., U.S.A. 99, 2002, 10893.*). The Institute will be focusing on utilization of these genes in improvement of plant species for abiotic stress tolerance and signal transduction using halophyte models.

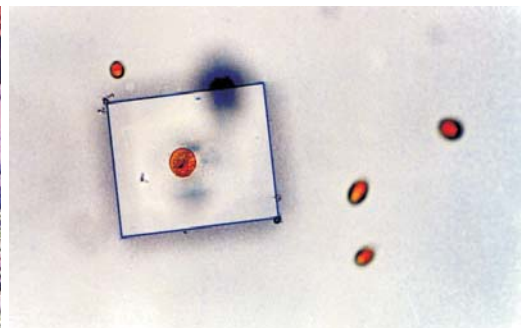


Double chamber for measuring root hydraulic conductivity

Identification of salt-responsive genes: *Salicornia brachiata* and *Dunaliella salina* were selected to study the number and nature of genes that are implicated in salinity tolerance. The specific intention was to compare and contrast the overlapping and unique sets of salt induced transcripts. Total RNA has been isolated from these model halophytes by the guanidium isothiocyanate method. The tester mRNA (from the salt-stressed cells/tissues) and the driver mRNA (from normal cells/tissues) have been isolated after annealing with biotinylated oligo-dT primer and incubation with streptavidin-linked paramagnetic beads. The first strand cDNA using superscript II RNase H-reverse transcriptase has been synthesized. The ligation of modified oligonucleotide to the 3' end of the first strand cDNA, preparation of driver cDNA and subtractive hybridization and PCR amplification of differentially expressed salt-induced genes are in progress. The study is being undertaken in collaboration with International Centre for Genetic Engineering and Biotechnology, New Delhi.

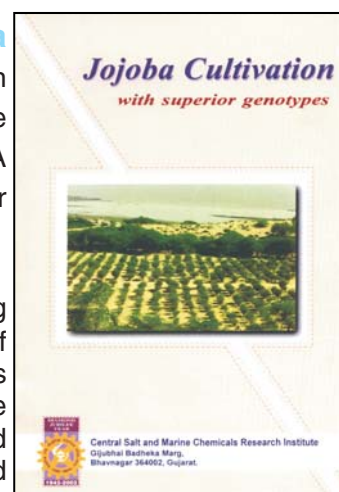


Salicornia brachiata growing on saline soils



Dunaliella salina growing on a salt crystal

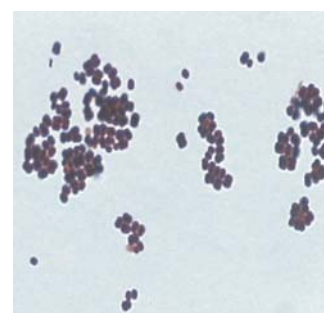
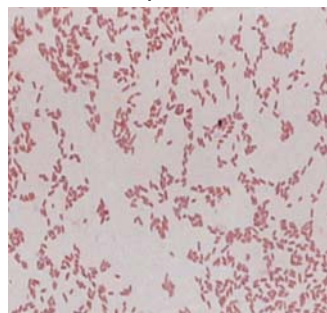
Performance assessment of matured Jojoba population: Matured Jojoba population raised on coastal sand dunes has been assessed for the performance of their progenies and various genotypes. A booklet entitled “Jojoba cultivation with superior genotypes” was published.



Bioactive plant extracts: As a participating laboratory under the network programme on study of plant extracts for bioactive substances, 45 plant species were processed and 383 extracts were prepared from the various plant parts. Of these, 55 extracts had showed bioactivities in primary preliminary testing. A purified fraction isolated from one of these extracts yielded an MIC value of 6.125 µg/ml against *M Tuberculosis* in in vitro studies while a purified fraction from another extract was found to be active against Falciparum malaria (MIC ~ 32 ng/mL). Additionally, a few extracts were active against neurological disorders (anti anxiety and anti Parkinson) and one was active against ulcer. Patent applications were filed for the work on TB.

Environmental Studies:

Bioremediation by marine microbes: Bioremediation of hazardous waste through microbial biotechnology may be advantageous over conventional processes in certain situations, as a result of which such studies are gaining in importance. Two promising marine bacterial cultures capable of degrading petroleum hydrocarbons were isolated and tested for their capability to degrade Kuwait crude oil. These cultures could grow luxuriantly even after 12-15 days of incubation period when Kuwait crude oil was supplied as a sole carbon source.



Marine bacterial isolates



Control

Crude oil emulsified by bacteria

Enterobacter cloacae, an exopolysaccharide-producing bacterial culture, was studied for bioaccumulation of heavy metals like cadmium, chromium, copper and cobalt. This isolate was not only resistant to Cr(VI) but also showed enhanced growth and exopolysaccharide production in the presence of up to 100 ppm of this ion. XRF analysis revealed that 60-70% of chromium was accumulated by this bacterium. This exopolysaccharide also demonstrated excellent chelating properties with respect to cadmium (65%) followed by copper (20%) and cobalt (8%) at 100ppm heavy metal concentration. The occurrence of high uronic acid in the exopolysaccharide may be responsible for its chelating properties (*Mar. Poll. Bull, in press*). Similarly, the marine seaweed (*Kappaphycus* sp.) associated fungi, *Aspergillus flavus* and *A. Niger*, were evaluated for hexavalent chromium tolerance and accumulation at 25, 50 and 100 ppm concentrations (*Mar. Poll. Bull., 2004, 48: 983-985*). These isolates exhibited luxuriant growth and could chelate 25% of chromium supplied.

Highly saline effluent containing complex organic and inorganic compounds such as sodium, calcium, magnesium salts, mono-, di- and tri-butyl phosphates, n-butanol etc. having very high COD from Heavy Water Board (BARC, Mumbai) was treated with different biomass such as cyanobacteria, macro algae, fungi and drumstick. The cyanobacterial consortium in the system pretreated with EDTA and adjusted to neutral pH shows up to 65% removal of phosphates. Better effects were also seen in the cases of macro algae *Ulva lectuca*. and fungal biomass of *Aspergillus niger*. The removal in these cases was ca. 55% and 54%, respectively. The most significant reduction in the COD was observed with cyanobacterial biomass (70-80%).

Assessment of environmental quality of Alang-Sosiya ship scrapping yard: Alang-Sosiya, located on the Western Coast of Gulf of Cambay, is the largest ship breaking yard in the world. Every year on an average 365 ships having a mean weight of $2.10 \times 10^6 \pm 7.82 \times 10^5$ LDT are scrapped. Studies on the impact of this activity on the environment have been initiated by the institute. The ship scrapping industry generates a huge quantity of solid waste in the form of rubber, insulation materials, metals, glass and ceramics, plastics, leather, chemicals, paints, thermocol, sponge, miscellaneous combustible and non-combustible materials. The study on quantification and classification of solid waste revealed that Sosiya is more polluted with such solid waste, i.e., 15.63 kg/m² as compared to 10.19 kg/m² at Alang. The quantity of combustible solid waste was estimated to be ca. 80 % of the total solid waste (*Mar. Poll. Bull.:* 46(12), 1608-1613. 2003). Predictive models of energy content of ship-scrapping solid waste using multiple regression analysis were developed based on physical composition, ultimate and proximate analysis. The energy potential of the solid waste was also assessed, the value being 90 million KJ/h, in the form of steam energy (63 million KJ/h) and electric power (5.28 MW) (*Intl. J. of Solid Waste Technol. and Management:* 30(2), 90-99. 2004.,).



Alang-Sosiya sea coast with heaps of solid waste

The degree of heavy metal contamination in Alang-Sosiya region has been studied by classifying the sediments into bulk (2 mm -63 μ m, BF) and fine (< 63 μ m, FF) fractions. Variations of metal concentrations in BF and FF sediment samples reflected organic matter content. Enrichment factors (EF) and geo-accumulation indices (I_{geo}) have been calculated and contamination levels were assessed. At Alang-Sosiya coast, the enrichment of heavy metals has been observed to be relatively higher than those at Mahuva (reference station). It was also observed that in the coastal waters of Alang-Sosiya region, heavy metal and PHC contamination is significantly high (*Mar. Poll. Bull.*: 48, 1055-1059.2004).

Data centre on algae and marine chemicals: A revised checklist of Indian marine algae was prepared and updated further by including 22 new species of seaweeds (17 species of Rhodophyta & 5 species of Chlorophyta) reported after the year 2001. Phycosearch, a quarterly journal, covering abstracts of research work on phycology, published in National and International journals were compiled and published.

Consultancy projects on Environmental Audit and Environment Impact Assessment: Considerable debate has been raging in the country on the possible environmental impact of *Kappaphycus* cultivation in Gulf of Mannar. Accordingly, an Environmental Impact Assessment (EIA) was made both in Gulf of Mannar and Palk Bay. The baseline study for the above project was carried out during pre-monsoon season in 2002. The overall study indicates that the *Kappaphycus* cultivation is eco-friendly and has no significant effect on indigenous flora, fauna and their environment. Long term continuous monitoring is required to assess its environmental impact, if any. These views are supported by leading algologists in the country.

As a recognized auditor, the institute carried out environmental auditing of several industries in Gujarat, including Tata Chemicals Ltd, Mithapur; Indian Rayon and Industries Ltd., Veraval; Hindalco Industries Ltd. (Unit: Birla Copper), Dahej; Gujarat Ambuja Cements Ltd., Kodinar; Atul Ltd., Atul; CLP Power India Pvt. Ltd., GPEC Power Plant, Paguthan, Bharuch; Gujarat Electricity Board, Thermal Power Station (TPS), Gandhinagar; TPS, Wanakbori and KLTPS,

Panandhro. A study on identification of disposal point for discharge of treated effluent from Veraval Industries Association's Common Effluent Treatment Plant at Veraval was carried out. Rapid environmental impact assessment for the discharge of treated effluent in to the Kadodara Khadi and finalizing the discharge point for the treated effluent of proposed Common Effluent Treatment Plant for M/s Palsana Enviro Protection Ltd., Palsana, were also completed successfully.

BIENNIAL REPORT : 2002-2004

CSMIGRI



4

**TECHNOLOGY
TRANSFER &
INFRASTRUCTURE
SERVICES**

Patents filed

2002-2003

Filed

1. Integrated method for production of Carrageenan and liquid fertilizer from fresh seaweeds; K. Eswaran, *P.K. Ghosh, A.K. Siddhantha, J.S. Patolia, C. Periswamy, A.S. Mehta, K.H. Mody, B.K. Ramavat, K. Prasad, M.R. Rajyaguru, S. Kulandivel, C.R.K. Reddy, J.B. Pandya and A. Tewari*; **US Patent** Application No. 10/222,977; **US Pre Grant Publication** No. 2004/0031302; **PCT Patent** Application No.: PCT/IB 02/04122; International Publication No.: WO 2004/016656; and **Indian Patent** Application No 0133/DEL/2003.
2. A process for the preparation of pure potassium iodate for salt iodisation; *P.K. Ghosh; G. Ramachandraiah, V.R.K.S. Susarla, P.M. Gaur, S.S. Vaghela and S.N. Patel*; **Indian Patent** Application No.: 0479/DEL/2003.
3. An eco-friendly process for acylation of alkylated benzene derivatives; *R.V. Jasra, B. Tyagi and Y.M. Badheka*; **US Patent** Application No.: 10/678,902; **PCT Patent** Application No: PCT/IN 03/00439 and **Indian Patent** Application filed on 30/5/2003.
4. A device for casting ion exchange membranes; *N. Pathak, S.L. Daga, P.A. Patel, B.G. Shah, G.S. Trivedi, S.K. Adhikary, P.M. Gaur and R. Rangarajan*; **Indian Patent** Application No.: 0968/DEL/2002.
5. An improved electrochemical method for the oxidation of bromide to bromine; *G. Ramachandraiah, P.K. Ghosh, V.R.K.S. Susarla and S.S. Vaghela*; **US Patent** Application No.: 10/400,918; **PCT Patent** Application No.: PCT/IN03/00126.
6. An improved process for the single pot synthesis of 2,4,4,6 tetrabromo-2,5 Cyclohexadione; *A.V. Bedekar, G. Ramachandraiah and P.K. Ghosh*; **US Patent** Application No: 10/335,124; **PCT Patent** Application No.: PCT/IB 02/05610; **US Pre Grant Publication** No.: 2004/0127750A1.
7. Animal powered mechanical device for water desalination; *N. Pathak, P.K. Ghosh, S.L. Daga, V.J. Shah and S.N. Patel*; **PCT Patent** Application No.: PCT/IB02/05606.
8. An improved process for the preparation of hydrotalcite; *P.M. Oza, S.H. Mehta, M.V. Sheth, P.K. Ghosh, M.R. Gandhi and J.R. Chunawala*; **US Patent** Application No: 10/334,121 ; **PCT Patent** Application No: PCT/IB 02 /05722 and **Indian Patent** Application No.: 0583/DEL/2003 [PCT National Phase].

9. A novel device for estimation of brine density in Solar salt works from afar; *P.K. Ghosh, K.M. Majeethia, M.R. Gandhi, J.N. Parmar, A.M. Bhatt, S.A. Chauhan, V.P. Mohandas and A.U. Hamidani*; **US Patent** Application No.: 10/393,405; **PCT Patent** Application No.: PCT/IN02/05609 and **Indian Patent** Application No.: awaited.
10. Process for the preparation of a molecular sieve adsorbent for the size/shape selective separation air; *R.V. Jasra, C.D. Chudasama and J. Sebastian*; **US Patent** Application No: 10/403,475; **PCT Application** GB No.: 2003-072071;; JP No.: 2003-091,378; KO No.: 2003-19794; DE No.: 10314576.1; CN No.: 2003-108451.6 and **Indian Patent** Application N.o.: 0564/DEL/2004.
11. A process for the recovery of palladium from spent silica; *A.B. Boricha, H.C. Bajaj, R.V. Jasra, P. Ghosh and P.K. Ghosh*; **US patent** Application No.: 10/308,170; **PCT Patent** Application No.: PCT/IB 02/ 05198 and **Indian Patent** Application No.: 063/DEL/2003 [PCT National Phase].
12. A process for the preparation of improved heterogeneous ion exchange spacer; *G.S. Trivedi; P. Ray; B.G. Shah; R. Rangarajan and P.K. Ghosh*. **Indian Patent** Application No.: 0472/DEL/2003.
13. Process for the preparation of a molecular sieve adsorbent for selectively adsorbing nitrogen and argon from a gaseous mixture with oxygen; **PCT Patent** Application No.: PCT/IN 03/00504: **Indian Patent** Application No.: 0101/DEL/2003.
14. Process for generation of finely divided calcium carbonate from calcium carbonate rich industrial by-product; *R. V. Jasra, P.M. Oza, R.S. Somani, J.R. Chunawala, M.V. Sheth, V.V. Thakar, Y.M. Badheka (All from CSMCRI) and J. Ayyer, V.B. Patel. (All from GNFC)*; **Under PCT filing, this application is filed in European countries, China and Japan.**
15. Process for generation of precipitated calcium carbonate from calcium carbonate rich industrial by product; *R. V. Jasra, P.M. Oza, R.S. Somani, J.R. Chunawala, M.V. Sheth, V.V. Thakar, Y.M. Badheka (All from CSMCRI) and J. Ayyer, V.B. Patel (All from GNFC)*; **Under PCT filing, this application is filed in European countries, China and Japan.**
16. Preparation of nutrient rich salt of plant origin; *P.K. Ghosh, M.P. Reddy, J.B. Pandya, J.S. Patolia, S.M. Vaghela, M.R. Gandhi, R.J. Sanghavi, V.G. SravanKumar and M.T. Shah*; **US Pre-Grant Publication** No.: 2003 / 0185954. **International Publication** No: WO 2003 / 079817; Under **PCT filed** in Japan, Australia, and European countries, Israel, Mexico, China, Brazil and Canada. [PCT National Phase].

Granted

1. A device for making spirally wound membrane module useful for water desalination by reverse osmosis; *N. Pathak, A.V. Rao, S.N. Sah and S.N. Patel*. **Indian Patent No.:** 186,522 dated 19/4/2002.
2. An eco-friendly method of preparation of high purity tetrabromo bisphenol-A; *G. Ramachandraiah, P.K. Ghosh, A.S. Mehta, R.P. Pandya, A.D. Jethawa, S.S. Vaghela and S.N. Mishra*; **US Patent No.** 6,365,786 dated 02/4/2002.

2003-2004

Filed

1. An improved process for the recovery of palladium from spent catalyst; *R.V. Jasra, P.K. Ghosh, H.C. Bajaj and A.B. Boricha*; **US Patent** Application No.: 10/448,459; **PCT Patent** Application No.: PCT/IN 03/00202 and **Indian Patent** Application No.: 0757/DEL/2003.
2. A catalytic process for the preparation of isolongifolene; *R.V. Jasra, B. Tyagi and M.K. Mishra*. **US Patent** Application No.: 10/ 448,457; **PCT Patent** Application No.: PCT/IN 03/00200 and **Indian Patent** Application No.: 0759/DEL/2003.
3. An improved process for the preparation of non-hazardous brominating reagent; *S. Adimurthy, G. Ramachandriah, A.V. Bedekar, P.K. Ghosh and D.B. Shukla*. **US Patent** Application No.: 10/ 449,723; **PCT Patent** Application No.: PCT/IN 03/00201 and **Indian Patent** Application No.: 0758/DEL/2003.
4. Process for the preparation of molecular sieve adsorbent for the adsorptive dehydration of alcohols; *R.V. Jasra, J. Sebastian and C.D. Chudasama*; **US patent** Application No.: 10/726,748; **PCT Patent** Application No.: PCT/IB03/05324 and **Indian Patent** Application No.: 1457/DEL/2003.
5. Process for the preparation of molecular sieve adsorbent for selective adsorption of oxygen from air; *R.V. Jasra and C.D. Chudasama*. **US patent** Application No.: 10/693,643 ; **PCT Patent** Application No.: **awaited** and **Indian Patent** Application No.: 1558/DEL/2003.
6. A process for the eco-friendly synthesis of bromobenzene; *A.V. Bedekar, P.K. Ghosh, S. Adimurthy and G. Ramachandriah*; **US patent** Application No.: 10/739,756; **PCT Patent** Application No.: PCT/IB03/05933 and **Indian Patent** Application No.: **awaited**.
7. Herbal extracts of Salicornia species, process of preparation thereof use against tuberculosis; *M.R. Rathod, B.D. Shethia, J. B. Pandya, P.K. Ghosh, and R.J. Dodia (All from CSMCRI) and B.S. Srivastava, R. Srivastava , A.*

- Srivastava and V. Chaturvedi (All from CDRI). US Patent* Application No.: 10/651,212; **PCT Patent** Application No.: PCT/IN03/00292 and **Indian Patent** Application filed on 28/8/2003.
8. An improved device for the concentration of aqueous herbal extract solution; *P.K. Ghosh, V.J. Shah and J. B. Pandya*; **US Patent** Application No.: 10/700,512; **PCT Patent** Application No.: PCT/IB03/05167 and **Indian Patent** Application No.: awaited.
 9. Process for production of glycine micronutrient enriched NaCl crystals with near spherical shape and improved flow characteristics; *P. Dastidar, P.K. Ghosh, A. Ballabh; D.R. Trivedi (all from CSMCRI) and A. Pramanik, and V.G. Kumar (both from HLL)*; **US Patent** Application No.: 10/ 745,758; **PCT Patent** Application No.: PCT/ IB 03/ 06237 and **Indian Patent** Application filed on 20/2/2004.
 10. Novel integrated process for the recovery of sulphate of potash (SOP) from sulphate rich bittern; *P.K. Ghosh, K J. Langalia, M.R. Gandhi, R.H. Dave, H.L. Joshi, R.N. Vohra, V.P. Mohandas, S.L. Daga, K. Halder; H.H. Deraiya; R.D. Rathod and A.U. Hamidani*; **US Patent** Application No.: 10/814,778 ; **PCT Patent** Application No.: PCT/ IN03/ 00463; **Indian Patent** application filed on 04/3/2004.
 11. Improved process for simultaneous recovery of industrial grade potassium chloride and edible salt enriched with KCl (Low sodium salt) from bittern; *R.N. Vohra, P.K. Ghosh, A.B. Kasundra, H.L. Joshi, R.H. Dave, M.R. Gandhi, K.J. Langalia, K. Halder, S.L. Daga, R.D. Rathod, H.H. Deraiya, P.R. Jadav; V.P. Mohandas and A.U. Hamidani*; **US Patent** Application No.: 10/814,779, **PCT Patent** Application No.: PCT/IN 03/ 00449 and **Indian Patent** Application No awaited.
 12. Polyamide composite membrane for reverse osmosis and method of producing the same; *V.J. Shah, P.K. Ghosh, S.V. Joshi, J.J. Trivedi, C.V. Devmourari, A.V. Rao, P.D. Parmar, V.K. Vaghani and T.B. Gohil (All CSMCRI) and K.V. Balaram and M.S. Swami (All from CPCL)* **Indian Patent** Application No.: : 1216/DEL/2004
 13. An improved catalytic process for the preparation of epoxides from alkenes; *N. H. Khan; S.H.R. Abdi, R.I. Kureshy; S. Singh, I. Ahmed; R. V. Jasra and P.K. Ghosh;*. **US Patent** Application No.: 10/ 823,318 ; **PCT Patent** Application No. awaited and **Indian Patent** Application No awaited.
 14. Low sodium salt of botanic origin; *P.K. Ghosh, K.H. Mody, M.P. Reddy, J.S. Patolia, E. Eshwaran; R.S. Shah, B.K. Rathod, M.R. Gandhi, A.S. Mehta, A.M. Bhatt and A.V.R. Reddy*; **US Patent** Application No.: 10/819,001; **PCT Patent** Application No. awaited and **Indian Patent** Application No. awaited.
 15. An eco-friendly method of preparation of high purity tetrabromobisphenol-A; *G. Ramachandriah, P.K. Ghosh, A.S. Mehta, R.P. Pandya, A.D. Jethva, S.S. Vaghela and S.N. Mishra. International publication No: WO 2002/057207, Indian Patent* Application No.: 1103/DEL/2003. [PCT National Phase].

16. Process for generation of finely divided calcium carbonate from calcium carbonate rich industrial by product; *R.V. Jasra, P.M. Oza, R.S. Somani, J.R. Chunawala, M.V. Sheth, V.V. Thakar, Y.M. Badheka J., Ayyer and V.B. Patel*. International publication No.: WO 2003/ 037796, **Indian Patent** Application filed on 30/10/2003 [PCT National Phase].
17. Process for generation of precipitated calcium carbonate from calcium carbonate rich industrial by product; *R.V. Jasra, P.M. Oza, R.S. Somani, J.R. Chunawala, M.V. Sheth, V.V. Thakar, Y.M. Badheka J. Ayyer and V.B. Patel*; **International Publication No.:** WO 2003 .037795, **Indian Patent** Application No.: 1693/DEL/2003[PCT National Phase].
18. Recovery of sodium chloride and other salts from brine; *R.N. Vohra, P.K. Ghosh, V.P. Mohandas, H.L. Joshi, H.H. Deraiya, R.H. Dave, K. Halder, R.B. Yadav, S.L. Daga, K.M. Majethia and U.P. Sarvaiya*; **Indian Patent** Application No.: 1689/DEL/2003.[PCT National Phase].
19. An improved clay based process for the preparation of acylated aromatic ethers; *R.V. Jasra, S. Muthusamy and Y.M. Badheka*; **Indian Patent** Application No.: 062/DEL/2004.
20. An improved process for preparing hydrotalcite and brucite type positive charged layers; *P.M. Oza, S.H. Mehta, M.V. Sheth, P.K. Ghosh, M.R. Gandhi and J.R. Chunawala*. **Indian Patent** Application filed on 08/03/2004 [PCT National Phase].

Granted

1. A process for the preparation of high quality refractory grade magnesia from bittern; *R.N. Vohra, H.L. Joshi, D.A. Chauhan, D.H. Oza, H.H. Deraiya and P. Natrajan*. **Indian Patent** No.: 188,534 dated 11/7/2003.
2. An improved process for the preparation of magnesium phosphate; *M.J. Mehta, R.A. Buch and U.P.Sarvaiya*; **Indian Patent** No.: 188,683 dated 01/8/2003.
3. A device for sea water/ highly saline brackish water desalination and other industrial separations; *S. SanalKumar, A. Prakash Rao, N.V. Desai, R. Rangarajan, A.V. Rao and P. Natrajan*; **Indian Patent** No.: 189,054 dated 26/9/2003.
4. Process for the preparation of a molecular adsorbent for selective adsorption of nitrogen and argon; *J. Sebastian and R.V.Jasra*; **US Patent** No.: 6,572,838 dated 03/6/2003.

II. External Cash Flow

2002-03

A. GRANT IN AID

Rupees in lakh

Sr. No	Title of Project	Funding Agency	Amount received
1.	Collection, identification and chemical investigation of marine flora	Dept. of Ocean Development, Govt. of India, New Delhi	13.78
2.	National Marine Data Centre on marine chemicals and algal resources parameters	Indian National Center for Ocean Information Services, Dept. of Ocean Development.	9.00
3.	Incorporation of anionic macrocyclic transition metal complexes into the inter gallery of layered double hydroxides and their catalytic properties towards selective oxidation reaction.	Dept. of Science & Technology, Govt. of India, New Delhi	0.70
4.	Model bio -village projects Phase II at Mocha-Gorser, Lilivav and Bhandar.	Dept. of Biotechnology, Govt. of India, New Delhi	17.38
5.	Dearsenification of drinking water from traces of arsenic left over from chemically treated well waters of West Bengal by selective ion-exchange resins.	Dept. of Science & Technology, Govt. of India, New Delhi	0.31
6.	Treatment of effluent containing valuable/toxic metal ions and their recovery by Electrodialysis.	Ministry of Environment & Forest, Govt. of India, New Delhi	2.91
7.	Studies on field cultivation and harvesting of seaweeds <i>Porphyra</i> (Nori), <i>Enteromorpha</i> (Aonori), <i>Eucheuma</i> (Tosaka Nori) and their use in processed foods.	Dept. of Biotechnology, Govt. of India, New Delhi	11.98
8.	Improving quality and yield of salt recovered from subsoil brine at LRK and increasing the income of agrarians through bittern value addition.	Industries Commissionerate, Govt. of Gujarat	65.00
9.	Development of adsorbents for separation of Oxygen/ Nitrogen/ Argon for air.	Dept. of Science & Technology, Govt. of India, New Delhi	2.50
10.	Studies on halophytes and their improvements	GSFC Science Foundation, Vadodara	3.40
11.	Side chain alkylation of toluene with methanol solid base catalysis.	Indian National Science Academy, New Delhi	0.50
12.	Integrated programme for scaled up cultivation and processing of phycocolloid seaweeds (<i>Gelidiella acerosa</i> and <i>Eucheuma</i>) and new technological platforms through biotechnological interventions.	Dept. of Biotechnology, Govt. of India, New Delhi SNAP Natural Alginate Products Ltd., Ranipet	11.77

13.	Development of durable membranes for the efficient separation of hexane from oil miscella.	CSIR, New Delhi	1.56
14.	Designing ligands for selective abstraction of potassium ion from bittern.	Dept. of Science & Technology, Govt. of India, New Delhi	5.00
15.	Study of the changes in sulphated polysaccharide contents of seaweeds as a function of life stages and season.	Dept. of Biotechnology, Govt. of India, New Delhi	3.64
16.	Conservation and propagation of agar yielding seaweeds of Gulf of Mannar.	Ministry of Environment and Forest, Govt. of India, New Delhi	4.27
17.	Studies on the role of bridging agent and non-bonding interactions in tuning metal poly nuclear complexes.	Dept. of Science & Technology, Govt. of India, New Delhi	8.96
18.	Developing ultra pure chalk , compatible chalkboard and high performance chalkboard duster.	Ministry of Human resource Development, Govt. of India, New Delhi	3.00
19.	Supramolecular synthesis of novel inclusion materials based on coordination complexes as building blocks.	Dept. of Science & Technology, Govt. of India, New Delhi	6.00
20.	Studies on carbonyl ylides towards the synthesis of terpenoid and alkaloid system.	Dept. of Science & Technology, Govt. of India, New Delhi	3.00
21.	Synthesis and characterisation of chiral metal complexes covalently bounded to organic and inorganic support.	Dept. of Science & Technology, Govt. of India, New Delhi	2.50
22.	Development of agronomic practices and improvement of Jatropha curcas.	Dept. Of Biotechnology, Govt. of India, New Delhi	5.57
23.	Development of heterogeneous ion exchange membranes to be used in electro dialysis process for the industrial effluent treatment.	Ministry of Environment and Forest, Govt. of India, New Delhi	1.72
		Total	184.45

B. COLLABORATIVE PROJECTS

Sr. No	Title of Project	Funding Agency	Amount received
1	Preparation and dissemination of Indian reference material	National Physical Laboratory, New Delhi	3.25
2	Commercialization of indigenous reverse osmosis membrane technology.	Center for High Technology, New Delhi	14.85

3.	Extraction of phycocyanin from Spirulina	Strides Arcolab Ltd. Bangalore	4.00
4.	Development of solvent resistant membrane for separation of solvent from de-waxed oil	Indian Oil Corporation & Chennai Petrochemical Corporation, Ltd	3.11
5.	Collaborative project for production of Silica based value added products from Kimberlite waste by	National Mineral Development Corporation, Hyderabad	7.99
6.	Salt crystallization and habit modification	Hindustan Lever Ltd., Mumbai	3.90
		Total	37.10

C. SPONSORED RESEARCH PROEJCTS

Sr. No	Title of Project	Funding Agency	Amount Received
1.	Development of viable technology for Hypnea cultivation, harvesting & manu-facturing Semi Refined Carrageenan (SRC)	PepsiCo India Holdings Ltd., Gurgaon.	13.08
2	R.O. Unit Installation at Ramanathpuram		5.00
3	Exploratory Work on Coconut Water Concentration by RO technique.	PepsiCo India Holdings Ltd., Gurgaon.	2.00
4	Installation of RO Desalination Unit at Gujarat Institute of Desert Ecology, Kutchh.	Gujarat Institute of Desert Ecology	0.95
5	Exploratory work for synthesis of specific grade of Precipitated Silica	Kadvani Chemicals, Jamnagar	0.70
6.	Feasibility study effluents generated from TBP plant at HWP-Talcher	Dept. of Atomic Energy, Heavy Water Board, Mumbai	0.60
	Recovery of Palladium from spent hydrogenation catalyst.	Narmada Chematur Petrochemicals Ltd., Bharuch	0.50
		Total	22.83

D. CONSULTANCY

Sr. No	Title of Project	Funding Agency	Amount Received
1	Environmental audit	TATA Chemicals L td, Mithapur	1.68
2	Environmental Audit	Indian Rayon & Industries, Veraval	1.90
3	Environmental Audit	Indo Gulf Corporation Ltd., Dahej	2.36
4	Environmental Audit	Gujarat Ambuja	5.86
5	Environmental Audit	Gujarat Electricity Board, Sikka	0.74

6	Study on intake of Seawater and disposal of RO reject water and its effect on marine environment for RO Plant at BCT, Muldwarka.	Ambuja Cements Ltd.	0.86
7	Environmental Audit	M/s. Perfect Environmental Control System Ltd.	0.76
8	Environmental Audit	Atul Ltd, Atul, Dist. Valsad	1.41
9	Testing of FGC Plant for Gujarat Electricity Board, Ukai	Chemithon Engineering Pvt. Ltd Silvassa	1.21
10	Environmental Audit	Gujarat Electricity Board, Ukai - Thermal Power Stn., Dist. Surat	1.24
11	Environmental Audit	Gujarat Electricity Board, (WTPS) Wanakbori, Kheda	0.57
12	Studies on Environmental impact assessment of Eucheuma cultivation, Gulf of Mannar Tamil Nadu.	PepsiCo India Holding Pvt., Ltd.	4.80
13	Environmental impact assessment of discharge of treated effluent from proposed CETP plant to Kadodara Khadi at Kadodara, Dist. Surat	Palsana Environment Pvt. Ltd.	3.05
14	Environment audit	Gujarat Electricity Board, SKV Nagar	1.14
15.	Environmental Audit	The Veraval Industries Association Ltd., Veraval.	0.95
		Total	28.53

ECF realized during the years 2002-03

	Amount
Grand-in-aid	184.45
Collaborative projects	37.10
Sponsored projects	22.83
Consultancy projects	28.53
Technical Assistance	0.58
Royalty / Premia	4.60
Testing & Analysis	19.99
Total	298.08

A. GRANT-IN-AID PROJECTS

Sr. No	Title of Project	Funding Agency	Amount Received
1.	Collection, identification and chemical investigation of marine flora.	Dept. of Ocean Development, Govt. of India, New Delhi.	24.28
2.	Development of improved electro dialysis system for obtaining potable water from seawater.	Dept. of Science & Technology, New Delhi.	5.00
3.	Studies on impact of over exploitation of commercial seaweeds on extent of Coral Reefs of Gulf of Mannar	Ministry of Environment & Forest, Govt. of India, New Delhi.	1.62
4.	Demonstration of indigenous reverse osmosis membrane technology and critical plant evaluation of desert region of Rajasthan.	Dept. of Science & Technology, New Delhi.	18.00
5.	Treatment of effluent containing valuable/toxic metal ions and their recovery by Electro dialysis.	Ministry of Environment & Forest, Govt. of India, New Delhi.	1.35
6.	Studies on halophytes and their improvements	GSFC Science Foundation, Vadodara.	0.13
7.	Side chain alkylation of toluene with methanol solid base catalysis.	Indian National Science Academy, New Delhi.	0.36
8.	Designing ligands for selective extraction of potassium ion from bittern.	Dept. of Science & Technology, Govt. of India, New Delhi.	3.00
9.	Studies on the role of bridging agent and non-bonding interactions in tuning metal – metal interface in bi and poly nuclear metal complexes.	Dept. of Science & Technology, Govt. of India, New Delhi.	3.00
10.	Developing ultra pure chalk, compatible chalkboard and high performance chalk - board duster.	Ministry of Human resource Development, Gov t. of India, New Delhi.	2.64
11.	Supramolecular synthesis of novel inclusion materials based on coordination complexes as building blocks.	Dept. of Science & Technology, Govt. of India, New Delhi.	3.00
12.	Studies on carbonyl ylides towards the synthesis of terpenoid and alkaloid system.	Dept. of Science & Technology, Govt. of India, New Delhi.	3.00

13.	Synthesis and characterisation of chiral metal complexes covalently bounded to organic and inorganic support: a strategy to develop a practical heterogeneous chiral epoxidation catalyst.	Dept. of Science & Technology, Govt. of India, New Delhi.	2.00
14.	Improvement of membrane and development of ed equipment for the recovery of metal value from effluents.	Dept. of Science & Technology, Govt. of India, New Delhi.	0.17
15.	Oxidative destruction of organic species in effluent waters: Voltammetric investigation of phenols, amines and their derivatives at various catalytic anode materials.	Dept. of Science & Technology, Govt. of India, New Delhi.	2.40
16.	Olefin Hydroformylation	Dept. of Science & Technology, Govt. of India, New Delhi.	3.00
17.	Investigation on physico-chemical properties of salt water system (organic solvent + salt water)	Dept. of Science & Technology, Govt. of India, New Delhi.	6.00
18.	Development of enantioselective catalysts for synthesis of drug intermediates based on chiral BINOL and BINOP metal complexes supported in inorganic porous solids.	Dept. of Science & Technology, Govt. of India, New Delhi.	3.00
19.	Bio degradable functional polyester and their membranes for bio medical applications	Dept. of Science & Technology, Govt. of India, New Delhi.	2.00
20.	Studies on differential expression of salt-induced gene(s) in Salicornia Brachiata	Dept. of Biotechnology New Delhi.	6.11
21.	Defluoridation of the groundwater in Gujarat & Saurashtra region by ion selective resins	Ministry of Rural Development, New Delhi.	4.10
22.	Development of novel sensing molecules and immobilization of the chemo sensors on to the surface comparative studies in solution state and bound state	Dept. of Science & Technology, Govt. of India, New Delhi.	5.00
		Total	99.16

B. COLLABORATIVE PROJECTS

Sr. No	Title of Project	Funding Agency	Amount received
1.	Establishing new salt farm in Rajasthan.	1. Salt Commissioner, 2A, Lavan Bhavan, Lavan Marg, Jaipur, 302004. 2. Commissioner of Industries, Industries Dept., Govt. of Rajasthan, Udyog Bhavan, Tilak Marg, Jaipur-302005, & 3. M/s. Sambhar Salts Ltd, B427, Pradhan Marg, Malavia Nagar, Jaipur 302 317.	12.00
2.	Production of High quality salt in the inland belts of Gujarat.	1. Salt Commissioner, Lavan Bhavan, 2A- Lavan Marg, Jaipur – 302004 & 2. Hindustan Salts Ltd, B-427, Pradhan Marg, Malavia Nagar, Jaipur-302017	3.50
3.	Development of a Pilot Scale Electrochemical Cell for the preparation of potassium iodate solution for direct salt iodisation	Salt Department, Jaipur	2.50

4.	Biofuel from eroded soil in India.	Daimler Chrysler, Germany	42.41
5.	Development of seaweed polysaccharide based soft gelatin capsule material	Strides Arcolab Ltd. Bangalore	5.40
6.	Salt crystallization and habit modification	M/s Hindustan Lever Ltd. Mumbai	1.95
7.	Development of Solvent Resistant Membrane for separation of solvent from de-waxed oil.	IOC & CPCL	9.19
8.	Collaborative project for product ion of Silica based value added products from Kimberlite waste by	National Mineral Development Corporation, Hyderabad	4.99
Total			81.94

C. SPONSORED RESEARCH PROEJCTS

Sr. No	Title of Project	Funding Agency	Amount received
1	Development of viable technology for Hypnea cultivation, harvesting & manu-facturing Semi Refined Carrageenan (SRC)	M/s. PepsiCo India Holdings Ltd., Gurgaon.	10.08
2	Installation of bullock driven water desalination plant in Kutchh.	M/s. PepsiCo India Holdings Ltd., Gurgaon.	3.80
3	Survey of the salt works located in Gandhar/ Dahej/ Jambusar.	M/s. Indian Petrochemicals Ltd.,	2.46
4	Treatment of Acidic Nitronaphthalene-trisulphonic Acid stream from Amal H-acid plant and Effluent AG –Div. 2, 4-D plant by nanofiltration.	Atul Ltd Atul – 396 020 Gujarat	1.76
5	Treatment of effluent waste from Amal H-acid plant and AG –Div. 2, 4-D plat by electro dialysis.	Atul Ltd.; Atul – 396 020 Gujarat	2.24
6.	Polyolefin Nano-composites	Reliance Industries & NCL, Pune	7.50
7.	To increase whiteness/ brightness of salt with sustainable free flow ability and stable iodate content, production of superior quality salt in the field coupled with the recovery of Low sodium salt and/or Muriate of Potash (MOP), in situ production of Potassium iodate through innovative routes.	M/s. Tata Chemicals Ltd.,	17.00
8.	Feasibility study effluents generated from TBP plant at HWP-Talcher	Department of Atomic Energy Heavy Board – Mumbai.	0.90
9	Exploratory work for synthesis of specific grade of Precipitated Silica	Kadvani Chemicals, Jamnagar	0.30
10	To prepare membrane separation module complete system for herbal concentrator with reverse osmosis components	Regional Research Laboratory, Jorhat and Central Institute of Medicinal Plants & Aromatic Plants (CIMAP), Lucknow	2.25
11	Development of ultra pure water system – Phase II	Infusil India Pvt. Ltd., Bangalore	5.00
Total			53.29

D. CONSULTANCY

Sr. No	Title of Project	Funding Agency	Amount received
1	Environmental Audit.	M/s. Gujarat Paguthan Energy Corporation P. Ltd., Baruch -392015	0.83
2	Environmental Audit.	Indo-Gulf Corporation Ltd., Village Lakhigam, PO: Dahej, Dt: Bharuch	2.55
3	Environmental Audit.	Gujarat Ambuja Cement Ltd, PO: Ambujanagar, Kodinar.	2.36
4	Environmental Audit.	Atul Ltd, DT: Atul, Valsad.	1.67
5	Environmental Audit.	Perfect Enviro Control Systems Ltd., Plot No.731/A, GIDC, Sarigam Tal., Umargam, Dt: Valsad -396 155	0.74
6	Environmental Audit.	Chief Engineer (G), Wanakbori Thermal Power Station, Dt.Kheda-388 239	2.42
7	Environmental Audit.	Indian Rayon & Ind. Ltd., VeravaJunagadh Road, Veravel362 266, Dist: Junagadh	0.46
8	Environmental Audit.	Tata Chemicals Ltd., Mithapur, Okhamandal	2.46
9	Environmental Audit	The Veraval Industries Association Ltd., Veraval.	1.39
10	Discussion on production of Phycocyanin	M/s. Sheth Enterprises Pvt. Ltd., 12, Pollock- St., 2 nd Floor Kolkatta-700001	0.09
11	Environmental impact assessment of discharge of treated effluent from proposed CETP plant to Kadodara khadi at Kadodara, Dist. Surat	Palsana Environment Pvt. Ltd.	4.45
12.	Cultivation of salt tolerant plant such as Salicornia and Salvadoran on saline land in Muscat	Birla Institute of Technology, Noida	0.47
13.	Environmental Audit.	Gujarat Electricity Board, SKV Nagar	0.70
14.	Environmental Audit.	Gujarat Electricity Board, Sikka	0.72
15.	Environmental Audit	Chemithon Engineering Pvt. Ltd Silvassa	0.93
16.	Environmental Audit	Gujarat Electricity Board, Gandhinagar	1.56
		Total	23.80

ECF realized during the years 03-04

Rs. In lakh

Type of Project	Amount
Grant – in - aid	99.16
Collaborative	81.94
Sponsored	53.29
Consultancy	23.80
Technical assistance	1.63
Premium and royalty	27.47
Analytical charges	3.94
Others	5.51
Total	296.74

Library & Information System

The CSMCRI Library is considered to be a premier one in this region having a rich collection of books, periodicals, reference materials etc in the areas of R & D being carried out in the Institute. Besides catering to the information needs of R & D staff of the institute, the Library also extends facilities to the Visiting Research Scholars, University Staff, R&D Staff of the Industries, Government Officials and others. A brief account of Library collection, facilities available, services provided is as under:

Annual collection of Library: 2002-03 & 2003-04

Sr. No.	Particulars	Available as on 1.4.2002	Addition during 2002-03	Collection as on 31.03.2003	Addition during 2003-04	Collection as on 31.03.2004
1.	Books	11637	34	11671	27	11698
2.	Back Vols.	24578	1202	25780	161	25941
3.	Translation	429	0	429	0	429
4.	Photocopy	2084	39	2123	26	2149
5.	Patents	333	6	339	1	340
6.	Standards	761	0	761	0	761
7.	Micro-cards	67	0	67	0	67
8.	Microfilms	1326	0	1326	0	1326
9.	Maps/Charts	265	0	265	0	265
10.	Reprints	2692	3	2695	2	2697
	Total	44172	1284	45456	217	45673

<i>Journals/Databases/E-Journals Subscribed</i>		2002-03	2003-04
1.	Foreign Journals	72	72
2.	Indian Journals	84	84
3.	Bibliographic Databases on CD (CA, BA, CC-A, CC-P)	04	04
4.	Access Rights to CD Databases (CSDS, Indian Standards-CHEM, ULLMANN)	03	00
5.	Online E-Journals Databases Science Direct	01	01

Information Services:

For easy and quick access to current and latest information by the R & D staff, library renders various information services to its readers. Through these services, scientific and technical staff is kept well informed about the current trends in the field of their interest. The services rendered are:

1. Inter-Library Loan Services.
2. Readers' Queries.
3. Document Delivery Service.
4. Bibliographies using Current Contents and Chemical Abstracts.
5. Reference service.
6. Literature search facility to outsider.

The library is having specialized up-to-date collection of International Abstracting & Indexing Services viz. Chemical Abstracts, Biological Abstracts, Current Contents, Back Volumes of Journals in Chemistry, Chemical Technology, Biological Sciences, CD-ROM Databases like Ullmann's Encyclopaedia of Industrial Chemistry, Chemistry Comes Alive, Young Scientists Encyclopaedia, World Book Encyclopaedia, Cambridge Structural Database System, Indian Standards-Chemical and Science-Direct Full Text E-Journals Database etc. Outsiders are also granted permission to consult the documents in the library. This fulfils the aim of maximum utilization of library documents.

During the period under report library has granted permission to outsiders as follows:

External Membership

	2002-03	2003-04
Long term permission	27	09
Short term permission	30	20
Corporate members	07	07
Outsiders who consulted the library.	375	300

Dateline

Date	Salient details
April 10, 2002	49 th CSMCRI Foundation Day celebrated. Dr. Brij Bhusan Lohray, President, Zydus Research Centre, Ahmedabad delivered the Foundation Day Lecture on "Asymmetric synthesis and its application in industry".
Sept. 26, 2002	The Diamond Jubilee of CSIR celebrated. Prof. Tejraj Aminabhavi, Director, National Centre of Excellence in Polymer Science, Karnataka University delivered a lecture on "Advance Membrane Processes and their Future prospects". (The function was observed with due solemnity following the attack on Akshardham in Gandhinagar)
Feb. 19-20 2003	National Seminar on Desalination & Membrane Technology: Present & Future held. Prof. M.M. Sharma, Ex -Director, UDCT, Mumbai was the Chief Guest. Dr. M.H. Mehta, Vice Chancellor, Gujarat Agricultural University and Dr. Ramgopal, President, InDA were the Guests of Honour. About 100 participants from various agencies/organizations attended the Seminar
October 24- & 25 2002	CSIR Programme on Youth for Leadership in Science (CPYLS) was organized at the Institute. 74 students - 34 boys and 40 girls - participated in the programme, along with their parent/teachers.
Feb. 28, 2003	National Science Day celebrated. A Science Fair was organised by the Institute. Students from thirty three schools of Bhavnagar participated in the fair and displayed working models and various experimental set-ups. In all about 3000 students visited the fair.
10 April, 2003	CSMCRI Foundation Day celebrated. Prof. Gautam R Desiraju, Univ. of Hyderabad delivered the foundation Day lecture entitled "Sir C.V. Raman - what his experiences hold for us today". Prof. V. Krishnan, Chairman, Research Council presided over the function.
17-21 June, & 26-30 June, 2003	CSIR Diamond Jubilee Exhibition organized at the Institute (17 -21 June), and at Gandhinagar (26-30 June)
26 September 2003	CSIR Foundation Day celebrated. Dr. A.S. Abhiraman, Executive Director (Research), Hindustan Lever Ltd. Mumbai delivered the Foundation Day Lecture entitled "Traveling across industry - Academia interface: an interactive discussion". Prof. V. Krishnan, Chairman, RC presided over the function.
6-7 Nov.2003	CSIR Programme on Youth for Leadership in Science (CPYLS) was organized at the Institute on November 6 -7, 2003. 67 students, 38 boys and 29 girls, participated in the programme along with their parents/ teachers.

DEPUTATION/VISIT OF FOREIGN SCIENTISTS TO CSMCRI

2002-2003

1. **Dr. George Francis**, Hohenheim Uni. **GERMANY** visited CSMCRI on 2-3 April, 2002 for discussion on a proposed collaborative project on Jathropha with Institute's scientists.
2. **Mr. Abdus Salam, Mr. Zillur Rahaman, Mr. Toufizur Rahaman, Mr. Mahin Akbar and Mr. Kazi Jahangir Kabir** of NGO Forum , Dhaka, **BANGLADESH** visited the Institute to know the mechanism of desalination of water during their visit to Bhavnagar in the context of salinity prevention through Rain Water harvesting and Recharging Conservation Method.
3. **Prof. Dr. Helmut Knozinger**, University of Munich, **GERMANY** visited CSMCRI from 1-3 July, 2002 on invitation during his visit to India under CSIR-DAAD Exchange Programme. During his stay, a detailed discussions were held on catalysts synthesis, characterization methods and reactor methodologies.
4. **Prof. Dr. R. Maly**, Daimler Chrysler AG and **Dr. George Francis**, Hohenheim University **GERMANY** visited CSMCRI on 17 & 18 July, 2002 for discussions about the proposed collaborative project on Jathropha.
5. **Dr. P.K. Dutta** of the Ohio State University, **USA** visited the Institute during 2-5 September, 2002 under the DST-NSF collaborative project for discussion and updating the on-going collaborative project "*Fundamental Studies of Nucleation & Crystal Growth of Zeolites and Hydrotalcite*".
6. **Prof. Dr. Heinz Hoffmann**, University of Bayreuth, Bayreuth, **GERMANY** visited CSMCRI under the CSIR-DAAD Exchange of Scientists Programme from 14- 21 October, 2002. During his visit he interacted with our scientists on research programmes and had discussion in the area of viscoelastic surfactants and gels and exploring possibilities for establishing collaboration with CSMCRI in the area of seaweed polysaccharides, particularly on physicochemical characterization of seaweed polysaccharides and their modification.
7. **Prof. Dr. Dieter Sellmann**, University of Erlangen-Nurnberg, **GERMANY** visited the Institute under the CSIR-DAAD Exchange of Scientists Programme from 16 to 25 November, 2002 to participate in our research programmes and discussion in the area of developing water soluble and insoluble complexes for nitrogen fixation by modern techniques.

2003-2004

1. **Mr. Iain Neish** from MARS/ PEPSI visited CSMCRI on 14th April, 2003 for discussion on cultivation of *Euचेuma under* a collaborative project with PEPSICo India Holding on seaweed farming.
2. **Prof. Dr. Klaus Becker, Dr. Moti Harari, and Dr. George Francis** of the University of Hohenheim, **GERMANY** visited CSMCRI fro 31st July to 3rd August, 2003 for discussion on a collaborative project also involving DaimlerChrysler, Germany on *Jatropha* cultivation.
3. **Prof. Dr. Mathias Ulbricht**, University Duisburg-Essen, **GERMANY** visited the Institute under the CSIR-DAAD Exchange of Scientists Programme from 7-23 September, 2003 to participate in research programmes and mutual exchange of views on various aspects of membranes viz. surface functionalization of membranes, affinity membranes, molecularly imprinted membranes membranes for facilitated or triggered transport, catalytically active membranes, etc.
4. **Prof. Probir K. Dutta** of the Ohio State University, **USA** visited under DST-NSF Collaborative project from 1-4 December, 2003 to review the progress of project "*Fundamental Studies of Nucleation & Crystal Growth of Zeolites and Hydotalcite*".
5. **Ms. Nuru Igumba Kameka** from the Open University of Tanzania, **TANZANIA** visited CSMCRI under the award of CSIR-TWAS Fellowship for Postgraduate Studies from 28th January, to 25th March, 2004 for pursuing research on "*Inorganic techniques including characterization of mineral phases by XRD and others*".
6. **Prof. Dr. M. Ballauff**, University of Bayreuth, Bayreuth, **GERMANY** visited CSMCRI on 22-23 February, 2004 on invitation during his visit to India for delivering lecture and discussions with Scientists in the area of Spherical Polyelectrolyte Brushes as Synthesized by Photoemulsion Polymerization.

DEPUTATION ABROAD OF CSMCRI SCIENTISTS

2002-2003

1. **Shri M.R. Gandhi**, Scientist EII visited **ISRAEL** Under the award of **Raman Research Fellowship-2002** from 1st May, 2002 to 30th August, 2002 'To develop energy economic process for the recovery of potassium chloride from the mixed salt containing KCl, NaCl and MgCl₂' During this period Shri Gandhi also visited Bulgaria from 21st to 27th July, 2002 to attend 10th International Symposium on solubility Phenomena and workshop on Solubility Phenomena- Application for Environmental Improvement and

for delivering a plenary lecture on “*Emergence of Environmentally Friendly Technologies employing Phase Equilibrium Principles*”.

2. **Dr. D.B. Shukla**, Scientist-E-II visited **JAPAN** under the HRD Programme of CSIR from 3 to 16 April, 2002 to participate in a specialized training programme on “*Intellectual Property Rights for India (IDIP) held at AOTS Centre, Tokyo*”.
3. **Dr. R.S. Somani**, Scientist-E-I visited **USA** under DST-NSF collaborative project during 3- 28 May, 2002 to carry out project work on “*Fundamental studies of nucleation and crystal growth of zeolites and hydrotalcites*”.
4. **Dr. R.V. Jasra**, Scientist-F visited **KOREA** from 9-22 July, 2002 under an invitation by KIER, Korea for holding discussion and deliver a seminar lecture on “*Characteristics of hydroxylation Catalyst*”. At KIER, Korea.
5. **Dr. R S. Shukla**, Scientist E-II visited **KOREA** Under INSA-KOSEF Exchange Programme from 1st August, 2002 to 31st October, 2002 to learn and gain knowledge and training on '*advanced molecular engineering and chemical technology in the specialized area of the catalytic hydrocarbonoxidation process involving molecular oxygen and carbon dioxide*'.
6. **Dr. V.K. Shahi**, Scientist C visited **GERMANY** from 3rd September, 2002 to 30th November, 2002 under CSIR-DAAD Exchange Programme-2002 to carry out research work on '*surface modifications of membranes by UV and electron beam curing, its characterization and applications*'..
7. **Dr. Amitava Das**, Scientist E-I visited **USA** under DST- NSF Collaborative Project, entitled “*Fundamental Studies of nucleation and crystal growth of zeolites and hydrotalcites*”, from 5th November to 3rd December, 2002.
8. **Dr. Suresh E**, Technical Officer-A visited **JAPAN** under JSPS Post Doctoral Fellowship (JSPS-PDF) offered by Japan Society for the Promotion of Sciences (JSPS) for one year from 25th November 2002.
9. **Dr. R.V. Jasra**, Scientist F visited **KOREA** under INSA-KOSEF-Exchange programme (and partial travel support form CSIR) from 25th November, 2002 to 2nd December, 2002 to participate in the KOREAN Indian Seminar on “*Adsorbent and Adsorption Technologies*” and to present a paper entitled “*New adsorbents for Oxygen, Nitrogen, and Argon Separation*”.
10. **Dr. P.S. Anand**, Scientist-E.II visited **KOREA** under INSA-KOSEF-Exchange programme (and partial travel support form CSIR) from 25th November to 2nd December, 2002 to participate in the KOREANINDIAN Seminar on “*Adsorbent and Adsorption Technologies*” and to present a paper entitled “*Development of Porous Polymeric Adsorbents, Ion-Exchange and Ion-Selective Resins for various Separations*”.

11. **Dr. P.K. Ghosh**, Director visited **GERMANY** on invitation by Hohenheim University, Germany from 19-22, January, 2003 to have discussion with the scientists of Hohenheim Uni. on the collaborative project on “*Bio fuel from Eroded land of India*”.
12. **Dr. S.K. Thampy**, Scientist E-II visited **KOREA** on an invitation from Kwangju Institute of Science and Technology, KJIST from 26-31 March, 2003 for Scientific discussion in the field of ion exchange membranes process.
13. **Dr. P.K. Ghosh**, Director visited **AUSTRALIA** to represent CSIR (nominated by DG, CSIR) in the GRA Water Workshop from 29th March to 4th April, 2003 to participate in the *Global Research Alliance (GRA) Technology fusion Workshop on water* and to make presentation on CSIR contribution on Water.

2003-2004

1. **Dr. Pradyut Ghosh**, Scientist-C visited **GERMANY** under the AvH Fellowship from 7th May 2003 to 31st October, 2003 to carry out research work on “*Template directed synthesis of rotaxane molecules and studies dynamic properties*” at Universität Bonn, Kekulé-Institut für Organische Chemie und Biochemie, Bonn, Germany.
2. **Dr. C.R.K Reddy**, Scientist E-II visited **USA** under the award of Raman Research Fellowship from 29th May, 2003 to 27th February, 2004 to carry out research work on “*Modification of Fatty acid Content in Edible Seaweeds through Genetic Transformation*” at Northeastern University, Boston, USA.
3. **Dr. R.S. Somani**, Scientist E-I visited **KOREA** under the grant of Sabbatical Leave from 22nd July, 2003 to 21st July, 2004 to avail Research Associateship under Korea Brain Pool Program sponsored by the KOFST and KOSEF, Korea for pursuing research on “*Development of Olefin Selective Adsorbents and Separation Technology*” at KIER, Korea.
4. **Dr. B. Jha**, Scientist-F visited **GERMANY** from June 8 to July 5, 2003 under BMBF Fellowship to conclude and write a report on the ongoing joint project IND 011/99 and to discuss and formulate a new proposal in the area of common interest in the field of “*Environmental Biotechnology*” between CSMCRI and the GSF-Institute for Bodenoekologie, Munich.
5. **Dr. Srinivasan Kannan**, Scientist-E-I visited **HUNGARY** under the Indo-Hungarian Programme of Cooperation in S&T from 18-24 May, 2003 to attend the conference entitled “*Indo-Hungarian Conference on Surface Chemistry and Catalysis on Nano-particles*” held in Budapest, Hungary and to deliver a lecture entitled “*Hydrotalcites and their catalytic applications*”.

6. **Dr. A.K. Siddhanta**, Scientist-E-I visited **GERMANY** from July 1 to September 18, 2003 on an invitation by Prof. Dr. Heinz-Hoffmann, Uni. of Bayreuth, Germany to carry out research work in the area of *hybrid gel materials based on seaweed polysaccharides-silica gels* for bilateral collaboration and to familiarize and get an exposure to the research facilities available in the proposed area.
7. **Dr. M. P. Reddy**, Scientist-E-II visited **JAPAN** under INSA-JAPAN Exchange Programme from 3rd September to 29th November, 2003 to *identify markers responsible for tissue specific compartmentalization of Na⁺ and increase in succulence in Salicornia brachiata* at Okayama University, Japan.
8. **Dr. M. Ganesan**, Scientist-B visited **USA** under the award of “DBT Overseas Associate ship (short-term) for the year 2002-2003 from 24th October, 2003 to 24th April, 2004 to carry out research work on “*Molecular phylogeny of the economically important red algae from the Gulf of Mannar based on rbcL sequence analysis*” at University Louisiana, Lafayette, Louisiana. USA.
9. **Dr. Srinivasan Kannan**, Scientist E-I visited **JAPAN** from 24th September, 2003 to 20th May, 2004 under the INSA-JAPAN Exchange Programme to carry out research work on (a) *Selective catalytic reduction of nitric oxide by hydrocarbons using catalysts derived from hydrotalcite-like compounds*, and (b) *synthesis of welldefined (VO)₂P₂O₇ catalyst through layered vandy -alkyl phosphates for selective oxidation of n-butane to maleic anhydride* at Nagoya University, Japan.
10. **Dr. V.R.K.S. Susarla**, Scientist-E-II was deputed to **GERMANY** under the DAAD-Re-invitation Program from September 1 to October 25, 2003 for advanced studies on “*the crystallization of salts from supersaturated solution and the growth habits*”, and to get acquainted with the various methods employed to have an idea of the effect of impurities on them at Martin-Luther Universitat Halle-Wittenberg, Institut fur Verfahrenstechnik, Halle(Saale), Germany.
11. **Dr. Parthasarathi Dastidar**, Scientist-C is on deputation to **JAPAN** under JSPS Post Doctoral Fellowship (JSPS-Invitation Fellowship - Long Term) for ten months with effect from January 6, 2004
12. **Dr. Amitava Das**, Scientist E-I visited **USA** under DST-NSF Collaborative Project from November 4 to December 2, 2003.
13. **Dr. P.K. Ghosh**, Director visited **GERMANY** on an invitation by Daimler Chrysler, Germany during 15- 21 November, 2003 to discuss some important aspects of the collaborative project on “*Bio-fuels from Eroded*

Soils in India using Jatropha Plants”(with DaimlerChrysler and Hohenheim University), and to participate in the Third Environment Forum, Magdeburg Conference and make a presentation on “*Renewable Fuels - Biofuel (Jatropha, Choren, etc)*”.

14. **Dr. R.V. Jasra**, Scientist-F visited **KOREA** on an invitation by Korea Institute of Energy Research (KIER), Taejon, Korea under an agreement between CSMCRI and KIER, Korea during December 12-24, 2003, to discuss and review the progress of the project entitled “*Characteristics of hydroxylation catalyst*”.
15. **Shri M.R. Gandhi**, Scientist-F was deputed to **BANGLADESH** (under a consultancy project with M/s. Tata Chemicals Ltd., Mumbai) from 10 to 16 January, 2004 to explore possibility of upgrading solar salt produced in Bangladesh for M/s. Tata Chemicals Ltd.
16. **Dr. J.S. Patolia**, Scientist-F was deputed to **OMAN (Muscat)** for Business Promotion/ Development during 13-16, March, 2004 to explore the feasibility of taking up a consultancy project on cultivation of *Salicornia brachiata* on the farm of Oman Agriculture Development Company, Sohar, Oman

Facilities created/ upgraded

2002-03

Ion Chromatograph
Scanning Electron Microscope (SEM)
Thermal Analyser (TGA, DSC & DMA)
Goniometer

2003-04

CCD-based Single Crystal X-ray Diffractometer.
Inductively Coupled Plasma (ICP) - Perkin Elmer.
X-Ray Fluorescent Spectrometer (XRF) - Brucker AXS, S4 Pioneer.
Anton Paar Vibrating Tube Density meter.
The Ploidy analyser has been equipped with Argon Laser (488 nm) and long life HBO lamp that can facilitate the analysis of ploidy levels in plants, cell cycles and absolute DNA quantity in plant cells.
Diffuse reflectance attachment for Varian make spectrophotometer