

III. AUTONOMOUS BODIES

III-A. COUNCIL OF SCIENTIFIC & INDUSTRIAL RESEARCH

S&T CONTRIBUTIONS

1.1 BIOLOGICAL SCIENCES AND TECHNOLOGY

(Healthcare, Food & Nutrition and Agriculture & Floriculture)

CSIR, as India's apex science agency, over the years, has carved out for itself a niche in scientific and technological research domain, particularly in biology and healthcare areas. Internationally recognized, CSIR laboratories are flag bearers in development of generic as well as patented drugs such as 'Risorine- an anti-TB drug', 'Improved Saheli' - a popular female contraceptive', 'Memory Enhancer' on one hand and among the frontrunners in Genomic research on the other. Contributions in basic understanding of sciences are also noteworthy as is evident from research publications in top journals of the world such as: Nature, Science, Nature Genetics, Nature Chemical Biology, Molecular Cell, American Journal of Respiratory and Critical Care Medicine, Plos Genetics etc.

1.1.1 S&T Contributions

CSIR opens new vista through Ayurgenomics

Ayurgenomics is an integrative approach of Ayurveda and Genomics for discovery of predictive markers for preventive and personalized medicine. IGIB Scientist has reported in Proceedings of National Academy of Sciences, identification of a gene and a genetic marker linked to high altitude adaptation and hypoxia responsiveness, through genetic analysis of extreme constitution types as defined in Ayurveda. EGLN1, a key oxygen sensor

gene was linked to high altitude adaptation and Hypoxia responsiveness using this novel integrative approach of clinical phenotyping methods of Ayurveda, population genetics and disease genomics. Following one of the cues from gene expression differences, wherein a gene could be identified and the genetic marker associated with high altitude adaptation and a high altitude illness. The predictive markers that are identified within this gene by the CSIR group have also been filed for patent. Ayurgenomics study so far has not only provided a novel molecular framework for integration of these two disciplines, but also highlighted that this integrative approach of Ayurgenomics can accelerate/assist discovery of markers for predictive and personalized medicine.

Launch of Risorine, an anti tuberculosis drug

IIIM, in collaboration with M/s Cadila Pharmaceutical Ltd. Ahmedabad has released a new drug formulation called 'Risorine' useful in the treatment of Tuberculosis. The formulation has been approved for marketing by Drug Controller General of India. The drug has been launched recently. It is a new product, developed for the first time in the World. Lead for this novel therapy was obtained from Ayurveda. The Ayurvedic literature describes various medicinal plant derived products to enhance the bioavailability of other drugs - one of them is Trikatu. Concerted research led to identification of Piperine as an active ingredient of Trikatu responsible for enhancement of bioavailability. Innovative R&D and drug development thereafter led to development of "Risorine". Each capsule of Risorine contains: Rifampicin; Isoniazide; and Piperine, where inclusion of Piperine results in

significant improvement in bioavailability of Rifampicin. Increased bioavailability of Rifampicin has led to reduction in dose of Rifampicin from

450 mg to 200 mg. Commercialization of Risorine will reduce cost of Rifampicin - Isoniazide containing formulation by about 20%. (Fig. 8).

An Management of Tuberculosis

Risorine

Rifampicin 200mg + Isoniazid 300mg + Piperine 10mg Capsules

An outcome of Public Private Partnership
between Indian Institute of Integrative Medicine
(Formerly RRL, Jammu), an Institute of
Council of Scientific & Industrial Research (CSIR),
Govt. of India and Cadila Pharmaceuticals Ltd.

Fig. 8

Open Source Drug Discovery

OSDD seeks to develop molecules for the treatment of tuberculosis in open source mode. It has received overwhelming response in terms of active participation from various institutions and scientific groups of India as well as from abroad. Presently there are more than 2000 contributors in the OSDD web portal which also include contributors from Berkeley, Harvard, IISc, AIIMS, IITs etc. The OSDD distributed virtual library has over 50 institutions and more than 2000 researchers as a part of this initiative.

Mapping human genetic diversity in Asia

Asia harbours a wide cultural and linguistic diversity, but the geographic structure of genetic variation across the continent remains enigmatic.

A large-scale survey of autosomal variation from a broad geographic sample of Asian human populations conducted by IGIB shows that genetic ancestry is strongly correlated with linguistic affiliations as well as geography. Most populations show relatedness within ethnic/linguistic groups, despite prevalent gene flow among populations. More than 90% of East Asian (EA) haplotypes could be found in either South-East Asian (SEA) or Central-South Asian populations and show clinal structure with haplotype diversity decreasing from south to north. Furthermore, 50% of EA haplotypes were found in SEA only and 5% were found in CSA only, indicating that SEA was a major geographic source of EA populations. This study with deep implications has been very well received in scientific society and has resulted in well cited publications (Fig. 9).

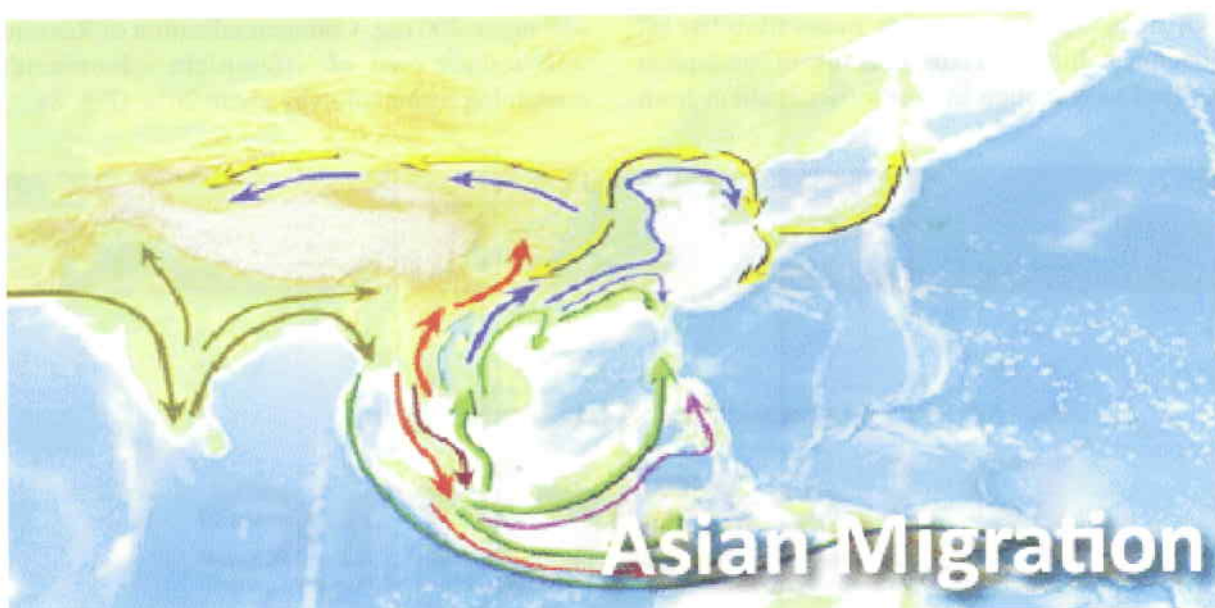


Fig. 9

Agreement with Industry for development and commercialization of fourth generation thrombolytics

Recently on November 24, 2010 IMTECH signed an agreement with Nostrum Inc., USA for the clinical development and commercialization of fourth generation of thrombolytics at a total price of US \$ 150 million and royalty. These current candidates are clot specific in action (which is very beneficial since this minimizes risk of internal bleeding). In addition they have longer circulating half-lives so that lower doses can be given in a single shot bolus (a tremendous benefit of great clinical significance). These have "healing" properties so that the tendency of re-occlusion is minimized (since in about 20-30% cases even after clot buster therapy, clots are re-formed and lives are consequently lost).

Indibacter, a new bacterial genus, in honour of India

Microorganisms from alkaline and saline habitats could be a source of biomolecules, which could catalyze reactions under high salinity and high pH. CCMB scientists have isolated a haloalkaliphilic bacterial species, which led to the identification of a novel bacterial genus from a water sample from Lonar Lake, Buldhana district, Maharashtra. This Gram-negative rod-shaped bacterium (strain LW1T)

based on its morphological, physiological, chemotaxonomic and phylogenetic analysis was identified as a novel genus and was named *Indibacter alkaliphilus* gen. nov. sp. nov. in honour of India. The bacterium is tolerant to high salinity (8% sodium chloride), high alkalinity (pH 12) and could be used as a potential source for enzymes required for hydrolysis of starch under extreme conditions of salinity and pH.

Regulator of Bacterial Cell Division

CCMB has discovered a novel function for HtpG (a bacterial analogue of mammalian Hsp90 protein) that in association with division protein FtsZ regulates bacterial cell division. Using human tumor cells, two major organelle specific effects of Hsp90 inhibition pertaining to mitochondria and cytoskeleton were identified. Hsp90 has been identified as a pharmacological target that could be effective in combating cancer.

Role of Repetitive DNA in cell type specific genome packaging

Genome is packaged in cell type specific manner to establish cell type specific expression pattern of the identical genome that exists in all cell types. The role of repetitive DNA in this process was identified. Not only this resolves long standing

debate on whether or not repetitive DNA has any role or they are parasite on functional part of genome but also explain why highly evolved organisms with complex genomes have remarkably higher proportion of repetitive DNA.

Cell Signaling in Mycobacterium tuberculosis

Serine/Threonine protein kinases (STPKs) mediated signaling in Mycobacterium tuberculosis plays an important role in bacterial survival and pathogenesis. Study conducted at IGIB presents possible mechanism of regulation of mycobacterial virulent lipids by STPKs. The regulation may occur directly through PapA5 or indirectly through Rv0019c.

Construction of metagenomic libraries

IMTECH screened 4 metagenomic libraries and isolated 23 clones for cellulose activity. Three cold active protease (one with alkali tolerance), one highly thermotolerant endocellulase bacteria & one cellulolytic enzymes producing fungi (with sugarcane bagasse degrading capability) were short listed & identified for further development.

In the area of microbial manipulation a salt inducible expression system for E. coli for over production of desired protein has been developed. Similarly an ABC transporter responsible for multi drug resistance in Mycobacteria has been isolated.

Novel anti-ALI (Acute Lung Injury) lead compounds

IGIB synthesized novel anti-inflammatory heterocyclic acid esters of Pyridin-2-yl sulfanyl compounds and characterized it in collaboration with NEIST. These compounds were found to exhibit potent anti-inflammatory activities with respect to inhibition of adhesion of neutrophils, isolated from human peripheral blood, onto the surface of human umbilical vein endothelial cells (HUVEC) as a result of inhibition of the cytokine-stimulated expression of cell adhesion molecule ICAM-1. Most effective compound, RS-Z, significantly alleviated in mice the inflammation mediated by excessive leukocyte

infiltration leading to inflammatory condition or disorders such as acute lung injury (ALI), acute respiratory distress syndrome (ARDS), septic shock, ischemia-hyperfusion etc. This compound, designated as RS-Z, was found to be the most potent anti-inflammatory compound of the series with lowest IC 50 values for ICAM-1 and neutrophil adhesion inhibition. This compound was also found to have maximum tolerable dose in-vitro for HUVEC and caused reduction of the neutrophil influx in the lungs in a mice model of acute lung injury at low doses and also caused attenuation of the LPS-induced lung injury in mice at low dosages.

A novel plant cell wall degrading enzyme

Plant pathogenic bacteria have to overcome the complex plant cell walls to invade and infect plant hosts. To this effect, these bacteria have evolved arsenals of hydrolyzing enzymes that can degrade the host cell walls. The X-ray crystal structure of LipA, as found by CCMB scientists shows that this protein is the prototype of a new family of plant cell wall degrading enzymes that are characterized by a novel mode of substrate binding. The structure reveals a typical catalytic domain found commonly in hydrolyzing enzymes, in conjunction with a unique domain that binds to glycoside ligands through a pocket for anchoring glucose and a hydrophobic tunnel for binding to the acyl/aryl group of the substrate. Blocking the tunnel far away from the enzyme active site is sufficient to disrupt the ability of the pathogen to cause the disease, demonstrating that the tunnel is crucial for enzyme function within the rice host. The phylogenetic analysis and structural homology studies on LipA indicate the evolution of a specialized module on an existing scaffold to recognize carbohydrate-rich plant-specific substrates, showing how plant pathogens might acquire novel features towards becoming efficient pathogens. This new family of plant cell wall degrading enzymes has also been identified in several other plant pathogens of commercial crops like tomato, cabbage, pepper, citrus etc. This work has important implications in the development of biofuels and a new generation of plant protection chemicals that revolve around their ability to inhibit LipA action.

Repeats contribute to packaging the genome and bringing out cell type specific gene expression

Non-coding DNA has consistently increased but the number of genes has remained relatively static during the evolution of complex organisms. It is believed that increased degree of sophisticated regulation of genes has contributed to the increased complexity. Higher proportion of non-coding DNA, including repeats, is likely to provide more complex regulatory potential. CCMB developed a model in which repeats play a regulatory role by contributing to the packaging of the genome during cellular differentiation. Repeats, and in particular the simple sequence repeats, serve as landmarks that can target regulatory mechanisms to a large number of genomic sites with the help of very few factors and regulate the linked loci in a coordinated manner. Repeats, therefore, function as common target sites for regulatory mechanisms involved in the packaging and dynamic compartmentalization of the chromatin into active and inactive regions during cellular differentiation.

Discovery of novel antithrombotic molecule S-007-867

CDRI has identified novel anti-platelet synthetic molecules that prevent platelet collagen interaction. Among them anti-platelet compound S-007-867 offered significant protection against collagen-epinephrine induced thrombosis in mice; ferric chloride induced arterial thrombosis and arterio-venous shunt thrombosis in rats. Moreover, in hyperlipidemic hamster model, significant reversal of collagen mediated platelet hyperactivity (viz. adhesion and aggregation), amelioration of endothelial dependent relaxation in aortic rings, reduction in expression of pro-inflammatory cytokines in the splenocytes, was seen following treatment with S-007-867. It also exhibited specific inhibitory activity towards collagen-induced activation and aggregation of human platelets. The inhibitory mechanism included inhibition of platelet adhesion over collagen coated surface, collagen induced increase in intracellular Ca^{+2} ($[Ca^{+2}]_i$), ATP secretion, thromboxane B2 release, thrombin generation as well as the multitude of intracellular signaling events being orchestrated following platelet

collagen interaction involving tyrosine phosphorylation of numerous non receptor tyrosine kinases. The CDRI compound S-007-867 thus seems to be a potential candidate for the antithrombotic drug development due to its specific inference with collagen mediated platelet adhesion and activation.

Involvement of ancient Leishmania coronin (CRN12) in microtubule remodeling during cytokinesis

In general, coronins play an important role in actin-based processes and are expressed in a variety of eukaryotic cells, including *Leishmania*. CDRI scientists have shown that *Leishmania* coronin preferentially distributes to the distal tip during cytokinesis, and interacts with microtubules through a microtubule-based motor, kinesin K39. Reduction in coronin levels by 40-50% in heterozygous coronin mutants results in generation of bipolar cells (25-30%), specifically in the log phase, owing to unregulated growth of the corset microtubules. Further analysis of bipolar cells revealed that the main cause of generation of bipolar cell morphology is the intrusion of the persistently growing corset microtubules into the other daughter cell corset from the opposite direction. This defect in cytokinesis, however, disappears upon episomal gene complementation. Additionally, attempts to prepare homozygous mutants were unsuccessful, as only the aneuploid cells survive the selection process. These results indicate that coronin regulates microtubule remodeling during *Leishmania* cytokinesis and is essentially required for survival of these parasites in culture. (Fig. 10).

Self-assembly of bacteriophage-associated Hyaluronate lyase (HYLP2) into an Enzymatically Active Fibrillar Film

The *in vitro* assembly of a soluble protein into its mature fibrillar form is usually accompanied by loss of its functional activity. CDRI's study is the first demonstration of a natural enzyme (HyLP2) retaining its enzymatic activity on conversion from pre-fibril to mature fibril and supports the contention that minor conformational changes in the native folded form of a protein can lead to the formation

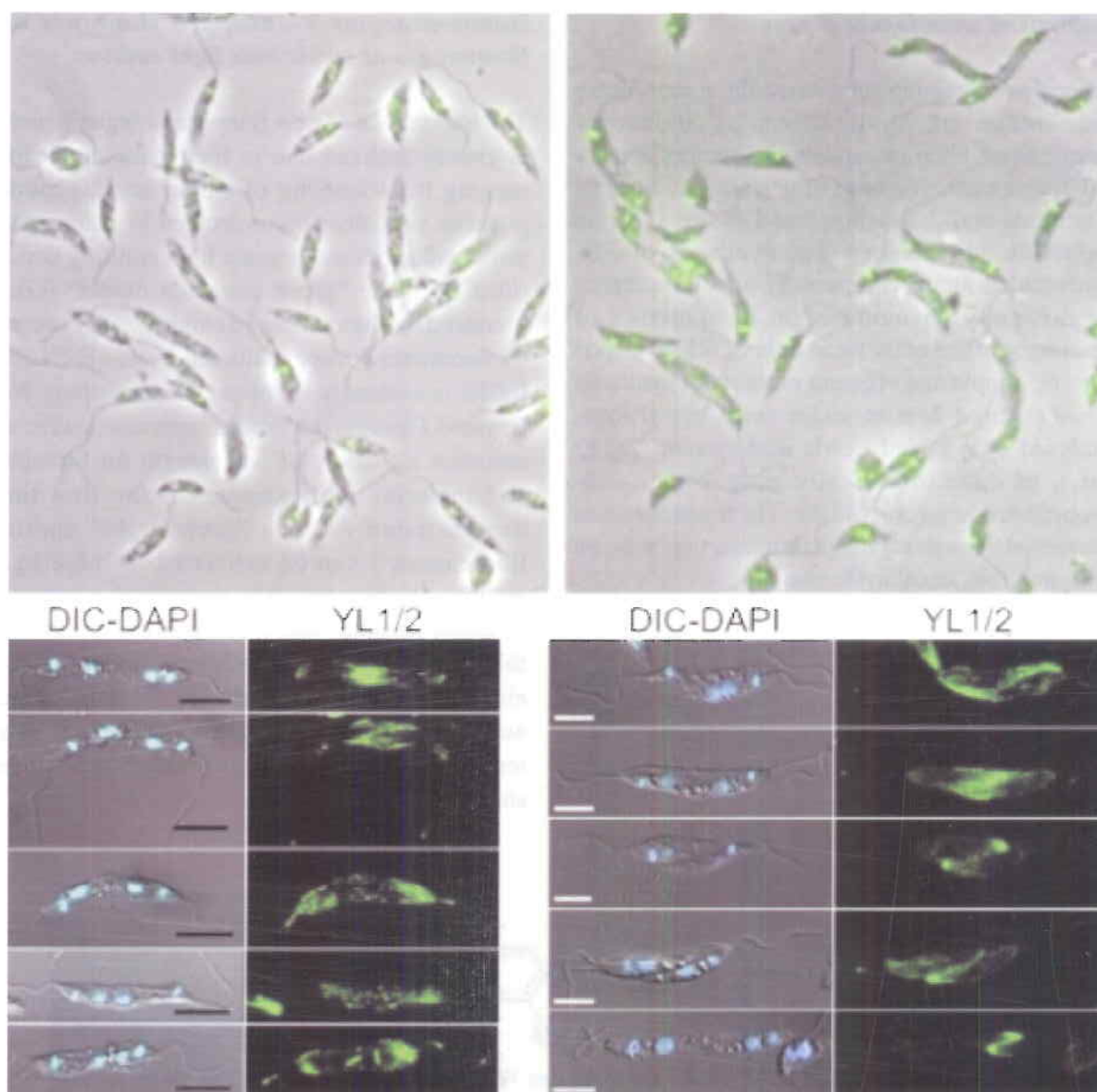


Fig. 10: Formation of bipolar cells in *CRN12*^{+/-} mutants

of a functional fibril. Hyaluronate lyase (HylP2) is a natural enzyme of bacteriophage 10403 of *Streptococcus pyogenes*. At pH 5.0, the enzyme undergoes partial unfolding localized in its N-terminal domain while the C-terminal domain maintains its folded trimeric conformation. This structural variant of HylP2 retains about 70% enzymatic activity with hyaluronan. It further self-assembles into a fibrillar film in vitro through solvent-exposed nonpolar surfaces and intermolecular sheet formation by the strands in the protein. Interestingly, the mature fibrillar film of HylP2 also retains about 60 and

20% enzymatic activity for hyaluronic acid and chondroitin sulfate, respectively. The possession of broad substrate specificity by the fibrillar form of HylP2 indicates that fluctuations in pH, which do not lead to loss of functionality of HylP2, might assist in bacterial pathogenesis. The formation of fibrillar film-like structure has been observed for the first time among the hyaluronidase enzymes. After acquiring this film-like structure in bacteriophage, HylP2 still retains its enzymatic activity, which establishes that these fibrils are a genuinely acquired protein fold/structure.

Synthesis of enantiopure furans

Molecules containing substituted furan motif have wide range of applications as industrial intermediates, pharmaceuticals, insecticides, flavors and fragrances. Among substituted furans, 2-substituted and 2,3-disubstituted furans form an important sub-category. The synthesis of 2,3-disubstituted furans is especially important due to the difficulty encountered in introduction of substitution at C-3 of the furan ring. CDRI developed a newer, simple and efficient process for synthesis of substituted furans under mild conditions, catalysed by a mixed Lewis acid system ($ZrCl_4/ZnI_2$), of enantiomerically pure 2- and 2,3-disubstituted furan derivatives. The transformation is achieved through a synergistic interaction between $ZrCl_4$ and ZnI_2 in catalytic amounts.

This is the first report on the synthesis of enantiomerically pure 2,3-disubstituted furans starting from hex-2-enopyranosides. The present method also demonstrates for the first time the transformation of Morita Baylis-Hillman (MBH) adducts into substituted furans.

Donor-acceptor 9-uncapped fluorenes and fluorenones as stable blue light emitters

The importance of new fluorescent organic probes is greatly realized due to their wide application ranging from labeling of amino acids, peptides, proteins and other biomolecules to nano crystal semiconductors and organic light emitting devices (OLEDs). The "green emission defect" (GED) produced by fluorenones has significantly retarded the commercial scope of fluorene-based B-OLEDs. CDRI is currently involved in developing New Organic Fluorescent Probes with absorption and emission at variety of wavelength for biological and material applications, for the first time, demonstrated that the "green light" emitting fluorenones 7 can be converted to "blue light" emitting fluorenones 10 by appropriate positioning of donor-acceptor and chromophoric groups onto the fluorene/fluorenone backbone. Additionally, an elegant highly rapid synthetic route for donor-acceptor fluorenes and fluorenones at room temperature with excellent yields has also been shown. (Fig. 11).



Fig. 11: Small library of donor-acceptor fluorenes with variable emission characteristics

Release of new Medicinal & Aromatic Plant (MAP) varieties

CIMAP developed and released during the period of report the following high oil yielding varieties of MAPs for commercial cultivation.

Chamomile var. "CIMAP SAMMOHAK": It is a high blue oil yielding variety of Chamomile (*Chamomila recutita* (L.) Rauschert). This improved variety has shown dry flower yield of 7.53q/ha and dark blue oil yield of 6.63kg/ha. The dark blue oil

was found to contain 12.98% of the active ingredient Chemuzuline. This variety is suitable for North Indian plains. (Fig. 12).

Lemongrass var. "CIMAP SUWARNA": It is high oil yielding variety of Lemongrass (*Cymbopogon khasianus*) suitable for growing under conditions of water stress. This variety is highly promising for fast growth, high herbage (50t/ha) and oil yield (200kg/ha) of better quality (citral 80%). The variety is suitable for rain-fed conditions/drought prone areas. (Fig. 13).



Fig. 12: Chamomile 'Sammohak'



Fig. 13: Lemongrass 'Suwarna'

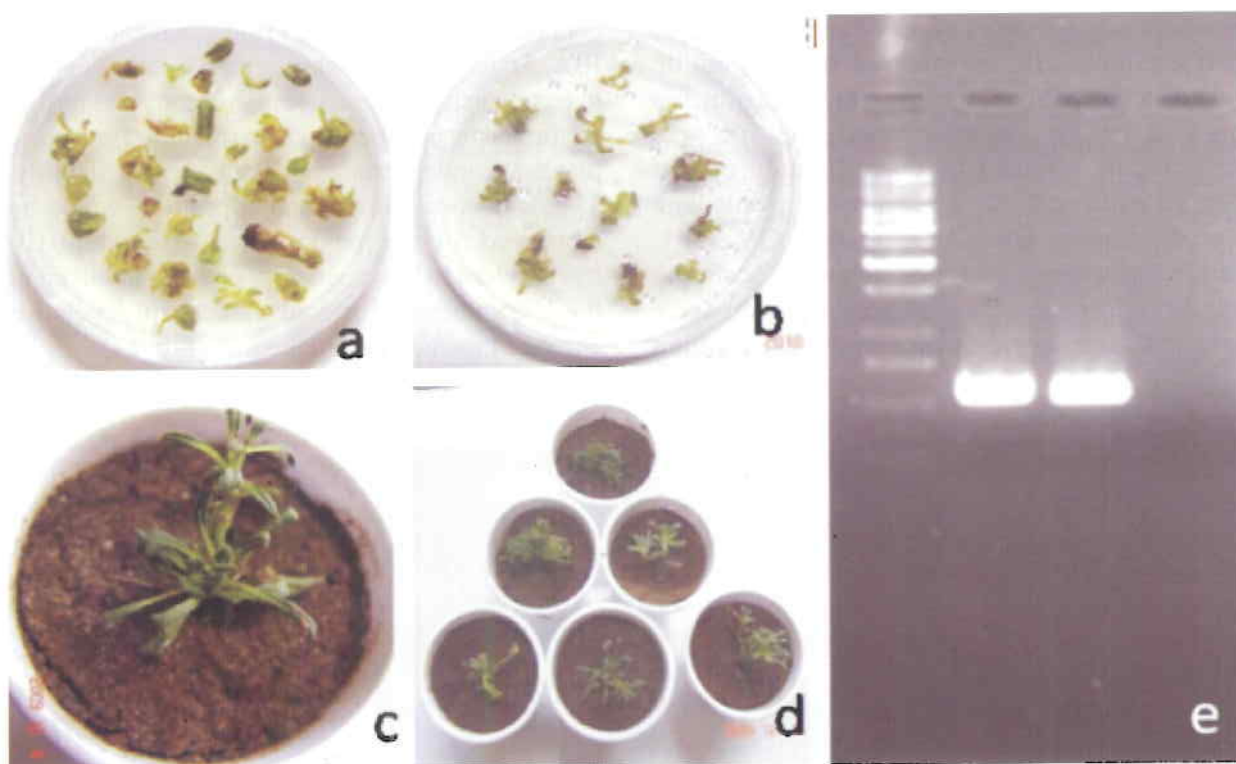


Fig. 15: Selection of transformants on media containing cefotaxime and hygromycin (a) & regeneration of transformants (b); Acclimatization of putative transgenic plants (c & d) confirmed by PCR using *gfp* specific primers (e).

have no adverse impact on vaginal ecology, while Nonoxynol-9 is known to damage vaginal microflora that renders the subject susceptible to opportunistic infections including HIV.

Significant spermicidal as well as virucidal activities with apparently no possible mutagenic effects and adverse effects on vaginal ecology highlight the credential of Acaciaside-B as a prospective candidate molecule for future development of spermicidal microbicide, which is, however, subject to proper evaluation of its safety margins. (Fig. 15).

Process for preparation of Flavanoid compounds (Vitamin P)

IICB developed a process of preparation of flavanoid compound with general formula XI wherein R1 is selected from a group consisting of morpholinyl, N-methyl piperiziny, piperidinyl and N,N -dimethylamino groups, and value of n is 3 to 6. *Anti Helicobacter pylori* activity has been demonstrated successfully and gastric antisecretory

activity of semisynthetically designed flavonoid compounds, The compound can be used for the prevention and treatment of gastroduodenal disorders in general and peptic ulcer diseases in particular. The compound is non toxic. Unlike currently available modern medicines which require triple or quadruple therapy involving 1-2 antibiotics like clarithromycin, amoxicillin, metronidazole, one antisecretory drug like H2 receptor blocker or gastric H⁺ pump inhibitor and one mucus coating agent, the molecule CPP-1 is unique and also gastric antisecretory thus having high therapeutic potential.

Rose scented geranium (*Pelargonium hybrid sp. Cutivar 'burbon'*)- biotechnological interventions

Rose-scented geranium (*Pelargonium Sp.*) is a highly prized, essential oil bearing crop that finds wide acceptance in perfumery, cosmetic aromatherapy, pharmaceutical and food industries. The current international demand for Geranium oil is more than 600 tonnes per annum and the Indian demand is around 200 tonnes as against the meager production of 5 tonnes per annum. Geranium oil



Fig. 16: Various stages of development of rose scented geranium

sells at a premium price of Rs. 4000-4500 per kg in domestic market. India meets its requirement mainly through imports from major geranium oil producing countries. One of the main reasons for its limited production in India is because that its cultivation is mainly restricted to its peninsular parts; although in recent years its cultivation has been extended to parts of Uttar Pradesh and Uttarakhand also. Nevertheless, its growing demand has not been matched by the identification of new potential areas for its cultivation.

IIM developed an efficient single recipe *in-vitro* protocol for the complete plantlet formation within four weeks from induced callus, initially obtained from tissue-specific explants of Rose Scented Geranium. The method developed has enabled regeneration of somaclonal variants/calliclones at a faster pace for their evaluation and molecular

characterization to identify elite types within desired attributes and also to screen somaclones under varied climates to assess acclimation to environmental stresses such as high humidity and temperatures. (Fig. 16).

Gene expression, biodistribution, and pharmacoscintigraphic evaluation of chondroitin sulfate-PEI nanoconstructs mediated tumor gene therapy

Tumor-specific gene delivery constitutes a primary challenge in nonviral mediated gene therapy. IITR scientists fabricated a library of CS-PEI (CP) nanoconstructs by altering the content of CS and evaluated it in terms of size, surface charge, morphology, pDNA loading efficiency, pDNA release assay, pDNA protection study, cytotoxicity, and transfection efficiency. In vitro transfection

efficiency of CP nanoconstructs was examined in HEK293, HEK293T, HepG2, and HeLa cell lines, while their cytotoxicity was investigated in HepG2 and HeLa cells. DNase I protection assay showed that the plasmid was protected from degradation over a period of time. The CP nanoconstructs possess significantly lower toxicity and enhanced transfection efficiency compared to PEI (25 kDa) and commercial transfection reagents (i.e., superfect, fugene, and GenePORTER 2). Further, the CP nanoconstructs were also found to transfect cells in serum-containing medium. *In vivo* studies were carried out with pDNA loaded CP-3 nanoconstruct after intravenous (iv) injection in Ehrlich ascites tumor (EAT)-bearing mice. The outcome revealed higher concentration of CP-3 nanoconstruct in tumor mass. These findings demonstrate that CP nanoconstructs could be exploited as carriers for nanomedicine for efficient management of solid tumor.

DNA damaging potential of zinc oxide nanoparticles in human epidermal cells

At present, more than 20 countries are manufacturing and marketing different varieties of nanotech-based consumer products of which cosmetics form the largest category. Due to the extremely small size of the nanoparticles (NPs) being used, there is concern that they may interact directly with macromolecules such as DNA. IITR assessed the genotoxicity of zinc oxide (ZnO) NPs, one of the widely used ingredients of cosmetics, and other dermatological preparations in human epidermal cell line (A431). A reduction in cell viability as a function of both NP concentration as well as exposure time was observed. ZnO NPs demonstrated a DNA damaging potential as evident from an increased Olive tail moment (OTM) of 2.13 ± 0.12 ($0.8 \mu\text{g/ml}$) compared to control 1.37 ± 0.12 in the Comet assay after an exposure of 6 hours. ZnO NPs were also found to induce oxidative stress in cells indicated by depletion of glutathione (59% and 51%); catalase (64% and 55%) and superoxide dismutase (72% and 75%) at 0.8 and 0.08 $\mu\text{g/ml}$ respectively. This data demonstrates that ZnO NPs, even at low concentrations, possess a genotoxic potential in human epidermal cells which may be mediated through lipid peroxidation and oxidative stress. Hence, caution should be taken in their use in dermatological preparations.

Hazardous effect of tannery solid waste leachates on development and reproduction in *Drosophila melanogaster*

Rapid industrialization has increased the burden of chemicals in the environment. These chemicals may be harmful to development and reproduction of organisms. IITR analyzed the adverse effects of leachates from a tannery solid waste on development and reproduction using *Drosophila*. A significant delay was observed in mean emergence of flies at the higher concentrations of the leachates, indicating their effect on the organism's development. Significant leachate-induced effect on reproduction of *Drosophila* was also observed. Sub-organismal analyses revealed Hsp70 expression and tissue damage in a sex-specific manner. Refractoriness of Hsp70 expression in accessory glands of male flies and ovaries of females was concurrent with tissue damage. Genes encoding certain seminal proteins (Acp70A and Acp36DE) from accessory glands were significantly down-regulated at higher concentrations of the leachates. The study suggests that (i) sub-organismal adverse responses are reflected at organismal level, (ii) tannery waste leachates cause adverse effects on the expression of genes encoding seminal proteins that facilitate normal reproduction and (iii) Hsp70 may be used as a marker of cellular damage for reproductive organs.

Probing novel allergenic proteins of commonly consumed Indian legumes

Leguminous crops are the main source of protein in Asian subcontinent including India, however their proteins may induce allergic reactions in sensitized individuals. Pepsin resistance of proteins is a characteristic feature of most of the allergens. IITR proved the presence of non-digestible proteins in some of the commonly consumed Indian legumes. Crude proteins extracts (CPE) of soybean, peanut, chickpea, black gram, kidney bean and Bengal gram were digested *in vitro* to detect their non-digestible proteins. Six proteins from soybean and seven from peanut remained undigested after Simulated Gastric Fluid (SGF) digestion. Likewise, seven proteins from chickpea, ten from black gram, five from kidney bean, and one from Bengal gram remained

undigested in. Most of the proteins stable in SGF for more than 2 min showed similarity with characterized allergens on the basis of their molecular weights as in case of soybean, peanut, chickpea and black gram. Also, soybean and chickpea stable proteins showed IgE binding property with respective allergic patient's sera. The non-digestible proteins from the chickpea, black gram, kidney bean and Bengal gram were reported for the first time.

Genetic engineering tool for generating male sterile lines

NBRI developed a genetic engineering tool for male sterility induction in plants. Novel use of the BECLIN 1 gene of *Arabidopsis* was identified in inducing male sterility in plants, when expressed in the anther-tapetum of tobacco. A stringently regulated and high-level tapetum specific expression system by using a two-component transcription regulation system was developed. The tapetum specific, two-component transcription system utilizes the TGTA-TBPM3 complementation principle. Complete male sterility was achieved by expressing BECLIN 1 gene with the two component system. The two-component system was further modified for glucocorticoid-dependent expression of a candidate gene (in this case AtBECLIN 1) in tapetum, thereby developing glucocorticoid inducible male sterility in plants. In future, this technology may prove useful in hybrid-breeding programmes. (Fig. 17).

Arsenic hypertolerant bacterial strains as bioinoculant for concurrent growth promotion in *Oryza sativa*

NBRI conducted Greenhouse assays to evaluate the effect of arsenic resistant bacterial isolates on plant growth of *O. sativa*. Sterilized seeds were sown in plastic pots filled with sterilized arsenic contaminated soil (level of As in soil 15µg/kg). After one week of seedling growth bacterial suspensions (50 ml pot⁻¹) were sprayed on the soil surface. Control plants received 50 ml of sterile distilled water. Inoculated and uninoculated plants were reared in pots under greenhouse conditions [temperatures of 18°C (night) and 24°C (day), 80% relative humidity]. Growth parameters like plant height, root length, wet and dry weight were recorded after 60 days of sowing. Leaves for protein, chlorophyll, carotenoid and sugar assays were stored frozen at -20°C until analyses were performed.

Bacterial strains which showed significant effects on the growth of *O. sativa*, were NBRIEAG-6 (60.67% shoot length; 38.67% root length), NBRIEAG-7 (60.33% shoot length; 44% root length) and NBRIEAG-8 (68% shoot length; 34.67% root length), NBRIEAG-9 (65% shoot length; 41% root length). All seven bacterial strains have potential to be used as Plant growth-promoting rhizobacteria. (Fig. 18).



Fig. 17: Pollen of male sterile plant



Fig. 18: PGPR effect of NBRIEAG-9 on *Oryza sativa*

Petal abscission in rose

NBRI identified the RbFBL (gene encoding an F-box like protein) as a gene that was expressed early and transiently during ethylene induced abscission. Expression of RbFBL under the CaMV35S promoter

in transgenic *Arabidopsis* resulted in plants that flowered earlier by about 8 days. These plants also displayed aerial rosettes. Interestingly expression of the gene as a GUS fusion could only be seen in the abscission zones and carpels even under the 35S promoter. (Fig. 19).



Fig. 19: Early flowering in transgenic *Arabidopsis* plants expressing the RbFBL gene and aerial rosettes

Surfactant-collagen interactions

CLRI studied the effect of surfactants on the physico-chemical properties of collagen. The secondary structure of collagen shows changes only in the molar ellipticity on interaction with surfactants. The role of charge and concentration of surfactants in influencing the various physico-chemical properties of collagen has been elucidated. The sequence-structure and stability of collagen like peptide has been elucidated. The importance of D-amino acids residues in the stabilization of collagen like peptides has been assessed.

Single-stage Biological Nitrogen Removal (SBNR) process for treatment of ammonia rich wastewaters

NEERI developed a SBNR process using a laboratory scale fixed film bioreactor for anaerobic oxidation of ammonia to nitrogen. The process is based on a novel combination of partial nitrification and anammox process in a single stage. The oxidation of ammonia to nitrogen is achieved through a 'two-way' process control of alkalinity and dissolved oxygen (DO). The control of alkalinity and DO concentrations in feed is necessary for inhibiting nitrification and for enhancing partial nitrification and anammox as can be seen from the contour plots presented in Fig.1.29. The fixed film bioreactor provides an ecological advantage for natural development of various microbial niches in a biofilm system and achieves stable autotrophic nitrification. The metagenome of the biofilm reveals presence of many hitherto unreported autotrophic microorganisms. The process is completely autotrophic and oxidizes ammonia with an efficiency of >85% at optimized conditions. The SBNR process is useful for treatment of ammonia rich wastewaters having very low C:N ratio.

Fusarium wilt resistance in chickpea

A complex interaction between plant and its fungal pathogen is an outcome of expression of both, plant defense genes as well as fungal pathogenesis related genes. Multiple events are involved in bringing about successful plant defense during pathogen attack. Wilt is one of the most important diseases of

chickpea caused by *Fusarium oxysporum*. NCL studied semi quantitative RT-PCR analysis of defense related genes using gene targeted primers in wilt-resistant and wilt-susceptible chickpea varieties upon exposure to Foc races at various time points. In addition, expression analysis of fungal pathogenesis related genes and their race specific response was also determined throughout the course of chickpea- Foc interaction. Some of the genes, which were previously not reported to be involved in chickpea defense against *Fusarium* wilt, have been unveiled in this study. An F9 RIL population of chickpea (JG 62 x Vijay) was evaluated for resistance to three Foc races (1,2and3) in pot culture. Flanking and tightly linked DNA markers were identified on LG2 of the chickpea map for resistance genes corresponding to these three races. These markers were also validated using 16 diverse chickpea genotypes. Thirteen of these genotypes were resistant to all the three Foc races and also carried the corresponding resistance genes.

Association of the stramenopilan protists, the aplanochytrids, with zooplankton of the equatorial Indian Ocean

Thraustochytrids and aplanochytrids, belonging to the *Labyrinthulomycetes* of the Kingdom Stramenopila, have been frequently reported to occur as parasites or symbionts in a number of coastal invertebrates. Since that these protists are widespread in coastal and oceanic waters, it is possible that they are also associated with pelagic zooplankton. NIO scientists examined their occurrence in zooplankton from equatorial waters of the Indian Ocean. A total of 171 of 2100 individual specimens of zooplankton yielded *Labyrinthulomycetes* in culture, the colony morphology and/or life cycles of which corresponded to aplanochytrids. Small-subunit ribosomal DNA (SSU rDNA) sequence analysis of 8 of the isolates placed them in a distinct clade among aplanochytrids, but closest to *Aplanochytrium yorkensis* or *A. kerguelensis*. Eight isolates were further segregated into 2 clusters, corresponding to isolates obtained from 2 different seasons. Biotinylated probes for 2 isolates of *A. kerguelensis* from the 2 different seasons were developed based on internal transcribed spacer (ITS)

sequences. In situ hybridization (ISH) of zooplankton using the probes with streptavidin-alkaline phosphatase showed that aplanochytrid cells fed to copepods were grazed and could subsequently be detected in the animals. ISH on natural samples of zooplankton yielded a positive but diffuse reaction in copepods, while cells resembling aplanochytrids were detected within chaetognaths. ISH using streptavidin-peroxidase conjugate lent further support for their presence within chaetognaths. This study suggests the predominant occurrence of *A. kerguelensis* in association with mesozooplankton of the equatorial Indian Ocean, particularly with chaetognaths.

1.1.2 Significant Technology Transfers

New generation clot specific protein

IMTECH designed and developed a new generation clot specific protein that displays plasminogen activation property. The technology for this new drug molecule has been transferred to M/s Nostrum Pharmaceuticals, USA.

Caerulomycin A

IMTECH developed a technology for Caerulomycin A, its proprietary derivatives and analogues ("Caerulomycin") for their novel indication of

immuno-suppression - a discovery of immense importance in tissue transplantation like in kidney and heart. The technology has been licensed to M/s Nostrum Pharmaceuticals, USA.

Recombinant streptokinase

The technology, developed by IMTECH, for the production of recombinant streptokinase produced from *E. coli* gives yield higher than that of conventional system. This technology would bring down the prices of clot busters significantly. M/s Shasun Drugs & Chemicals through M/s Lupin Pharmaceuticals and M/s Alembic Chemicals launched the product recently.

MTB diagnostic kit

CDRI developed PCR based MTB diagnostic kit and transferred to M/s Biotron Healthcare Ltd., Mumbai. The product has been commercialized under the trade name MycoView.

Launch of 'Memory Sure'

CDRI has developed Bacosides Enriched Standardised Extract of *Bacopa* - a single plant based unique natural memory enhancer formulation and patented its technology. The product under the brand name - Memory Sure is being marketed by M/s Lumen Marketing Co. and M/s Zaar Distributors Pvt. Ltd. (Fig. 20).



Fig. 20: Photograph of the memory enhancer 'Memory Sure' available in the market

Plant 1020F147- a nutraceutical and dietary supplement for optimum bone health

Plant 1020F147, a standardised fraction isolated from plant source, has been found to promote peak bone mass achievement and prevent bone loss in ovariectomized rats. The fraction has not exhibited estrogen like effect in the uterus, which is an added advantage. The product is a nutraceutical and dietary supplement for optimum bone health, which would help alleviate the severity of osteoporosis later in life. CDRI licensed the know-how for the plant 1020F147 to M/s Natural Remedies Private Ltd., Bangalore for commercial production.

Improved process for centchroman (a non-steroidal oral contraceptive)

Centchroman is the world's first nonsteroidal oral contraceptive. It is a weak estrogen and a potent antiestrogen with a high therapeutic index. It is marketed by M/s Hindustan Latex Ltd under the trade name, 'Saheli'.

An improved, economical, safe, environmental friendly process for production of DI-Centchroman was developed by CDRI. The drawbacks of earlier processes namely (i) use of stannic chloride an imported corrosive agent (ii) requirement of noble metal catalyst and high pressure reactor which adds

to capital investment and limits the batch size and need for isomerization step to trans chroman have been eliminated. The other advantages of the improved process include lesser number and convergent, instead of linear steps compared to that of earlier process. CDRI licensed the improved patented process of synthesis of ormeloxifene (Centchroman) to M/s Hindustan Lever Life Care Ltd., Thiruvananthapuram.

DIASTEPI: Off the shelf footwear for low risk diabetics

CLRI designed special footwear suitable for low-risk diabetic patients. A specially derived angle of slant has been provided in the sole to give the 'rocker' effect which is essentially used to offload pressure from the plantar surface of the feet. This would ensure that the patient does not experience areas of stress concentration in his underfoot and therefore he would not progress to the next stage of risk. The upper has been designed to take special care of fluctuations in foot volume and is provided with adjustable fasteners. The back is rigid with a counter stiffener for limiting joint mobility. The vital role of the footwear is very well described through the biomechanics of diabetic foot. The technology has been transferred to M/s MV Health Care and product has been named as 'Diastep'. (Fig. 21).



Fig. 21: Typical Diastep

plastics and enhanced gravity separation in multi-gravity separator. The dry purification circuit consists of electrodynamic and electrostatic separation. Substantial enrichment of the ground powder with good recovery of metals was achieved using the flowsheet. The starting PCB powder, ground to -0.5 mm size, had about 23% metal. Complete liberation of metals from plastics was achieved below 100 μm size. Metal values were found to be more abundant in the coarser sizes. A concentrate grade of over 93% total metal at a recovery of over 54% or a grade of 66% total metal at 95% recovery were achieved using this flowsheet as compared to the conventional gravity separation system.

Community size reactor for production of methane rich biogas from waste vegetable

Based on laboratory studies for production of methane rich biogas from rotten vegetables, IMMT developed a community size, 5 m³ capacity biogas reactor. The feed material to the reactor is prepared from decomposed vegetables such as pumpkin, brinjal, potato etc. that are collected from vegetable markets and converted into pulp by a mincing machine (patented design of IMMT), which is then mixed with spent liquid sludge. No water is used in the feed material. The whole lot of the decomposed vegetables is converted into biogas and liquid sludge without any solid residue. 65-75% Methane and 4-5% hydrogen are obtained in the biogas. The

community biogas plant comprises of a concrete chamber and a mild steel gas holder. Methane rich biogas can be utilized for cooking and lighting application as well as for power generation. This is a green technology for conversion of decomposed vegetables into high quality biogas. The community biogas plant has been installed in a vegetable market for field trial and demonstration.

Template assisted highly ordered novel self assembly of micro-reservoirs and its replication

Micro-patterned polymers are being increasingly used in micro-nano-devices, bio-mimetics, tissue engineering scaffolds and biosensors. NCL developed a novel process for the creation of unique highly ordered mixed micro-cavity arrays. Simple micropatterns on PDMS mold are used to create complex geometries via solvent vapor back pressure in a biodegradable polymer. Interestingly with this technique it is also possible to achieve control over the fabrication of isolated or interconnected cavities beneath the original patterns. Cavities are, in turn, replicated in complimentary PDMS mushroom like microstructures to generate multiple copies of the said patterns. It can be useful for fabrication of tissue engineering scaffolds for directed growth, microdevices for drug delivery, microreactors, MEMS devices, micro-lens molding and many other applications. (Fig. 25).

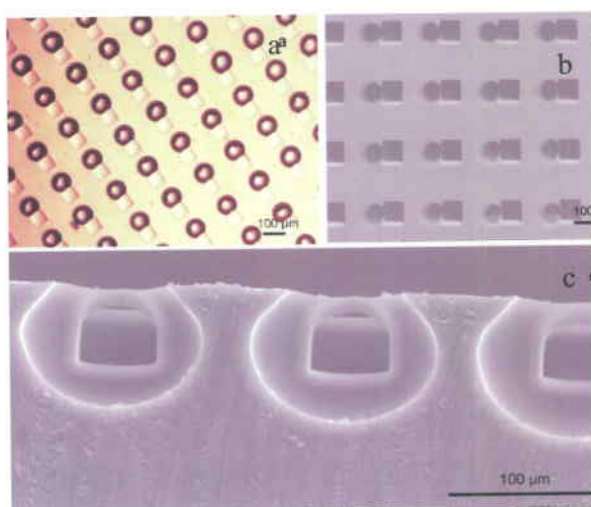


Fig. 25: (a) Optical (b) SEM images of self assembled micro-cavities in micropatterned polymer [poly(TMPTA-CO-TMDP)]. (c) cross section image.

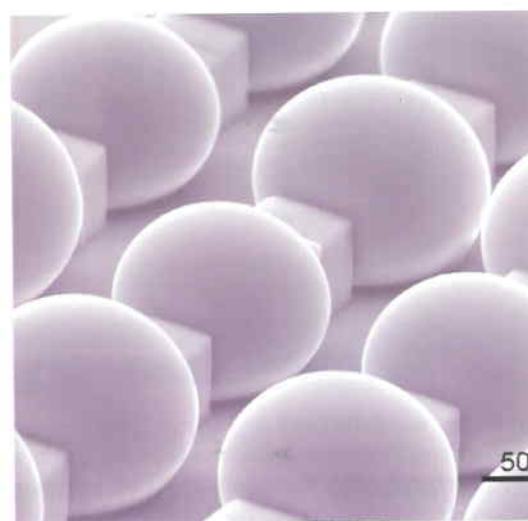


Fig. 25 (d): SEM image of complimentary micro-mushroom PDMS patterns

1.2.2 Significant Technology Transfers

L (+) Lactic Acid from Sugar Cane Juice

Under a NMITLI program for the development of the process for polymer grade lactic acid and polylactic acid, a generic continuous process for the synthesis of lactic acid has been developed at NCL. Based on the Basic Engineering Package prepared by NCL, a 300 tpa continuous demonstration plant for L (+) Lactic acid (LA) has been set up at Godavari Biorefineries Ltd., Sameerwadi, Karnataka.

Sulphate of potash (SOP) plant

CSMCRI patented and transferred technology for production of sulphate of potash from sulphate rich bittern to M/s Archean Group of Companies, Chennai. 60,000 acre of land has been allotted to the company in the Greater Rann of Kutch to establish a 100,000 TPA sulphate of potash (SOP) plant, integrated with MgO production.

High grade industrial salt

During the year 16,000 tons of high grade industrial salt [Ca, 0.03-0.05%; Mg, 0.04-0.07%; SO₄ -2 0.16-0.25%; Fe, 25-50 ppm] was manufactured based on CSMCRI's patented know how and marketed to leading chlor-alkali and soda ash industries in Gujarat.

Innovative technology for upgrading fuel oil components into premium refinery products

IIP developed an innovative technology, based on concept of combining two apparently distinct and unrelated disciplines viz. 'solvent extraction' and 'catalytic cracking'. This novel approach provides a unique solution for producing additional quantity of de-aromatized feed (raffinate) for secondary conversion unit i.e. Fluid Catalytic Cracking (FCC), which otherwise would have been wasted by being blended into fuel oil pool. In the process, clarified oil is subjected to 'solvent extraction' for selective removal of undesirable polynuclear

aromatics from feed. The de-aromatized clarified oil is circulated to FCC unit along with fresh feed to produce better quality products, while the extract is taken out as standalone marketable refinery product (premium CBFS) used for carbon black manufacture. The technology is being used commercially by M/s Hindustan Petroleum Corporation Ltd., and has the potential of being replicated gainfully in refineries globally. It has won the CSIR Technology Award for the year 2009.

Technology for the treatment of Bio refractory wastewater without sludge and odor emission

CLRI developed a technology known as Fenton Activated Carbon catalytic oxidation, (FACCO), for the treatment of wastewater containing refractory organics through halophiles immobilized mesoporous activated carbon. The immobilized halophiles help to fragment the organics in wastewater. The fragmented organics are oxidised by the hydroxyl radicals generated from two sources namely oxidation of hydroxyl ion and secondly from reaction between ferrous ion and hydrogen peroxide. The combination of sorption with destruction of the sorbates in wastewater by catalytic and other chemical processes may offer several advantages. Generally adsorption of contaminants in wastewater to the catalyst surface leads to an increase in their residence time within a fixed-bed reactor. Moreover, the pre-concentration of contaminants in the vicinity of reactive centres might greatly enhance rates and efficiencies of degradation reactions.

The technology has been implemented in leather industry, Tamil Nadu for the treatment of saline wastewater of volume 30 m³/day and in chemical industry clusters, Vapi, Gujarat for a volume of 72 m³/day.

Process for 1,1,1,2-Tetrafluoroethane (HFC-134a)

IICT developed and patented a process for 1,1,1,2-Tetrafluoroethane (HFC-134a): a high temperature refrigerant for domestic refrigeration and

that the meal provides all the nutrition needed for children. Appropriate hygiene has been guaranteed in the choice of material (mostly SS304), which come in contact with the food. The machines are designed in such a way that no sharp corners, fissures or cracks exist, where food particles may adhere after washing. The machine consists of a number of modules, namely a sigma mixer for making semi-solid, highly viscous (having

15% moisture), uniformly mixed dough of corn flour, honey, essential oil etc. The dough is then fed to an extruder to make bars of cake at the output. An automatic cut-to-length mechanism gives bars of rectangular shape and uniform size. The bars are then packed using a horizontal flow wrap machine with automatic packing and printing of manufacturing date. The bar has a shelf life of 3 months. (Fig. 28).



Fig. 28: Cereal cake making machine assembly

Adoption of 'Harsha' multi-fuel cooking stove in mid-day meal programme of schools for green house gas reduction and conservation of biomass

IMMT disseminated 'HARSHA', a multi-fuel cook stove in Mid-Day-Meal Programme in certain schools of Odisha. Fifty such community size stoves have been installed in primary, upper primary and middle schools in eight districts of Odisha to study its performance in a pilot scale. Live demonstrations of the cook stove were carried out in presence of teachers, students and staff of the beneficiary schools. Preliminary results show nearly 40-50% reduction in fuel consumption over conventional open *Chullhas*. Substantial reduction in smoke and pollution has also been recorded during preparation of Mid-day-Meal in these schools. Based on final performance, report and feed back, use of 'HARSHA' multi-fuel cook stove is being recommended for adoption in mid-day-meal programme of schools throughout the country.

Grey water treatment and reuse

NEERI developed a simple method for treatment of grey water and to reuse systems at institutional and household levels. The grey water reuse systems collect, treat and reuse bathroom water (shower/non toilet/black water) for flushing of toilets. The drive for this technology was a result of decreasing availability of water and lowering of groundwater table. Grey water treatment plants constructed in the institutions particularly in residential schools (Ashrams) mainly consist of sedimentation or settling unit and filters. Process of sedimentation allows removal of suspended solids by gravity and natural aggregation of the particles without use of coagulants. The major processes in filtration are sedimentation in the pore spaces, adhesion to the media particles, and bio-chemical degradation of captured particles in slow-sand filter. The concept of grey water reuse from the institutions has been extended to the households to treat and recycle grey

water. This system also consists of sedimentation and filtration and possible reuse of treated grey water includes toilet flushing and irrigation.

Stevioside from Stevia rebaudiana

An economically viable, green technology for the production of stevioside from *Stevia rebaudiana* has been developed by ihbt which is currently grown in 1010 hectares and an annual production of 50500 quintals. The new process technology has helped in increase in production and quality. The current revenue is ` 66 crore per year and involves around 8 lakh mandays per year.

Muga Heal

Bio-formulation "Muga Heal" developed by NEIST was released to farmers of Assam. This can be used against Flatcherie disease of Muga silkworm and also enhance the silk fibre.

BLI-ARUN - a new strain of Lemon grass

NEIST developed BLI-ARUN - a new strain of Lemon grass. The package and practice for cultivation and distillation of oil had been released to four parties in Itanagar, Arunachal Pradesh.

Satawar (Asparagus racemosus)

A high yielding variety of Satawar (*Asparagus racemosus*) with high root yield and high saponin content named CIM-Shakti has been developed by CSIR. This finds its applications in herbal drugs and would help farmers to increase their earnings.

Studies on Seaweeds diversity

For the first time ever in India, the diversity and distribution of Seaweeds of India containing 198 species of marine macroalgae representing all three major groups of Chlorophyta, Phacophyta and Rhodophyta collected from Gujarat coast has been carried by CSIR. The findings have been brought out in a publication form by Springer which provide most reliable baseline data on seaweed biodiversity for monitoring and evaluating the impact of any

coastal developmental activities aimed at long term economic gains or environmental changes as a result of global warming and climate change.

1.3.2 Significant Technology Transfers

Steviol glycosides from Stevia rebaudiana

Steviol glycosides from *Stevia rebaudiana* is being used as a natural calorie-free sweetener, and as an alternative to artificial sweeteners such as saccharine, aspartame and cyclamate. IHBT developed an economically viable green technology for the production of steviol glycosides from *Stevia rebaudiana* that uses no hazardous organic chemical solvents. The technology is being upscaled from pilot plant to commercial scale having 1000kg/batch capacity. The quality of steviol glycosides produced on pilot scale is well within the prescribed limits.

The technology has been transferred to four industries namely (a) M/s. Malnad Biotechnology Pvt. Ltd., Bangalore, (b) M/s. Contractor Agro Processors, Ahmedabad, and (c) M/s. Vadamalai Consultancy Services, Bangalore and (d) M/s Jallan Trini-Tea Processing (P) Ltd., Gurgaon for commercial exploitation.

Setting up processing plant for fresh Ginger in Sikkim

NIIST initiated setting up two commercial ventures in the states of Sikkim and Mizoram for processing of fresh ginger. The unit produces fresh flavour Ginger oil, cleaned waxed ginger and ginger powder. The erection of the plant for processing 5 tons of fresh ginger per day has been completed.

The ginger produced in the state is 'Organic', and the value added products are expected to fetch premium price. The institute extended its process and engineering skills for setting up the facility and it is the first commercial venture set up for processing ginger in the state of Sikkim. The unit has a state-of-the-art washing and cleaning system distillation facility and a fluid bed drier for making ginger powder.

Semi-continuous type biodiesel plant suitable for rural sector

CMERI designed fabricated, installed and tested two numbers of semi-continuous type biodiesel plants. The plant design is based on process timing and simulation so that all the components can work for the designated time and ultimately produce 00 litre of biodiesel per day (24 hours working basis). The maximum power onsumption of the plant is 3 kW at peak time. Both the plants have been

successfully tested with Jatropha (non-edible oil with FFA content of 3.9) and soybean (edible oil having free fatty acid content of 0.8). The fuel properties of jatropha and soybean biodiesel produced from the plants have been tested and the results obtained are within the limit of American Society for Testing Materials, United States of America, standards. The technology has been transferred to M/s Fabcon Engineers, M/s Best Engg. Technologies, M/s York Steel Fabricators, and M/s Hindustan Bio-Diesel Pvt. Ltd. (Fig. 29).



Fig.29: A view of the Bio-diesel plant

1.4 EARTH SYSTEM SCIENCES

CSIR, mainly through its two constituent laboratories namely NGRI and NIO, is pioneer in scientific studies of ocean, earth mantle and lithosphere leading to development of many significant databases, processes, products etc.

1.4.1 S&T Contributions

Imaging fossil collision structures beneath the Eastern Ghats belt, India

The Proterozoic Eastern Ghats belt of India is often believed to be the ancient analogue of the present-day Himalayas. However, the geological and geophysical signatures that can be traced and linked to the Eastern Ghats belt origin due to a Precambrian collisional episode are sparse and evidence of such a geotectonic process in the deep lithosphere remains elusive. NGRI imaged depth signatures of this convergence event and its lateral extent using the P and S receiver function imaging technique. P and S receiver functions that predominantly sample the Eastern Dharwar

craton-Eastern Ghats belt reveal the presence of two distinct westerly dipping interfaces at depths centered on 150 km and 200 km in the study region. Drawing analogy from similar tectonic settings of Proterozoic age and younger Paleozoic times around the globe, these boundaries are inferred to represent remnant structures fashioned by the collisional processes that affected this region. Recent geological, geochemical, and geochronological evidences from the region strongly

favor a model which support these delineated dipping structures as possible vestiges of a Proterozoic collision event that are preserved due to their coherent translation with the overlying lithosphere. Due to this long-lasting record of Proterozoic tectonics, NGRI results add a complication to simple models of the Indian subcontinent in which relatively the thin lithosphere underwent rapid transit during the Cretaceous. (Fig. 30).

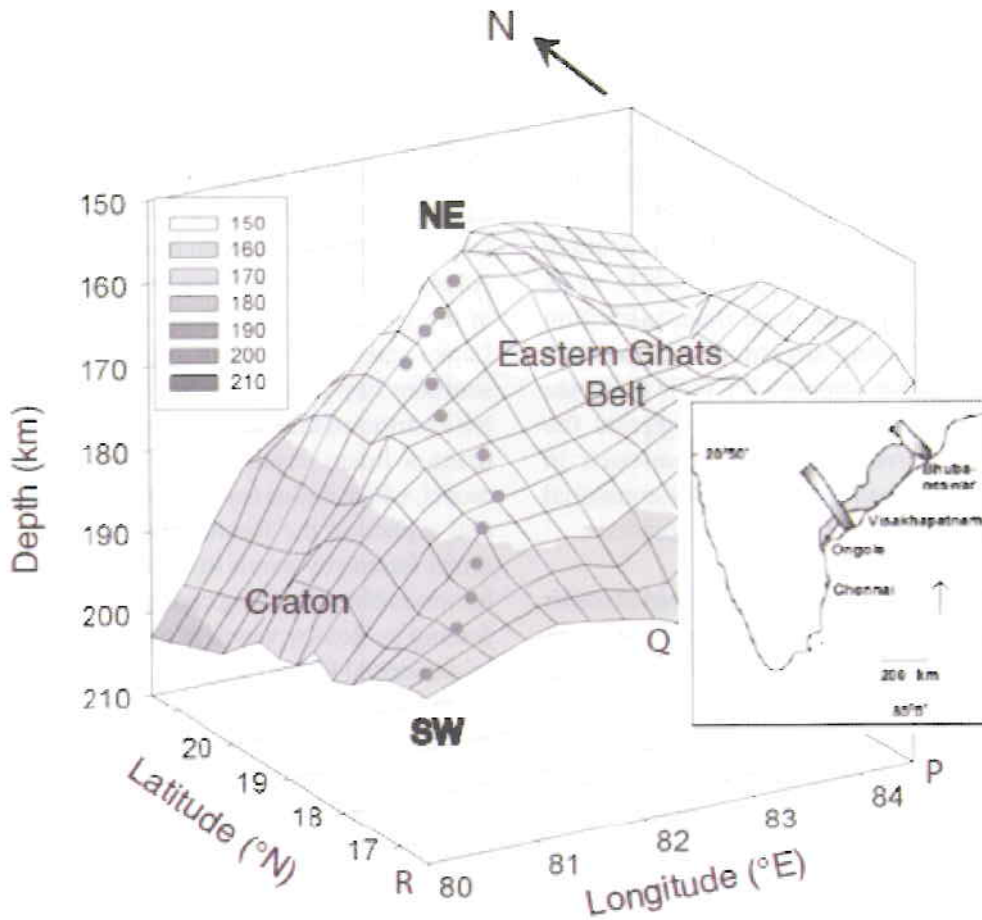


Fig. 30: Three-dimensional perspective view of westerly dipping surface preserved at depth (160-200 km) constructed on the basis of *Sp*-receiver-function delay times. The study region is divided into grids of 1° 1° dimension. Grids sampled by more than 10 *Sp* data are considered. Shaded area in the Inset map shows location of the EGGT.

Association of the stramenopilan protists, the aplanochytrids, with zooplankton of the equatorial Indian Ocean

Thraustochytrids and *aplanochytrids*, belonging to the *Labyrinthulomycetes* of the Kingdom Stramenopila, have been frequently reported to

occur as parasites or symbionts in a number of coastal invertebrates. Since that these protists are widespread in coastal and oceanic waters, it is possible that they are also associated with pelagic zooplankton. NIO scientists examined their occurrence in zooplankton from equatorial waters of the Indian Ocean. A total of 171 of 2100

individual specimens of zooplankton yielded *Labyrinthulomycetes* in culture, the colony morphology and/or life cycles of which corresponded to aplanochytrids. Small-subunit ribosomal DNA (SSU rDNA) sequence analysis of 8 of the isolates placed them in a distinct clade among aplanochytrids, but closest to *Aplanochytrium yorkensis* or *A. kerguelensis*. Eight isolates were further segregated into 2 clusters, corresponding to isolates obtained from 2 different seasons. Biotinylated probes for 2 isolates of *A. kerguelensis* from the 2 different seasons were developed based on internal transcribed spacer (ITS) sequences. *In situ* hybridization (ISH) of zooplankton using the probes with streptavidin-alkaline phosphatase showed that aplanochytrid cells fed to copepods were grazed and could subsequently be detected in the animals. ISH on natural samples of zooplankton yielded a positive but diffuse reaction in copepods, while cells resembling aplanochytrids were detected within chaetognaths. ISH using streptavidin-peroxidase conjugate lent further support for their presence within chaetognaths. This study suggests the predominant occurrence of *A. kerguelensis* in association with mesozooplankton of the equatorial Indian Ocean, particularly with chaetognaths.

Detection of DNA damage in fish *Oreochromis mossambicus* induced by co-exposure to phenanthrene and nitrite

Mutagenic nitrated polycyclic aromatic hydrocarbons (nitro-PAHs) arise in the environment through direct emissions from combustion sources and nitration of PAHs, primarily in the atmosphere. In the marine environment, PAHs are one of the classic anthropogenic organic pollutants, while nitrite (NO_2^-) is produced naturally via various biological processes like imbalance in nitrification/denitrification or eutrophication and subsequent oxygen depletion from an oversupply of nutrients. NIO reported the formation of PAH-DNA adducts in fish contaminated with PAHs and exposed to NO_2^- in the ambient water. Electrospray ionization tandem mass spectrometric (ESI-MS/MS) analysis of the bile of the euryhaline fish *Oreochromis mossambicus* exposed simultaneously to field relevant sublethal concentrations of phenanthrene

and NO_2^- and collision-induced dissociation of selected ions revealed the presence of DNA-PAH adducts. Results indicated that, although several high sensitivity techniques have been developed for the analysis of PAH derived DNA adducts, MS/MS has emerged as a powerful tool in the detection and structure elucidation of DNA adducts.

Minima of interannual sea-level variability in the Indian Ocean

Wavelet analysis of altimeter sea level in the Indian Ocean shows regions of high variability (maxima) and low variability (minima) at all time scales. At interannual time scales, i.e., at periods of 17 months or more, minima are seen at several places: in the central equatorial Indian Ocean; in the Arabian Sea along the south and west coasts of India and Sri Lanka, along the northern boundary, in the Gulf of Aden, and in patches along the coast of Oman; and in the Bay of Bengal along the east coasts of Sri Lanka and India south of approx. 10 N, and in the southern bay east of the Sri Lanka thermal dome. NIO estimated the cause of these interannual minima using a linear, continuously stratified numerical model, which is able to simulate the observed minima and separated the forcing into a set of processes: direct forcing by winds in the interior ocean, forcing by winds blowing along continental boundaries, and forcing by Rossby waves generated by the reflection of equatorial Kelvin waves at the eastern boundary. At interannual periods, minima (maxima) of interannual variability occurred where the direct wind forcing and reflected Rossby waves interfere destructively (constructively). At interannual periods within the tropics, the adjustment time scale of the system is less than that of the forcing, leading to a quasi-steady balance, a property that distinguishes the interannual minima from those at annual and semiannual time scales. Idealized solutions show that the presence of India causes the minimum along the Indian west coast, and that it extends around the perimeter of the Arabian Sea into the Gulf of Aden.

Stability constants of cadmium-humate complexes

Diffusion coefficients of Cd-humate complexes are dependent on pH and $[\text{Cd}]/[\text{Humic Acid (HA)}]$

ratio in a Cd-HA system. These two factors mainly control the mass transport and complexation kinetics of Cd that may influence bioavailability and toxicity of Cd species in environmental systems. Determination of diffusion coefficients of Cd-HA systems by Scanned stripping voltammetry and dynamic light scattering techniques can provide a better understanding of the systems and can be very useful for extracting other speciation parameters of the systems. NIO found that Cd²⁺ ion along with small dynamic Cd complexes was predominantly present in a Cd-HA system at pH 5 with high diffusion coefficients. HA molecules were in aggregated form at pH 5. However, HA molecules were in disaggregated form at pH 6 and concentrations of Cd²⁺ ion and small Cd-dynamic complexes decreased with a decrease in diffusion coefficients of Cd complexes at this pH due to formation of Cd-humate complexes. No further decrease in the hydrodynamic radii of HA was observed with the increase of pH from 6 to 7. The Cd-humate system partially lost its lability at pH 7. Conditional stability constants were calculated for Cd-humate complexes by combining the diffusion coefficient data obtained by two techniques. The log K values calculated in this study are in good agreement with the data available from the literature.

Evaporation-precipitation changes in the eastern Arabian Sea for the last 68 ka: implications on monsoon variability

NIO reconstructed variations in sea surface temperature (SST), $\delta^{18}\text{O}$ of sea water ($\delta^{18}\text{O}_w$), and salinity for the past 68 ka using a sediment core (AAS9/21) from the eastern Arabian Sea (EAS) in order to understand the changes in evaporation and precipitation associated with the monsoon system. The Mg/Ca-derived SST record varies by approx. 4°C; it shows that marine isotope stage (MIS) 4 was warmer than MIS 3, that the Last Glacial Maximum was 4°C cooler than the present, and that there was a 2°C increase within the Holocene. MIS 4 records higher $\delta^{18}\text{O}_w$ and salinity values than MIS 2, suggesting variable flow of low-salinity Bay of Bengal flow into the EAS during glacial periods. The transition from MIS 4 to MIS 3 was marked by a conspicuous shift from higher to lower $\delta^{18}\text{O}_w$ values, which

reflects a decrease in the evaporation precipitation budget in the EAS, perhaps due to the strengthening of southwest monsoon. Monsoon reconstructions based on $\delta^{18}\text{O}_w$ reveal that monsoon-driven precipitation was higher during MIS 3 and MIS 1 and was lower during MIS 2 and MIS 4. This is consistent with earlier monsoon reconstructions based on upwelling indices from the western Arabian Sea. However, the amplitude of monsoon fluctuations derived through upwelling indices and $\delta^{18}\text{O}_w$ varies significantly, which may indicate spatial variability of monsoon rainfall.

1.4.2 Significant Technology Transfers

Plastic waste sorting machine

CEERI developed Near Infra Red (NIR) spectroscopy based plastic waste sorting system. The system can cater to plastic waste containing six types of materials namely, polyethylene, poly ethylene terephthalate, poly propylene, poly vinyl chloride, high density polyethylene and poly styrene. The technology has been transferred to M/s Dintis Technoloies Pvt. Ltd. Bangalore where for commercialization.

Biomedical Instruments

Pulse Oximeter

The technology for Pule Oximeter, was developed by CSIO in collaboration with Semi-Conductor Laboratory (SCL), Mohali. The technology was transferred on exclusive basis for a period of 18 months to M/s Rajasthan Electronics & Instruments Ltd. (REIL), Jaipur.

Surgical microscope for cataract surgery, Anaesthesia ventilator, and Sodium/potassium analyzer: The instruments were developed by CSIO and has been transferred to M/s SAP Healthcare Equipments Pvt. Ltd., Howrah.

Piezoelectric accelerometers

Measurement of shock and vibration is vital for development, testing, and operational monitoring of engines, structures, and machines, in all fields of

engineering. The heart of all vibration monitoring equipments is a vibration sensor, called accelerometer. Both core and strategic sectors are the potential users of accelerometers, apart from the other industrial sectors. Cost of the imported accelerometer unit was exorbitant, ranging from `40,000 to `1,20,000 each, and the import investments were several crores of rupees,

every year. The country was, however, totally dependent on import sources, till NPL developed the high quality indigenous accelerometers. NPL's device is available indigenously at a cost of Rs. 10,000. The process know-how for commercial production of the device has been transferred to three industries, in different parts of the country. (Fig. 31).



Fig. 31: Piezoelectric accelerometers

Portable Relative Humidity (RH) Generator

NPL developed a Portable Relative Humidity (RH) Generator, the technology know-how for which has

been licensed to M/s Belz Instruments Pvt. Ltd., Faridabad. (Fig. 32).



Fig. 32: Portable Relative Humidity (RH) Generator

1.4.3 Unique National Facility

National facility for medical instruments calibration

ISO 9001-2000 certified National Facility for Medical Instruments Calibration has been established at CSIO's Delhi Centre. This facility enables calibration of a wide range of medical equipment to manufacturers specification. Measurements are taken using equipment that have traceability with national standards. On-site and in-house test/calibration services are provided by this facility. All the calibrations are optimized, thereby helping the beneficiaries of this service in saving money. (Fig. 33).



Fig. 33: National Facility for Medical Instruments Calibration

'Sindhu Sankalp'- journey from fisheries training vessel to multidisciplinary research vessel

One of the major activities of NIO during the year was to convert newly acquired 'Sindhu Sankalp' - a fisheries training vessel - into a multidisciplinary research vessel. NIO signed contract with the Cochin Shipyard Limited, Kochi, for carrying out modifications and bringing the vessel under class. Some of the major tasks undertaken were (i) strengthening the deck for installation of deck equipment such as winches, cranes and A frame; (ii) installation data and sample acquisition equipment; (iii) creation of laboratories for data

and sample processing and analyses and (iv) relaying accommodation that is complying with the statutory requirements and more suitable to the long voyages. The Indian Register of Shipping conducted detailed surveys of the vessel after the modifications and issued class and statutory certificates on 11th March 2010. Since the vessel has undergone major modifications, it was felt desirable to have sea trials before proceeding with regular scientific voyages. The performance of the vessel was remarkably good during the sea trials. RV Sindhu Sankalp is operating in the Bay of Bengal to deploy instrumented moorings for acquisition of pre-monsoon time series oceanographic data. (Fig. 34).



Fig. 34: Sindhu Sankalp - a fisheries training vessel

Primary Ozone Standard Facility

In India and adjoining countries of South Asian region, various institutes and organizations have undertaken measurements of surface ozone to understand various Global change related problems and also to study air quality of the region. It is also very important that these measurements are made traceable to International standards. Keeping in view of the above importance, a NIST's Standards Reference Photometer (SRP-43) - Primary Ozone Standard Facility has been setup.

The facility commissioned at NPL will be a unique in the South Asian region. NPL is expecting lot of potential users of this facility from this region to calibrate their ozone measurement systems. It is also planned to provide secondary ozone standards after calibration against primary standard at NPL to various institutes for their use to calibrate their ozone analyzer systems.

1.5 ENGINEERING STRUCTURES & ELECTRONICS

This area calls for indigenous solutions for local problems using globally applied benchmarks. Some

CSIR institutions have been able to propose some innovative solutions to the needs of the community at large, as under:

1.5.1 S&T Contributions

Preventing falling stones by stabilizing rock slopes around Konkan Railway lines, Maharashtra

CIMFR stabilized the rocky slopes along one of the prestigious railway tracks between Maharashtra and Karnataka for the Konkan Railway Corporation Limited (KRCL) of the Indian Railways without damaging the tracks and hampering the daily train-schedules. Site-specific controlled blasting techniques were applied to the sites of Barewadi, Sheravali (North and South), Ambivali, Wave, Sherpe, Berdewadi, Harwada, Chinchavali, Kamthe, Verawali, Anjanari, Wagde etc. As a result of efforts by CIMFR, KRCL has been able to maintain uninterrupted traffic movement for the last 4 years. (Fig. 35).

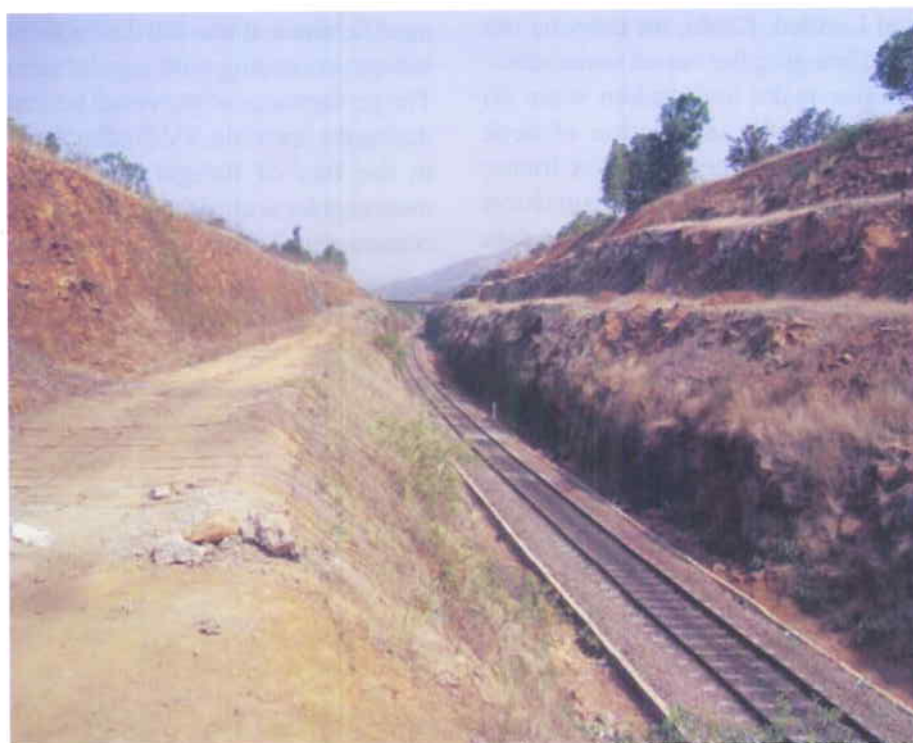


Fig.35: Flattening of rock slopes by controlled blasting at Chinchavali Site of KRCL

Controlled blasting technique using bamboo spacers

CIMFR provided technical guidance and constant supervision to build a 1.5 km stretch through the hilly and treacherous terrain of Midumkham in Mizoram to construct a 160 km long road in difficult hilly terrain connecting Aizawl-Thenzawl-Lunglei.

A special technique with bamboo spacers was used, for the first time, during controlled blasting to make stable and undamaged rock slope without damaging close-by high-tension cables and residential structures. A similar kind of work was also completed in Durtlang-Leitan (through cutting) in Aizawl gate, Mizoram. (Fig. 36).



Fig. 36: View of final road after widening by controlled blasting (Midumkham Area), Mizoram

Design of Highwall Mining in India

Highwall mining is a new technology which can extend the life of opencast mines without disturbing the surface dwellings, thus maintaining economy and productivity. This technology is in use in United States and Australia but is yet to be introduced in Indian coalfields. It is a remotely operated coal mining technology closely related to underground mining machinery. The method comprises extracting coal from a series of parallel entries driven in the coal seam from the face of the highwall. These entries are unmanned, unsupported and unventilated. CIMFR is instrumental in adapting this new technology for Indian geomining conditions

by providing scientific extraction design for the first two Highwall Mining sites at Ramagundem Opencast Project-II of M/s Singareni Collieries Company Ltd., and West Bokaro of M/s Tata Steel Ltd.

Indian geomining conditions are found to be widely different from those existing in other parts of the world, with the existence of multiple seams and frequently varying geology. CIMFR conducted a series of numerical modelling studies coupled with empirical approach and decades of experience in coal mine geomechanics to come up with optimum Highwall Mining extraction designs. Coal recovery up to 60% has been designed by CIMFR at the above mining sites.

Achieving longer pull and higher coal yield using newly-developed Pentadyne-HP explosive

Bord and Pillar mining is the predominant underground coal mining system in India, contributing to almost 98% of underground coal production in the country. In this system, more than 96% of coal production is through drilling and blasting. With the present conventional solid blasting pattern being followed for the last three decades (wedge cut/fan cut); the production of coal (yield) per blast is about 10 to 16 tonnes. The pull obtained per blast remains stagnant at 1.2 m. Therefore, efforts to mechanize bord and pillar workings by introducing SDLs and LHDs could not achieve expected production targets due to poor coal availability at the faces.

CIMFR used a newly developed Pentadyne-HP explosive, which has a gap sensitivity of 15 cm, and conducted extensive field trials in mines of M/s Singareni Collieries Companies Ltd. Different patterns like Modified Gronlund Cut, Swedish Cut, and Sarrois Cut were tried and it was established that the blast results obtained with modified angled cut (wide V-cut pattern) were better than all other cuts. The pull obtained in modified V-cut with 2.4 m blasthole depth varied between 1.7 and 2.2 m whereas in conventional blasting it is maximum 1.2m only. The calculated yield achieved in depillaring panel (4.0 m × 3.8 m face dimension) varied between 39 and 50 tonne of coal. This particular development would fulfill the long-awaited requirement of the coal mining industry in India for mechanization of underground mines with improved production and productivity, making mines economically viable and safe.

Mobile Teleclock: adding new dimension to time dissemination

NPL developed an innovative system for transmission of digital time data via mobile network. It receives time data through a general packet radio system (GPRS) modem to access the wireless mobile telephone network. It has an in-built clock run by a crystal oscillator. The receiver has the provision of dialing the telephone number of the line dedicated for this service manually by pressing a switch or

automatically at a pre-programmed time. The frequency of automatic dialing is normally once in a day but may be increased or decreased at the user's demand. Through dialing, the receiver gets the data corresponding to the standard time of the day, e.g., in India, Indian Standard Time (IST) and sets its own time accordingly, displays it and disconnects itself. The improved Teleclock receiver is an inexpensive and advanced solution to access standard time of the day without any dedicated landline telephone connection. Mobile Teleclock receiver uses the SIM card in the way that it is used in any ordinary Global system for mobile communication (GSM) mobile phone. However, only "Data Communication Enabled Subscriber Identity Module (SIM)" card should be used for this purpose. Such an inexpensive, simple and mobile accessibility of Standard Time is unique and is not yet available elsewhere.

Enhanced conversion efficiency in dye sensitized solar cells based on hydrothermally synthesized TiO₂-MWCNTs nanocomposite

Dye-sensitized solar cell (DSSCs) represents a key class of cell architecture that has emerged as a promising candidate for the development of next generation solar cells. NCL achieved a 50% enhancement in conversion efficiency (4.9% to 7.37%) in dye-sensitized solar cells (DSSCs) using hydrothermally synthesized TiO₂-multi wall carbon nanotube (MWCNTs) nanocomposite as compared to hydrothermally synthesized TiO₂ without MWCNT. Several characterizations are employed to reveal the nature of the modification imparted to the MWCNTs under hydrothermal processing conditions and the resulting TiO₂-MWCNT conjugation through -COOH groups. Efficient charge transfer in the nanocomposite and efficient electron transport by MWCNT are suggested to be the possible reasons for the enhancement.

1.5.2 Significant Technology Transfers

Column floatation for processing of iron ore tailings: pilot plant demonstration

About 10 million tons of iron ore tailings containing

50-60% iron and significant quantities of alumina and silica are being generated and discarded as slimes in the existing washing plants. IMMT established that most of the iron values can be recovered by column flotation technique in the form of high quality fines which can be utilized for pellet making. The institute demonstrated the technology for recovery of additional iron values from tailings of the existing iron ore processing plant to M/s Tata Steel at its Joda mines. Nearly 3 tonne per hour

iron ore tailings were processed to recover iron values from 50% Fe in feed to 66% Fe in product with 30% yield. This attempt led to recovery of additional iron values from the tailings and the life of the tailings dam were increased by 30%. Nearly 10% of high grade super fine iron concentrate can be produced; thereby equal amount of high grade iron ore can be conserved. M/s Tata Steel is in the process of commercializing the technology to recover valuables from slimes. (Fig. 37).



Fig. 37: Column flotation technique for processing of iron ore tailings

Process for recovery of lead from zinc plant residue

Huge quantity of leached residue containing lead is generated during the processing of zinc. The residue containing lead falls under the category of hazardous wastes as defined by the Environmental Protection Agency. Lead, a vital metal, usually goes waste on one hand and poses potential environmental risk,

on the other. It is desirable that the lead from the residue be recovered before dumping not only to obtain economical advantages of the recovered values but also to prevent possible environmental pollution. NML developed a simple process for recovery of lead, as cement lead by leaching and cementation process which can be easily refined to obtain pure lead. The development and adaptation of the process is expected not only to ensure

sustainability of the various secondary zinc plants but is also environmental safety. More than 99% lead was recovered in the leaching steps with an overall recovery of above 96%. After successful demonstration, the process was transferred to the M/S Chakradhar Chemicals Pvt. Ltd.

Flotation column for the beneficiation of sillimanite from beach sands at IREL, Chavara

NML developed an innovative technology using mode of bubble generation/air sparging system for floating column for the beneficiation of sillimanite from beach sands. Generally, the industrial columns use external spargers, which need both water and air at high pressures (8-10 kg/cm²) for bubble generation. Frequent failures of pump are encountered due to high pressure. The sparger was developed using low cost abrasive resistant material and it does not need addition of water for bubble generation. It works at low air pressures (3 kg/cm²). The sparger can be maintained online without disturbing the column operation. The unit has low energy consumption due to absence of moving parts in the system and one column is capable of replacing multi-stage conventional flotation cells. The technology of column flotation has export potential as the demand for high grade minerals is increasing.

The unit with a capacity of 6 tph (150 tons/day) was installed at M/s Indian Rare Earths Ltd., Chavara, Kerala. It resulted in increase in productivity by about 40%, with 15% savings in energy.

Work related to Common Wealth Games Village

Delhi Development Authority (DDA) reposed their faith & confidence in CSIR by entrusting a prestigious assignment for quality assurance of the proposed construction of Commonwealth Games Village for the Commonwealth Games to be held in Delhi in the year 2010.

1.5.3 Unique National Facilities

Commissioning of accelerated pavement testing (ATP) facility

CRRRI procured a 'Heavy Vehicle Simulator', an on-site version of 'Accelerated Pavement Testing Facility'. The South-Africa built facility was received and commissioned within the premises of the institute. Accelerated Pavement Testing involves the controlled application of a prototype wheel loading, at or above the appropriate legal load limit to a prototype or actual, layered, structural pavement system to determine pavement response and performance under a controlled, accelerated accumulation of damage in a compressed time period.

Objectives of Creating APT Facility

- Establishment of Centralised National Accelerated Pavement Testing Facility (APTF).
- To generate data similar to Long Term Pavement Performance (LTPP) Studies and to develop pavement deterioration models for flexible and rigid pavements (for typical pavement structures).

Advantages of APTF: Extend to advance information on pavement performance; evaluation of new designs, specifications, mixes and materials; studies for anticipated traffic conditions; greater control over uniformity and quality of construction because of small size of test sections; control over environmental factors such as pavement temperature and subgrade moisture; simulated field conditions; economical and ready to use technical solutions; substantial savings with improvements in pavement design procedures and maintenance practices; well targeted pavement research programme; knowledge gained from APTF affects decision of road authorities; and determination of magnitude and timing of asset establishment and preservation costs. (Fig. 38).



Fig. 38: 'Heavy Vehicle Simulator'

Formation of Sensor Hub in CGCRI, Kolkata

CGCRI has carried out extensive research in the development of oxide based ceramic sensors. The effort has generated notable knowledgebase for developing semiconductor sensors for identification of toxic and flammable gases like methane, LPG and CNG; Also PZT based wafers for Non-Destructive Evaluation of thin-wall structures and ceramic humidity sensors for leakage detection have also been fabricated, A 'Sensor Hub' has been formed within CGCRI campus at Kolkata, besides CGCRI, the other Institutes in the hub are: Jadavpur University, Calcutta University, Bengal Engineering & Science University and Centre for Development of Advanced Computing. The immediate objectives of this multi-dimensional platform are i) Electronic nose for tea aroma ii) MEMS based methane gas sensors and iii) Arsenic detection kit. These Institutes in the Hub will work jointly to develop, fabricate and test sensors in batches so that the technology can be transferred directly to the public domain through interested parties. The Hub will provide facilities for pilot production and testing of sensors and sensor array modules for food, agriculture and environmental applications.

1.6 SMART AND FUNCTIONAL MATERIALS

With global emphasis on climate change, energy-efficient manufacturing processes, materials- new

and smart- play an important role. They can increase process/ products efficiencies, save energy and what not. Several CSIR institutes contribute towards such works, as below:

1.6.1 S&T Contributions

Porous SiC ceramic material

Imitation of the fibrous morphology of cellulosic bio-materials in SiC ceramic structure leads to the formation of a bulk porous material that can be used as a substrate for hot gas cleaning. The net-working of converted SiC filaments results in the form of void space (pores) in the final material, while fibrous structure contributes to strength. CGCRI developed porous SiC material followed by the fabrication of fibrous tubular shapes. It was the basis of development of a prototype hot gas filter substrate through a biomimetic technique using processed plant bio-structure such as cellulosic material of wood pulp as precursor. Perfect retention of fibrous structure with formation of porous network was obtained in carbon templates as also in SiC ceramics.

Hydrothermal synthesis of petal-like alumina flakes

For the first time CGCRI synthesized petal-like alumina flakes through a soft solution approach

without using any surfactant-based templating agents and organic solvent. It is the new approach for obtaining the stated morphology of alumina with aqua-based precursor materials like aluminum nitrate, urea and water by a single-step hydrothermal process carried out for 6 hours at 170°C. Under the reaction condition, the boehmite particles are formed through the controlled hydrolysis of aluminum nitrate in presence of urea, which transforms to $\gamma\text{Al}_2\text{O}_3$ at about 455°C and $\theta\text{Al}_2\text{O}_3$ at about 900°C, the latter is stable up to 1200°C.

Nanoindentation study of microplasma sprayed hydroxyapatite coating

The microplasma sprayed (MPS) hydroxyapatite (HAp) coating on surgical grade SS316L, is an emerging material for bio-ceramic based implant application involving higher reliability. CGCRI developed a 200 mm thick MPS-HAp coating on SS316L substrate and characterized by XRD, SEM

and FESEM techniques. The local mechanical properties of the coating, such as the nano-hardness and Young's modulus were evaluated by nanoindentation technique carried out with a Berkovich indenter at various depths in the range of about 170-3000 nm on a polished top surface.

Advanced lightweight metallic materials for engineering applications

AMPRI developed aluminium metal matrix composites brakedrum, aluminium foam filled crash boxes and sandwich panels. Foam filled crash boxes are meant for automobiles where these crash boxes take the impact of collision. It is used between bumper and chasis. The high energy absorption capability of hybrid structure (foam-filled tube) makes it suitable against deformation by bulking. Similarly brake drums of diameters 300 mm for four wheelers and 150 mm for two-wheelers were fabricated and analysed. Fig. 39 shows prototypes of crash box and brake drums.



Fig. 39 (a): Foam Filled Crash Box

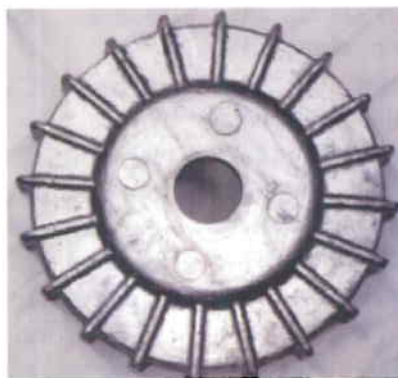


Fig. 39 (b): MMC Brakedrum - 300 mm - Four Wheeler



Fig. 39 (c): FiMMC Brakedrum - 300 mm - Four Wheeler

Ion-Polymeric Metal Composites biomimetic actuators

Making use of biological cells to power the ionic polymeric metal composite (IPMC) explores the possibility of biological control of IPMCs in operation as an artificial muscle. This novel technique has the potential to assist cardiac, intestinal, paralysis, and ocular patients, among others. Electrical activation of the synthetic

biocompatible polymeric materials (artificial muscle) by means of biological cells or nerves could be of great significance for people suffering from various muscular diseases. These are highly efficient and may have far reaching application consequences in biomedical engineering and medicine. CMERI developed IPMC based actuator at laboratory scale. Actuation response of IPMC based actuator is shown in Fig. 40.

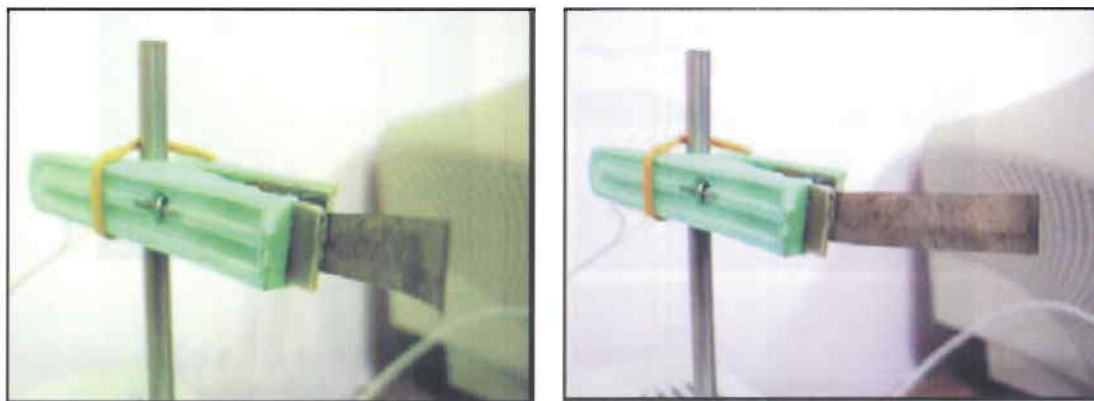


Fig. 40: Successive photographs of the IPMC strip showing deformation under time-varied voltage

Processing of natural resourced hydroxyapatite ceramics from fish scale

CMERI scientists illustrated the processing parameter associated with the preparation of natural resourced ultrafine hydroxyapatite (HAp) powders in a cost effective way through thermal decomposition of chemically treated fish scale. The optimization of processing calcification temperature of HAp powder was identified through thermal gravimetric analysis and corresponding X-ray diffraction studies. The optimized calcined hydroxyapatite powder derived from fish scale was wet ball milled for several hours and compacted into different shapes at lower pressure (850 kgf/cm²). The green compacts were sintered at different temperature for 1 hour in dry air atmosphere. The average grain size of sintered samples remain mostly in the submicrometre range and ~91% of theoretical density was achieved even at lower compacting pressure. It is expected to help in development of biodegradable/biocompatible porous scaffolds for applications in tissue engineering.

1.7 STRATEGIC SECTOR

Ever since its establishment, CSIR through its constituent institutions has been contributing to the

technological needs of the strategic sectors, be it defence, atomic energy or the like. During the period of this report several such contributions have been made, as under:

1.7.1 S&T Contributions

Autonomous Underwater Vehicle (AUV) for 150 depth under sea

CMERI developed a torpedo configuration modular shaped AUV which is equipped with light weight Li-polymer batteries, and can provide mission duration of 4-6 hours. The unit has 5 controllable degrees of freedom, which are controlled by 5 propellers placed in the various directions of AUV. Surge, sway, heave, pitch and yaw are controlled. Advanced controller has been used to control AUV through different paths during various missions. The positional and velocity information of the AUV are monitored using navigational sensors, which help in navigation and guidance of the AUV. The payload sensors have been used for seabed mapping and underwater data collection. Special grade Al alloy (Al-6061-T6) is used for AUV development to keep the mass of the vehicle as light as possible. (Fig. 41).



Fig. 41:

Wankel Engine - Powered Unmanned Air Vehicle (UAV)

NAL in partnership with DRDO (VRDE, ADE) designed and developed first Indigenous Wankel Engine - Powered Unmanned Air Vehicle (UAV) 'NISHANT' which performed its maiden flight during the year at Kolar, Karnataka. The critical core engine, including the special cylinder composite nickel-silicon carbide anti-wear coating and the special aluminum castings, was designed and developed by NAL.

Long-period waveguide gratings in silica-on-silicon

CEERI successfully fabricated long-period corrugated grating in silica-on-silicon-based channel waveguide by making periodic corrugation on top of a relatively high-indexed (contrast ~8%) Germanium--doped silica waveguide. This Ge-doped silica waveguide was sandwiched between undoped silica undercladding and boro-phospho-silicate-glass overcladding layers. Resonance wavelength of the 15-mm-long grating was found at ~1581 nm, having negligible polarization dependency at room temperature, with a grating strength of ~11 dB and 3-dB bandwidth of 7 nm. The temperature characteristic of the grating was also investigated, and found to be similar to that of

the long-period fiber grating. This device has significant potential for various integrated-optic communication and sensing applications. The temperature tenability of the device has been tested for transverse electric (TE)-like, transverse magnetic (TM)-like and unpolarized light, where it can be used as temperature-tunable band rejection filter. It can also be used for sensing refractive index of any liquid.

New generation terahertz devices

CEERI developed electron gun which is a component of high frequency (in terahertz range), moderate power and efficient devices based on microelectromechanical system semiconductor and vacuum electronics technologies. The devices comprise of electron gun, radio frequency structure, and collector with wave guide couplers. The electron gun has been designed and simulated in two-gun design computer simulation tools, such as e-GUN and computer simulation technology Particle Studio. The gun has been developed and qualified for the temperature and emission characteristics. Techniques so developed would be utilised to develop terahertz sources of more than 100 GHz frequencies. These devices have applications in high data rate communication, imaging, detection of explosive devices at strategic and public places, medical and in astronomical sciences.

Solid-state versatile pulsar for high-voltage and high-power applications

High voltage pulse generators are used in varied applications, for scientific, industrial and societal applications. They are used for characterization of high power microwave tubes (Klystrons and Gyrotrons), water purification, sterilization etc. CEERI developed, fabricated and tested a solid-state pulsar for high-voltage and high-power applications. Provision for independent variation of pulse amplitude, width and repetition rate, make it a versatile source for many pulse power applications and experiments. The basic module is rated for 2.5 kV and 50 A. Experimental prototype with 20 series connected modules is used to generate 50 kV pulse. Pulse width variation from 5 to 50 msec and pulse repetition frequency (PRF) from 1 Hz to 200 Hz has been achieved. Pulses of positive or negative polarity can be generated by changing the earth connection.

The Legal Metrology Act - 2009

Legal metrology is a vital part of a country's regulatory framework and affects commercial transactions as well as people's everyday life. From a public administration's point of view, legal metrology is also intrinsically tied to the issue of "good governance", by ensuring Consumer protection: assurance of reliable transactions between customers and suppliers etc. As a custodian of National Standards, NPL maintains all the primary base units except Mole and all derived units. NPL provides the traceability of any measurement. Legal Metrology Act-2009 passed in Parliament and received the assent of the President of India on 13th January, 2010.

Deployment of mousche using shape memory alloys

NAL fabricated carbon fibre reinforced polymer (CFRP) Mousche to withstand the full load test. The fore plane or Mousche is an additional aerodynamic control surface. It is attached to the fore body of the Naval version of Light Combat Aircraft (LCA). The Mousche is deployed during landing to improve the landing characteristics of

the aircraft using Shape Memory Alloy (SMA). The electronics circuit assembly of Smart Actuator Drive Electronics (SADE) has been designed and developed in the form of mother and daughter boards. Each daughter board has six miniaturized DC-DC converters; the required power and control signals are routed to the motherboard.

Road Safety Audit Manual

CRRRI prepared a 'Road Safety Audit Manual'. The manual is useful for decision-makers, engineers and technicians of the Indian road sector, irrespective of whether they work at National, State, District or Local level. It is intended for all those who can, and should, contribute to safety on Indian roads. It details procedures for applying quality assurance to road projects, from the standpoint of road safety. It also helps to ensure that all road schemes function as safely as possible, which means that the road users are exposed to a minimal risk of accident, both on new roads as well as on existing roads. The concept of road safety audit, like when to conduct, quality assurance, procedure to conduct audit and value of safety audits has been discussed in the manual. The manual covers the stages of road safety audit i.e., during feasibility study, completion of preliminary design, completion of detailed design, construction stages, pre-opening and on existing roads. It was statutory requirement of this sector which has now been met with.

Portable analog seismic recorder

CSIO developed Portable Analog Seismic Recorder to monitor process and record the field seismic data from remote sites. The electrical signal produced by the seismometer (seismic sensor) in response to ground motion is fed directly to the portable analog recorder. The analog recorder has been matched with seismometers of different manufacturing concerns. It is battery powered, portable and fully field worthy. It has lower running cost and is simple in operation. It produces seismograms without any separate data retrieval unit. IMD has installed these recorders at various places in the country as a part of the National Network of Seismic Observatories for recording the seismic activities. (Fig. 42).



Fig. 42: Portable Analog Seismic Recorder

Probabilistic seismic hazard map of India

SERC developed a probabilistic Seismic hazard Map of India. Due to the diverse seismotectonic setup of Indian subcontinent, there are several seismically active regions important from engineering point of view. Seven regions were considered for evolving the attenuation relations. The digitised map of India was created based on the Survey of India map. The boundaries of the different regions are identified and marked on the digitised map of India.

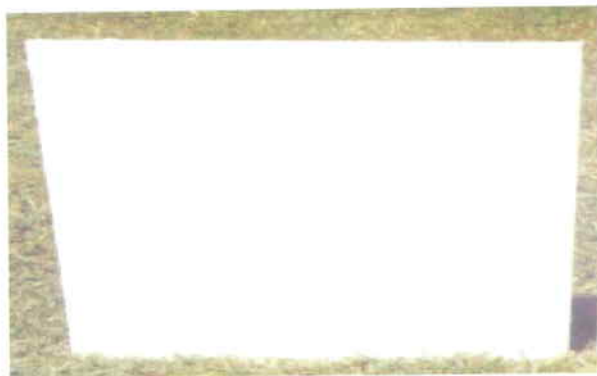
Building materials from H-Acid Gypsum

H-acid gypsum, a waste material is produced to the tune of 0.5 million tonnes per annum from the dye intermediate by the neutralization of free sulphuric acid with limestone. CBRI developed a process to

utilize waste gypsum to manufacture building materials from H-acid gypsum. The plaster boards (Breaking load: 450-550-N, water absorption: 18-20% thermal conductivity 0.12-0.18 Kcal/m/hr/o_c and bulk density 1000-1100 kg/m³ and blocks (compressive strength: 2.2-3.5 MPa, bulk density: 1150 Kg/m³) of improved properties complied with Indian standards were produced from the beneficiated H-acid gypsum. Some typical photographs are shown in Fig. 43.

1.8 SUSTAINABLE ENERGY

Energy- clean and sustainable, its production and use, is the focus of all research organizations world over. CSIR is also into that league with several of its laboratories working on processes, products or solutions with emphasis on energy saving/ production/ clean and efficient processes etc.



a Gypsum Plaster Boards



b Gypsum Blocks

Fig. 43: Various poses of AUV

1.8.1 S&T Contributions

Process for conversion of waste plastics to value added hydrocarbons

IIP developed a simple catalytic process for conversion of waste plastics, particularly polyethylene and polypropylene, into value added products. The products include gasoline or diesel or LPG. The process is environment friendly, produces fuel meeting most of Euro-III specifications and has the potential of solving the ever increasing problem of disposal of waste plastics in an environment friendly way as well as augmenting the supply of these petroleum products.

Hydrotreating of vegetable oil for green diesel production

Non-edible and used vegetable oils are renewable feedstock for production of bio-fuel, contributing to decreased greenhouse gas emission, decreased dependence on fossil fuels, improvement of rural economics, and increased national security. Biodiesel production by transesterification is currently the primary route to bio-fuel from vegetable oils. However, this process produces by-product glycerol, and new biodiesel plants require a large capital investment. An attractive by-product free route, that also offers engine compatibility and feedstock flexibility, using the existing petroleum refinery infrastructure, is vegetable oil hydrotreatment, with petroleum - derived feed stocks such as gas oil, to very high cetane diesel fuel. IIP has developed the process for hydrotreating gas-oil and vegetable oil mixtures, to develop a process for diesel production in the same reactor within a petroleum refinery.

Lithium antimonite: A new class of anode material for lithium-ion battery

CGCRI developed a new anode material, LiSbO_3 , with a perovskite like structure. Flat charge-discharge plateau together with low Li intercalation/de-intercalation potential (0.2/0.5 V) versus Li and a specific capacity of $\sim 600 \text{ mAhg}^{-1}$ make it a promising anode. The results also stimulated

investigation on other lithium antimonites such as LiSb_5O_8 , Li_3SbO_4 etc as prospective anode materials.

Anode supported planar solid oxide fuel cells by electrophoretic deposition

IMMT fabricated nickel oxide- yttrium stabilized zirconia (NiO-YSZ) anode substrates for solid oxide fuel cells (SOFC) by slipcasting, tapecasting and uni-axial pressing. Inexpensive electrophoretic deposition technique was used in making about 10 micron thin and dense YSZ electrolyte on NiO-YSZ substrate. The single SOFC cell, when tested using H_2 as fuel, and ambient air as oxidant exhibited an open circuit voltage (OCV) of 1.03 V and the peak power density of about 624 mW/cm^2 at 800°C .

Wind turbine

NAL designed, developed and installed a 500 kW wind turbine at Sangeeth Wind Farm. The wind turbine was designed in such a way that costly yaw control and pitch control system are not required.

1.9 WATER

This area represents a natural resource, which is used by everyone- locally and globally. With increasing demand for safe drinking water, industrial needs or needs for various processes/ products, its availability always remains of concern. Several CSIR institutions are contributing in different ways to ensure its availability daily and in times of need.

1.9.1 S&T Contributions

Ceramic membrane based iron removal plant in Sikkim

North Eastern States of India account for a large storehouse of replenishing freshwater, but the people of the hill region often lack access to safe and adequate drinking water or sanitation or agriculture and livestock. Mainly iron and sometimes arsenic and fluoride are the major contaminants which mar the quality of water in this region. An iron removal plant of 5000 LPD capacity developed by CGCRI has been installed at Sikkim Science Centre, at

Gangtok, Sikkim. The pilot plant demonstration of ceramic membrane based iron removal plant of CGCRI was made to Sikkim State Council for Science & Technology. The responsibility of operation and maintenance of the plant has been given to the Sikkim Science Centre. This is the sixteenth pilot plant scale demonstration plant set up in the north eastern region of India.

Membrane technology for drinking water

CSMCRI set up several brackish water and sea water desalination plants nationally and

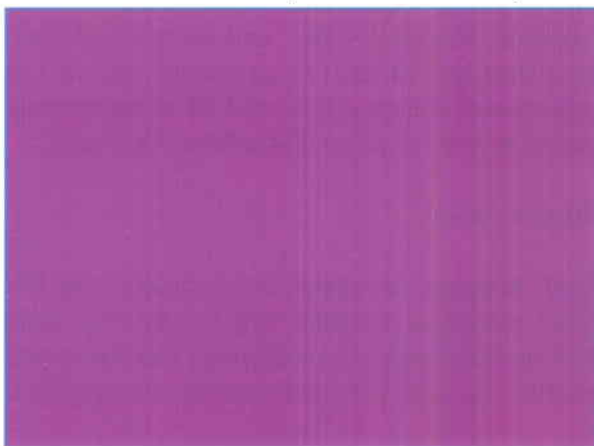


Fig.44 (a): RO desalination plants in Afghanistan

Gravity flow Terafil water purification plant for community use

IMMT developed high capacity Terafil™ based water purification plants for filtration of ground water and supply of iron-free clean drinking water through pipeline to rural households. The Terafil plant operates by gravity and is simple to use with

internationally using indigenously developed membrane technology for drinking water. Around 15 brackish water desalination plants have been set up in Afghanistan which is serving about 50000 people in different villages.

The indigenous water purification unit was put in to service for providing drinking water to the people affected by cyclone Aila where the existing water bodies had become saline and rendered unsuitable for drinking. (Fig. 44).



Fig. 44 (b): Relief-Post cyclone Aila

semiautomatic cleaning arrangement. Plants having different filtration capacity in the range of 1000-75,000 litres/day have been designed and developed for large scale implementation. Initial batch of plants have been installed in Odisha, Karnataka, Shillong and Meghalaya. The plant removes more than 95% soluble iron, 99% turbidity, 95% of bacteria, bad odour, and colour. (Fig. 45).



Fig. 45: Terafil Water Purification Plant with a capacity of 5000 Lt. per day installed in Karnataka

Chemo-defluoridation

NEERI developed Chemo-defluoridation process for removal of excess fluoride from drinking water by chemical precipitation and adsorption. It is based on the principle of reaction of two chemicals added in fluoride containing water, precipitation, and formation of complex with fluoride in water, followed by adsorption and removal of fluoride by settling on specially designed sand filter bed. This novel process is suitable for supplying fluoride safe potable water in fluoride affected areas. The unit can be operated at domestic as well as community level, which does not require electrical power. The process is suitable for treatment of water with fluoride concentration up to 15 mg/L. The process produces treated water with fluoride concentration of <1mg/L. The taste of water is palatable.

Water filters

To provide potable water to the masses, immt developed Terafil water filters with food grade plastic containers, over 50,000 water filters have been distributed and sold through various government agencies and NGO's. Likewise, another product - the NEERI-Zar' developed by CSIR is a

water purification system suitable for potable water supply particularly under emergency situation like floods. 100 units of NEERI-Zar were successfully deployed during cyclone Aila affected areas

Groundwater information system for farmers and policy makers

NGRI developed a globally-accessible web-based Groundwater Information System. This has detailed layers of information on the groundwater level and quality with reference to major chemical species as well as information on the pesticide residues. This information is available at village-level 'Knowledge Centers' in the districts. Highly cultivated central parts of Punjab viz., old Amritsar and Jalandhar districts were chosen for the study as these areas over-exploit ground water. This online system brings information to the door step of farmers about the status of groundwater condition in a particular village with reference to the depths at which the groundwater is available and the quality of the potable drinking water in terms of major ion concentrations and persistence of pesticide residues. The web page has been temporarily linked to NGRI website www.ngri.org.in