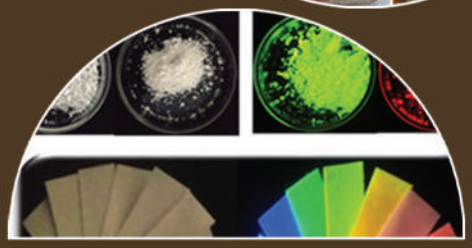

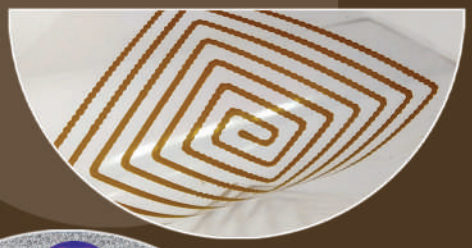

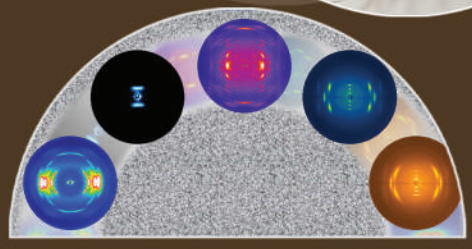

CSIR-NIIST

# वार्षिक प्रतिवेदन
# ANNUAL REPORT
# 2020 - 2021

## राष्ट्रीय अंतर्विषयी विज्ञान तथा प्रौद्योगिकी संस्थान
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## National Institute for Interdisciplinary Science & Technology
(Council of Scientific & Industrial Research)
Thiruvananthapuram

CSIR-NIIST

# वार्षिक प्रतिवेदन
# ANNUAL REPORT

## 2020-2021

**सी एस आई आर - राष्ट्रीय अंतर्विषयी विज्ञान तथा प्रौद्योगिकी संस्थान**

**CSIR-National Institute for Interdisciplinary Science & Technology (NIIST)**

(वैज्ञानिक तथा औद्योगिक अनुसंधान परिषद्)

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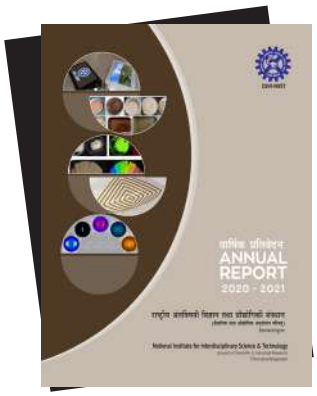
**तिरुवनंतपुरम** / Thiruvananthapuram




1. Hand held Raman Spectrometer developed at NIIST
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# वार्षिक प्रतिवेदन 2020-2021
# ANNUAL REPORT


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CSIR-NIIST

# प्रस्तावना

मुझे 2020-21 की अवधि के लिए सीएसआईआर-एनआईआईएसटी की वार्षिक रिपोर्ट प्रस्तुत करने का सौभाग्य मिला है जिसमें सीएसआईआर-एनआईआईएसटी द्वारा अंतर्विषयी अनुसंधान के अग्रणी क्षेत्रों में किए गए महत्वपूर्ण योगदान का विवरण है। सीएसआईआर-एनआईआईएसटी ने साल भर की महामारी और अन्य प्रतिकूलताओं और प्रतिबंधों के कारण हुए झटके के बावजूद भी पिछले वर्षों की तरह अच्छा प्रदर्शन करना जारी रखा और कई महत्वपूर्ण उपलब्धियां और कई प्रशंसा हासिल की। सीएसआईआर-एनआईआईएसटी को सीएसआईआर मुख्यालय और केंद्र, राज्य सरकारों, सार्वजनिक और निजी क्षेत्रों, उद्योगों और शिक्षाविदों सहित अन्य हितधारकों से मजबूत वित्तीय समर्थन प्राप्त था। मैं उन सभी को इस अवसर पर समर्थन व सहयोग देने के लिए धन्यवाद देता हूं।

सीएसआईआर- एनआईआईएसटी अन्य सीएसआईआर प्रयोगशालाओं के साथ कोविड महामारी के खिलाफ लड़ाई में शामिल हुए और सीएसआईआर के रणनीतिक समूह की पहल का भी एक हिस्सा बने, जिसमें कोविड -19 के लिए दवाओं के पुनर्प्रयोजन सहित नए उपचार विकसित किए गए थे। हम तीन शक्तिशाली दवा उम्मीदवारों के लिए व्यवहार्य और लागत प्रभावी सिंथेटिक रणनीति विकसित कर सकते हैं; गैलीडेसिविर (बायोक्रिस्ट फार्मास्यूटिकल्स), नाइटाज़ोक्सानाइड (रोमार्क लेबोरेटरीज), और ईआईडीडी 1931 और 2801 (एमोरी यूनिवर्सिटी)। स्थानीय प्रशासन और सामान्य रूप से जनता की मदद करने के लिए, सीएसआईआर-एनआईआईएसटी ने टच-फ्री ऑटोमैटिक हैंड सेनिटाइज़र डिस्पेंसर (आंतरिक और बाह्य), एयर सैनिटाइज़र, यूवी-क्लीन डिसइंफेक्टिंग यूनिट, एकीकृत स्व-कीटाणुनाशक मेंब्रेन आदि के साथ पुन: प्रयोज्य स्टॉपगैप फेस मास्क जैसे उत्पादों का विकास किया गया। इन सभी तकनीकों को एमएसएमई में स्थानांतरित कर दिया गया।

महामारी के दौरान रोगजनक अस्पताल कचरे के सुरक्षित संचालन और निपटान के लिए विकसित तकनीक, सीएसआईआर- एनआईआईएसटी का एक प्रमुख महत्वपूर्ण योगदान रहा है, जो उद्योग के लिए लाइसेंस प्राप्त है। इस्तेमाल की जाने वाली प्लास्टिक कटलरी जैसे प्लेट, कप, चम्मच आदि को बायोडिग्रेडेबल कृषि अपशिष्ट के साथ बदलने के लिए विकसित तकनीक सीएसआईआर-एनआईआईएसटी की एक अन्य प्रमुख औद्योगिक और सामाजिक रूप से प्रासंगिक प्रमुख योगदान है। इस तकनीक को कुछ उद्योगों को लाइसेंस दिया गया है। साथ ही इस तकनीक पर और विकास किया जा रहा है।

रिपोर्ट की अवधि के दौरान, हमारे पास विभिन्न निधीयन एजेंसियों और संबंधित मंत्रालयों द्वारा समर्थित सहायता अनुदान परियोजनाओं की एक बड़ी संख्या भी थी। संस्थान के पास विभिन्न प्रतिष्ठित द्विपक्षीय कार्यक्रमों के तहत परियोजनाएं भी हैं, जैसे; इंडो-यूके ग्रांट चैलेंज, इंडो-नॉर्डेन, इंडो-ऑस्ट्रेलियन सामरिक अनुसंधान कोष परियोजना, उन्नत अनुसंधान को बढ़ावा देने के लिए भारत-फ्रांस केंद्र (सीईएफआईपीआरए), इंडो-जर्मन, और ये सभी निष्पादन के विभिन्न चरणों में हैं। सीएसआईआर-एनआईआईएसटी ने राज्य सरकार के संगठनों से कई प्रमुख परियोजनाएं हासिल की हैं।

सीएसआईआर-एनआईआईएसटी ने वर्ष 2020 में रमन स्पेक्ट्रोमीटर बनाने में जानकारी विकसित करने के लिए सर्वश्रेष्ठ नवाचार के लिए सीएसआईआर-प्रौद्योगिकी पुरस्कार प्राप्त किया। हमारे वैज्ञानिकों ने सीएसआईआर युवा वैज्ञानिक पुरस्कार, केरल राज्य विज्ञान प्रौद्योगिकी और पर्यावरण पुरस्कार आदि सहित कई मान्यताएँ जीती हैं। हमारे अकादमिक कौशल विकास और कार्यक्रमों ने विज्ञान की प्रगति और सामाजिक उत्थान में महत्वपूर्ण योगदान दिया है।

मैं इस अवसर पर अपने समर्पित समर्थन के माध्यम से संस्थान की प्रगति में योगदान देने वाले सीएसआईआर- एनआईआईएसटी के हरेक को धन्यवाद देता हूं। साथ ही मैं सीएसआईआर, केंद्र और राज्य सरकारों, सार्वजनिक और निजी क्षेत्रों के हितधारकों, हमारे विभिन्न ग्राहकों, शुभचिंतकों और मीडिया को भी धन्यवाद देता हूं जिन्होंने सीएसआईआर-एनआईआईएसटी को एक जीवंत संगठन के रूप में बदलने में योगदान दिया है। हमारा प्रयास रहेगा कि हम ज्ञान सृजन के साथ-साथ उच्च गुणवत्ता वाले बुनियादी और ट्रान्स्लेशनल अनुसंधान के माध्यम से राष्ट्र निर्माण के लिए प्रतिबद्ध रहें। हमारी गतिविधियों में पूरे दिल से समर्थन देने के लिए डीजीसीएसआईआर, सीएसआईआर- मुख्यालय और आरसी सदस्य विशेष प्रशंसा के पात्र हैं।

**ए अजयघोष**

CSIR-NIIST

# FOREWORD

I'm indeed privileged to present the Annual Report of CSIR-NIIST for the period 2020-21, which details the significant contributions made by CSIR-NIIST on frontier areas of interdisciplinary research. Despite the setbacks caused by the pandemic and other adversities and restrictions round the year, CSIR-NIIST continued to perform well as in the previous years and accomplished several important milestones and received many accolades. CSIR-NIIST of course had the strong financial backing from CSIR Headquarters and other stake holders including Central and State Governments, public and private sector, industries and academia. I thank all of them for their kind support and cooperation.

CSIR-NIIST joined the fight against COVID along with other CSIR laboratories and was also a part of CSIR's strategic group initiative to develop new therapies including the repurpose of drugs for COVID-19. We could develop viable and cost effective synthetic strategies for three potent drug candidates; Galidesivir (BioCryst Pharmaceuticals), Nitazoxanide (Romark Laboratories) and EIDD 1931 & 2801 (Emory University). In order to help the local administration and public in general, CSIR-NIIST developed the products such as, Touch-Free Automatic Hand Sanitizer Dispenser (Indoor & Outdoor), Air sanitizer, UV-Clean Disinfecting Unit, Reusable Stopgap Face Mask with integrated self-disinfecting membrane etc., during the initial days of the pandemic. All these technologies were transferred to MSMEs.

A major breakthrough contribution of CSIR-NIIST during the pandemic is a technology developed for the safe handling and disposal of pathogenic hospital wastes, which is licensed to an industry. Another major industrially and socially relevant major contribution of CSIR-NIIST during the period is a technology developed to replace one time used plastic cutleries such as plates, cups, spoons etc with biodegradable agri waste. This technology has been licensed to a few industries. Further development on this technology is under progress.

During the period under report we also had a significant number of grant –in-aid projects supported by various funding agencies and line Ministries. The Institute also has projects under various prestigious bilateral programmes namely; Indo-UK Grant Challenge, Indo-Norden, Indo-Australian Strategic Research fund project, Indo-French Centre for the Promotion of Advances Research (CEFIPRA), Indo-German and these are under various stages of execution. CSIR-NIIST bagged many major projects from State government organizations.

CSIR-NIIST bagged CSIR-Technology Award for the best innovation for the year 2020 for developing the know-how in fabricating Raman spectrometers. Our scientists have won several recognitions including the CSIR Young Scientist Award, Kerala State Science Technology and Environment Award etc. Our academic skill development and outreach programs have made significant contribution to the progress of science and societal upliftment.

I take this opportunity to thank one and all of CSIR-NIIST who had contributed to the progress of the Institute through their dedicated support. I also thank CSIR, Central and State Governments, stake holders from Public and Private sectors, our various clients, well-wishers and media who have all contributed in transforming CSIR-NIIST into a vibrant organization. It will be our endeavor to remain committed to the Nation building through high quality basic and translational research along with knowledge generation. A special word of appreciation to DGCSIR, CSIR-Head Quarters and RC members for their wholehearted support to our activities.

**A. Ajayaghosh**

# महत्वपूर्ण उपलब्धियां 2020 - 2021

2020-21 की अवधि के दौरान, सीएसआईआर-एनआईआईएसटी ने केंद्र, राज्य सरकार की एजेंसियों, शैक्षणिक संस्थानों, सार्वजनिक और निजी क्षेत्रों के हितधारकों से महत्वपूर्ण निवेश के साथ वैज्ञानिक, तकनीकी और जनशक्ति विकास में निरंतर वृद्धि हासिल करना जारी रखा। औद्योगिक, निजी और सार्वजनिक क्षेत्रों और प्रौद्योगिकी हस्तांतरण से जुड़े नए सहयोगों में वृद्धि ने बाहरी स्रोतों से राजस्व उत्पन्न करने में पर्याप्त वृद्धि किया है। रिपोर्टिंग अवधि के दौरान सीएसआईआर से वित्तीय सहायता के साथ-साथ बाहरी फंडिंग में लगातार वृद्धि ने सीएसआईआर-एनआईआईएसटी को उच्च गुणवत्ता वाले प्रकाशनों के साथ-साथ ट्रांसलेशनल अत्याधुनिक अनुसंधान और प्रौद्योगिकी विकास पर ध्यान केंद्रित करने में मदद की है।

2020-21 की अवधि के दौरान विभिन्न फंडिंग एजेंसियों द्वारा वित्त पोषित 148 परियोजनाएं थीं। इस साल में एनसीपी (आला बनाने वाली परियोजनाएं), एफबीआर (फोकस्ड बेसिक रिसर्च), एफटीटी (फास्ट ट्रैक ट्रांसलेशनल), एफटीसी (फास्ट ट्रैक व्यावसायीकरण), और मिशन मोड योजनाओं के तहत सीएसआईआर से 23 परियोजनाओं की सफल शुरुआत को निम्नलिखित विषयों के तहत चिह्नित किया है: 1. खनन, खनिज, धातु और सामग्री 2. रसायन (चमड़े और पेट्रोकेमिकल सहित) 3. ऊर्जा (पारंपरिक और गैर-पारंपरिक) और ऊर्जा उपकरण 4. पारिस्थितिकी, पर्यावरण, पृथ्वी विज्ञान और जल 5. कृषि, पोषण और जैव प्रौद्योगिकी और 6. स्वास्थ्य देखभाल। सीएसआईआर-एनआईआईएसटी ने ग्यारह प्रौद्योगिकी हस्तांतरण और अच्छी संख्या में निजी उद्योग के साथ अनुसंधान एवं विकास सहयोग समझौते किए है।

सीएसआईआर-एनआईआईएसटी एक एनएबीईटी मान्यता प्राप्त, श्रेणी ए सलाहकार संगठन है, जिसके दो क्षेत्रों में यानी 1) खनन और 2) पर्यावरण प्रभाव आकलन अध्ययन (ईआईए) करने के लिए बंदरगाह में मान्यता है। परियोजनाओं की वैधानिक मंजूरी के लिए अनिवार्य ईआईए सेवाओं का उपयोग सरकारी और निजी क्षेत्र द्वारा किया जाता है। सीएसआईआर-एनआईआईएसटी की परीक्षण और विश्लेषण प्रयोगशाला सुविधा को एनएबीएल द्वारा आईएसओ/आईईसी 17025: 2005 के अनुसार पानी, अपशिष्ट जल, डाइऑक्सिन, फुरान और पॉली क्लोरीनेटेड बाइफिनाइल्स (पीसीबी) के विश्लेषण के लिए मान्यता प्राप्त है। इसके अलावा, पर्यावरण, वन और जलवायु परिवर्तन मंत्रालय (एमओईएफसीसी), भारत सरकार द्वारा पर्यावरण मंजूरी के लिए डाइऑक्सिन विश्लेषण के लिए रेफरल प्रयोगशाला के रूप में सीएसआईआर-एनआईआईएसटी को सिफारिश की गई है।

वर्ष 2020-21 में कोविड-19 महामारी का प्रकोप और प्रसार के कारण सदी की सबसे चुनौतीपूर्ण स्थिति देखी गई। सीएसआईआर ने कोविड-19 से संबंधित गतिविधियों को कम करने के लिए 5 कार्यक्षेत्रों की पहचान की, अर्थात् 1. डिजिटल और आणविक निगरानी 2. तेजी से और किफायती निदान दवाओं और नई दवाओं के पुनर्प्रयोजन सहित नए उपचारों का विकास 4. अस्पताल सहायक उपकरण 5. आपूर्ति श्रृंखला और रसद। सीएसआईआर-एनआईआईएसटी भी अन्य सीएसआईआर प्रयोगशालाओं के साथ कोविड से युद्ध लड़ने में तुरंत उठ खड़े हुए। इसके अलावा, एनआईआईएसटी सीएसआईआर की रणनीतिक समूह पहल का एक हिस्सा था, जिसमें कोविड-19 के लिए दवाओं के पुनर्प्रयोजन सहित नए उपचार विकसित किए गए थे। सीएसआईआर-एनआईआईएसटी तीन शक्तिशाली दवा उम्मीदवारों के लिए व्यवहार्य और लागत प्रभावी सिंथेटिक रणनीति विकसित कर रहा है; गैलीडेसिविर (बायोक्रिस्ट फार्मास्युटिकल्स), नाइटाज़ॉक्सानाइड (रोमार्क लेबोरेटरीज), और ईआईडीडी 1931 और 2801 (एमोरी यूनिवर्सिटी)।

सीएसआईआर-एनआईआईएसटी ने इम्युनिटी बूस्टर, स्मार्ट टच-फ्री स्वयंगतिशील हैंड सैनिटाइज़र डिस्पेंसर (भीतर और बाहर), एयर सैनिटाइजर, यूवी-क्लीन डिसइंफेक्टिंग यूनिट, एकीकृत स्व-कीटाणुनाशक झिल्ली के साथ पुन: प्रयोज्य स्टॉपगैप फेस मास्क के क्षेत्र में सक्रिय रूप से उत्पादों और प्रक्रियाओं को वितरित किया और विभिन्न उद्योगों को प्रौद्योगिकियों को स्थानांतरित किया। कोविड 19 को कम करने वाली गतिविधियों के संबंध में विकसित अन्य प्रौद्योगिकियां कुशल रोगाणुरोधी सूत्रीकरण, पुन: प्रयोज्य पीपीई (मास्क / गाउन) के लिए सूती कपड़ों पर कोटिंग्स, प्राकृतिक उत्पाद-आधारित सेल्फ-सैनिटाइज़िंग कम्पोजिट कोटिंग्स - अयूरकोट, नॉवेल सॉलिडिफिकेशन/जेलेशन सिस्टम कीटाणुनाशक गुण, प्राकृतिक उत्पाद आधारित स्टीम इनहेलर ड्रॉप्स और हर्बल सैनिटाइज़र हैं।

संस्थान के पास एक पूर्ण उन्नत विश्लेषणात्मक सुविधा है जिसका उपयोग उच्च गुणवत्ता वाले बुनियादी और अनुवाद अनुसंधान के लिए पूरी क्षमता के साथ किया जा रहा है, साथ ही उद्योग और शिक्षाविदों से नमूनों के परीक्षण से राजस्व उत्पन्न किया जा रहा है। सीएसआईआर-एनआईआईएसटी ने सीएसआईआर कौशल पहल कार्यक्रम के माध्यम से विभिन्न खंडों के तहत अल्पकालिक पाठ्यक्रम शुरू किए। संस्थान उच्च गुणवत्ता वाले मानव संसाधनों का पोषण करना जारी रखता है, हर साल 30 से अधिक पीएचडी प्रदान करता है। एनआईआईएसटी उच्च प्रभाव कारक पत्रिकाओं में हर साल 200 से अधिक पत्र प्रकाशित करता है और इसका एक मजबूत पेटेंट पोर्टफोलियो है।

इस पृष्ठभूमि के खिलाफ, 2020-2021 की वार्षिक रिपोर्ट सीएसआईआर-एनआईआईएसटी द्वारा किए गए नवाचार, उपलब्धियों, प्रगति और प्रभाव को सीमांत अनुसंधान के गतिशील रूप से परिवर्तनशील और चुनौतीपूर्ण अंत:विषय वातावरण में अपनी योजनाओं के साथ संरेखित करती है। यह सभी और अधिक रोमांचक कहानियां वार्षिक रिपोर्ट 2020-21 में सामने आई हैं।

# Significant Achievements 2020-2021

During the period 2020-21, CSIR-NIIST continued to achieve sustained growth on Scientific, Technological and manpower development with significant investment from stake holders comprising of Central, State Government agencies, Educational institutes, public and private sectors. The upsurge in new collaborations involving industrial, private and public sectors and technology transfers translated to a substantial increase in generating revenue from external sources. The funding support from CSIR during the reporting period along with a steady rise in external funding, have helped CSIR-NIIST focus on translational cutting edge research and technology development along with high-quality publications.

There were 148 projects funded by various funding agencies during the period 2020-21. The year also marked the successful initiation of 23 projects from CSIR under NCP (Niche creating projects), FBR (Focused Basic Research), FTT (Fast Track Translational), FTC (Fast Track Commercialization) and mission mode schemes under the following themes: 1. Mining, Minerals, Metals and Materials 2. Chemicals (including Leather and Petrochemicals) 3. Energy (Conventional and non-conventional) and Energy devices 4. Ecology, Environment, Earth Sciences and Water 5. Agri. Nutrition and Biotechnology and 6. Healthcare. There were eleven technology transfers and a good number of private industries with which CSIR-NIIST entered into R & D collaboration agreements.

CSIR-NIIST is a NABET accredited, Category A consultant organisation with accreditation in two areas Viz., The 1) Mining and 2) Ports & Harbour for carrying out Environment Impact Assessment Studies (EIA). The mandatory EIA services are used by government and private sector for statutory clearance of projects. The Testing and Analysis Laboratory facility of CSIR-NIIST is accredited by NABL as per ISO/IEC 17025: 2005 for analysis of Water, Waste water, Dioxins, Furans and Poly Chlorinated Biphenyls (PCBs). In addition, CSIR-NIIST has been recommended by Ministry of Environment, Forest and Climate Change (MoEFCC), Govt. of India as a referral laboratory for Dioxin analysis for environmental clearances.

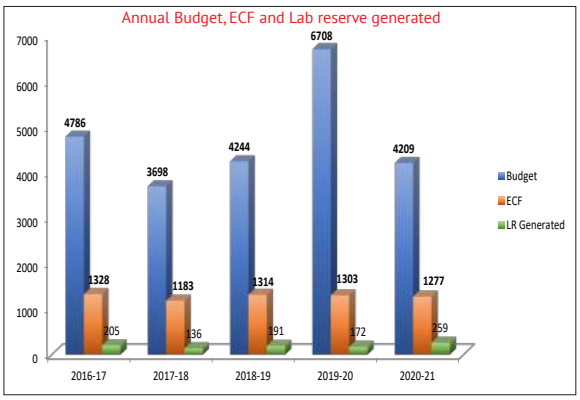
The year 2020-21 witnessed the century's most challenging situation as there was outbreak and spread of covid-19 pandemic. CSIR identified 5 verticals for mitigating COVID 19 related activities namely 1. Digital and Molecular Surveillance 2. Rapid and Economical Diagnosis Development of new therapies, including repurposing of drugs and new Drugs 4. Hospital assistive devices 5. Supply chain and logistics. CSIR-NIIST immediately rose up to the occasion in fighting the war with COVID along with other CSIR laboratories. Also NIIST was a part of CSIR's strategic group initiative to develop new therapies including the repurpose of drugs for COVID-19, CSIR-NIIST is developing viable and cost effective synthetic strategies for three potent drug candidates; Galidesivir, Nitazoxanide and EIDD 1931 & 2801.

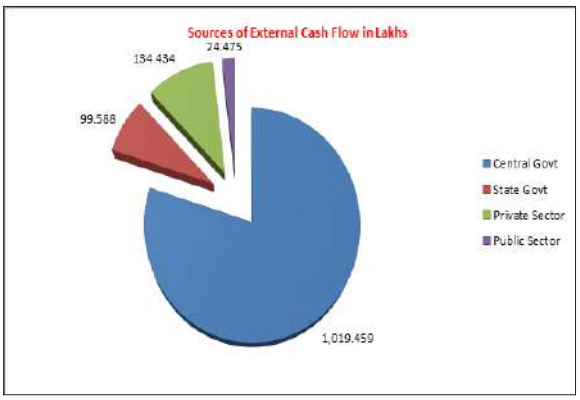
CSIR-NIIST actively delivered products and processes in the area of Immunity boosters, Smart Touch-Free Automatic Hand Sanitizer Dispenser (Indoor & Outdoor), Air Sanitizer, UV-Clean Disinfecting Unit, Reusable Stopgap Face Mask with integrated self-disinfecting membrane and transferred the technologies to various industries. Other technologies developed in relation to COVID 19 mitigating activities are Efficient Antimicrobial formulations, coatings on cotton fabrics for reusable PPE's (masks/gowns), Natural Product based Self-Sanitizing Composite Coatings – Ayurcoat, Novel solidification/ Gelation system disinfecting properties, Natural products based Steam inhaler drops and Herbal Sanitizer

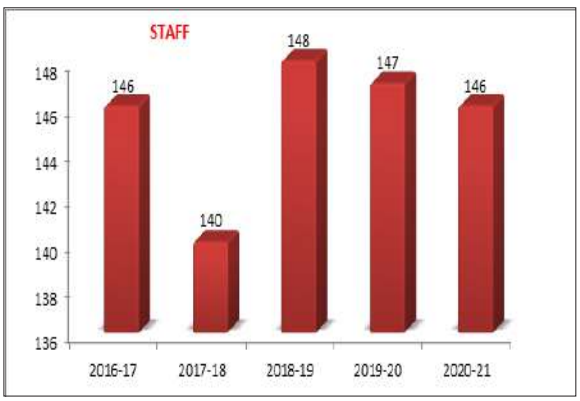
Institute has a full-fledged advanced analytical facility which is being utilized to the full capacity for high quality basic and translation research, besides generating revenue from testing of samples from industry and academia. CSIR-NIIST introduced short term courses under various segments through CSIR Skill Initiative programme. The Institute continues to nurture high quality human resources, awarding over 30 PhDs every year. NIIST publishes over 200 papers every year in high impact factor journals and has a robust patent portfolio.

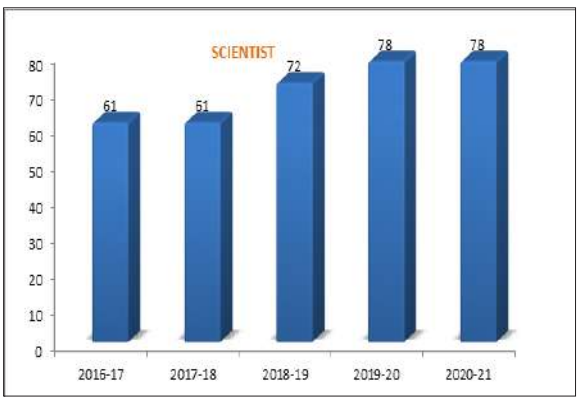
Against this backdrop, the Annual Report for the period 2020-2021 sets out the innovation, achievements, progress and impact made by CSIR-NIIST aligning with its plans in a dynamically mutating and challenging interdisciplinary environment of frontier research. All this and more exciting stories unfold in the Annual Report 2020-21

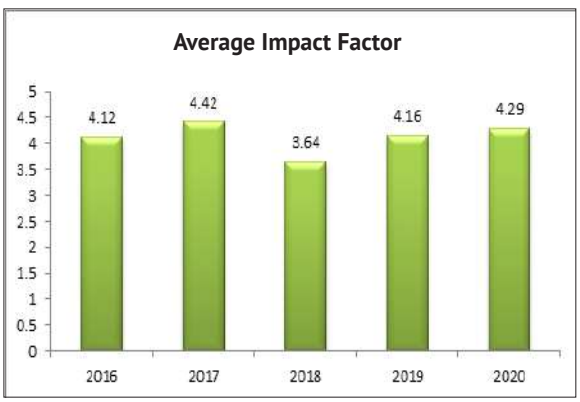
# Resource Base Output Statistics 2020-2021

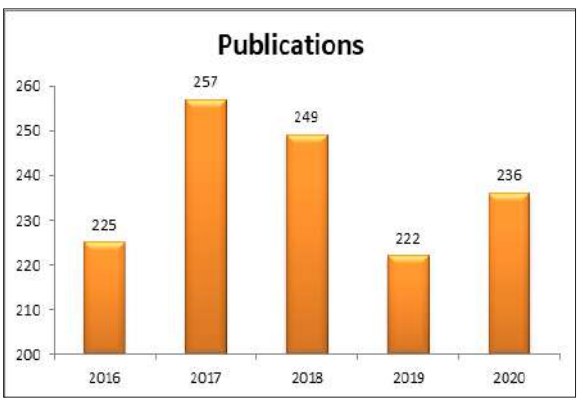


# Glimpse of Technology Transfer and Commercialization Initiatives

Agroprocessing and Technology Division is engaged in Technological interventions handholding with industries, agri entrepreneurs and various other stakeholders. During last year, the Division was successful in transferring the developed technologies and setting up decentralized processing units as part of technology commercialization in the area of post harvest value addition of various agri crops. Some of the technologies developed by the Division were also shortlisted as socially relevant CSIR rural Technologies in Unnat Bharath Abhiyaan.

The list of Technology Transfers / Technolgy Commercialization during last year are:

1. Biodegradable tableware from wheat residues, Aura Exim, Ernakulam, Kerala.
2. Biodegradable tableware from rice residues, Marikar Green Earth Pvt Ltd, Kerala.
3. Establishment of 500 kg dehydration unit, Horticorp, Govt of Kerala.
4. Ready to cook products from raw banana, Moza Organics, Kochi.
5. Formulation of Trikatu Syrup and scale-up, Trivandrum-district Palm Products Development Co-operative Federation Ltd, Kerala.

## Development of biodegradable tableware from agro residues

Nowadays, the inevitable usage of non-degradable, single-use plastic-based tableware such as crockeries, glasses and cutleries have created huge environmental pollution due to its adverse effect. The extensive usage and accumulation of non-degradable plastics resulted in chocking of water bodies and subsequent environmental degradation.

In this regard, Scientists from CSIR-NIIST have taken up the task of developing biodegradable products like plates, cups etc from various agricultural residues and by-products. The objective is to present a viable cost-effective technology for establishment of the agro-waste based biodegradable cutlery and plates manufacturing unit and for ensuring a agro culture production enactment in the region and also replacement of single-use plastic in India by agro-waste-based biodegradables cutleries and plates.

The novel technology developed by CSIR-NIIST involves an integrated extrusion-compression molding process for the production of cost effective biodegradable products such as plates, bowls, spoons, forks etc., The developed product shows good heat resistance, microwave friendly, biodegradable and possesses good water holding capacities. This technology has been successfully transferred to two companies so far.

## DEVELOPED PRODUCTS


### Establishment of decentralized processing units for fruits and vegetables value addition

The technologies developed for the post-harvest value addition of indigenous fruits and vegetables is transferred to various Government, self-help groups and farmers consortium in order to prevent the post-harvest loss and to support the local farmers groups. A turnkey execution of 500 kg per day processing unit for dehydration, preservation and value addition of regional fruits & vegetables was successfully completed for HORTICORP, Govt of Kerala . A second project owned by HORTICORP aimed for dehydration of fruits and vegetables and for developing honey based fruit preserves, is under implementation . Another project for setting up processing units for value added products from regionally grown agri-crops at Ranni village, Pathanamthitta, Kerala is in progress.


## Ready to cook products from banana grits

CSIR-NIIST introduces a novel nendran grit to the consumers, which can become a boon to nendran cultivating farmers. Since, Nendran growing farmers have often been affected by the fall of prices, value addition of raw nendran becomes essential. Years of research on nendran helped CSIR-NIIST to open a new segment of application to the starch-rich vegetable. Nendran is generally consumed in ripe form by Keralites, and used as an ingredient in avial or thoran, typical Kerala dishes. There is also the practice of using it as a first weaning food for infants. For the first time, a new concept of utilizing the raw nendran is being introduced as a breakfast product, a mid-day brunch, an evening snack or as a main course dinner, which is named "banana grit." The concept was introduced to utilize the presence of resistant starch in bananas, which is reported to improve gut health. Hence, the dishes prepared with banana grit and its byproduct banana powder inclines to the new focus on gut health, which the scientific community is widely discussing now to maintain health and wellbeing. Banana grit mixed with green gram is another variant. This blending gives a combination of carbohydrates and protein with other micronutrients. This is also an attempt to utilize the local ingredients for healthy, sustainable living.

After the inception of farming 10,000 years ago, the human population depends on cereals, dairy, and meat products as the chief energy source. By 2050, the best diet to feed people is a question that needs to be carefully addressed. There are many vegetables and tubers, which can be considered as an alternative source. Raw nendran is one of them. The cooking time for the products is only 3-4 minutes. The process developed retains carotenoids and resistant starch. Supplementing the product with green gram will provide a dish balanced with healthy carbohydrates, proteins, micronutrients, and phytochemicals. The inventive/innovation step is the utilization of vegetable starch to plan a novel diet. This will help shift focus from cereal crops to vegetables as an alternative source of energy.

Consumers can make a variety of dishes with banana grit and banana powder. Grit can be used for making upma, and it can be mixed with banana powder in a 1:1 ratio for making porridge with milk or coconut milk or coconut itself. The banana powder can be used in cake and bread preparation, along with refined wheat flour. The porridge from banana can be taken as a daily health drink. Combination of banana grit and green gram can be made as upma, where it becomes an ideal diet with carbohydrate, protein and other micronutrients. To make upma more wholesome, consumers can garnish it with any vegetable of their choice. Institute foresees a vast market for the products and is happy to introduce it at the right time, when the farmers are looking for alternatives to get a fixed price for nendran. The know-how is now transferred to M/s. MOZA ORGANIC, Cochin and is expected to be in the market very soon.

Technology Transfer of developed Product

Formulated Products

## NIIST Onsite Wastewater Treatment Technology (NOWA); Field installation, Technology transfer, and Process scale-up.


The NIIST Onsite Wastewater treatment technology (NOWA) is an innovative system developed for treating and recovering resources from organic-rich wastewater. The major highlights of the system include compact size (0.02 ft2/L), modular (pre-fabricated unit) with minimum civil work at the site, recover reuse quality water and bioenergy and organic manure, free from sludge disposal difficulties, less capital and operational cost, and the unit can be retrofitted to existing infrastructure. This unit will be ideal for treating discharges from small establishments like hotels, restaurants, catering units, canteens, agro-based MSMEs, etc.

### Modular onsite wastewater treatment unit developed by NIIST (NOWA)

Recently, the performance of NOWA was tested under field conditions. It was installed at Jaihari food products Pvt. Ltd. in Adoor, Pathanamthitta dist., Kerala. The industry discharges daily around 2000 L wastewater (COD ~3.5 g/L, pH 4.5, TS-3.3 g/L, NH4-N-9.2 mg/L, TP-12.6 mg/L). The wastewater was treated continuously with NOWA for nearly one year and recovered reuse quality water (for gardening) and biogas (~4 M3/D).


NOWA unit installed in a medium scale industry recovering reuse quality water and biogas from wastewater.

A patent (product and process) was filed for NOWA, and the know-how for NOWA was transferred to M/s AB Tech Engineering Solutions, Kerala.

Technology transfer of NOWA to M/s AB Tech Engineering Solutions, Kerala

The NOWA technology was scaled up, and a 10 KLD unit was installed in the CSIR-NIIST campus for recovering water and biogas from the NIIST canteen wastewater. The modular unit is fabricated in FRP, and it is presently under working condition.


NOWA unit installed in NIIST campus treating 10 KLD wastewater from NIIST canteen.

# Technologies for Covid mitigation

## Trikatu syrup - formulation and scale-up

We have successfully developed two spice enriched formulations under the GAP project entitled "Can enrichment of palm neera syrup cause Immunomodulation?" funded by KSCSTE, Kerala, India. Palm sap enriched syrups were tested to draw the immunomodulatory effect they had on selectively immune compromised/challenged animals. In the context of the COVID-19 pandemic, the honorable Prime Minister urged the use of Ayurveda and traditional medicine for immune boosting. Trikatu is used in Ayurveda to treat respiratory tract infections, asthma, immunomodulation, gastric and abdominal disorders, diarrhea, asthma, cough, and bronchitis. It is also used to prepare several classical Ayurveda formulations used in the treatment of common cough and cold, respiratory disorders and digestive disorders. Trikatu is also reported to increase the bioavailability of nutrients, herbal, and pharmaceutical drugs. With the backup of the traditional knowledge and preliminary findings from our group, during COVID 19 lockdown in April 2020, we took the initiative to transfer the Trikatu syrup Know-how on a non-exclusive basis to Trivandrum-district Palm Products Development Co-operative Federation Ltd. an MSME from Parassala.

## NIIST Air Disinfection system (NIIST Air Sanitizer)

Many infectious diseases of bacterial, fungal and viral origin are transmitted through the air. Micron size aerosols containing human secretions from diseased individuals can transmit the disease to many people around. It is reported that these aerosols can travel up to 12 feet, and many pathogens (including the COVID-19) can stay alive in these aerosols for up to a few hours. These aerosols can gradually get deposited onto surfaces leading to a source of contact transmission. In the present scenario of COVID-19, the latest studies have revealed aerosol-mediated spreading of the disease as a matter of great concern. CSIR-NIIST has developed an air disinfection system called NIIST Air Sanitizer, a compact stand-alone system that takes air and exposes them to filters and UVC (254 nm) radiations that will destroy associated aerosol pathogens. This unit will be most ideal for places like closed rooms, cabins, washroom areas, clinics, hospital wards, etc. The system is tested against bacteria and externally (Sree Chitra Institute, Trivandrum) validated for its efficiency. The know-how for the NIIST Air Sanitizer already licensed to two companies, and installations were done at major places like Doordarsan Kendra, Thiruvananthapuram. RBI Thiruvananthapuram, etc.

## AUTOMATIC HAND SANITIZER DISPENSER

Automatic hand sanitizer dispenser is a sensor-based device for dispensing the sanitizer to avoid any physical contact. These IR-sensor-based technology detect the proximity and 0.5 to 1 mL sanitizer solution will be sprayed/


NIIST Air Disinfection system (NIIST Air Sanitizer)

Licensing of NIIST Air Sanitizer

dispensed onto the detected surface. The system is compact, which can have a capacity of 500 ml to 1,000 ml and can be wall-mounted or table topped. It can be easily installed in places where a regular 2/3-pin power plug is available. Knowhow of the automatic hand sanitizer dispenser is transferred to Cabeio Technologies, Thiruvananthapuram.


Automatic hand sanitizer dispenser developed at NIIST

## NIIST UV-CLEAN disinfecting unit (λ- Flashbox)

The developed NIIST UV-CLEAN disinfecting unit is a non-chemical approach to pathogen disinfection. UV-CLEAN unit uses UV-C light (λ =254 nm) which has germicidal effects to destroy microorganisms, including bacteria, virus, protist, and fungus/mold (effective UVC dose > 80%). The UV-C light penetrates the cell and inactivates micro-organisms by damaging nucleic acids. UV-C attacks the DNA of a cell, rendering it unable to reproduce or spread and die. UV-CLEAN unit can be used for disinfection of commonly used accessories such as electronic gadgets (mobile, watches, wireless gadgets), stationery items, metallic items, paper, plastic/ leather accessories (wallets, currency, key, spectacles, bags etc.), PPEs (musk, gloves, etc.) and much more. UV-CLEAN unit kills 99.9 % of pathogens on high-touch surfaces within a short period of time (~ 5 min) without using any chemicals and thus not causing any secondary pollution. UV-CLEAN unit is customized with a digital controller that auto-powers the unit while a scheduled cleaning cycle is in progress. The unit gets powers off when the cleaning cycle is discontinued. Installing UV-CLEAN units is simple, low-maintenance, and easy for fast deployment in the present coronavirus crisis. The know-how license for the NIIST UV-CLEAN disinfecting unit is transferred to M/S. Panch-Tatva Technologists & Services, Maharashtra, India.

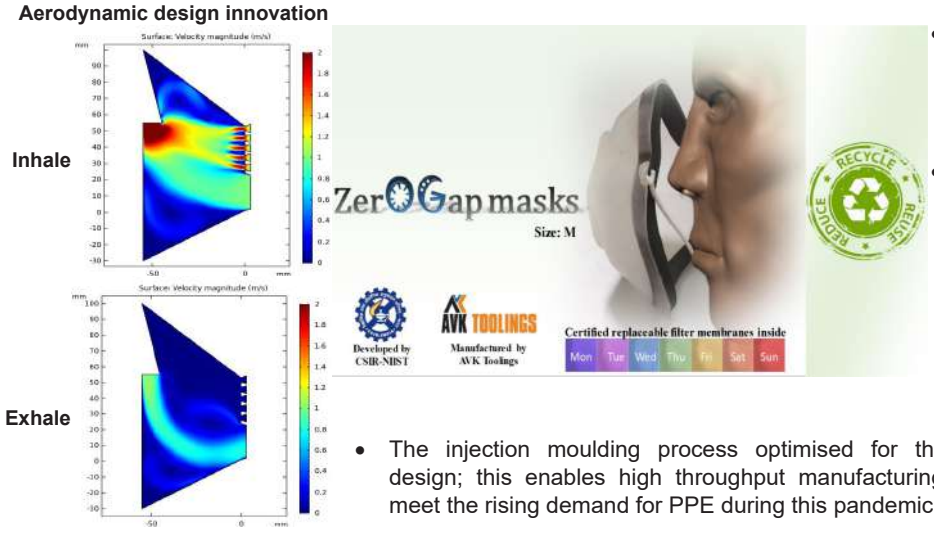
NIIST UV-Clean disinfecting unit

## Smart, touch-free hand-sanitizer dispenser ("Palm Safe")

A touch-free, smart hand sanitizer dispenser ("Palm Safe") that can automatically dispense a pre-set amount of sanitizing liquid (1-10 ml) to the user has been designed, fabricated and demonstrated. The device is very useful in controlling the transmission of infectious diseases such as Covid-19 by avoiding cross-contamination by operating in touch-free mode. The smart sensor technology along with the novel 'line of sight' design enables the device to use in the indoor as well as outdoor applications by avoiding false triggering. The wire-less operation feature is added to the latest version (Version-2) of 'Palm Safe', in which the device operates with a 9 V rechargeable battery. It can dispense various gels, foams or soap solution up to 1 L and have refilling option. The technology has been licensed to M/s. Tachlog Pvt. Ltd, Thiruvananthapuram on Non-exclusive basis at the royalty of 15% on 28th May 2020. The hundreds of units have been sold by the firm (M/s. Tachlog Pvt. Ltd.) in the market and CSIR-NIIST is regularly earning the royalty out of it. (Listed in the 'CSIR Technologies or igation' by t


Photograph of "Palm Safe" and technology licensing event.

## Aerodynamically designed Stopgap Face Mask (SFM) with Replaceable Membranes




- Aerodynamic design innovation in the SFM increase the average airflow velocity ~ 55%
- SFM reduce the usage of non-woven polymer filter membrane by an order of 1/4th when compared with existing N95 respirators
- The injection moulding process optimised for the developed design; this enables high throughput manufacturing of SFM to meet the rising demand for PPE during this pandemic situation

1/3

02-03-2022

# DIVISIONAL DETAILS

| | |
|---|---|
| Name | Agro Processing and Technology Division |
| Expertise | Post-harvest technologies, Validation studies and Biological Evaluation |
| Number of scientist | 12 |
| Number of Technical staff | 2 |
| Number of students | 24 |
| Facilities | Pilot scale level dryers, Evaporators, GCMS, LCMS, HPLC, Cell culture lab, Real-time PCR, FACS. |
| No. of ongoing projects during 20-21 (GAP, SSP, CNP,TSP, In-house) | 12 |
| No. of publications (SCI+non SCI) during 20-21 | 46 |
| No. of Ph. D. awarded during 20-21 | 6 |

# कृषि प्रसंस्करण तथा प्रौद्योगिकी प्रभाग

कृषि प्रसंस्करण और प्रौद्योगिकी प्रभाग एक बहुआयामी केंद्र है, जहां विभिन्न कृषि फसलों की कटाई के बाद मूल्यवर्धन में प्रौद्योगिकी विकास और व्यावसायीकरण, प्रसंस्करण इकाइयों की स्थापना, प्रक्रिया संबंधी मुद्दों के लिए प्रौद्योगिकी समाधान की पेशकश करने वाले उद्योगों के साथ सहयोग पर मुख्य ध्यान दिया जाता है। यह प्रभाग न्यूट्रास्यूटिकल्स, कार्यात्मक खाद्य पदार्थ, आहार पूरक, फाइटोफार्मास्युटिकल्स, जैव-उर्वरक और जैव कीटनाशकों, बायोडिग्रेडेबल कटलरी बनाने के लिए प्रक्रिया और उत्पाद विकास अध्ययनों पर भी ध्यान केंद्रित करता है। प्रभाग उत्पादों के वैज्ञानिक सत्यापन, रासायनिक मूल्यांकन, शेल्फ लाइफ और भंडारण अध्ययन आदि में भी विशेषज्ञ है।

विभाजन के प्रमुख क्षेत्रों में से एक वैज्ञानिक और तकनीकी हस्तक्षेप और नवाचार के माध्यम से अपनी उपज का उच्च रिटर्न सुनिश्चित करके किसानों के सामान्य कल्याण में सुधार करना है। इस प्रभाग में कृषि-प्रसंस्करण और खाद्य प्रौद्योगिकी के क्षेत्र में प्रायोगिक संयंत्र सुविधाएं और प्रयोगशालाएं हैं। एपीटीडी समृद्ध जैव विविधता की खोज करने वाले पोषण और हर्बल उत्पादों के विकास और सत्यापन में भी शामिल है, और साथ ही इस क्षेत्र में प्रचुर पारंपरिक ज्ञान की उपलब्धता और प्रभाग में उपलब्ध विशेषज्ञ है। एंडोफाइटिक रोगाणुओं से जैव-उर्वरक और जैव-कीटनाशकों का विकास, मसालों और फलों से सक्रिय अवयवों को अलग करने के लिए औद्योगिक रूप से महत्वपूर्ण कई एंजाइमों का उत्पादन करने में सक्षम नोवेल स्वदेशी माइक्रोबियल उपभेदों का खनन भी सुविधा के क्षेत्रों में से एक है।

यह प्रभाग मधुमेह, हृदय, कैंसर और गैर-मादक वसायुक्त यकृत रोगों के लिए यौगिकों की इन विट्रो जांच और तंत्र-आधारित अध्ययनों की सुविधाओं से भी सुसज्जित है। पर्यावरण के अनुकूल और बायोडिग्रेडेबल कटलरी के विकास के लिए कृषि-अपशिष्ट का उपयोग शुरू किया गया है और प्रौद्योगिकी को सफलतापूर्वक दो उद्योगों में स्थानांतरित कर दिया गया है। यह प्रभाग पारस्परिक लाभ के लिए उत्पाद विकास और प्रौद्योगिकी हस्तांतरण के लिए विभिन्न एमएसएमई के साथ भी काम करता है। प्रभाग में उद्योगों और शैक्षणिक संस्थानों की जरूरतों को पूरा करने खाद्य विज्ञान और जैव चिकित्सा विज्ञान के क्षेत्र में मानव संसाधन विकास के लिए शैक्षणिक कार्यक्रम (पीएचडी) हैं।

**अनुसंधान की मुख्य विशेषताएं**

- कृषि उत्पाद और खाद्य प्रसंस्करण के क्षेत्र में कटाई उपरांत प्रौद्योगिकी और प्रौद्योगिकी व्यावसायीकरण गतिविधियां।
- उत्पाद और प्रक्रिया विकास, प्रौद्योगिकी उन्नयन, और स्वास्थ्य लाभों के वैज्ञानिक सत्यापन के लिए अनुसंधान एवं विकास, उद्योग इंटरफेस कार्यक्रम (प्रायोजित और परामर्श)।
- पर्यावरण के अनुकूल और बायोडिग्रेडेबल कटलरी के विकास के लिए कृषि अपशिष्ट/अवशेषों का उपयोग।
- विभिन्न मूल्य वर्धित कार्यक्रमों के माध्यम से गुड़ प्रसंस्करण इकाइयों, पामनीरा प्रसंस्करण इकाइयों जैसे पारंपरिक क्षेत्रों को पुनर्जीवित करने के लिए गतिविधियाँ जो जैव विविधता को बनाए रखने और ग्रामीण आबादी के लिए रोजगार प्रदान करने में मदद करती हैं।
- पारंपरिक अनाज और कम उपयोग वाले फलों और सब्जियों से मूल्य वर्धित उत्पाद।
- पोषण और जैव सक्रिय घटकों के लिए गैर-डेयरी पेय और वितरण प्रणाली
- चयापचय बढ़ाने में कृषि/खाद्य प्रसंस्करण व्यय सामग्री से आहार फाइबर
- चयापचय संबंधी विकारों और कैंसर के खिलाफ जैव सक्रिय यौगिकों का औषधीय मूल्यांकन।
- प्राकृतिक उत्पादों के साथ ट्राइफेनिलफोस्फोनियम के संयुग्मन के माध्यम से माइटोकॉन्ड्रिया-लक्षित एंटीऑक्सिडेंट का विकास।
- कैंसर और आंत माइक्रोबायोम डिस्बिओसिस के खिलाफ आहार स्रोतों से एक्सोसोमल और गैर-एक्सोसोमल miRNAs की खोज।
- सूजन के खिलाफ और वनस्पति मांस अनुप्रयोगों के लिए शाकाहारी स्रोतों से बायोएक्टिव प्रोटीन और पेप्टाइड्स।
- खाद्य नैनोकणों (आहार एक्सोसोम और प्रोटीन नैनोकणों) के उपयोग से कैंसर के लिए दवा वितरण प्रणाली का विकास।
- आयुर्वेद में नियोजित विशिष्ट उपचार के नियमों के जैव रासायनिक, सेलुलर और आणविक स्तर के सत्यापन अध्ययन।

# Agro Processing &Technology Division

Agro Processing & Technology Division is a multifaceted center with main focus on Technology developement and commercialization in post harvest value addition of various agricrops, setting up of the processing units, handhold with industries offering technology solutions for process related issues. The Division also focus on process and product development studies for making nutraceuticals, functional foods, dietary supplements, phytopharmaceuticals, bio-fertilizers & bio pesticides, biodegradable cutleries. Division also has expertise in scientifc validation of the products, chemical evaluation, shelf life & storage studies etc,

One of the thrust area of division is improvement of general welfare of farmers by ensuring high returns of their produce via scientific and technological intervention and innovation. This division has pilot plant facilities and laboratories in the area of agro-processing and food technology. APTD is also involved in the development and validation of nutritional and herbal products exploring rich biodiversity, availability of abundant traditional knowledge in this region and available expertise in the division. The development of bio-fertilizers & bio-pesticides from entophytic microbes, mining of novel indigenous microbial strains capable of producing industrially important multiple enzymes for active ingredients isolation from spices and fruits are also one of the area of interest. This division is also equipped with facilities for in vitro screening of compounds and mechanism based studies for diabetes, cardiovascular, cancer and non-alcoholic fatty liver diseases. Utilization of agrowaste for development of eco-friendly and biodegradable cutleries has been initiated and the technology is successfully transferred to two industries. Division also work with various MSME for product development and technology transfer for mutual benefits. The division has academic programmes (Ph. D) for human resource development in the field of food science and biomedical sciences for meeting the needs of industries and academics institutes.

## Research Highlights

- Post-harvest technology and technology commercialization activities in the area of agro produces and food processing.
- R&D, Industry interface programs (sponsored & consultancy) for product and process development, technology up-gradation and scientific validation of health benefits.
- Utilization of agricultural wastes/residues for the development of eco-friendly and biodegradable cutleries.
- Activities for reviving traditional sectors like Jaggery processing units, palmneera processing units through various value addition programs which help in sustaining the biodiversity and providing employment for rural population.
- Value added products from traditional grains and underutilized fruits and vegetables.
- Non-dairy beverages and delivery systems for nutritional and bioactive components
- Dietary fibre from agro/food processing spent materials as metabolic enhancers
- Pharmacological evaluation of of bioactive compounds against metabolic disorders and cancer.
- Development of mitochondria targeted antioxidants through conjugation of triphenylphosphonium with natural products.
- Exploration of exosomal and non-exosomal miRNAs from dietary sources against cancer and gut microbiome dysbiosis.
- Bioactive proteins and peptides from vegetarian sources against inflammation and for vegetable meat applications.
- Development of drug delivery systems for cancer using edible nanoparticles (dietary exosomes and protein nanoparticles).
- Biochemical, cellular and molecular level validation studies of specific treatment regimens employed in Ayurveda.

## 1. Renewable energy for post-harvest technologies

CSIR NIIST has developed a dehumidified drying mechanism for the post-harvest processing of various agro produces for their shelf life enhancement. The process of dehumidification is done by refrigeration principles. Low humidity in the drying chamber ensures drying at controlled lower temperature and uniform distribution of air. The advantage of this drying technology is the retention of functional properties and retention of micro-nutrients & flavor in the material.

However, this model consumes more electricity in some cases eg: in the dehydration of fresh fruits, vegetables etc. having higher moisture & sugar content. Hence as an upgradation of the existing process is required and in the current proposal, we aim to integrate the dehumidified dryer with solar energy panels so that the energy cost can be reduced drastically and the usage of renewable energy resource can be utilized and promoted in commercial processing units. Detailed calculation of energy consumption, optimization of process parameters like temperature and time, scale-up and feasibility studies will also be done in this project. On the other hand, works have been started in the area of solar thermal energy systems too for cost-effective post harvest technology of agro produces.

Integrated rooftop model for solar dehumidified driers

## 2. Modernization of jaggery production units

Next to Brazil, India is the largest producer of sugar-cane in the world. Till a few decades back, the entire sugar-cane cultivated in India was primarily used for jaggery making. However, due to the introduction of modern sugar mills, jaggery production has been on decline. The current jaggery process involves crushing of sugarcane to obtain juice, skimming of juice using lime based clarifying agents, boiling and sun-drying


Preliminary studies

of syrup to obtain solid blocks of jaggery. Due to promotion of traditional products and MSME's in the agriculture sector, Jaggery market has huge potential and technological interventions in the area of Jaggery production become essential.

Under this initiative, the DST project has been sanctioned in the area of Jaggery process troubleshooting and optimization and works have been initiated to develop an alternative energy efficient process.

The proposed technology for jaggery production involves crushing of sugar-cane juice, ozonation for microbial reduction, addition of natural flocculants, boiling of juice in steamers and evaporators, tray drying of products and packaging.

The overall objective is to establish hygienic, efficient and scientific validated jaggery products.

## 3. Technology development and incubation activities for millets and herbs

A major developmental activity has been initiated for the benefit of agri entrepreneurs to nucleate their new product making ideas, where the technical support of the institute will be extended by sharing the infrastructure like pilot plant and analytical services and also providing the training . The project is sponsored by the Agriculture Department, Govt of Kerala. The major focus will be millet based products as functional foods and formulated products and extracts based on herbs and botanicals.

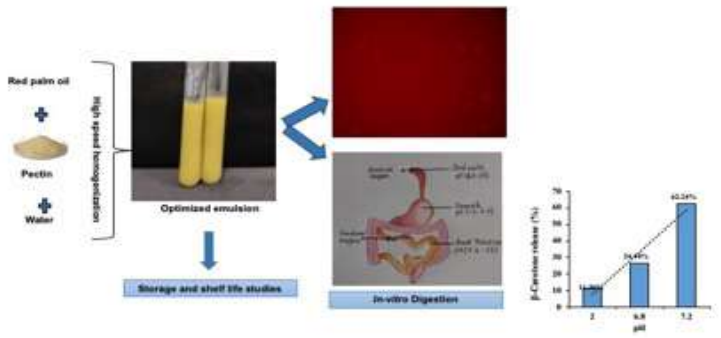
## 4. Industrial linkages for process/product development & technology upgradation

The divisional activities for strengthening the industrial linkages were successful and many industrial projects were envisaged during the year 2020-21 in connection with the process/ product development activities, technology/product fine tuning, quality assessment etc. Some of the ongoing industry linked programmes are:

1. Process development for instant rice and broken wheat for M/s. Manjilas Food Tech Pvt Ltd, Trissur, Kerala
2. Phytochemical profiling of biological samples (Sponsored by M/s Pankajakasthuri Herbals Pvt Ltd, M/s AVP Coimbatore)
3. Development/fine tuning of innovative products in Ayurvedic Sector through pilot scale optimization & quality evaluation (Sponsored by M/s Pankajakasthuri Herbals Pvt Ltd, M/s AVP Coimbatore)

## 5. Pectin as a pickering particles for emulsion stabilization

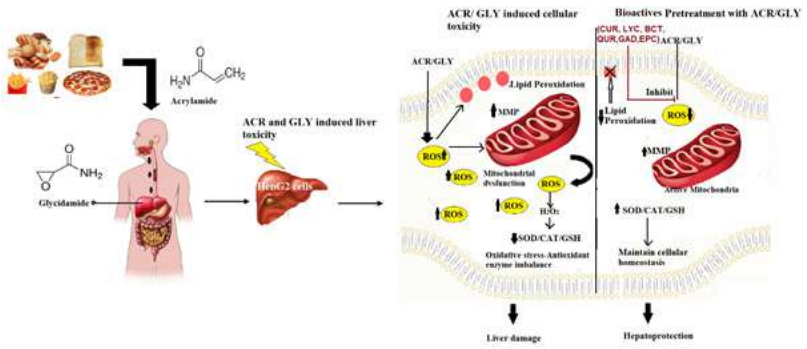
Pectin is gaining lot of importance in food industry owing to its functional properties and health benefits. The emulsion forming properties of pectin was investigated in a model system of o/w Pickering emulsion of RPO using Resonance Surface Methodology (RSM). Emulsion was characterized in terms of creaming index, particle size, zeta potential, thermogravimetry, FTIR & rheology. It was found that a stable emulsion (RPE) was formed with 3% pectin and 30% RPO a zeta potential of -32.5 mV. The emulsion was elastic in nature (G' > G") which was independent of the frequency. Micro structure of RPE demonstrated well dispersed oil droplets in the



continuous phase. The emulsion was found to yield a significant increase in gastrointestinal bioaccessibility of β-carotene. The emulsion was stable for 15 days at both ambient conditions (30 ±2 °C) and refrigerated storage (4 ±1 °C) conditions with negligible creaming index of 3.75 ± 0.1%. The work throws light into the potential of pectin as a Pickering agent for emulsions applications in food systems and as active carriers of nutritionally important and bioactive compounds.

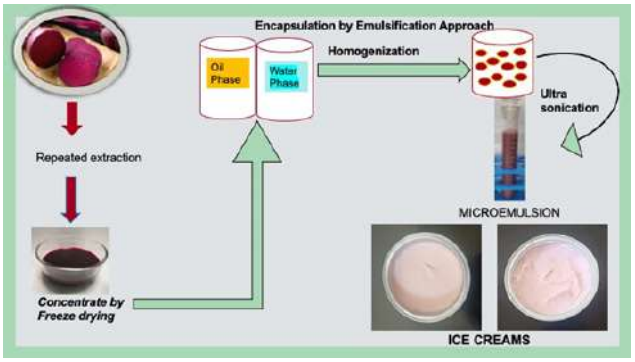
## 6.Bioactive phytochemicals attenuate acrylamide and glycinamide induced cytotoxicity in hepg2 cells by modulating oxidative stress

Acrylamide is a carcinogen and neurotoxin which is formed in high temperature processed foods as a product of Maillard reaction product. Acrylamide is converted to toxic metabolite, glycidamide, in cells by epoxidation in cells. The toxicity of glycedamide in not studied much unlike acrylamide. The present study investigates the potential of dietary bioactive compounds (curcumin-CUR, lycopene-LYC, β-carotene-BC, quercetin- QC, gallic acid- GA, epigallocatechin gallate- EGCG) against ACR and GLY induced toxicity in human liver cell line (HepG2) with regard to cytotoxicity (MTT), production of ROS (H2DCFDA), MDA level, hepatic antioxidant enzymes (SOD, CAT), GSH level, and mitochondrial membrane potential (MMP). The results demonstrated that the treatment of HepG2 cells with bioactives for 2h prior to ACR and GLY exposure enhanced cell viability, MMP and decreased ROS production with curcumin being the most effective. The SOD, CAT and GSH level increased significantly with reduction in MDA level on pre-treatment of the cells with bioactives. These evidences support the enhancement of cellular antioxidant defense mechanism by the dietary antioxidant compounds behind the protection of cells from ACR and GLY induced toxicity.




## 7. Ice-cream as a model system to evaluate the food colorant functionality of red beet extract emulsion

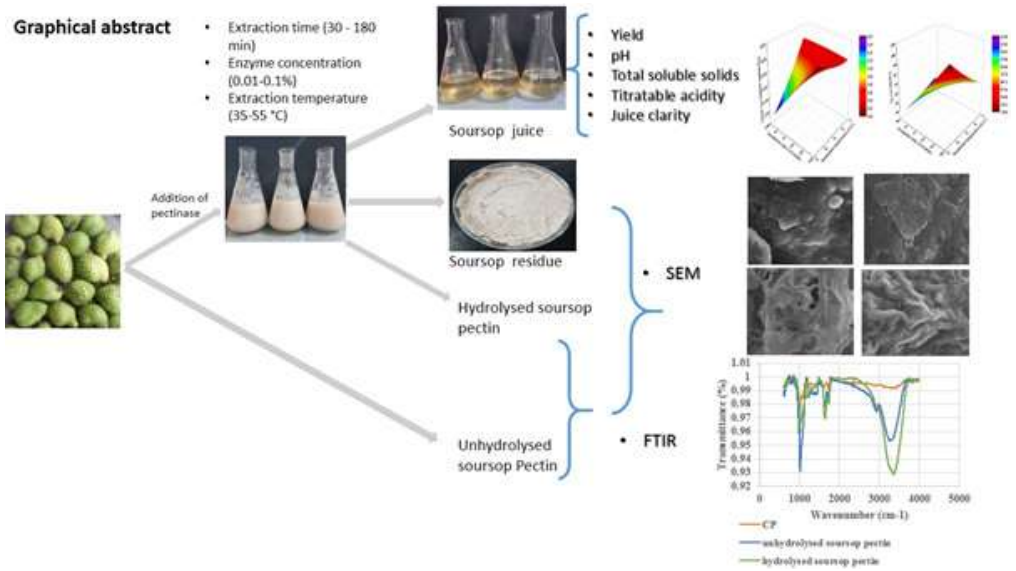
In continuation to the fabrication of micro- and Nanoemulsions of beetroot as natural food colorant with enhanced stability that was reported previous year, attempts were carried out to investigate the application of developed red beet extract-loaded oil-in-water emulsion as a natural colorant in ice-cream. The beet root extract emulsion was produced by a combination of rotor-stator homogenization and ultrasonication techniques.



The resultant emulsion had a mean droplet diameter and polydispersity index of 1439.7 ± 47 nm and0.402 ± 0.04, respectively. Ice-creams with beet extract emulsion at varying concentrations (10-30%) were prepared and compared with synthetic red colorant (ICS) (INS 122). The colour (redness ,-a value) and sensory properties of ice-creams with 15and 20% of beet extract emulsion were comparable to that of the synthetic one.Though the incorporation of the beet extract emulsion influenced the proximate composition and overrun of ice-cream, it did not alter its sensory characteristics, especially the product's color. The study suggested the use of beet extract emulsion as an effective natural alternative to the synthetic red colorant (INS 122) in ice-creams.

## 8. Process development for enzyme assisted extraction of *Annona muricata L.* juice and the impact of liquefaction on the structure of pectin

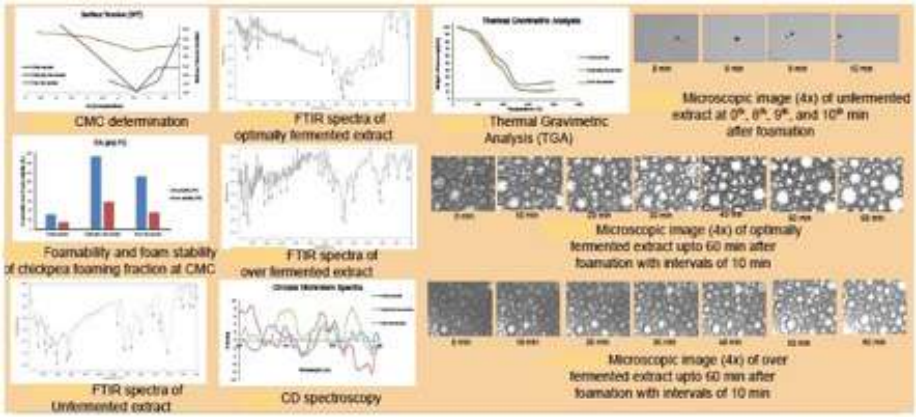
Use of enzymes for improving the yield of extraction of food components is gaining lot of industrial attention. Soursop (*Annona muricata* L.) is an underutilized tropical fruit which is enriched with nutritional and bioactive compounds. High perishability due to lack of post-harvest value addition results in about a loss of 76% of its total production. The possible value addition by extraction of juice is attempted and presented here. The optimization of the conditions of pectinase-assisted extraction method of soursop using Doehlert design, with three factors including incubation time (30 – 180 min), enzyme concentration (0.015 – 0.095%, w/w) and incubation temperature (36.84 – 53.16 °C) were used for process optimization. Predicted models were validated and highly significant ($p \leq 0.05$) for all responses studied with high regression coefficients ranging from 0.9047 to 0.9874. The morphological analysis using SEM revealed that pectinase hydrolyzed the pectin in soursop and improved the juice extraction process. The pectinase-assisted extraction of soursop juice, is found to be a promising method for the value addition of soursop.




## 9. Natural foaming agents for food applications: enhancing the foaming capacity and foam stability of chickpea foaming fractions by natural fermentation

Foaming is one of the important functional properties of proteins, conferred upon them by their amphiphilic nature. Foams can be defined as gas entrapped in liquid films, or, in simple terms as, gas in liquid colloids. Currently, dairy-based proteins like sodium caseinate and whey protein isolate are widely used as foaming

agent in beverages. Whereas, egg albumin is an animal protein, mostly used as foaming agent in bakery and confectionary products. Globally, there is a developing trend in plant-based foods, which results in the demand for plant based foaming agents as well. The present work involves the isolation of foaming fractions from the plant source, chick pea (*Cicer arietinum*) and improvising its foaming capacity and foam stability by allowing the isolate to ferment naturally. To isolate the foaming fractions of chick pea, it was subjected to various unit operations such as soaking, grinding and filtration. The filtrate was used for further studies; whereas, the insoluble fraction was discarded in the form of residue. The filtrate was incubated at 40°C to enhance the natural fermentation. The samples were taken at regular time intervals and centrifuged to obtain clear supernatant for determining the pH and titratable acidity to monitor the fermentation process. The foaming capacity and foam stability were maximum when the pH and titratable acidity of the filtrate reached the values of 5.08 ± 0.05 and 2.192 ± 0.19 g/l of lactic acid equivalents, respectively. On the other hand, the unfermented fraction and over-fermented fraction showed poor foaming capacity and foam stability, respectively. After determining the optimum pH and titratable acidity, three samples, namely, unfermented, optimally-fermented and over-fermented filtrates were prepared and freeze-dried for further analysis. Finally, the effect of fermentation on foaming fractions was characterized by determining the surface tension of the aqueous solutions of foaming fractions using drop shape analyzer (tensiometer) and studying their rheology (rheometer). Also, the kinetics of foam stability was unraveled by imaging the microstructure of foams for extended time.




## 10. Role of Methylglyoxal in the Onset and Progression of Metabolic Disturbances in HepG2 Cells

Methylglyoxal (MG) is a highly reactive cellular metabolite that acts as a precursor for advanced glycation end product (AGEs) formation. MG has been implicated in several pathologies, including diabetes, cardiovascular diseases, kidney disorders, aging, and cancer. It also induces liver toxicity. The present study

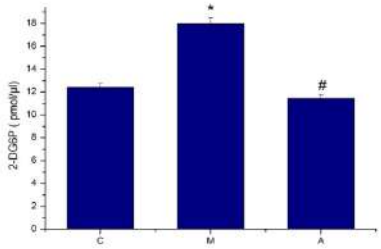



Fig 1. Effect of MG on glucose uptake. 2-DG6P uptake increased in response to MG treatment in HepG2 cells. Values are expressed as mean ± SD (n=3). *Mean values are significantly different from the control group ($p \leq 0.05$)

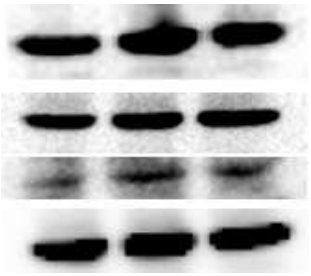


Fig 1. Effect of MG on GLUT1 and glycolytic enymes. Proteins expression increased in response to MG treatment in HepG2 cells. Values are expressed as mean ± SD (n=3). *Mean values are significantly different from the control group ($p \leq 0.05$)

is designed to check the effect of MG on various physiological and cellular functions of HepG2 cells. HepG2 cells were incubated with MG for 24 hrs and cells were subjected to various biochemical and cellular studies. Glucose uptake, ROS generation, lactate production, andexpression of glycolytic enzymes were studied. Aminoguanidine (A), an methylglyoxal (MG) scavenger, is used as a positive control in the study. Glucose uptake was found to increase significantly along with the expression of GLUT1, glycolytic enzymes, and lactate production. There is also a significant increase in the deposition of lipid droplets and an increase in the expression of fatty acid synthase (FASN) in the cells treated with MG. MG also increased ROS generation. Glyoxalase, a metabolizing enzyme of MG, also got impaired significantly in the presence of MG in HepG2 cells and RAGE expression increased. The increase in glucose uptake and de novo lipogenesis with MG reveals the role of the same in the promotion of cancer cell growth with increased aerobic glycolysis. Overall results show that MG is a potent toxic metabolite with pleiotropic effects affecting HepG2 cells adversely.

## 11. Identification of proprotein convertase subtilisin kexin-9 (PCSK-9) inhibitors from medicinal plants

This study was to investigate the potential of NIIST-PCSK9 (a bioactive isolated from edible plant) as a PCSK9-9 inhibitor for the treatment of hypercholesterolemia employing *in vitro* and *in vivo*models. *In vitro* studies revealed that NIIST-PCSK-9 decreases the PCSK-9 in the lysate of LPDS serum treated HepG2 liver carcinoma cells. NIIST-PCSK9 inhibits *PCSK9* expression by inducing proteasomal degradation of hepatic HNF1α protein. High-fat diet (HFD) fed C57BL/6J mice was used as in vivo model.Compared with the control group, the HFD fed mice demonstrated a deteriorated blood lipid profile and exhibited increased expression levels PCSK-9 protein in their liver . In addition, the high-fat diet decreased the expression levels of LDL-R. However, the administration of NIIST-PCSK9 reversed the blood lipid profile changes, reduced the expression levels of PCSK-9 proteins, and increased the expression levels of LDL-R proteins in the hypercholesterolemic mice. From the *in vitro* and *in vivo* studies, it can be concluded that NIIST-PCSK-9 is effective in treating hypercholesterolemia in mice. The therapeutic mechanisms of NIIST-PCSK9 may be associated with increasing the expression of LDL-R protein and decreasing the expression of PCSK-9 protein in liver tissues.

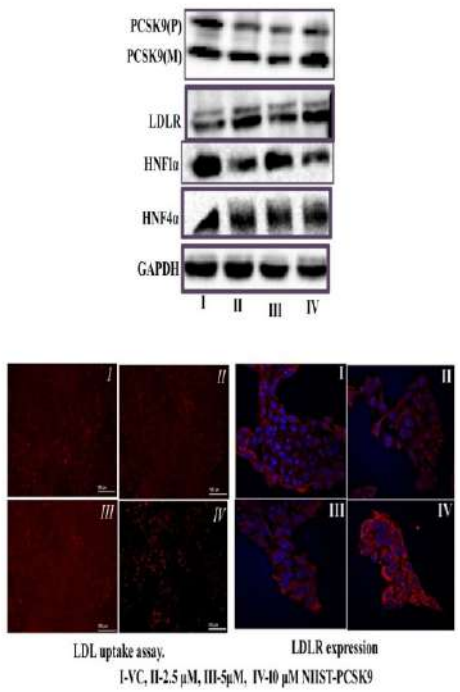



Fig 1. The protein expression of PCSK9 and associated proteins in LPDS serum activated HepG2 cells treated with vehicle or NIIST-PCSK9 at different concentrations. The experimental groups are I-vehicle control; II, III, are in the concentrations 5,10 µM and IV statin at 10 µM concentrations respectively.

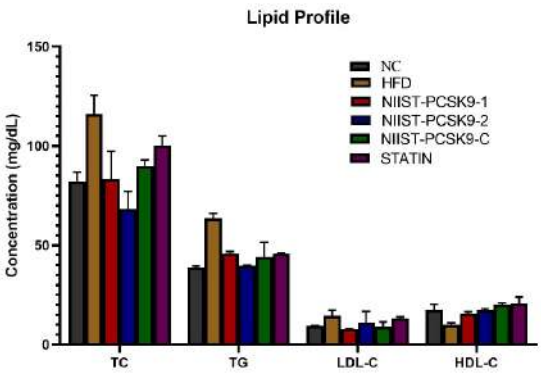



Figure 2. Effect of NIIST-PCSK9 on serum lipid profile at different concentrations. Lipid profile in high cholesterol diet c57BL/6 mice treated with vehicle or NIIST-PCSK9 or Atrovastatin. The experimental groups are I-vehicle control; II-HFD, III and IV are in the concentrations ,10 µg, 25 µg, and IV statin at 10 µg, concentrations respectively.

## 12. Involvement of endoplasmic reticulum stress in the genesis of diabetic cardiomyopathy and the effect of chlorogenic acid

Diabetic cardiomyopathy finds out diabetes-related changes in the structure and function of the myocardium that is independent of coronary artery diseases or hypertension. However, the causes of DCM are unclear, and the best ways to mitigate the risks are still being investigated. Endoplasmic reticulum (ER) and associated signaling pathways are involved in DCM. However, detailed studies are not available. The present study investigated the role of ER stress and associated pathways such as calcium homeostasis, ER-phagy, apoptosis, and their underlying mechanisms using appropriate models. The beneficial effect of chlorogenic acid was evaluated against ER stress-mediated DCM. H9c2 cells incubated with high glucose (33mM, *in vitro* study) showed significant activation of the ER stress response (GRP78, PERK, IRE1$\alpha$, ATF6$\alpha$) and altered its regulatory proteins (PDI, ERO1$\alpha$). Calcium homeostasis was found altered with Ca2+ overload and increased pCaMKII activity. pCaMKII mediated RYR2 hyperactivity and reduction of SERCA2A were also found in*in vitro* model.Also, it enhanced ER-phagy through upregulation of Sec62, RTN3, and FAM134B. Moreover, high glucose caused apoptosis via increased levels of CHOP, caspase 12, and calnexin.All these proteins ( PERK, IRE1$\alpha$, ATF6$\alpha$, pCaMKII, RYR2, NCX1, RTN3, Sec62, FAM134B) have been found to have a significant role in the functioning of the heart, such as excitation-contraction coupling, and we expect these alterations to induce cardiomyopathy.This was confirmed *in vivo* study too. A high-fat, high fructose diet (HFFD) caused an increased expression of BNP and copeptin, revealing cardiac injury. Besides, enhanced expression of fetuin-A observed in HFFD rats shows insulin resistance as well. Results from the present study reveal the significant role of ER stress in the genesis of DCM. We found chlorogenic acid is effective against hyperglycemia-induced pathological alteration both *in vitro* and *in vivo* models.

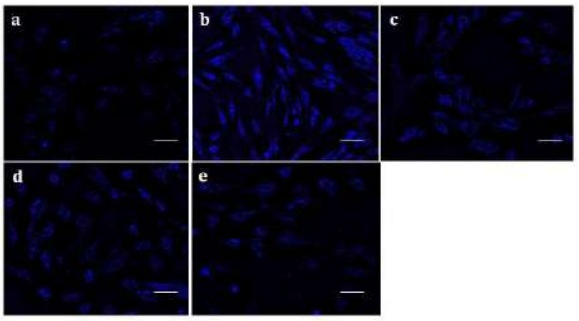



Fig.1 Autophagy in H9c2 cardiomyocytes after HG (33mM) treatment for 48 h in presence or absence of various concentrations of chlorogenic acid or metformin. (a) Control, (b) high glucose treated group , (c) HG + metformin, (d) HG + chlorogenic acid (10 μM), (e) HG + chlorogenic acid (30 μM). Scale bar corresponds to 50 μm.

## 13. Alpinia galanga down regulates TLR4/MyD88/p38MAPK and JAK/STAT pathway in RAW 264.7 to protect cells from inflammation

*Alpinia galangal* is widely used in Ayurveda against various inflammatory disorders. Some of the Ayurvedic preparations using the rhizome of *Alpinia galanga* are *Rasnadi kashayam*, *Rasna panchakam*, *Rasnapthakam*, and *Rasnarendadi*. The aromatic rhizome from *Alpinia galanga*is the source of the drug greater galangal, and it is also used as a spice in South and Southeast Asia. However, the molecular mechanism of action of *A galanga* against inflammation remains poorly understood. The present study aimed to elucidate the anti-inflammatory effect of hydroalcoholic extract of *Alpinia galanga* rhizome (AGE). The study showed that pre-treatment with AGE downregulated the release of pro-inflammatory mediators (IL-6, TNF-$\alpha$, NO, and ROS) and stimulated the release of anti-inflammatory mediator IL-10 in LPS stimulated RAW 264.7 cells. The vital enzymes of inflammation (iNOS, COX-2, and MMP-9) were also downregulated by pre-treatment with AGE. AGE targeted the upstream elements of the inflammatory cascade by blocking LPS induced activation of TLR4 and JAK/STAT pathway. The phosphorylation of downstream kinases was significantly affected. The inhibition of nuclear translocation of NF$\kappa$B further confirmed the specific inhibition of the TLR4 pathway. Particularly AGE inhibited the phosphorylation of JNK, p38, I$\kappa$B$\alpha$, and STAT. HPLC analysis of the AGE showed the polyphenol-rich nature of the extract. In summary, our study revealed that *Alpinia galanga* inhibited LPS stimulated inflammatory response in RAW 264.7 cells via downregulating TLR4 and JAK/STAT pathway.

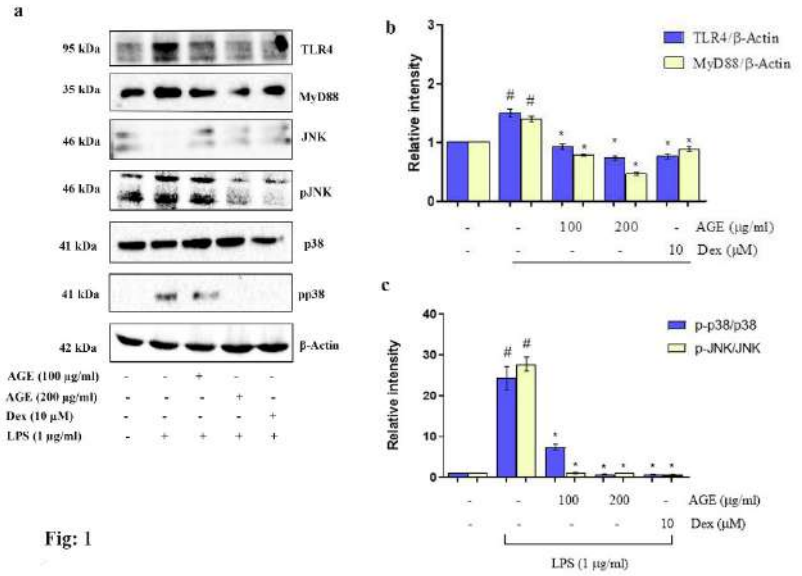



Fig: 1

Fig: 1.Effect of AGE on TLR4 activation and on MAPK phosphorylationin LPS stimulated RAW 264.7 cells. The RAW 264.7 cells after pretreatment with AGE (100 and 200 μg/ml) and dexamethasone (10 μM) was incubated with LPS (1 μg/ml) for 24 h. Immunoblotting was performed using total cell lysate a) protein expression was done using the specific antibodies of TLR4, MyD88, JNK, pJNK, p38, and pp38. Total JNK and p38 served as internal control for their phosphorylated forms and β-actin served as internal control for the rest of the proteins b) and c) The relative band intensity of each band was quantified against their respective internal controls using densitometry. Values are mean ± SD of three independent trials; # denotes significant difference from control ($p \leq 0.05$) and * denotes significant difference from LPS treated groups ($p \leq 0.05$).

## 14. Unfolded protein response in endoplasmic reticulum and mitochondria: Molecular targets of fructose and palmitate induced steatosis in HepG2 cells

The global epidemic of metabolic syndrome imposes drastic threats to the public health system due to the prevalence of associated comorbidities. The development of caloric exuberance and sedentary lifestyle leads to an imbalance between energy uptake and its utilization. This, in turn, negatively affects liver function and its homeostasis. NASH is the most common hepatic disorder affecting 25% of the general population worldwide. It encompasses a spectrum of clinical and histopathological features, varying from simple steatosis to cirrhosis, fibrosis and hepatocellular

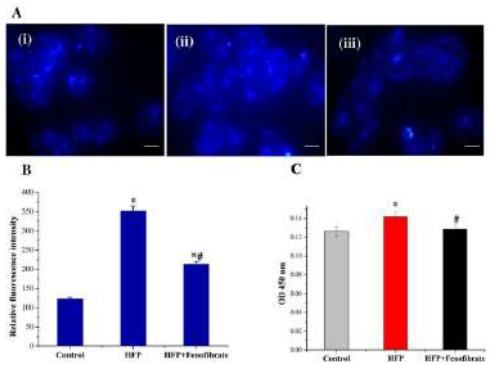



Fig 1. HFP favors intracellular cholesterol accumulation and via SREBP2 activation. (A)Measurement of intracellular cholesterol droplets accumulation in HFP treated HepG2 cells. (i) Control cells; (ii) Cells treated with HFP; (iii) Cells treated with HFP+Fenofibrate. Scale bar corresponds to 50 μM (B) Absorbance was spectrophotometrically measured at 470 nm. (C) Detection of SREBP-2 by ELISA. Data are expressed as mean ± SD; where n = 6.* indicates significantly different from the control group. # indicates significantly different from the HFP treated group ($p \leq 0.05$).

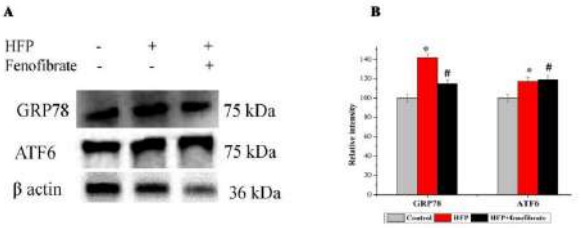



Fig 2. HFP induces ER stress in HepG2 cells via upregulation of ATF6 pathway of UPRER: (A) The protein expression of GRP78 and ATF6 during steatosis. (B)The relative intensity of each band was quantified with β actin. Data are expressed as mean ± SD; where n= 3. * indicates significantly different from the control group. # indicates significantly different from the HFP treated group ($p \leq 0.05$).

carcinoma. The aim of our study was to validate the potential role of high fructose and palmitate similar to our modern dietary pattern and validate the molecular mechanism relevant to unfolded protein response in the endoplasmic reticulum (UPRER) and mitochondria (UPRmt). We also validated its regulatory role in steatosis and analyzed the behavior of ER-mitochondria interaction during steatosis.Our results revealed surplus lipogenesis (452.30%) during steatosis with a significant reduction of lipolysis (86.08%) in HepG2 cells. The intracellular cholesterol level was increased (186.66 %) along with SREBP2 (43.86 %). The expressions of UPRER marker proteins GRP78 (57.6%) and ATF6 (79.84%) were increased significantly along with expression of biomarkers of MAM proteins like IP3R2 (18.88%), VDAC1 (9.13%), and PACS2 (12.96%) is also found decreased reflecting adverse effect on communication between ER and mitochondria. Overall results conclude that UPRmt and UPRER have a crucial role in the genesis of steatosis *via* high calorie and thereby importance in designing new therapeutic strategies for hepatic steatosis.

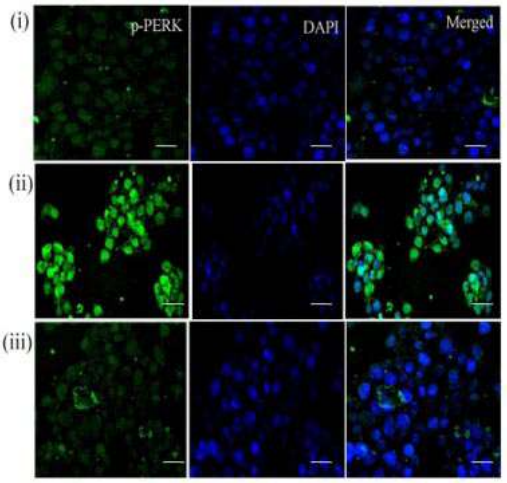



Fig 3. HFP stimulates the activation of PERK pathway of ER stress: (A) Immunofluorescence staining of phosphorylated PERK. (i) Control cells (ii) Cells treated with HFP; (iii) Cells treated with HFP + fenofibrate. Original magnification 40X. Scale bar corresponds to 20 μM.

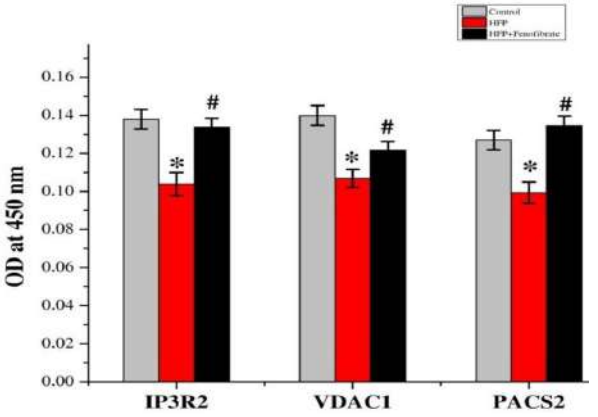



Fig 4. HFP induced steatosis impaired the mutual interaction between ER and mitochondria: The presence of MAM proteins: IP3R2, VDAC1, and PACS2 were detected using ELISA technique. Data are expressed as mean ± SD; where n= 6. * indicates significantly different from the control group. # indicates significantly different from the HFP treated group ($p \leq 0.05$).

## 15. Synthesis and characterization of TPP-functionalized guar gum nanoparticlesas mitochondrial antioxidants for cardiac hypertrophy

Heart failure (HF) is a significant public health concern and a leading cause of morbidity and mortality worldwide. Mitochondrial dysfunction plays a crucial role in the development of heart failure.In this regard, mitochondria are emerging as one of the important druggable targets for the management of cardiac hypertrophy and other associated complications. Mitochondrial-related diseases of clinical relevance still lack effective therapeutic options. The ability to design mitochondrial targeting systems may therefore provide valuable alternative strategies to enhance therapeutic outcomes of mitochondrial-related diseases while at the same time minimizing side effects. Guar gum, a natural polymer derived from the seeds of *Cyamopsis tetragonolobus*was used to prepare rutin (Ru) loaded triphenylphosphonium (TPP) functionalized guar gum (GG) nanoparticles (Ru-TPP-GGN).TPP is a non-toxic chemical moiety that functionally behaves as a mitochondrial targeting signal in living cells. Rutin, a bioflavonoid and an antioxidant was loaded to TPP-GG nanoparticles to target its delivery directly to mitochondria. The present study aimed to synthesize and characterize Ru-TPP-GGN by nanoprecipitation and crosslinking method. The synthesized nanoparticles were characterized by DLS, TEM, SEM, and FTIR. The characterization study showed that the prepared particles were of ~100 nm. In this regard, the effect of the prepared Ru-TPP-GGN against various vital parameters like cell viability, uptake of Ru-TPP-GGN by the cells was studied, and the results of 24 h and 48 h of incubation onH9c2 cells were non-toxic.The effects of Ru-TPP-GGN,

against mitochondrial dysfunction in angiotensin II-induced hypertrophy in H9c2 cardiomyoblasts werealso evaluated. H9c2 cells with Ang II exhibited pathological hypertrophic responses and mitochondrial dysfunction which was evident from MTT assay, alteration in mitochondrial transmembrane potential ($\Delta\Psi m$), and opening of mitochondrial permeability transition pore (mPTP). Compared to GGN and Ru treatment,Ru-TPP-GGN significantly protected the mitochondria by preventing dissipation of $\Delta\Psi m$, opening of mPTP.Overall results revealed the protective effects of Ru-TPP-GGN against mitochondrial dysfunction in hypertrophy in H9c2 cells, and the present findings may shed new light on the therapeutic potential of Ru-TPP-GGN.

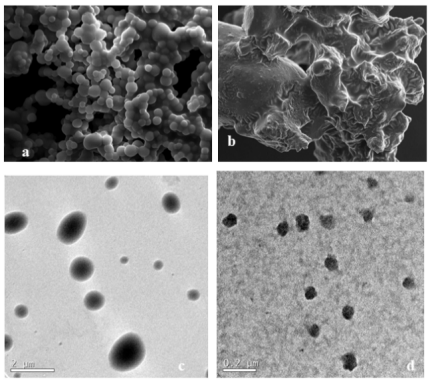



Fig 1.SEM images of (a) GG nanoparticle (b) Ru-TPP-GGN nanoparticle. TEM images of (c) GG nanoparticle (d) Ru-TPP-GGN nanoparticle

## 16. Cinnamic acid mitigates diabetic cardiomyopathy by inhibiting MyD88 dependent TLR4 pathway

Management of diabetic cardiomyopathy has been a challenge for decades. The nutraceutical outlook for the control of cardiovascular complications is gaining importance nowadays. The exact molecular events associated with the genesis of diabetic cardiomyopathy (DCM) is not elucidated in detail so far, and there is a need to design a therapeutic strategy for the same. Based on this, we conducted a detailed investigation on various inflammatory pathways in the heart in male Wistar rats and evaluation of the therapeutic potential of cinnamic acid (CiA) against DCM. Rats fed with a high-energy diet with a single dose of streptozotocin (25 mg/kg bwt) were used as *in vivo* models. We observed an increase in the levels of troponin, TNNI3K, brain natriuretic peptide (BNP), creatine kinase- MB (CK-MB), lactate dehydrogenase (LDH), nitrite, C-reactive protein (CRP), monocyte chemoattractant protein-1 (MCP-1) in the diabetic group. CiA treatment reduced the levels of these cardiac injury markers. Also, dyslipidemia was also observed in our study as evidenced by the increased levels of triglycerides, total cholesterol, and LDL- cholesterol and reduced levels of HDL- cholesterol. CiA treatment prevented dyslipidemia that was observed in the diabetic group. The inflammatory pathways involving the TLR4, MyD88, GATA-4, O-GlcNAc, and NLRP3 were found to be upregulated in the diabetic hearts. CiA prevented the activation of the TLR4/MyD88 pathway. There was overexpression of TNNI3K and downregulation of ST2L during diabetes. Histopathology revealed cardiac fibrosis and inflammatory infiltration in the diabetic group. CiA treated groups prevented the disarray of myofibres and attenuated cardiac fibrosis. Overall, CiA and metformin were effective against inflammation during DCM. CiA was also observed to be a potential therapeutic agent for cardiovascular diseases.

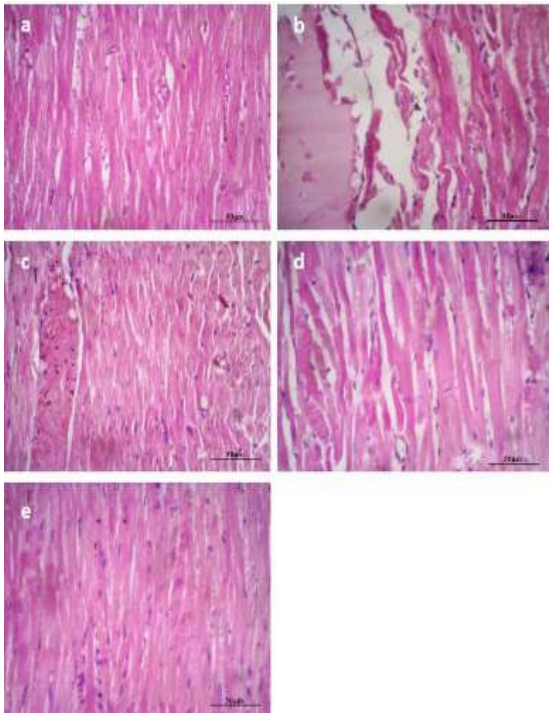
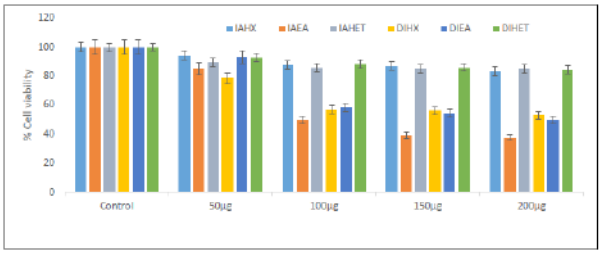


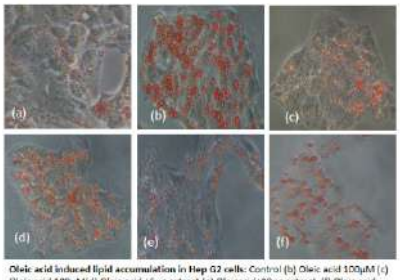

Fig 1.Diabetes induced inflammatory infiltration. Histopathological analysis of heart tissues. Hematoxylin and eosin staining. a) control, b) diabetic (HG), c) HG + metformin (50 mg/kg bwt), d) HG + cinnamic acid (5 mg/kg bwt), e) HG + cinnamic acid (10 mg/kg bwt).

## 17. Exploring the antiobesity potential of medicinal plants, *Dillenia indica and Ipomoea aquatica*

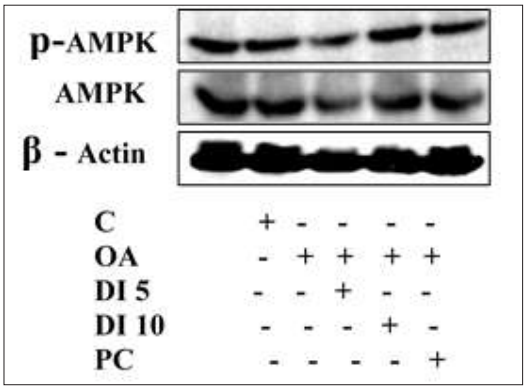
Obesity is a disorder involving excessive body fat that increases the risk of health problems. Ideal medications are not available for obesity; currently, available medications also have lots of side effects. Therefore, there is enormous demand for plant-derived phytochemicals for alleviating obesity-related complications.In this study, we selected two medicinal plants, *Dillenia indica* and *Ipomoea aquatica*, which are already reported as anti-dyslipidemic and inhibit excess body fat accumulation.These plants were subjected to extraction and fractionation. The extracts of *Dillenia indica* showed the presence of various phytochemicals such as elagic acid, chlorogenic acid, quercetin, syringic acid, ferulic acid, p-coumaric acid, myricetin, and cinnamic acid. *Ipomoea aquatica* showed*the* presence of ferulic acid, myricetin, cinnamic acid, syringic acid, and elagic acid. These results showed that extracts are rich in polyphenols.Cytotoxic test of all extracts was done on HepG2 cell lines. Extracts were found to be nontoxic up to 200µg/ml (*I.aquatica* hexane, hydroethanol extract, *D.indica* hydroethanol extract) and nontoxic up to 50µg/ml (*I.aquatica* ethyl acetate extract, *D.indica* hexane and ethyl acetate extract). In order to develop an*in vitro* model of obesity, HepG2 cells were treated with oleic acid (100µM) for 24 hours. Oil red O staining and triglyceride (TG) assay was done to check the lipid droplet accumulation in treated (5µg/ml and 10µg/ml) HepG2 cells. Oil red O staining showed that lipid accumulation was reducd in *D.indica* ethyl acetate and hydroethanol extract (5µg/ml, 10µg/ml, and 20µg/ml) treated HepG2 cell lines. TG assay also showed that lipid accumulation was decreased in *D.indica* hydroethanol extract (5µg/ml, 10µg/ml) treated HepG2 cell lines. In order to find the expression of proteins involved in lipid metabolism, western blot analysis was done. Results showed that the p-AMPK expression was upregulated

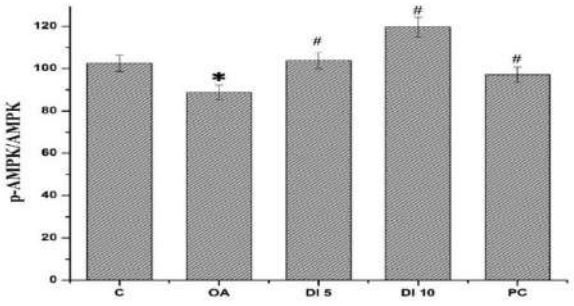



Cell viability assay. Graph showing the cell viability, when treated with plant extract *Ipomoea aquatica*(IA) and *Dillenia indica*(DI), solvents such as hexane(HX), ethyl acetate(EA), Hydroethanol(HET).



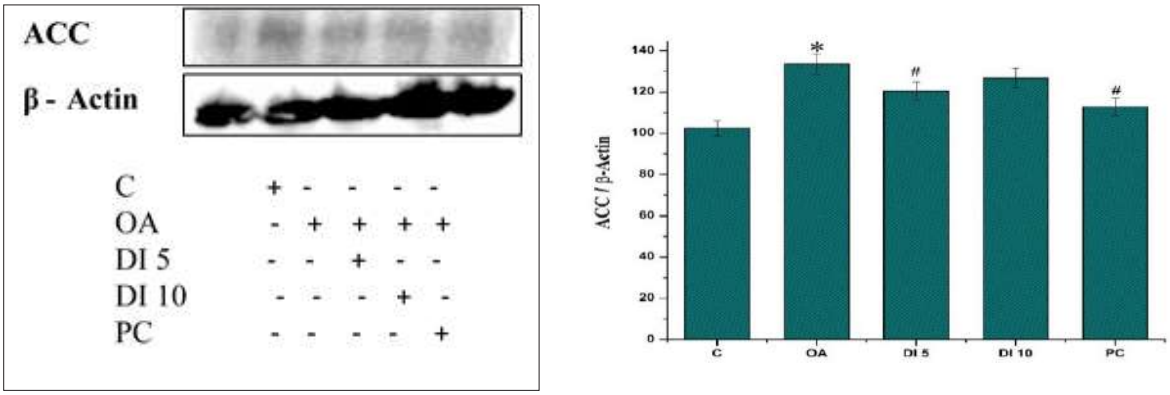

**Oleic acid induced lipid accumulation in Hep G2 cells:** Control (b) Oleic acid 100µM (c) Oleic acid 100µM(d) Oleic acid +5µg extract (e) Oleicacid+10µg extract (f) Oleic acid +20µg plant extract.




DI-HET plant extract activates AMPK: The expression of p-AMPK and AMPK in OA induced (100µM) condition and in treated group (DI-5µg/ml and DI-10µg/ml) and positive control (fenofibrate 20 µM).The relative intensity of each band was quantified with β-actin. Data are expressed as mean ± SD, where n=3. * indicates significantly different from control group. # indicates significantly different from the OA induced group ($p \leq 0.05$).

in DI-HET plant extract treated group when compared to oleic acid treated diseased group. ACC (Acetyl CoA carboxylase) expression was downregulated when treated with plant extract when compared to oleic acid treated diseased group. The results showed that the extracts were effective in lowering the TG content when compared to positive control (fenofibrate) and also DI-HET plant extract caused significant increase AMPK phosphorylation, which leads to anabolic effect in treated group. ACC expression were downregulated which inhibits fatty acid synthesis and thereby lipid accumulation.




DI-HETplant extract downregulates ACC: The expression Acetyl CoA carboxylase in OA induced condition ( 100μM) and in treated group (DI-5μg/ml and DI-10μg/ml) and positive control (fenofibrate 20 μM). The relative intensity of each band was quantified with β-actin. Data are expressed as mean ± SD, where n=3. * indicates significantly different from control group. # indicates significantly different from the OA induced group ($p \leq 0.05$).

## 18. Molecular characterization of functional domain in CC2D2A associated with ciliopathy

Cilia are microtubule-based hair-like organelles that extend from the surface of almost all cell types of the human body. Cilia are involved in numerous physiological and developmental processes and their biogenesis involves many proteins. Hence mutations in genes encoding these proteins can cause multi-system disorders called as ciliopathies.CC2D2A is a gene localized in basal body which is required for the cilia assembly.CC2D2A contains 2 coiled coil domains and a C2 domain.Mutations in the gene encoding CC2D2A can lead tociliopathies like Meckel and Joubert syndromes. Null mutations inCC2D2A can result in lack ofprotein, (thereby lack of cilia), as in Meckel Gruber syndrome (MKS) and missense mutations in CC2D2A can route for abnormal cilia and hence toJoubert syndrome(JBS).Most of the mutations in C2 domain of CC2D2A are known to affect the function of photoreceptors& brain, and the patients with JBS survive with blindness and mental retardation.However, the role of C2 domain of CC2D2A is not clear.The major objective of the study is to decode the function of C2 domain in CC2D2A in cilia forming cells IMCD-3.Mutations in human are simulated by gene knockdown, using custom made shRNAin cilia forming IMCD3cells.The effect of gene knockdown is analysed by immunofluorescence and western blot, using antibodiesspecificto cilia and CC2D2A.Custom made anti-CC2D2A, specific for C2 domain raised in rabbits, is being tested on cells and growing cilia and for western blotting.Standard primary antibodies were used for analysing the basal body markers and immunostains of cilia. The research indicates that C2 domain is necessary for cilia function.

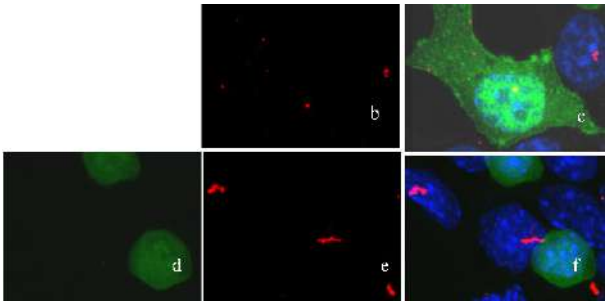


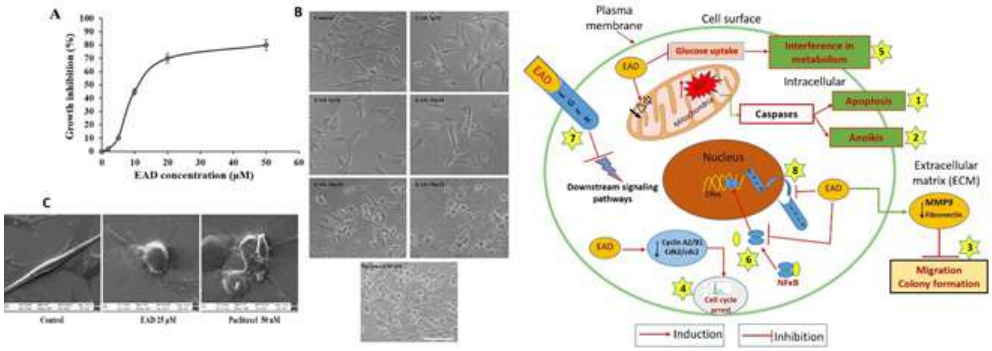

Fig 1. Immunostaining for anti-Arl13b (highlighting cilia;red) in control and C2 domain knockdown cells. (1) control cells (a)eGFP, (b) Arl13b (c) merged images after transfection with scrambled construct both nucleus and cilia are intact. (2) (d) eGFP e) Arl13b (f) merged images of C2 domain knockdown cells, the cilia(red)are missing. Transfected cells are green (e GFP). Anti-Arl13b is used to highlight cilia. Nucleus is stained with DAPI.

## 19. Protective effect of Vanillic acid during hyperinsulinemia in HepG2 cells

Type 2 diabetes, obesity, and metabolic syndrome are pathologies where insulin resistance plays a central role, and that affects a large population worldwide. These pathologies are usually associated with a dysregulation of insulin secretion leading to a chronic exposure of the tissues to high insulin levels (i.e. hyperinsulinemia), which diminishes the concentration of key downstream elements, causing insulin resistance. The complexity of the study of insulin resistance arises from the heterogeneity of the metabolic states where it is observed. In diabetes, Glucokinase (GK), a key regulator of hepatic glucose metabolism in the liver, a glucose sensor, and mediator for the secretion of insulin in the pancreas, is not studied in detail for its therapeutic application. Herein, we study the alteration in GK activity during hyperinsulinemia-induced insulin resistance in HepG2 cells. We also investigated the relation between GK and Bcl-2-associated death receptors (BAD) during hyperinsulinemia. There are emerging demands for GK activators from natural resources, and in the study, vanillic acid (VA)is used to evaluate its potential as GK activators during hyperinsulinemia in HepG2 cells. VA is a phenolic compound and a commonly used food additive in many food industries. The results showed that VA prevented the depletion of glycogen synthesis during hyperinsulinemia, which is evident from protein expression studies of phosphoenolpyruvate carboxykinase, glucose-6-phosphatase, glycogen synthase, and glycogen synthase kinase-3β. VA was also observed to be a potential therapeutic agent forhyperinsulinemia in HepG2 cells and safeguarded GK inhibition during hyperinsulinemia in HepG2 cells.

## 20. Apoptosis/anoikis inducing effects of epoxyazadiradione in triple negative breast cancer cells

Triple negative breast cancer (TNBC) is characterized by the absence of estrogen receptors, progesterone receptors, and HER2 amplification, which accounts for about 15-20% of overall breast cancer cases. The lack of specific molecular targets and the low sensitivity/ specificity of available immuno-histochemical markers are the main limitations that render the commonly used clinical interventions ineffective for TNBC. Apoptosis and anoikis (detachment induced cell death) induction by small molecules can prevent TNBC metastasis to a greater extent.*Azadirachta indica* A. Juss (neem) is the plant belonging to the Meliaceae family, and different parts of this tree are a large storehouse of limonoids (>150 nos). Neem limonoids and their derivatives exhibit diverse biological activities such as antimicrobial, antimalarial, antiviral, anticancer, etc. Most studied neem limonoids with anticancer activities include azadirachtin, nimbolide, nimbin, deacetylnimbin, mahmoodin, salannin, epoxyazadiradione, deacetylgedunin, and gedunin. Epoxyazadiradione (EAD) induced mitochondria mediated apoptosis and anoikis in TNBC cells (MDA-MB-231). Apart from this, it promotes antimigration, inhibition of colony formation, downregulation of MMP-9 and fibronectin, induce G2/M phase arrest with downregulation of cyclin A2/cdk2, interference in cellular metabolism and inhibition NFκB nuclear translocation. Moreover, there observed a significant reduction in the expression of EGFR on the plasma membrane and nucleus upon treatment with EAD. Among the diverse cellular effects, anoikis induction, metabolic interference and downregulation of membrane/nuclear EGFR expression by EAD are reporting here for the first time.



## 21. Role of selected flavones in alleviation of endoplasmic reticulum stress mediated stress in skeletal muscle cell lines

Type 2 Diabetes (T2DM) is a chronic metabolic disorder which involves abnormal blood glucose levels leading to insulin resistance (IR). According to recent studies, endoplasmic reticulum (ER) stress has emerged as one of the underlying causes in progression to diabetes pathophysiology. ER stress is also involved in mitochondrial dysfunction, dysregulation in calcium signalling, oxidative stress which can further contribute to diabetic complications. The currently used drugs are associated with severe side effects leading to their restricted use. So targeting the underlying causes of IR such as the ER stress mediated pathways provides newer therapeutic strategies for T2DM management. Phytochemicals based research for management of T2DM is on the rise due to their abundance, cost effectiveness and lesser side effects. Our work deals with studying the efficacy of three flavones, namely Apigenin, Luteolin and Tangeritin against ER stress mediated stress.Tunicamycin (TM) was used as the ER stress inducer. Phenylbutyric acid, a standard ER stress inhibitor has been used as the positive controls in all the experiments. L6 cell line was used as the in vitro model. Figure 1 shows induction of insulin resistance by TM concentrations. Figure 2 depicts the efficacy of flavones in restoring TM induced insulin resistance in L6 myotubes. Effect of TM flavones co-treatment on mitochondrial membrane potential was studied (Figure 3). Selected flavones showcased promising efficacy in mitigating ER stress related stress pathways.

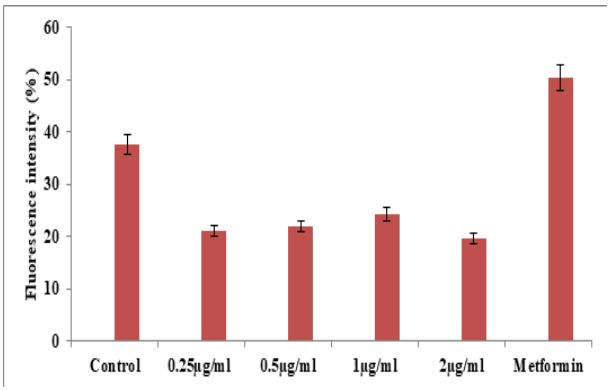



Figure 1: Induction of insulin resistance by Tunicamycin concentrations. All values are represented as mean+SD (n=2).

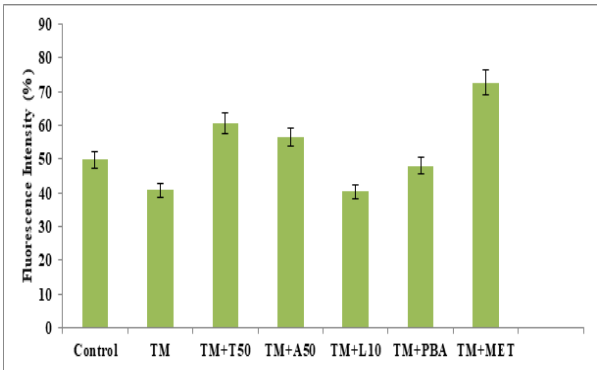



Figure 2:Effect of TM flavone co-treatment on glucose uptake in L6 myotubes. Control: untreated cells, TM: Tunicamycin only(0.25µg/ml), TM+T50:(TM+ Tangeritin(50µM), TM+A50: TM+Apigenin(50µM), TM+L10:TM+Luteolin(10µM), TM+PBA:TM+PBA(1mM), TM+MET:TM+Metformin(100µM).

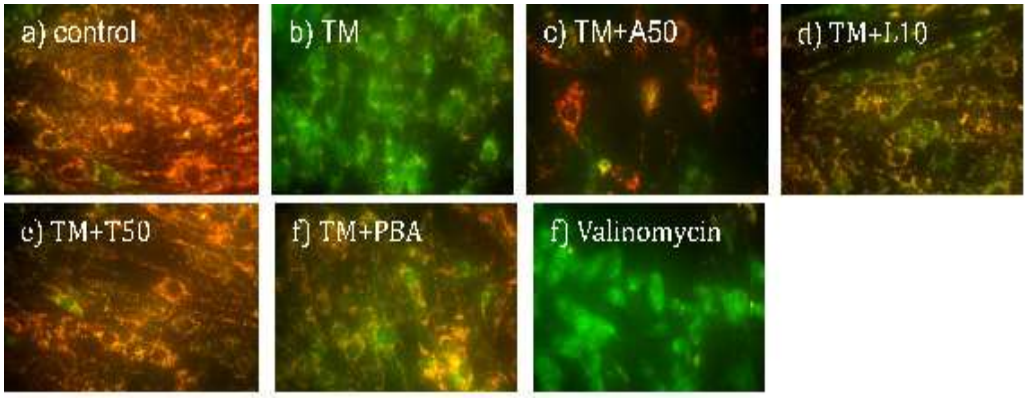



Figure 3:Effect of TM flavone co-treatment on mitochonrial membrane potential.a)control cells, b)TM only treated cells(0.25µg/ml), c)TM+Apigenin (50µM), d)TM+Luteolin (10µM), e) TM+Tangeritin (50µM), f) TM+ PBA(1mM), g) TM+Valinomycin (1µg/ml).

## 22. Trapping glycation intermediates for the modulation of diabetes and its complications: a natural product derived therapeutic approach

Advanced glycation end products (AGEs) is being reported for causing diabetes and majorly its complications. While there is a substantial progress made in the treatment of diabetes, effective therapy for its complications and management remain scanty. Currently there is no therapeutic intervention to inhibit the formation of these AGEs.

There are certain $\alpha$-dicarbonyl species formed due to hyperglycemia, methylglyoxal (MG) being the most prevalent in diabetic patients. These act as intermediates in the production of AGE by conjugating with proteins. A proper analysis of these mechanisms helped us reach the conclusion that trapping the intermediates like methylglyoxal would curtail its accumulation in the blood, and decrease the downstream effects caused due to signaling pathways starting from binding of the AGE to their receptors viz RAGE. Our study involved evaluation of MG trapping potential of a range synthetic compounds using analytical techniques like HPLC, LC-MS. MG is dynamic in nature and hence was derivatised to form 2-methylquinoxaline(2-MQ) which is stable and measurable. Results obtained by HPLC aided in selecting three compounds which showed good activity against MG. Peak area value helps in understanding the scavenging potential of the compounds. Accordingly if the peak area obtained is small it indicates that the compound has high MG scavenging ability. From the results, it can be seen that three of the compounds showed high MG scavenging activity viz., 4i (50.03%),4x (69.58%), 4aa (93.37%), while aminoguanidine showed 79.82% of scavenging activity (Fig 1a). These were further subjected for LC-MS analysis to confirm if the compound can actively trap MG and reduce the intensity of derivatised MG. The mass spectrum of reaction product of the above mentioned 3 test compounds along with MG showed a decrease in the peak intensity at 145*m/z* indicating that much of the MG got trapped by the compounds and only lesser amount got derivatized (Fig 1b). This investigation lead to the conclusion that MG is being trapped by the compound alone. An AGE model mimicking the ones present *in-vivo* were prepared using BSA-MG and anti-glycation potential of these compounds were tested. Compared to positive control aminoguanidine (76.92%), pioglitazone which is shown to possess antiglycation potential in in-vivo models, exhibited only 28.59% antiglycation activity.

To the best of our knowledge this is the first study involving in-depth screening of novel synthetic compounds, and we further took 3 lead molecules to in-vitro cell based study to investigate and affirm their proposed mechanism of action. The compound 4i demonstrated highest antiglycation activity (94.95%) followed by 4x and 4aa (52.55 and 55.09% respectively) (Fig 2)

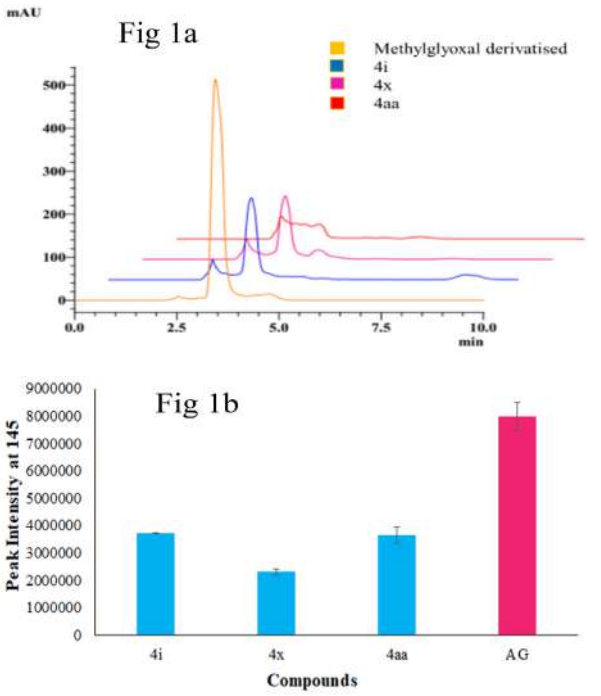



Fig.1a MG trapping potential of synthesized compounds using HPLC. AG: Aminoguanidine; represents the positive control (For selected compounds only) Three of the compounds showed high MG scavenging activity viz., 4x (69.58%), 4aa (93.37%), 4i (50.03%); while aminoguanidine showed 79.82% of scavenging activity.

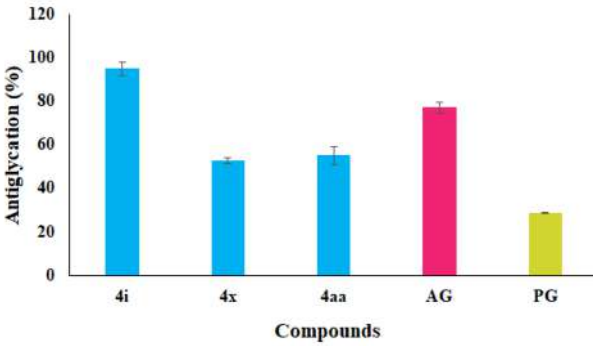



Fig 2 Antiglycation effect of active compounds measured by BSA-MG model, The compound 4i demonstrated highest antiglycation activity (94.95 %) followed by 4x and 4aa (52.55 and 55.09 %, respectively).

## 23. Isolation of potential bacterial strains and their bioactive metabolites from Kerala and their exploitation in agriculture and medicine

Bacterial strains from different ecologically important niches of Kerala state were isolated and screened against common plant and human pathogens. The strains exhibited *in vitro* antagonism against the test pathogens were selected for their possible utilization in agriculture and medicine. For this, the strains isolated shown broad spectrum antibiosis against test plant pathogens particularly *to Rhizoctonia solani* were evaluated for their ability to enhance plant growth, biomass and yield besides the suppression of sheath blight disease in rice plants (*Oryza sativa*) under laboratory, gnotobiotic and


*Fig 1: Plat growth promotion studies under nursery conditions after 120 days*

nursery conditions. Two endophytic *Bacillus* strains were initially taken for this studies. The plant growth data was recorded up to 28 days at an interval of six days and the yield was recorded after 120 days of swing. Both the strains and their combination treatments resulted an enhancement of all the test parameters observed over the non-treated control plants. The combination treatment was recorded as the best and as on 28th day, the combination treatment recorded a percent increase of plant growth in terms of shoot height (10.25), root length (21.56), fresh weight (73.42), dry weight (158.82) The total chlorophyll shown a per cent increase of 71.02 and yield per plant recorded 77.44% increment. The disease suppression studies recorded was 61.*17%* after 2th days over pathogen alone treated plants. The bioactive metabolites produced by the strains were isolated and identification studies confirmed both strains produced alpha keto bidendates as a major metabolite.

A strain of *Streptomyces* exhibited broad spectrum antibiosis against the human test pathogens was studied in detail. For this, the crude metabolite produced by the strain was isolated and attempts were made for their characterization. From the crude metabolite four distinct fractions were separated and each fraction was purified through column chromatography technique. *In vitro* antibiosis study of these pure fractions were screened against one selected test pathogen, *Staphylococcus aureus,* of whichtwo fractions exhibited a zone of inhibition of 15mm and 12mm whereas, the combination of these fractions had a improved inhibition zone of 20mm which indicated that a synergism of two fractions. Further studies are under progress.

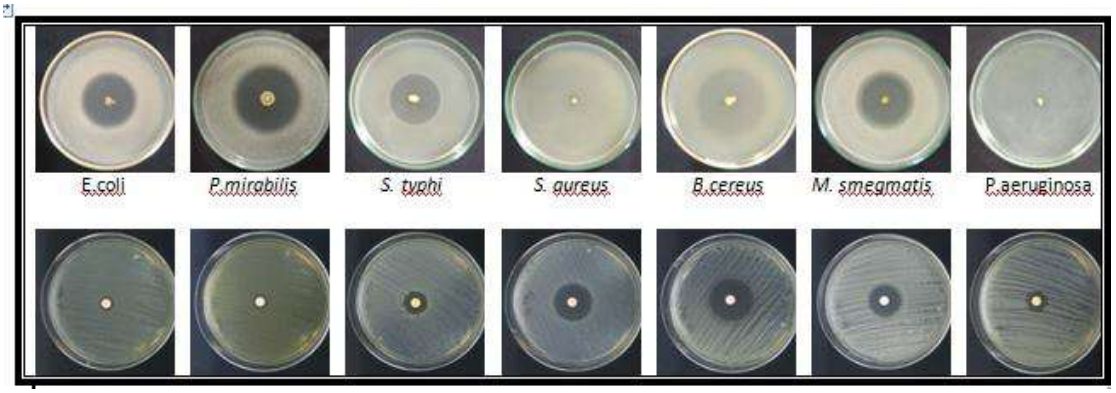
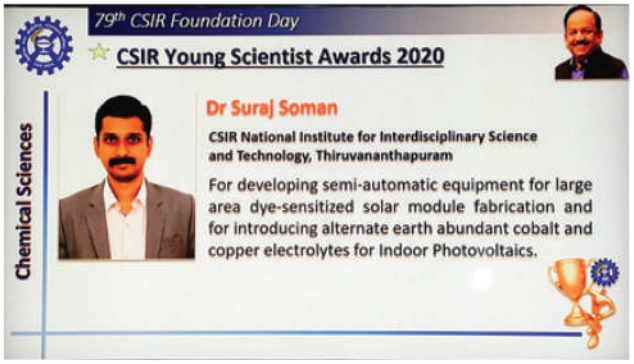



*Fig 2: In vitro antagonism of the live and crude metabolite from a Streptomyces strain against human pathogens*

# DIVISIONAL DETAILS

| | |
|---|---|
| Name | Chemical Sciences and Technology Division |
| Expertise | Functional materials and devices, optoelectronic devices for energy generation and conservation, materials and devices for disease diagnostics, fluorescent materials and their application, synthetic organic chemistry, process development of API's, supramolecular chemistry, phytochemicals and herbal drugs, photochemistry and ultrafast spectroscopy, functional coatings |
| Number of scientists | 21 |
| Number of Technical staff | 5 |
| Number of students | 118 |
| Facilities | HRTEM, Confocal Raman Spectroscopy, GCMS, HRMS,500MHz NMR, AFM, Large area fabrication and characterization of thin film optoelectronic devices |
| No. of ongoing projects during 20-21 (GAP, SSP, CNP,TSP, In-house) | 51 |
| No. of publications (SCI+non SCI) during 20-21 | 93 (Average I.F. : 5.71) |
| No. of Ph. D. awarded during 20-21 | 9 |


# रसायन विज्ञान तथा प्रौद्योगिकी प्रभाग

रसायन विज्ञान और प्रौद्योगिकी प्रभाग अणुओं के विकास और विभिन्न यंत्र प्लेटफॉर्म और प्रोटोटाइप में कार्यात्मक सामग्री और उनके अनुप्रयोग पर ध्यान केंद्रित कर रहा है। संस्थान के तीन प्राथमिकता वाले क्षेत्रों को प्रभाग द्वारा समन्वित किया जाता है - (1) कार्बनिक और हाइब्रिड इलेक्ट्रॉनिक्स (ऊर्जा उत्पादन और भंडारण, क्रोमोजेनिक कोटिंग्स, प्रवाहकीय कोटिंग्स, कार्बनिक ऑप्टोइलेक्ट्रॉनिक्स, कम्प्यूटेशनल रसायन विज्ञान); (2) फ्लोरोसेंट सामग्री (सुरक्षा अनुप्रयोग, संवेदन, निदान, और इमेजिंग जांच और अल्ट्राफास्ट कैनेटीक्स); (३) फाइटोकेमिकल्स, और ड्रग इंटरमीडिएट्स (औषधीय पौधों और उन्नत फार्मास्युटिकल इंटरमीडिएट का जैव-मूल्यांकन)। यह प्रभाग संस्थान स्तर पर सीएसआईआर की विभिन्न विषयगत गतिविधियों का नेतृत्व करता है, जैसे ऊर्जा (पारंपरिक और गैर-पारंपरिक) सामग्री और उपकरण, और रसायन। 4एम रूपरेखा के तहत "कोटिंग्स" पर स्टैंड-अलोन वर्टिकल को भी डिवीजन द्वारा समन्वित किया जा रहा है। प्रौद्योगिकी विकास में भागीदारी के अलावा, यह प्रभाग ज्ञान सृजन में भी बहुत सक्रिय है, जैसा कि 2020-21 में उच्च प्रभाव कारक के साथ अंतरराष्ट्रीय स्तर पर प्रतिष्ठित सहकर्मी-समीक्षित पत्रिकाओं में 90 प्रकाशनों से प्रमाणित है। इस अवधि के दौरान संभाग को 15 पेटेंट दाखिल या दाखिल करने की प्रक्रिया में शामिल हैं।

प्रभाग ने पूरे संस्थान में मोलनुपिरवीर जैसे एंटीवायरल ड्रग अणुओं के संश्लेषण के लिए प्रक्रियाओं को विकसित करके, और लेबल-मुक्त रामन स्कैटरिंग का उपयोग करके कोविड -19 की जांच के लिए एक नया नैदानिक प्लेटफ़ॉर्म विकसित किया है साथ ही फेस मास्क डिजाइन विकसित करके, हर्बल जेल सैनिटाइज़र विकसित करके, स्टीम इनहेलेशन के लिए नए फॉर्मूलेशन विकसित करके, तथा पूरे संस्थान को हैंड सैनिटाइजर की आपूर्ति करके कोविड -19 शमन गतिविधियों में सक्रिय रूप से भाग लिया है।

वर्ष 2020-21 के दौरान संभाग की गतिविधियों और उपलब्धियों के मुख्य अंश के साथ-साथ महत्वपूर्ण घटनाओं के संक्षिप्त सार नीचे प्रस्तुत किया हैं।

## विशेषताएं

- भारतीय मुद्रा मुद्रण हेतु उपयुक्त फ्लोरोसेंट पिगमेंट के विकास के लिए बैंक नोट प्रेस, देवास (भारत सरकार के वित्त मंत्रालय के तहत भारत प्रतिभूति मुद्रण एवं निर्माण निगम लिमिटेड की एक इकाई) के साथ एक समझौता ज्ञापन पर हस्ताक्षर किया।
- पारदर्शी कंडक्टिंग कोटिंग्स विकसित करने के लिए एमएसएमई इकाई द्वारा विकसित स्वदेशी रूप से निर्मित स्प्रैरी कोटिंग इकाई स्थापित की गई।
- 15 सक्रिय फार्मास्युटिकल अवयवों के आधार पर विकास के लिए केरल राज्य ड्रग्स तथा फार्मास्युटिकल्स लिमिटेड के साथ समझौता ज्ञापन पर हस्ताक्षर किया।
- टेट्रा-टेरपाइरीडीन लिगैंड्स का उपयोग करते हुए आयरन *(II)* आधारित मेटलोसुप्रामोलेक्यूलर पॉलीमर नेटवर्क फिल्मों के संयोजन के साथ स्प्रे लेपित, उच्च प्रदर्शन-इलेक्ट्रोक्रोमिक सेल विकसित किया गया।
- एक प्रतिवर्ती रंग-से-रंगहीन थर्मोक्रोमिक स्विच के रूप में आयरन (II) क्लोराइड और बाइपिरिडीन के मिश्रण का प्रदर्शन किया।
- थर्मोइलेक्ट्रिक अनुप्रयोगों के लिए बेंज़ोडिथियोफीन-थिएनोथियोफीन (बीडीटी-टीटीई) आधारित संयुग्मित बहुलक और बहु-दीवार वाले कार्बन नैनोट्यूब (एमडब्ल्यूसीएनटी) का एक हल्का ऑल-ऑर्गेनिक नैनोकम्पोजिट तैयार किया गया था।।
- पेरोव्स्काइट नैनोक्रिस्टल/स्क्वायराइन डाई कंपोजिट पर आधारित तकनीकी दृष्टि से महत्वपूर्ण दृष्टिगोचर अपारदर्शी और निकट-अवरक्त संचारण सामग्री विकसित की।
- पेंटासीन डिमर में सिंगलेट विखंडन का अध्ययन किया गया
- प्रतिस्थापकों के प्रभाव में विभिन्न दाताओं की दान शक्ति का आकलन करने के लिए आमतौर पर डाई-सेंसिटाइज़्ड सोलर सेल्स (डीएसएससी) में उपयोग किए जाने वाले डोनर-$\pi$-स्वीकर्ता (डी-$\pi$-ए) सिस्टम का अध्ययन किया गया है।
- उच्च प्रदर्शन वाले सुपरकैपेसिटर ने हेट्रोस्ट्रक्चर्ड MoS2-RuO2 नैनोकम्पोजिट आधारित इलेक्ट्रोड के साथ रिपोर्ट किया
- दवा प्रतिरोध को दरकिनार करने और कैंसर स्टेम कोशिकाओं को फिर से शुरू करने वाले ट्यूमर को मिटाने के लिए एमएसएन-चिटोसन कोर-शेल स्व-विनाश और प्रतिरक्षा उत्तेजक सुविधाओं के साथ चिकित्सीय नैनो-वितरण प्रणाली को विकसित किया गया।
- लेबल मुक्त सतह द्वारा बढ़ाया रमन फिंगरप्रिंट और केमोमेट्रिक्स से सर्वाइकल कैंसर के ग्रेड की स्थापित विभेदक पहचान की।
- एंटीवायरल ईआईडीडी 2801 (मोलनुपिरवीर) और इसके सक्रिय फार्मास्युटिकल इंटरमीडिएट ईआईडीडी 1931 के संश्लेषण के लिए लागत प्रभावी और औद्योगिक रूप से व्यवहार्य प्रक्रियाएं विकसित की।
- कोविड-19, "क्लीननीस्ट" की रोकथाम और प्रसार के लिए एक हर्बल जेल सैनिटाइज़र विकसित
- स्टीम अन्तःश्वसन, "नीस्टस्टीम" के लिए एक नोवेल निरंतर रिलीज तरल फॉर्मूलेशन विकसित किया है। साथ ही विकसित प्रौद्योगिकी के लिए भारतीय पेटेंट दायर किया है।
- बहुऔषध प्रतिरोधी उपभेदों के खिलाफ फाइटोमोलेक्यूल्स का उपयोग करके सामयिक एंटीबायोटिक क्रीम विकसित की।
- बीओडीआईपीवाई-आधारित 2D सुपरमॉलेक्यूलर पॉलिमर का विकास जो उत्साहित-राज्य कैस्केड ऊर्जा हस्तांतरण मध्यस्थता कई उत्सर्जन दिखा रहा है।
- एक नए पेंटासाइक्लिक पाइरिलियम फ्लोरोसेंट जांच का विकास जो एपोप्टोसिस के दौरान पीएच असंतुलन का जवाब देता है।
- NO2 गैस सेंसिंग की संवेदनशीलता बढ़ाने के लिए सेमीकंडक्टिंग SWNTs के अलाइनिंग और इन-सीटू सॉर्टिंग के लिए सिलिकॉन शैडो मास्क तकनीक।
- मोटापे और हाइपरलिपिडिमिया के खिलाफ कुरकुमा अमाडा से संभावित अर्ध-सिंथेटिक लीड की पहचान की गई।
- डायस्टेरियोसेलेक्टिव स्पिरोफुरन ऑक्सिंडोल्स और -फंक्शनलाइज्ड एलिनोएट्स के लिए बेस-सक्षम एक्सेस।

# Chemical Sciences and Technology Division

The Chemical Sciences and Technology Division has been focusing on the development of molecules and functional materials and their applications in various device platforms and prototypes. Three priority areas of the Institute are coordinated by the Division – (1) Organic and Hybrid Electronics (Energy generation and storage, chromogenic coatings, conductive coatings, organic optoelectronics, computational chemistry); (2) Fluorescent Materials (Security applications, sensing, diagnostics and imaging probes and ultrafast kinetics); (3) Phytochemicals, and Drug Intermediates (Bio-evaluation of medicinal plants and advanced pharmaceutical intermediates). The Division leads various thematic activities of CSIR at the institute level, such as Energy (conventional and non-conventional) Materials and Devices, and Chemicals. The stand-alone vertical on "Coatings" under 4M theme is also being coordinated by the Division. Scientists in the division have also undertaken a large number of important projects funded by various government agencies and industries. In addition to the involvement in technology development, the division is also very active in knowledge generation as evidenced from 90 publications in internationally reputed peer-reviewed journals with high impact factor in 2020-21. The division has also got 15 patents filed or in the process of filing, during this period.

The division has actively participated in the Covid-19 mitigation activities by developing processes for synthesis of antiviral drug molecules such as Molnupiravir,and developing new diagnostic platform for screening Covid-19 using label-free Raman scattering, developing flocculent materials for biomedical waste disposal, designing face masks, developing a herbal gel sanitizer, developing new formulations for steam inhalation and supplying hand sanitizer to the whole Institute.

The highlights of the activities and achievements of the Division during the year 2020-21 along with brief abstracts of important developments are given below.

## Highlights

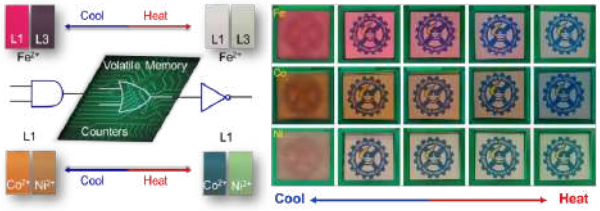
- Signed an MoU with the Bank Note Press, Dewas (A unit of Security Printing and Minting Corporation of India, under the Ministry of Finance, Govt. of India) for the development of the fluorescent pigments suitable for Indian currency printing
- Installed an indigenously made spary coating unit developed by an MSME unit for developing transparent conducting coatings
- Signed MoU with Kerala State Drugs and Pharmaceuticals Limited for the development of knowledge base on 15 active pharmaceutical ingredients
- Developed spray coated, high performance-electrochromic cells with assemblies of iron(II) based metallosupramolecular polymer network films using tetra-terpyridine ligands
- Demonstrated a mixture of iron(II) chloride and bipyridine as a reversible color-to-colorless thermochromic switch
- A lightweight all-organic nanocomposite of benzodithiophene-thienothiophene (BDT-TTE) based conjugated polymer and multi-walled carbon nanotube (MWCNT) was prepared for thermoelectric applications
- Developed technologically important visibly opaque and near-infrared transmitting material based on perovskite nanocrystal/ squaraine dye composite
- Singlet fission in pentacene dimers studied
- Donor–π–acceptor (D–π–A) systems typically used in dye-sensitized solar cells (DSSC) have been studied for assessing the donating strength of various donors under the influence of substituents
- High performance supercapacitors reported with heterostructured $MoS_2$-$RuO_2$ nanocomposite based electrode
- Developed MSN-Chitosan core-shell targeted theranostic nano-delivery system with self-destruction and immunostimulatory features to circumvent drug resistance and wipe-out tumour reinitiating cancer stem cells

- Established differential recognition of the grades of cervical cancer by label-free surface enhanced Raman fingerprints and Chemometrics
- Developed cost-effective and industrially viable processes for the synthesis of the antiviral EIDD 2801 (Molnupiravir) and its active pharmaceutical intermediate EIDD 1931
- Developed an herbal gel sanitizer for prevention and spread of COVID-19, "CLEANiiST"
- Developed a novel sustained release liquid formulation for steam inhalation, "NiiSTEAM". Indian patent has been filed for the developed technology
- Developed topical antibiotic cream using the phytomolecules against multidrug-resistant strains
- Development of BODIPY-based 2D supramolecular polymers showing excited-state cascade energy transfer mediated multiple emission
- Development of a new pentacyclic pyrylium fluorescent probe that responds to pH imbalance during apoptosis
- Silicon shadow mask technology for aligning and in situ sorting of semiconducting SWNTs for sensitivity enhancement of $NO_2$ gas sensing
- Identified potential semi-synthetic leads from Curcuma amada against obesity and hyperlipidaemia.
- Base-enabled access to diastereoselective Spirofuran oxindoles and γ-Functionalized allenoates

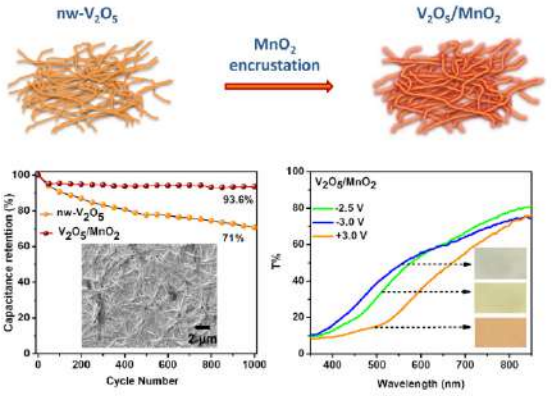
## Organic and hybrid electronics

### Chromogenic Materials and Devices

### Temperature as a Precision Input using Thermochromic Metal-Organic Complexes and Hybrid Gels




Temperature is often not considered as a precision stimulus for artificial chemical systems in contrast to the host-guest interactions related to many natural processes. Similarly, mimicking multi-state volatile memory operations using a single molecular system with temperature as a precision stimulus is highly laborious. We demonstrated how a mixture of iron(II) chloride and bipyridine can be used as a reversible color-to-colorless thermochromic switch. The generality of the approach was illustrated using Co(II) and Ni(II) salts that resulted in color-to-color transitions. DMSO gels of these systems, exhibited reversible opaque-transparency switching. More importantly, optically readable multi-state volatile memory with temperature as a precision input has been demonstrated. The stored data is volatile and is lost instantaneously upon withdrawal or change of temperature. Simultaneous read-out at multiple wavelengths results in single-input/multi-output sequential logic operations such as data accumulators (counters) leading to volatile memory states. The present system provides access to thermoresponsive materials wherein temperature can be used as a precision stimulus [Shankar, S., Ajayaghosh, A. et al. Angew. Chem., Int. Ed. 2021, 60, 455-465].




Ultra-thin Manganese Dioxide Encrusted Vanadium Pentoxide Nanowire Mats for Electrochromic Energy Storage Applications

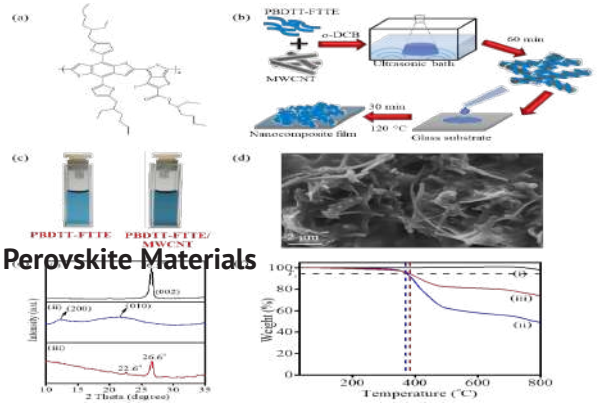
$V_2O_5$ electrochromic (EC) coatings are attractive for various photonic applications owing to their multiple oxidation states discernable by distinct colors. The material also showed massive potential for electrochemical energy storage because of their layered structure and high theoretical capacitance. Here we report the solution processing of the electrodes composed of an ultra-thin layer of $MnO_2$ encrusted $V_2O_5$ ($V_2O_5/MnO_2$) nanowire mats on FTO substrates that offer much enhanced electrochemical stability along with a superior energy storage performance compared to a bare $V_2O_5$ electrode. The areal capacitance of the $V_2O_5$ showed 25.7% enhancement (10.90 to 13.70 mF $cm^{-2}$ at 5.0 mV $cm^{-2}$) due to $MnO_2$ encrustation. The fabricated electrochromic devices showed three distinct colors; i.e., orange (+3.0 V), green (-2.5 V) and blue (-3.0 V).

Capacitance retention of bare $V_2O_5$ at 1000 cycles was 71% that increased to 93.6% after $MnO_2$ coating due to the enhanced electrochemical stability [Adv. Mater. Interfaces 2019, 6, 1901038]

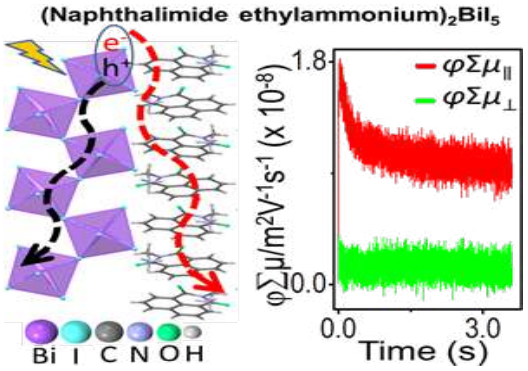
## Thermoelectricity

### MWCNT/Thienothiophene based All-Organic Thermoelectric Composites: Enhanced Performance by Realigning of the Fermi Level through Doping

Thermoelectric (TE) polymer nanocomposites are an emerging class of functional materials that have immense potential for commercial usage. In this work, a lightweight all-organic nanocomposite of benzodithiophene-thienothiophene (BDT-TTE) based conjugated polymer poly[4,8-bis(5-(2-ethylyhexyl) thiophene-2-yl)benzo[1,2-b;4,5-b']dithiophene-2,6-diyl-alt-(4-(2-ethylhexyl)3-fluorothieno[3,4-b']thiophene-)-2-carboxylate-2-6-diyl)] (PBDTT-FTTE) and multi-walled carbon nanotube (MWCNT) was prepared for TE applications. The peak electrical conductivity in the composite was obtained with 45 wt% MWCNT content and the resulting composite exhibited a temperature tolerance up to 350 °C. The as-prepared nanocomposite was further p-doped with an oxidizing agent for tuning its Fermi level positioning leading to the further enhancement in TE output. The electrical conductivity was further boosted by 6.7x post-doping with concurrent 2.5x enhancement in the Seebeck coefficient. Thus, the power factor increased from 1.28 μW/m.$K^2$ to 48.21 μW/m.$K^2$, leading to the highest value for the thienothiophene based conjugated polymer/MWCNT nanocomposite. The device performance was demonstrated with a prototype exhibiting the power delivery of ~7 nW/$cm^2$ when tested with applied temperature difference across the hot and cold junction of 65 K [Vijayakumar C., B. Deb et al. Chem. Eng. J. 2021, 409,128294].




## Perovskite Materials

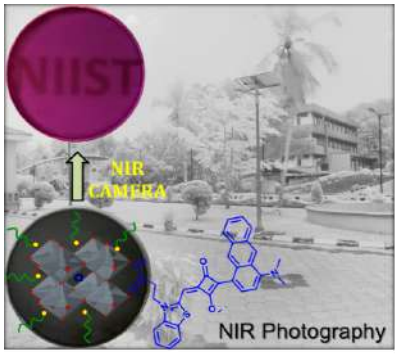



Anisotropic Photoconductivity and Long-Lived Charge Carriers in One-Dimensional Perovskite with Type-IIa Band Alignment: Bismuth-based perovskites are attracting intense scientific interest due to low toxicity and excellent moisture stability compared to lead-based analogues. However, high exciton binding energy, poor charge carrier separation, and transport efficiencies lower their optoelectronic performances. To address these issues, we have integrated an electronically active organic cation, naphthalimide ethylammonium, between the $[BiI_5^{2-}]_n$ chains via crystal engineering to form a novel perovskite-like material (naphthalimide ethylammonium)$_2BiI_5$ (NBI). Single crystal analysis revealed a one-dimensional quantum-well structure for NBI in which inter-inorganic well electronic coupling is screened by organic layers. It exhibited anisotropic photoconductivity and long-lived charge carriers with milliseconds lifetime, which is higher than that of $CH_3NH_3PbI_3$. Density functional theory calculations confirmed type-IIa band alignment between organic cations and inorganic chains, making the former electronically contribute to the overall charge transport properties of the material [Vijayakumar et al., J. Phys. Chem. Lett. 2020, 11, 6757-6762].

**Perovskite Nanocrystal/ Squaraine Dye Composite based Visibly Opaque and Near-Infrared Transmitting Material**

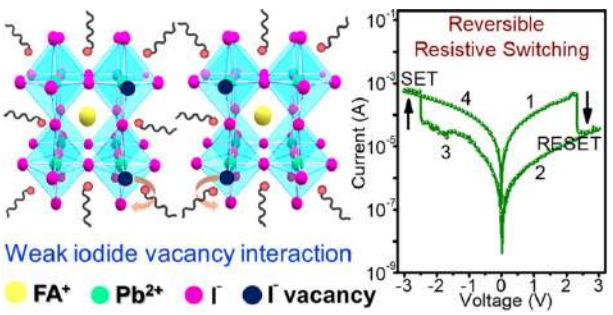
Visibly opaque and near-infrared transmitting (VONIRT) materials play a crucial role in forensic detection, security imaging, night-vision photography, and biomedical applications. In this work, the development of such material using alpha-formamidinium lead iodide-based perovskite nanocrystals (PNCs) and squaraine (SQ) dyes is described. It is achieved by gradually increasing the size of PNCs followed by attaching them with a novel low-bandgap SQ dye as capping ligand. The acid group present in the SQ dye efficiently interacts with the surface of the nanocrystals via non-covalent

interactions. Incorporation of SQ dyes onto PNCs yielded composite films with uniform transmittance of below 2% in the visible region (380-740 nm) and above 60% in the NIR region, the prime requisites for VONIRT materials. Further, the addition of SQ dyes imparted better moisture stability and high film quality to the nanocrystals. Opaqueness in the visible region and excellent NIR transparency of the nanocomposite make them useful as a security material and for NIR photography application [Vijayakumar et al., Adv. Optical Mater. 2020, 2001130].




## Resistive switching in perovskite nanocrystals: a contradiction to the bulk form

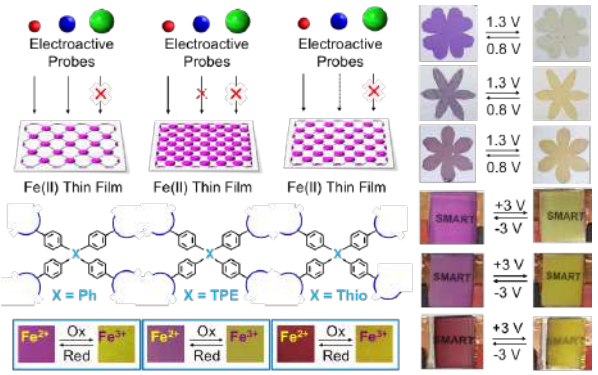
Hybrid perovskites have emerged as an excellent class of materials for resistive random-access memory (ReRAM) devices and neuromorphic computing applications. Among numerous perovskites, formamidinium lead triiodide ($\alpha$-$FAPbI_3$) is an important material due to its superior optoelectronic properties. However, it does not show resistive switching due to the difficulties in rupturing the filaments formed by iodide vacancies. Herein, we report the ReRAM device characteristics of $\alpha$-$FAPbI_3$ in the nanocrystals form, prepared in a single-step method. Unlike the bulk form, the nanocrystals show reliable, and reproducible memory characteristics in terms of program/erase operations, data retention, and endurance with an operating set voltage of around 2 V. Our studies revealed that the iodide vacancies are responsible for the switching and the presence of capping ligands play a significant role on it. The capping ligands reduce the interaction energy between the iodide vacancies, and hence the filaments formed by the latter are easy to rupture during the reset process resulting in excellent ReRAM characteristics [Vijayakumar et al., J. Mater. Chem. C, 2021, 9, 288].




## Functional Supramolecular materials

### Ligand Controlled Electrochromic Diversification in Metallosupramolecular Polymer Assemblies

We designed three tetra-terpyridine ligands with variations in their core architecture (phenyl vs tetraphenylethynyl vs bithiophene) to create spray coated electrochromic assemblies of iron(II) based metallosupramolecular polymer network films on transparent conducting oxide substrates. These assemblies exhibited molecular permeability and spectroelectrochemical properties that are in turn dictated by the ligand structure. Electrochromic films with high coloration efficiencies (up to 1050 $cm^2/C$) and superior optical contrast (up to 76%) with a concomitant color-to-color redox transition were readily achieved. These functional switching elements were integrated into sandwich-type electrochromic cells (CE up to 641 $cm^2/C$) that exhibited high contrast ratios up to 56%, with attractive ON-OFF ratios, fast switching kinetics and high operational stability.

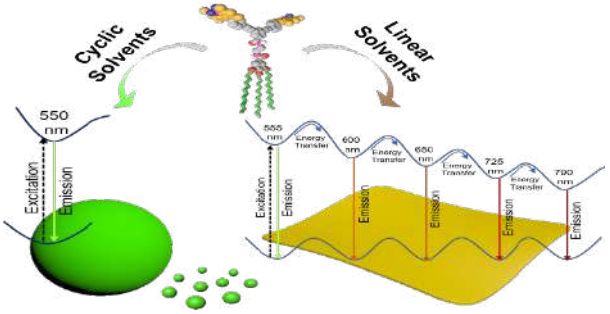



Every measurable spectroelectrochemical property of the films and devices is an associated function of the ligand structure that coordinates the same metal ion to different extents. While exhibiting a ligand structure induced differential metal coordination leading to porosity and spectroelectrochemical diversification,

these assemblies allow the creation of electrochromic patterns and images by a simple spray coating technique [Shankar, S., Deb, B. And Ajayaghosh, A. et al. ACS Appl. Mater. Interfaces, 2021, 13, 5245–5255].

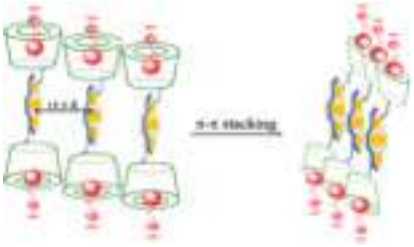
## Tweaking a BODIPY Spherical Self-Assembly to 2D Supramolecular Polymers Facilitates Excited-State Cascade Energy Transfer

Excited state properties such as emission, exciton transport, electron transfer, etc., are strongly dependent on the shape, size and molecular arrangement of chromophore based supramolecular architectures. In this work, we demonstrate creation and control of distinct supramolecular energy landscapes for the reversible control of the excited-state emission processes through cascade energy transfer in chromophore assemblies, facilitated by an unprecedented solvent effect. In methylcyclohexane, a tailor-made Y-shaped BODIPY derivative self-assembles to form an unusual spherical architecture of 400–1200 nm size,which exhibits a single emission at 540 nm upon 475 nm excitation through a normal excitation deactivation process. However, in n-decane, the same BODIPY derivative forms two-dimensional supramolecular sheets, exhibiting multiple emission peaks at 540, 610, 650, 725 and 790 nm with 475 nm excitation due to cascade energy transfer. Further control on the morphology and excitation energy transfer is possible with variable solvent composition and ultrasound stimulation, resulting in enhanced near-infrared emission with an overall pseudo Stokes shift of 7105 $cm^{-1}$ [V. K. Praveen, A. Ajayaghosh et al. Angew. Chem., Int. Ed. 2021, 60, 7851].



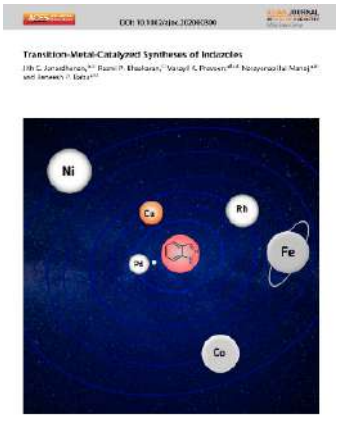

## Structural Deformation to β-Cyclodextrin due to Strong π-Stacking in the Self-Assembly of Inclusion Complex

Severe distortion to the structure of β -cyclodextrin and partial de-encapsulation of included guest prompted by strong π -stacking of appended pyrene moieties in the self-assembly of inclusion complex into toroidal nanostructures. The inclusion complex formed from bis(b-cyclodextrin)-substituted pyrene and bis(adamantane)-substituted methyl viologen assembled into ring-like structures. The rings undergo further self-assembly which involve strong face-to-face π -stacking of pyrene chromophores. Close approach of the pyrenes for π -stacking demands severe distortion of the cyclodextrin truncated cone structure and partial de-encapsulation of the guest from the cavity. The understanding that β -CD can be distorted severely during self-assembly may be helpful in the design of molecular architectures [Gopidas et al. ChemistrySelect, 2021, 5, 14966-14970).



## Transition-Metal-Catalyzed Syntheses of Indazoles

zole is an important heterocyclic scaffold exhibiting a wide range of biological and pharmacological properties and plays a crucial role in drug design. In recent years, indazoles have gained attention in materials chemistry owing to their promising photophysical properties.

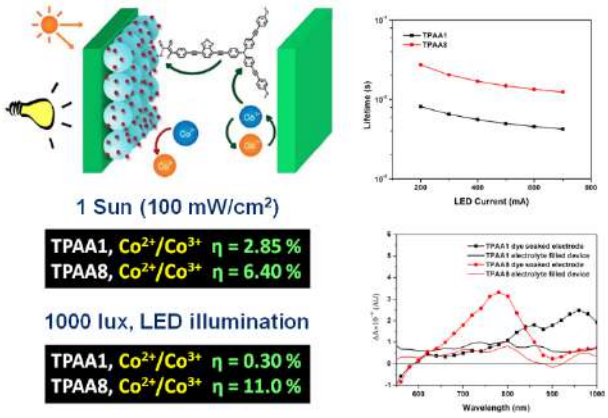



The biomedical importance and natural rarity inspire the development of new practical syntheses of the indazole core. In this review, we are presenting a comprehensive overview of recent developments in the transition metal-catalyzed synthesis of indazole during the last decade [V. K. Praveen et al., J Asian J. Org. Chem. 2019, 9, 1410. (Highlighted by a Frontispiece).

## Solar Energy

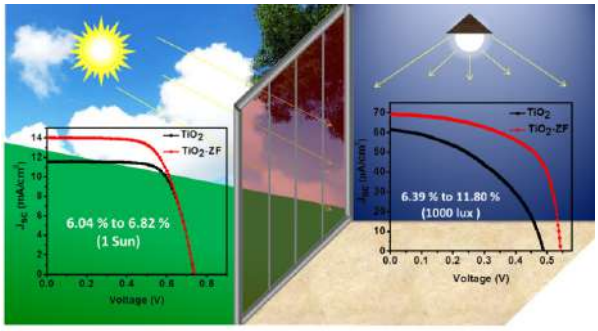
### Propellar Shaped Triple Bond Rigidified D-A-π-A Triphenylamine Dye as a Potential Back Electron Interceptor with Iodine and Cobalt Electrolyte based Dye Sensitized Solar Cells under Full Sun and Indoor Light

The synthesis and characterization of a new molecularly engineered triple bond rigidified D-A-π-A propeller shaped triphenylamine dye having benzothiadiazole as auxiliary acceptor (TPAA8) have been reported. We compared the behavior of TPAA8 with the parent dye TPAA1 in D-π-A architecture without auxiliary acceptor, which was reported previously from our group (Vinayak et al., 2016). TPAA8 was found to be efficient in harvesting light and was having a favourable energetics suitable to realize forward electron transfer process in fabricated devices.




TPAA8 with the introduction of auxiliary benzothiadiazole acceptor proved to be a promising candidate in preventing recombination with conventional iodine and alternate cobalt based redox electrolytes which was studied in detail employing various optical and electrical perturbation techniques. With alternate cobalt electrolyte ($[Co(bpy)_3]^{2+/3+}$) TPAA8 delivered an improved performance of 6.40 ± 0.05%, which is an improvement of 124% in power conversion efficiency compared to the parent TPAA1 sensitizer devoid of auxiliary acceptor having an efficiency of 2.85%. TPAA8 also proved to be an efficient candidate for indoor light harvesting delivering a power conversion efficiency of 11.03 ± 1.7% employing $[Co(bpy)_3]^{2+/3+}$ redox mediator under 1000 lux warm white LED illumination [Suraj Soman, K. R. Gopidas et al., Solar Energy, 216, 2021, 151].

### Bifacial Dye-Sensitized Solar Cells with Enhanced Light Scattering and Improved Power Conversion Efficiency under Full Sun and Indoor Light Conditions

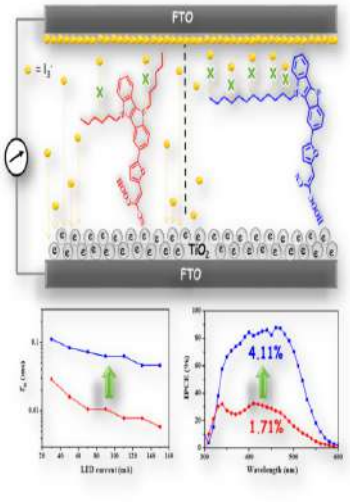



Improved photovoltaic performance in full sun (100 $mW/cm^2$) and indoor light (1000 lux, CFL) conditions were achieved in dye-sensitized solar cells (DSSCs) through surface texturing of $TiO_2$ photoanodes. Herein, surface roughness/imprints in $TiO_2$ layer was introduced through fugitive inclusions of ZnO microflowers leading to enhanced light scattering without adversely affecting the transparency. These imprints thus created acted as scattering centers enhancing the light absorption leading to an improvement of 13% and 85% in power conversion efficiency (PCE) under full sun and indoor light conditions respectively. Detailed interfacial charge transfer studies were conducted to investigate the origin of variation in photovoltaic performance. Photoanode surface engineering led to the development of semi-transparent, bifacial DSSCs with the ability to work under both solar radiation and artificial/indoor lighting enabling them to be used as facades for building integrated photovoltaic (BIPV) applications [K. N. N. Unni, Suraj Soman et al., ACS Applied Energy Materials, 3, 2020, 12584].

### Regulating Back Electron Transfer through Donor and π Spacer Alterations in Benzothieno [3, 2b] indole based Dye sensitized Solar Cells

Three metal free organic D-π-A dyes with benzothieno[3,2-b]indole as electron donor, cyanoacrylic acid as both electron acceptor and anchoring group with benzene (BID-1), thiophene (BID-2) and furan (BID-3) as π-spacers were designed and synthesized for application in dye-sensitized solar cells (DSSCs). Planar and electron rich heterocycle such as benzothieno[3,2-b]indole offers better backbone rigidity and improved charge transport properties in comparison to indolo[3,2-b]indole donor, previously reported from our group. Additionally, we synthesized benzothieno[3,2-b]indole donor grafted with longer alkyl chains which efficiently prevented the

approach of oxidized species in electrolyte coming closer to semiconductor thereby arresting recombination. Power conversion efficiency of 4.11% was achieved for dye-sensitized solar cells based on furan π-spacer benzothieno[3,2-b]indole dye BID-3 in comparison to the corresponding indolo[3,2-b]indole dye (IID-3) having an efficiency of 1.71%. Detailed interfacial electrical measurements along with theoretical calculations disclosed the mechanism of back electron transfer and improvement in photovoltaic performance with respect to variation in both donor and π-spacer [C. H. Suresh, J. John, Suraj Soman, A. Ajayaghosh et al. Chemistry-An Asian Journal, 21, 2020, 3503].

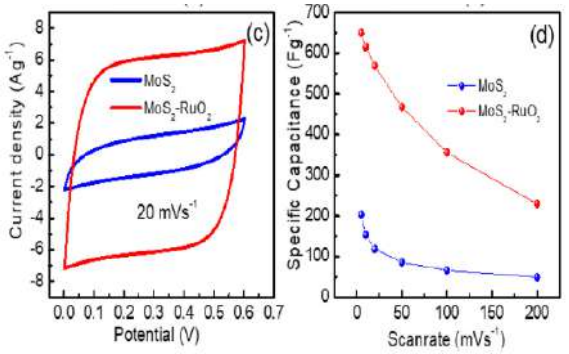



## Effect of Auxiliary Acceptor on D-π-A Based Porphyrin Sensitizers for Dye Sensitized Solar Cells

Among tetrapyrrolic class of compounds, porphyrin based sensitizers are appeal to considerable attention due to their excellent performance in dye-sensitized solar cells (DSSCs). Herein, we designed and synthesized two new donor-π-acceptor (D-π-A) concept based porphyrin sensitizer having donor 3-ethynylphenothiazine tethered at meso- position, zinc porphyrin as π-spacer and acceptor either 3-(4-(benzo[c][1,2,5] thiadiazol-4-yl)phenyl)-2-cyanoacrylic acid (LG22), and 3-(4-(benzo[c][1,2,5]thiadiazol-4-yl)thiophene-2-yl)-2-cyanoacrylicacid (LG23). Both the sensitizers were characterized by various spectroscopic techniques and electrochemical methods. Optical, electrochemical and optimized studies suggest that these dyes are suitable for sensitization of nanocrystalline $TiO_2$. The optimized device studies shows that the power conversion efficiencies (PCE) of 1.86% and 1.37% for LG22 and LG23 dyes, respectively using I-/I3 - liquid redox shuttle. Finally, we have adopted Charge Extraction (CE), Intensity Modulated Photovoltage Spectroscopy (IMVS), Intensity Modulated Photocurrent Spectroscopy (IMPS) and Open Circuit Voltage Decay (OCVD) measurements to understand in detail the electron transfer properties at various interfaces in a way to understand the performance limiting processes in these novel porphyrin sensitizers [Suraj Soman, L. Giribabu et al. Journal of Porphyrins and Phthalocyanines, 2020].

## Energy Storage

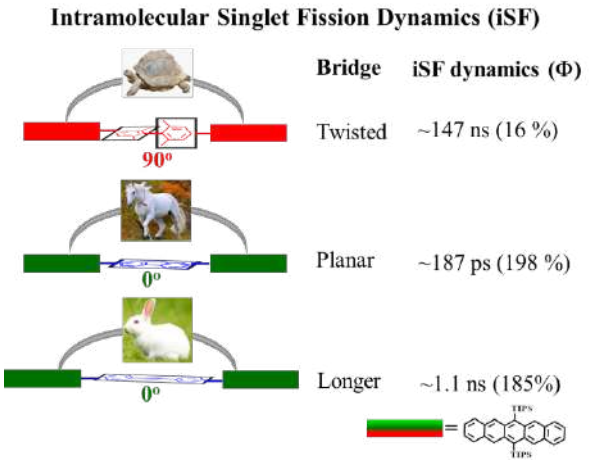
### Heterostructured $MoS_2$-$RuO_2$ nanocomposite: A promising electrode material for supercapacitors




A heterostructured nanocomposite material consisting of $MoS_2$ nanowires and $RuO_2$ nanoparticles has been synthesized by an easy hydrothermal method and a simple chemical reduction technique followed by a calcination process. For the first time, the electrochemical performance of the as-prepared $RuO_2$ nanoparticle dispersed $MoS_2$ hybrid composite has been evaluated in three-electrode as well as symmetric two-electrode configurations in 1 M KOH electrolyte. At 1 $Ag^{-1}$, the $MoS_2$-$RuO_2$ hybrid electrode exhibits specific capacitance (Csp) values of 972 $Fg^{-1}$ (3- electrode) and 719 $Fg^{-1}$ (two-electrode). Moreover, the symmetric supercapacitor based on the composite electrodes retains 100% cycling stability over 10000 cycles, which makes $MoS_2$-$RuO_2$ composite, a promising electrode for energy storage applications.[ K. N. N. Unni, R. B. Rakhi et al., Journal of Alloys and Compounds 836, 2020 155420]

## Ultrafast Spectroscopy

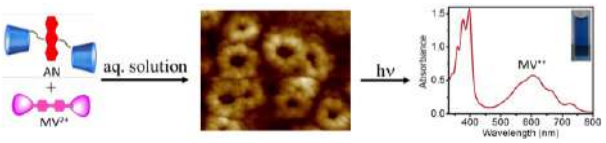
Planarity and Length of the Bridge Control Rate and Efficiency of Intramolecular Singlet Fission in Pentacene Dimers




Singlet fission (SF) improves power conversion efficiency of optoelectronic devices by converting high energy photons into two triplet excitons. SF dynamics and efficiency (Φ) are controlled by various factors. Here the effect of planarity and length of the bridge in pentacene dimers on intramolecular SF (iSF) process were investigated by synthesising the dimers connected by bridges having fluorene (FL-PD, planar), methyl substituted biphenyl (MBP-PD, twisted) and diphenyl acetylene (DPA-PD, longer) groups, and characterizing their excited state relaxation dynamics using nanosecond and femtosecond pump-probe spectroscopy. Transient absorption studies reveal that iSF dynamics of FL-PD having planar bridge are ~787 times faster (187 ps) and exhibiting higher Φ (198 %) by feasible electronic coupling, compared to MBP-PD possessing twisted bridge showing low Φ of ~16%. However compared to FL-PD, iSF dynamics of DPA-PD with increase of bridge length are slower by an order (1.09 ns) and showing comparable Φ of 185% through extended conjugation. Thus planarity and length of bridge in pentacene dimers control the rate and efficiency of iSF process [Karunakaran et al., J. Phys. Chem. B 2021, 125, 231–239].

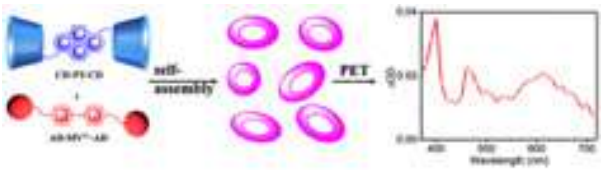
## Generation of Long-lived Photoinduced Charge Separation in a Supramolecular Toroidal Assembly

Efficiencies of artificial photosynthetic and photocatalytic systems depend on their ability to generate long-lived charge separated states in photoinduced electron transfer (PET) reactions. PET, in most cases, is followed by an ultrafast back electron transfer, which severely reduces lifetime and quantum yield of charge separated states. Generation of a long-lived charge separated state, thus is an important goal




in the study of PET reactions. Herein we report that this goal is achieved using a hierarchically self-assembled anthracene-methyl viologen donor-acceptor system. Anthracene linked to two β-cyclodextrin molecules (CD-AN-CD) and methyl viologen linked to two adamantane units (AD-$MV^{2+}$-AD) form an inclusion complex in water, which further self-assembled into well-defined toroidal nanostructures. The fluorescence of anthracene is highly quenched in the self-assembled system due to PET from anthracene to methyl viologen. Irradiation of the aqueous toroidal solution led to formation of a long-lived charge separated state. Rational mechanisms for the formation of the toroidal nanostructures and long-lived photoinduced charge separation are presented in the paper [Gopidas et al. ,J. Phys. Chem. B 2020, 124, 9546-9555].

## Photoinduced Electron Transfer in a Self-Assembled Bis(b-Cyclodextrin)-Linked Pyrene / Bis(Adamantane)-Linked Methyl Viologen Donor-Acceptor System in Aqueous Solution



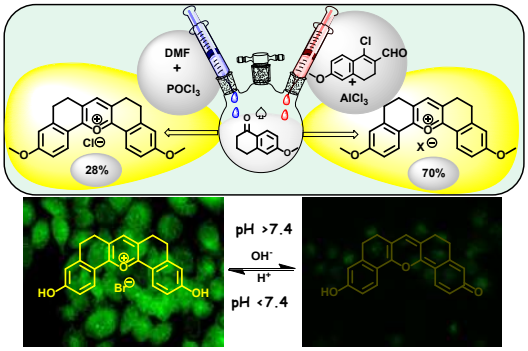

Pyrene linked to two β -CD molecules (CD-PY-CD) and methylviologen linked to two adamantane groups (AD-$MV^{2+}$-AD), self-assembled in water to give toroidal nanostructures. Photo processes taking place in the femtosecond and nanosecond time range within the assembly are reported. Fluorescence of the pyrene chromophore was quenched in the toroid suggesting very efficient photoinduced electron transfer taking place within the toroid assembly. The rate constant for electron transfer within the assembly was obtained from fluorescence lifetime studies. Evidence for photoinduced electron transfer from pyrene to methyl viologen in the assembly was obtained from nanosecond laser flash photolysis studies. Electron transfer leads to formation of radical ion products, $PY^{\bullet+}$ and $MV^{\bullet+}$, immediately following laser irradiation. Because of the close packing of chromophores, the radical ions undergo fast reactions with chromophores or similar ions in adjacent stacks to

give dimeric products. Since the dimeric species are not very stable, the reactions are reversed at longer time scales to generate the radical ions, which then undergo back electron transfer and regenerate the starting materials [Gopidas et al. J. Phys. Chem. B 2021, 125, 4428-4437].

## Diagnostics, Imaging and Targeted Drug Delivery System

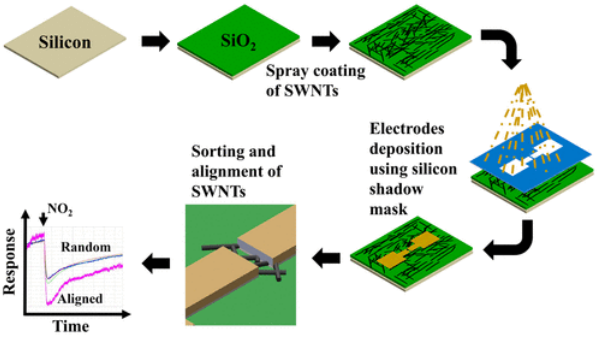
### A New Pentacyclic Pyrylium Fluorescent Probe that Responds to pH Imbalance During Apoptosis

Efficient fluorophores with easy synthetic routes and fast responses are of great importance in clinical diagnostics. Herein, we report a new, rigid pentacyclic pyrylium fluorophore, PS-OMe, synthesised in a single step by a modified Vilsmeier–Haack reaction. Insights into the reaction mechanism facilitated a new reaction protocol for the efficient synthesis of PS-OMe which upon demethylation resulted in a "turn-on" pH sensor, PS-OH. This new fluorescent probe has been successfully used to monitor intracellular acidification at physiological pH. From the fluorescence image analysis, we were able to quantify the intracellular dynamic pH change during apoptosis. This new pH probe is a potential chemical tool for screening, drug discovery and dose determination in cancer therapy [S. Varughese, S. Ghosh, K. K. Maiti, A. Samanta and A. Ajayaghosh et al. Chem. Sci. 2020, 11, 12695, Part of the themed collection: Celebrating 10 years of Chemical Science]




## Silicon Shadow Mask Technology for Aligning and In Situ Sorting of Semiconducting SWNTs for Sensitivity Enhancement: A Case Study of $NO_2$ Gas Sensor

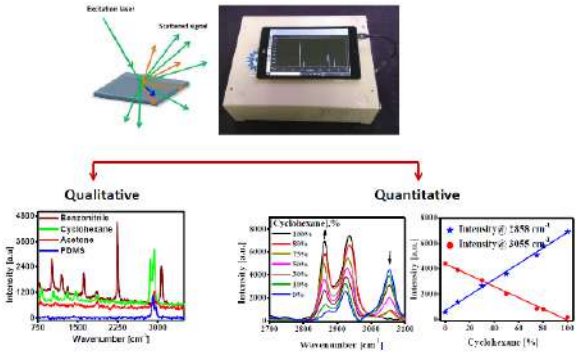
Single-walled carbon nanotubes (SWNTs) are incorporated in different device configurations such as chemiresistors and field-effect transistors as a sensing element for the fabrication of highly sensitive and specific biochemical sensors. For this purpose, sorting and aligning of semiconducting SWNTs between the electrodes is advantageous. In this work, a silicon shadow mask fabricated using conventional semiconductor processes and silicon bulk micromachining was used to make metal contacts over SWNTs with a minimum feature of 1 μm gap between the electrodes. The developed silicon shadow mask-based metal contact patterning process is cost-effective and free from photoresist chemical coatings and thermal processing. After a detailed investigation, sodium dodecyl sulfate, an anionic surfactant, along with ultrasonication process, was found to be effective for the removal of unclamped and metallic SWNTs, resulting in aligned and clamped semiconducting SWNTs between the electrodes. The presence of aligned semiconducting SWNTs was confirmed using atomic force microscopy, field emission scanning electron microscopy, and Raman spectroscopy techniques. The fabricated devices were tested for $NO_2$ gas sensing as a test case. The sensitivity enhancement of ~21 to 76% in the 20–80 ppm $NO_2$ concentration range has been observed in the case of aligned semiconducting SWNT devices compared to the random network SWNT-based sensors [A. Ajayaghosh et al., ACS Appl. Mater. Interfaces 2020, 12, 40901].




## Low-Cost Raman Spectrometer for Educational Purpose

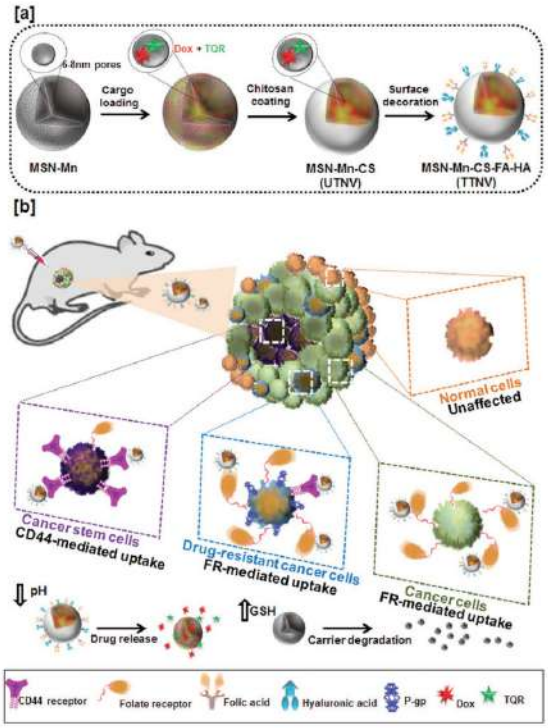
Raman spectroscopy probes molecular vibrations nondestructively and provides fingerprint information about materials. As a result, it has become a popular analytical tool. The advancements in the field of Raman spectroscopy and the expanding scope of applications necessitate the introduction of the topic in the formal education curriculum. The availability of a low cost and easy to set up Raman spectrometer will aid the teaching to better convey the spectroscopy basics better and demonstrate experiments. Furthermore, component-wise familiarization and fabrication training will help

students evolve their own methodologies to fabricate and customize the instrument for specific applications. Though many Raman spectrometers are commercially available, the high cost makes them unaffordable for most academic institutions. Herein, we demonstrated an easy and cost-effective method to make a fully integrated portable Raman spectrometer and a few simple experiments that can be conducted at the classroom level using the fabricated device. (Yoosaf K. et al., J. Chem. Educ. 2021, 98, 6, 2109−2116;)




## Targeted Theranostic Nano Vehicle Endorsed with Self-Destruction and Immunostimulatory Features to Circumvent Drug Resistance and Wipe-Out Tumor Reinitiating Cancer Stem Cells

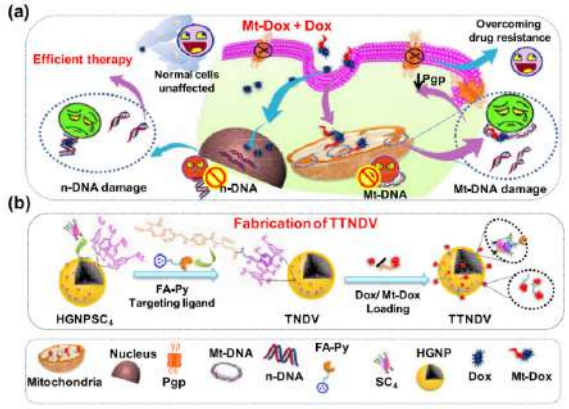
The downsides of conventional cancer monotherapies are profound and enormously consequential, as drug-resistant cancer cells and cancer stem cells (CSC) are typically not eliminated. In this report, we designed a targeted theranostic nano vehicle (TTNV) using manganese-doped mesoporous silica nanoparticle (5 wt% of Mn in MSN) with an ideal surface area and pore volume (389 m2/g and 6-8 nm) for co-loading an optimized ratio of antineoplastic doxorubicin and a drug efflux inhibitor tariquidar. This strategically framed TTNV was chemically conjugated with folic acid and hyaluronic acid as a dual-targeting entity to promote folate receptor (FR) mediated cancer cell and CD44 mediated CSC uptake, respectively. Interestingly, surface-enhanced Raman spectroscopy was exploited to monitor drug release kinetics, differentiate drug resistance and also to evaluate the molecular changes associated with therapeutic progression. Tumor microenvironment selective biodegradation and immunostimulatory potential of MSN-Mn core was safeguarded with a chitosan coating which modulate the premature cargo release and accorded biocompatibility. The superior antitumor response in FR-positive syngeneic and CSC-rich human xenograft murine models was associated with a tumor-targeted biodistribution, favorable pharmacokinetics, and an appealing bioelimination pattern of the TTNV with no palpable signs of toxicity. This dual drug-loaded, metal ion-doped nano vehicle, offers a feasible approach for efficient cancer therapy by on demand cargo release in order to execute complete wipe-out of tumor reinitiating cancer stem cells [Kaustabh K. Maiti et al. Small, 2020, 16, 2003309].




## Elucidating a Thermo-responsive Multimodal Photo-Chemotherapeutic Nano-delivery Vehicle to Overcome the Barriers of Doxorubicin Therapy

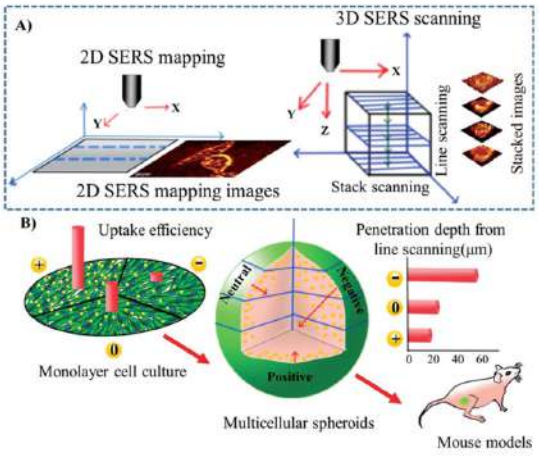
In an attempt to circumvent the major pitfalls associated with conventional chemotherapy including drug resistance and off-target toxicity, we have developed a targeted theranostic nano-delivery vehicle (TTNDV) to simultaneously target both mitochondrial DNA (Mt-DNA) and nuclear DNA (n-DNA). TTNDV constituted with a folic acid anchored p-sulfo-calix[4]arene ($SC_4$) capped hollow gold nanoparticles (HGNP) which was meticulously loaded with a pre-tuned ratio (1:100) of antineoplastic doxorubicin (Dox) and its mitochondria targeted analogue, Mt-Dox for sustained thermo-responsive release of cargo. This therapeutic strategy was enabled to eradicate both n-DNA and Mt-DNA leaving

no space to develop drug resistance. The $SC_4$ capped HGNPs ($HGNPSC_4$) was experimented for the first time as a photothermal (PTT) agent with 61.6% photothermal conversion efficiency, to generate tunable localized heat more efficiently than bare HGNPs. Moreover, the cavity of $SC_4$ facilitated the formation of an inclusion complex with folic acid to target folate receptor expressing cancer cells and imparted enhanced biocompatibility. The as-synthesized TTNDV demonstrated to be an ideal substrate for surface-enhanced Raman scattering (SERS) to monitor the molecular level therapeutic progression in cells and spheroidal model. A significant reduction in the tumor mass with a marked survival benefits was archived in syngraft murine models through this synergistic photo-chemotherapy. Collectively, this multifunctional nanoplatform offers a robust approach to treat cancer without any scope of generating Dox resistance and off-target toxicity [Kaustabh Kumar Maiti et al. ACS Applied Materials and Interfaces, 2020, 12, 39, 43365–43379].




## Surface charge modulates the internalization vs penetration of gold nanoparticles: comprehensive scrutiny on monolayer cancer cells, multicellular spheroids and solid tumors by SERS modality

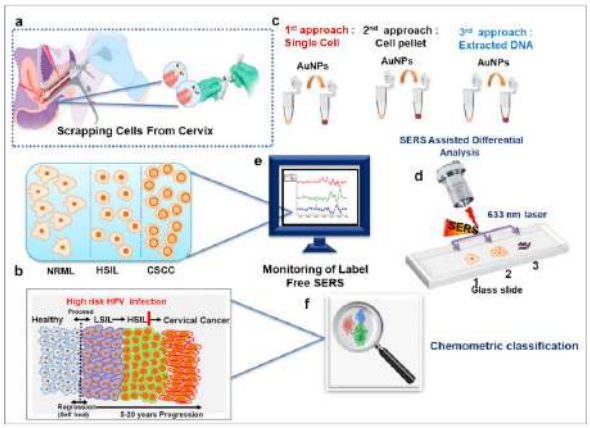
Precise control over the dynamics of nanoparticles (NPs) in tumor microenvironment is highly warranted for the development of an efficient nanotheranostic agent. Eventhough inductively coupled plasma mass spectrometry can provide the quantitative assessment regarding uptake efficiency of metal NPs, enumeration of deep tissue penetration capacity remains as a challenge. Herein, we have demonstrated an accurate tracking of the uptake efficiency and penetration phenomenon of gold nanoparticles (AuNPs: 40-50 nm) with respect to three different surface charges in monolayer (2D) cells, multicellular spheroids (3D) and in vivo tumors by surface-enhanced Raman spectroscopy (SERS). While positively charged AuNPs demonstrated around two-fold increased internalization in monolayer cells, SERS-tag based line scanning on multi-layered tumor spheroids illustrated almost nine-fold superior penetration capability with negatively charged AuNPs. Further, the enhanced solid tumor distribution contributed by the negatively charged AuNPs particles could appreciably escalate its clinical utility in cancer management [K. K. Maiti et al., Nanoscale, 2020, 12, 6971–6975].




## Diagnostic Spectro-cytology revealing differential recognition of cervical Cancer lesions by label-free surface enhanced Raman fingerprints and Chemomssetrics

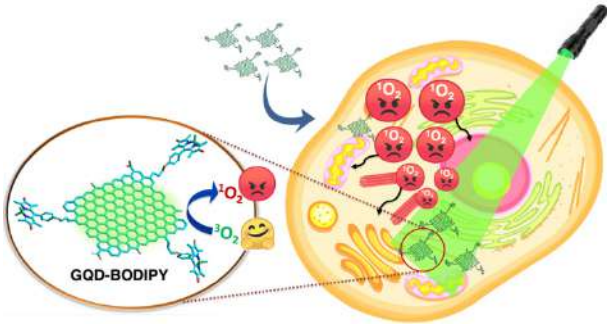
An attempt has been stepped-up on a strategic spectroscopic modality by utilizing label free ultrasensitive surface enhanced Raman scattering (SERS) technique to generate a differential spectral fingerprint for the prediction of normal (NRML), high-grade intraepithelial lesion (HSIL) and cervical squamous cell carcinoma (CSCC) from exfoliated cell samples of cervix by three different approaches i.e. single-cell, cell-pellet and extracted DNA from oncology clinic as confirmed by Pap test and HPV PCR. The tuneable plasmonic properties of the gold nanoparticles as SERS substrate favoured the increment of Raman intensity of the clinical sample by adopting the fusion of spectroscopy with liquid based cytology system, BD SurePath. Moreover, all the spectral invention was subjected to chemometrics including Support Vector Machine (SVM) which furnished an average diagnostic accuracy of 93.84 %, 74.26 % and 92.21 % of the three grades. Combined SERS read-out and machine learning

technique in field trial promises its potential to reduce the incidence in low resource countries [ K. K. Maiti et al., Nanomedicine: Nanotechnology, Biology and Medicine, 2020, 29, 102276].




## Graphene Quantum Dots Decorated with Boron Dipyrromethene Dye Derivatives for Photodynamic Therapy

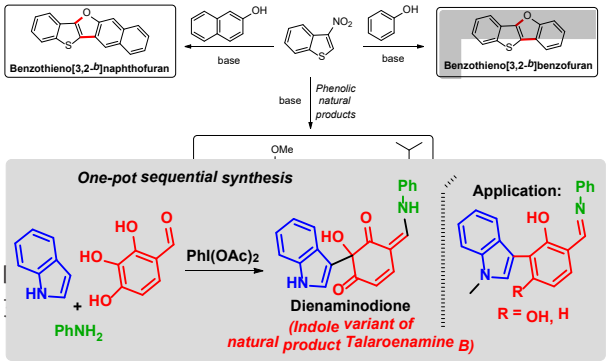
Photodynamic therapy (PDT) emerged as a promising cancer therapeutic technique due to the prospect of triggering and controlling the drug action with light, which will reduce the detrimental side effects of traditional chemotherapy. In recent years, PDT drug design has taken progressive approaches such as the use of nanocarriers and targeted delivery systems to improve the bioavailability and efficacy of the therapy. Synthesis, photophysical and photobiological properties are reported for a Graphene Oxide Quantum Dot (GQD) – BODIPY nanoconjugate (GQD-BDPA) which exhibits excellent water solubility, high triplet and singlet oxygen generation yields and high PDT efficiency. Green luminescent GQDs were synthesized from graphene oxide (GO) via a modified acid treatment method, and the amino BODIPY derivative (BDPA) was covalently attached to the GQDs via EDC-NHS coupling. These nanoconjugates, with average lateral dimensions of ~50 nm, exhibited characteristic absorption and fluorescence properties of both GQD and BDPA. Triplet quantum yield of GQD-BDPA was found to be 0.94±0.02 with a high singlet oxygen generation efficiency (90%), demonstrating the potential of these nanoconjugates for PDT applications. In vitro PDT activity of this nanoconjugate was investigated using MDA-MB-231 cancer cell lines and GQD-BDPA is found to be an efficient system for PDT treatment with an $IC_{50}$ value of 30 nM (sensitizer concentration). The apoptotic cell death was characterized and confirmed by various assays such as TMRM assay, Annexin V apoptotic assay nuclear condensation, etc. on MDA-MB-231 cell lines. The water soluble GQDs surpass the solubility and bioavailability issues of traditional sensitizers and the covalent-nanoconjugate approach enhances the local cellular concentration of the BPDA photosensitizer, realizing a useful strategy for efficient PDT applications [Joseph, J. et al., ACS Appl. Nano Mater. 2021, 4, 4162-4171]




## Synthetic Organic Chemistry and Medicinal Chemistry

### Synthesis of Benzothienobenzofurans via Annulation of Electrophilic Benzothiophenes with Phenols

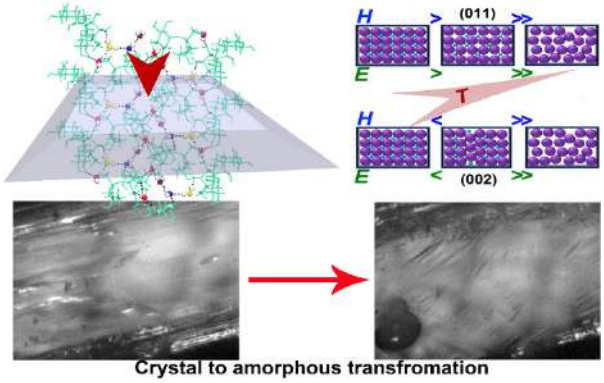
A metal-free, mild and green synthetic route towards benzothieno[3,2-b]benzofurans by the annulation of 3-nitrobenzothiophene with phenols was developed. The reaction was found to be general with a range of substituted phenols. In addition, we could extend the methodology for the synthesis of pentacenes and could demonstrate the synthesis in gram-scale. Moreover, we extended the strategy for the synthesis of benzothieno[2,3-b]benzofurans by starting from 2-nitrobenzothiophenes[Jubi et al.Org. Lett. 2021, 23, 1814–1819].




An atom-economical one-pot synthesis of a new push-pull

dienaminodiones from a 3,4-dihydroxysalicylaldehyde-derived Schiff base and indoles in the presence of phenyliodine(III) diacetate is described. Variation of indoles and anilines constitute a broad substrate scope of the methodology with good to moderate yields. Formation of Schiff base followed by an indole addition to afford dienaminodione takes place in one-pot; thus, the present method serves as a sequential multicomponent reaction. The present work also serves as a methodology to afford indole variants of natural product talaroenamine B. [Ravishankar et al. Tetrahedron Letters, 2020, 61, 152531].

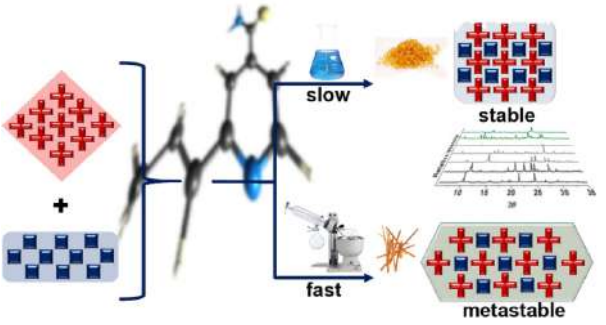
## Phase Transitions and Anisotropic Mechanical Response in a Waterrich Trisaccharide Crystal



Crystal to amorphous transfromation

Appreciating the mechanical response of molecular crystals in different hydration states is remarkable, and that under variable temperature conditions is hitherto unknown. We herein report the dehydration-driven anisotropic mechanical properties of raffinose pentahydrate (RF5W) single crystals as a function of temperature (T) using nanoindentation. The major face (011), with the initial loss of lattice water and the subsequent formation of defects, experienced a monotonous decrease in the hardness (H) and elastic modulus (E). Nonetheless, in the intermediate range of T, the minor face (002) exhibited a transient increase in the H and E due to dehydration-induced local structural rearrangements and the formation of slightly denser molecular packing and interactions. Beyond 65 °C, with the further loss of lattice water, the formation of defects predominates and interrupts the long-range ordering. The crystal-amorphous transformation leads to a drastic drop in the mechanical parameters. The optical and electron microscopy makes apparent observations on the expulsion of water from the crystal interior and the ensuing crystal surface transformations. The crystal hydrates are pervasive in drug formulations and could undergo dehydration to diminish the shelf life of a drug formulation. The mechanical response consequent to dehydration-driven crystal-amorphous transformation in an archetypal crystal hydrate highlights the probable ramifications on the pharmaceutical formulations [Sunil Varghese et al., Crystal Growth & Design 2020, 20, 442].

## Enhanced Aqueous Solubility of the Solid Forms of a BCS Class-II Anti-Tuberculosis Drug, Prothionamide




The second-line anti-tuberculosis (TB) drug prothionamide (PRT) has poor aqueous solubility but high permeability; hence, it belongs to the Biopharmaceutical Classification System (BCS) Class II. We report new solid forms a novel polymorph, 6 molecular complexes, and 11 eutectics of PRT. The solid forms showed superior aqueous solubility compared to the pristine PRT. The single-crystal and powder X-ray diffraction, thermal, spectroscopic, and microscopic data provide in-depth structural, compositional, stability, and phase correlations in the solid forms. Fast evaporation using a rotary evaporator, a kinetically controlled crystallization method, offers an effective strategy to access the coordinates in the landscape that otherwise remain inaccessible. Identified sets of H-bond donor and acceptor sites on PRT, based on the calculated gas-phase molecular electrostatic potential surfaces, provide an empirical route to screen for coformers. The torsional flexibility enjoyed by the thioamide moiety and the propyl chain introduce diversity in the conformational possibilities for PRT [Sunil Varghese et al. Crystal Growth & Design 2020, 20, 5086].

## MoU signed with Kerala State Drugs and Pharmaceuticals Limited (KSDPL) for the development of knowledge base on active pharmaceutical ingredients

The knowledge base for conducting pre-formulation studies of APIs, stability and dissolution profile; particle

and bulk material mechanical property (tabletability and compressibility) evaluation; establishment of drug excipients interactions; and development of drug formulations suitable for tablets as per Indian Pharmacopoeia. The MoU further emphasizes the development, scaling up, optimization and validation of product processes, including development of analytical methods, standard operating procedures and standard analytical procedures for the potent active pharmaceutical ingredients.

## Herbal gel sanitizer for prevention and spread of COVID-19, "CLEANiiST"

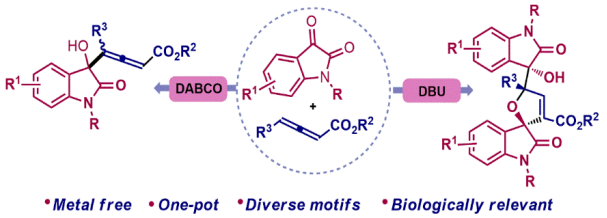
Hands are the primary mode of transmission of microbes and infections. Hand- cleanliness is extremely critical and essential in healthcare setting, food production, food service, homes and day care preparations. The developed product was aimed to prevent contact transmission of microbes and viruses leading to various infectious diseases, for instance, the pandemic, SARS-COV-2. The sanitizer was developed for use after washing hands or for those times when soap and water are not available. In most healthcare settings alcohol-based hand sanitizers are preferable to hand washing with soap and water, as alcohol being better tolerated and more effective. The general use of non-alcohol-based hand sanitizers has no recommendations due to its limitations over alcohol. The product was developed as a gel type formulation due to its advantages such as high adherence, formation of protective layer, nontoxic, excellent spreadability, cooling effect and especially its high stability when compared to liquids. The selection and use of organic medicinal herbs and their extracts are based on their antimicrobial efficacy and come with numerous health benefits. Due to the low concentration of synthetic chemicals, the likelihood of causing irritation and allergies are highly reduced. The ingredients and excipients required for present formulation also help in aiding the manufacturing process to protect, support, enhance stability and improve patient acceptability. The finished product was also compared to the presently marketed products such as Lifebuoy® and Dhathri® as well as several volunteers, which in turn support the effectiveness of CLEANiiST as an efficient hand sanitizer. Thus the presently developed product suggests and supports the incorporation and use of medicinal herbs in gel formulations to give better effect.


## A novel sustained release liquid formulation for steam inhalation, "NiiSTEAM"

The use of steam inhalation is the most widely used home remedy to prevent respiratory tract infections. But the use of only steam therapy or steam inhalation will clear up the nasal and respiratory passages, but will not cure the infection. Till date, there are only a handful of trials have been undertaken that have shown positive results. One well-designed clinical trial of 62 patients concluded that steam inhalation resulted in alleviation of cold symptoms and improved nasal patency compared to the placebo-treated group. Also, Ayurveda recommends the use of steam inhalation for a healthy respiratory system using several herbs especially Ocimum sanctum, Coleus aromaticus, turmeric etc. As part of the COVID-19 fight, the Ministry of AYUSH has recommended several guidelines for preventive health measures and immunity-boosting medications with special reference to respiratory health. However, steam inhalation drops available in the market are made up of water-insoluble ingredients which cause allergy and burning sensation to nose and eyes during inhalation. The major advantage of the present product over the commercially marketed products like Karvol Plus capsule® or Genvol Plus capsule® is its ability to release the active ingredients in a sustained or slow manner. Hence providing prolonged release of the herbal ingredients to the patient during the entire steam therapy session. The liquid can not only be used in steam therapy but can also be inhaled by sprinkling over the handkerchief or napkin to get immediate effects. The formulated product has the capability to be completely soluble and miscible in water as compared to the marketed products making it an efficient and reliable source of steam inhalation therapy with sustained release of the active ingredients to attain maximum benefit to the patients.

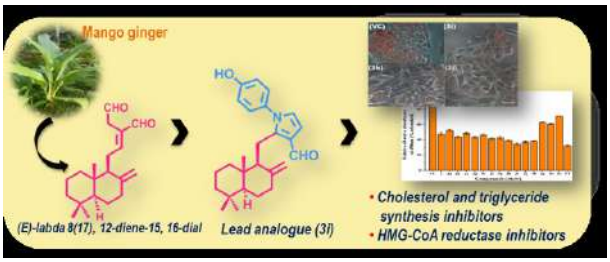
## Base-Enabled Access to Diastereoselective Spirofuran Oxindoles and γ-Functionalized Allenoates

Base assisted divergent reactivity of isatins and allenoates has been achieved, which afforded diastereoselective spirofuran oxindoles and γ-functionalized allenoates. DBU mediated Morita-Baylis-Hillman (MBH) reaction followed by the cascade annulation through the stabilized β–ammonium enolate intermediate led to the spiro-framework. Wherein the DABCO has furnished the γ-functionalized allenoates. These protocols offer a facile synthetic route to access the spiro and functionalized oxindoles. In particular, DBU promoted MBH type reaction provides unprecedented access to the spiro-furan oxindoles of medicinal importance. The method proceeds under mild reaction conditions and complements a diverse substrate scope [Sasidhar et al., Chem. Commun., 2021, 57, 1746-1749].




## Anti-hyperlipidemic Potential of Natural Product Based Labdane-pyrroles via Inhibition of Cholesterol and Triglycerides Synthesis

The design of tailor-made analogues conceived from the structural features of known ligands has paved the way for the discovery of promising pyrrole appended (E)-Labda-8(17),12-diene-15,16-dial synthesized via semi-synthetic strategy. The study reveals (E)-Labda-8(17),12-diene-15,16-dial derived pyrroles play a significant role in controlling hyperlipidemia by inhibiting TG and cholesterol synthesis in HepG2 cells. The HMGCoA reductase inhibitory activity of the compounds was consistent with that of inhibitory activity of cholesterol synthesis. Amongst, synthesized pyrrole derivatives, one of the compound (3i) possess the highest efficacy, which is comparable to the positive control Fenofibrate, Atorvastatin and Pravastatin. To the best of our knowledge this is the first report on the natural product derived (E)-Labda-8(17),12-diene-15,16-dial appended pyrrole and pyrazole analogues as anti-hyperlipidemic agents. Nonetheless, further detailed investigations are in progress to explore the lead analogue 3i as a potent and safe therapeutic clinical candidate [Sasidhar et al., Bioorg. Chem., 2021, 108, 104664].



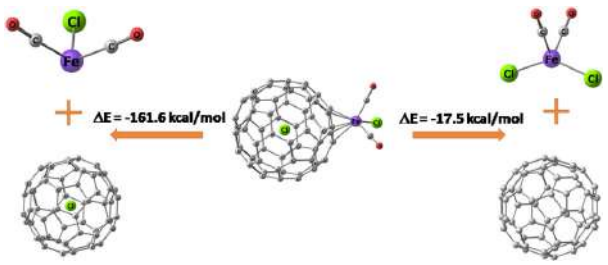

## Computational Chemistry

In Computational Chemistry, various models, functions and approximations are used for understanding chemical concepts, molecular interactions, reaction mechanisms, and ground and excited state properties of molecules. Two significant studies are summarized below.

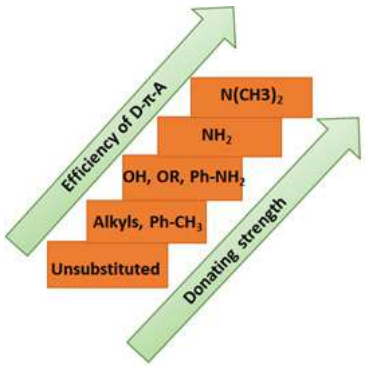
## Endo- and exohedral chloro-fulleride as $\eta^5$ ligands

$C_{60}$ fullerene coordinates to transition metals in $\eta^2$-fashion through its C–C bond at the 6-6 ring fusion site, whereas other coordination modes $\eta^3$, $\eta^4$, $\eta^5$ and $\eta^6$ are rarely observed. The coordination power of $C_{60}$ to transition metals is weak owing to the inherent π-electron deficiency on each C–C bond as 60 electrons get delocalized over 90 bonds. The encapsulation of $Cl^-$ by $C_{60}$ describes a highly exothermic reaction and the resulting $Cl^-@C_{60}$ behaves as a large anion. Similarly, the exohedral chloro-fulleride $Cl^-C_{60}$ acts as an electron-rich ligand towards metal coordination. A comparison of the coordinating ability of $Cl^-@C_{60}$ and $Cl^-C_{60}$ with that of the $Cp^-$ ligand is done for early to late transition metals of the first row using the M06L/6-31G** level of density functional theory. The binding energy ($E_b$) for the formation of endohedral $(Cl^-@C_{60})(ML_n)^+$ and exohedral $(Cl^-C_{60})(ML_n)^+$ complexes by the chloro-fulleride ligands ranges from −116 to −170 kcal $mol^{-1}$ and from −111 to −173 kcal $mol^{-1}$, respectively. Variation in $E_b$ is also assessed for the effect of solvation by o-dichlorobenzene using a self-consistent reaction field method which showed 69–88% reduction in the binding affinity owing to more stabilization of the cationic and anionic fragments in the solvent compared to the neutral product complex. For each $(Cl^-@C_{60})(ML_n)^+$ and $(Cl^-C_{60})(ML_n)^+$ complex, the energetics for the transformation to $C_{60}$ and $ML_nCl$ is evaluated which showed exothermic character for all endohedral and exohedral Co(I) and Ni(II) complexes. The rest of the

exohedral complexes, viz. Sc(I), Ti(II), Ti(IV), V(I), Cr(II), Mn(I), Fe(II) and Cu(I) systems showed endothermic values in the range 2–35 kcal $mol^{-1}$. The anionic modification makes the $C_{60}$ unit a strong $\eta^5$ ligand similar to $Cp^-$ for cationic transition metal fragments. The bulky anionic nature and strong coordination ability of chloro-fulleride ligands suggest new design strategies for organometallic catalysts [Cherumuttathu H. Suresh et al. Physical Chemistry Chemical Physics, 23 (2021), 3646-3655].




**Tuning the donating strength of dye sensitizers**




Donor–π–acceptor (D–π–A) systems typically used in dye-sensitized solar cells (DSSC) have been studied for assessing the donating strength of six donors (D1–D6) under the influence of substituents such as $CH_3$, $C_5H_{11}$, isopropyl, t-butyl, OH, $OCH_3$, $OC_2H_5$, $NH_2$, $N(CH_3)_2$, $PhCH_3$, and $PhNH_2$ along with π-spacer butadiene and acceptor moiety cyanoacrylic acid. The substituent effect enhances electron donation from D to A through the π-spacer. The enhancement in electron density at A has been quantified in terms of the difference in the molecular electrostatic potential (MESP) minimum at the cyano nitrogen ($\Delta V_{mA}$) between π–A and D–π–A. For unsubstituted D–π–A systems, $\Delta V_{mA}$ is in the range −0.1 to −5.7 kcal $mol^{-1}$, whereas the substitution enhances the negative character of $\Delta V_{mA}$ in the range −0.8 to −8.0 kcal $mol^{-1}$. In alkyls and $Ph–CH_3$ substituted D–π–A systems, $\Delta V_{mA}$ lies in the range −0.8 to −6.7 kcal $mol^{-1}$, whereas the $N(CH_3)_2$ substituted systems exhibit more negative $\Delta V_{mA}$ (more enhanced donating strength) in the range −5.1 to −8.0 kcal $mol^{-1}$. The more negative value of $\Delta V_{mA}$ implies the greater electron-donating ability of the D–π–A system. Optical and photovoltaic parameters ($\Delta G_{reg}$, $\Delta G_{inject}$, $eV_{OC}$) are analyzed at the TD-CAM-B3LYP/SMD/cc-pVDZ//B3LYP/cc-pVDZ level of DFT. An excellent linear correlation is observed in all six sets between $\Delta V_{mA}$ and the absorption maximum ($\lambda_{max}$) showing that $\lambda_{max}$ increases with enhanced donating strength. The higher absorption maximum obtained by $N(CH_3)_2$ substituted D–π–A systems lies in the range 430 nm to 490 nm, explaining the outstanding donating ability of $N(CH_3)_2$ compared to other substituents. The reduced highest occupied molecular orbital (HOMO) – lowest unoccupied molecular orbital (LUMO) gap (from 3.14 to 2.17 eV) with enhanced donating strength confirms the influence of substituent effects in broadening the absorption maximum. Furthermore, in photovoltaic parameters, a strong influence of the substituent effect is observed. The $N(CH_3)_2$ substituted D1–π–A (D1–$N(CH_3)_2$) exhibits the highest $eV_{OC}$ (1.38 eV). The strong linear correlation observed for the ground state property $\Delta V_{mA}$ and open-circuit voltage $eV_{OC}$ provides guidelines for developing an effective strategy for designing dye sensitizers for desirable photovoltaic applications [Cherumuttathu H. Suresh et al. New Journal of Chemistry, 45 (2021): 2496-2507].

# DIVISIONAL DETAILS

| | |
|---|---|
| Name | Environmental Technology Division |
| Expertise | Waste Management, Dioxin Research, Environmental Impact Assessment, Waste water treatment, Odour control, Data Analytics |
| Number of Scientists | 9 |
| Number of Technical staff | 3 |
| Number of students | 11 |
| Facilities | NABL accredited laboratory for the analysis of Water, Wastewater, Dioxins and PCBs<br>ICP-MS<br>Analysis of biodegradability of alternative to single use plastics<br>Odour measurement<br>Remote sensing and GIS software<br>Dust and emission modelling tools<br>NABET Accredited EIA Consultant Organization for carrying out EIA studies |
| No. of ongoing projects (GAP, SSP, CNP,TSP, In-house) | 22 |
| No. of publications (SCI+non SCI) | 8 |
| No of technology licenses | 4 |
| International Patents<br>Software copyright | One granted, one published and one filed |
| National level skill programme organized | 3 |


# पर्यावरण प्रौद्योगिकी प्रभाग

पर्यावरण प्रौद्योगिकी प्रभाग (ईटीडी) प्रदूषण नियंत्रण, पर्यावरण प्रबंधन और क्षेत्र के प्राकृतिक संसाधनों के मूल्यवर्धन के लिए विकासशील प्रक्रियाओं और प्रौद्योगिकियों पर ध्यान केंद्रित करता है। प्रभाग की गतिविधियां मुख्य रूप से अपशिष्ट प्रबंधन, डाइऑक्सिन अनुसंधान और पर्यावरण प्रभाव आकलन (ईआईए) के क्षेत्रों में हैं।

ईआईए अध्ययन और खनन और पोर्ट और हार्बर में नई परियोजनाओं की मंजूरी के लिए प्रभाग द्वारा प्रदान की गई पर्यावरण प्रबंधन सेवाओं से स्थानीय उद्योगों और सरकारी एजेंसियों को लाभ होता है। सीएसआईआर-एनआईआईएसटी केरल में एक एनएबीईटी मान्यता प्राप्त, श्रेणी ए सलाहकार संगठन है, जिसे खनन और पोर्ट और हार्बर क्षेत्रों में मान्यता प्राप्त है।

सीआरटीडीएच (सामान्य अनुसंधान एवं प्रौद्योगिकी विकास केंद्र) डीएसआईआर, भारत सरकार द्वारा वित्त पोषित एक परियोजना है। सीआरटीडीएच एमएसएमई के लिए पर्यावरणीय हस्तक्षेप को सक्षम करने हेतु अनुसंधान एवं विकास और परामर्श सेवाओं को सुविधाएं प्रदान करता है। एमएसएमई से जुड़े पर्यावरणीय मुद्दों को विकास, हस्तक्षेप और तकनीकी समाधान के लिए उठाया जाता है। डीआरटीडीएच के तहत विनियमों को पूरा करने, संसाधन खपत को कम करने और संचालन दक्षता में सुधार के लिए तकनीकी सहायता प्रदान की जाती है। सीआरटीडीएच परियोजना के तहत अत्याधुनिक डाइऑक्सिन विश्लेषण सुविधा भी स्थापित की गई है।

ईटीडी की परीक्षण और विश्लेषण प्रयोगशाला को एनएबीएल द्वारा आईएसओ/आईईसी 17025: 2017 के अनुसार पानी, अपशिष्ट जल, डाइऑक्साइन्स, फुरान और पॉली क्लोरीनेटेड बाइफिनाइल्स (पीसीबी) के विश्लेषण के लिए मान्यता प्राप्त है। इसके अलावा, सीएसआईआर-एनआईआईएसटी को पर्यावरण, वन और जलवायु परिवर्तन मंत्रालय (एमओईएफसीसी), भारत सरकार द्वारा पर्यावरण मंजूरी के लिए डाइऑक्सिन विश्लेषण के लिए एक रेफरल प्रयोगशाला के रूप में अनुशंसित किया गया है। ईटीडी विज्ञान से लेकर इंजीनियरिंग से लेकर प्रौद्योगिकी तक संपूर्ण मूल्य श्रृंखला में योगदान देता है।

## विशेषताएं

2020-21 के दौरान संभाग की प्रमुख गतिविधियाँ

- उद्योग इकाई में एनआईआईएसटी ऑनसाइट अपशिष्ट जल उपचार प्रणाली (नोवा) का क्षेत्र परीक्षण और सत्यापन।.
- नोवा के लिए एक पेटेंट दायर किया गया था, और प्रौद्योगिकी को दूसरे उद्यमी को स्थानांतरित कर दिया गया था।
- नोवा को बढ़ाया गया और एनआईआईएसटी परिसर में एनआईआईएसटी कैंटीन से उत्पन्न पूर्ण अपशिष्ट जल के उपचार के लिए 10 केएलडी इकाई स्थापित की गई।
- बीएआरसी, मुंबई,सीएसआईआर-नीरी, नागपुर और एमपीईडीए, कोच्चि जैसे प्रमुख संगठनों को डाइऑक्सिन और पीसीबी पर विश्लेषणात्मक सेवाएं प्रदान की गईं।
- आईसीपी-एमएस सुविधा हस्ताक्षरित एमओयू के तहत व्यापक रूप से मेसर्स पंकजाकस्तूरी हर्बल्स इंडिया प्राइवेट लिमिटेड द्वारा आपूर्ति किए गए आयुर्वेदिक दवा के नमूनों के नियामक अनुपालन के लिए उपयोग किया गया था।
- नींडकरा-क़ायमकुलम बेल्ट, चावरा, कोल्लम में परमाणु खनिजों के खनन के लिए ईआईए अध्ययन किए गए। इंडियन रेयर अर्थ्स (इंडिया) लिमिटेड की दो परियोजनाओं को पर्यावरण मंजूरी दी गई है और केरल खनिज तथा धातु लिमिटेड की एक परियोजना ने हमारी रिपोर्ट के आधार पर पर्यावरण मंजूरी के लिए सिफारिश की है।
- एमएसएमई के लिए वैकल्पिक एकल-उपयोग प्लास्टिक और जैवनिम्नीकरण वस्तुओं के बायोडिग्रेडेबिलिटी विश्लेषण के लिए परीक्षण सुविधा।
- कम ऊर्जा खपत, अपव्यय और पर्यावरणीय प्रभाव के संयोजन के साथ उच्च गुणवत्ता, सुरक्षा और मजबूती प्राप्त करने के लिए धातु कास्टिंग फाउंड्री में स्मार्ट विनिर्माण के लिए उद्योग 4.0।

# Environmental Technology Division

The Environment Technology Division (ETD) focuses on developing processes and technologies for pollution control, environmental management, and the value addition to the region's natural resources. The division's activities are mainly in the areas of waste management, dioxin research, and Environmental Impact Assessment (EIA). Local industries and government agencies benefit from the environmental management services provided by the division for EIA studies and clearances of new projects in mining and port & harbor. CSIR-NIIST is a NABET accredited, Category A consultant organization in Kerala with accreditation in mining and port & harbor sectors.

CRTDH (Common Research & Technology Development Hub) is a project funded by DSIR, Govt. of India. CRTDH provides facilities for R&D and consultancy services enabling environmental interventions for MSMEs. Environmental issues associated with MSMEs are taken up for development, interventions, and technological solutions. Technical support is provided to meet regulations, reduce resource consumption, and improve operation efficiency under CRTDH. The state-of-the-art Dioxin analysis facility has also been established under the CRTDH project.

The Testing and Analysis Laboratory of ETD is accredited by NABL as per ISO/IEC 17025: 2017 for analysis of Water, Waste water, Dioxins, Furans and Poly Chlorinated Biphenyls (PCBs). In addition, CSIR-NIIST has been recommended by the Ministry of Environment, Forest and Climate Change (MoEFCC), Govt. of India as a referral laboratory for Dioxin analysis for environmental clearances. ETD contributes across the entire value chain from science to engineering to technology.

## Highlights

### Major activities of the division during 2020-21.

- Field testing and validation of NIIST Onsite Wastewater Treatment System (NOWA) at an industry unit.
- A patent was filed for NOWA, and the technology was transferred to a second entrepreneur.
- NOWA was scaled up, and a 10 KLD unit was installed in the NIIST campus for treating complete wastewater generated from the NIIST canteen.
- Analytical services on Dioxins and PCBs were provided to major organizations such as BARC, Mumbai; CSIR-NEERI, Nagpur, and MPEDA, Kochi.
- ICP-MS facility was extensively utilized for the regulatory compliance of Ayurvedic drug samples supplied by M/s Pankajakasthuri Herbals India Pvt. Ltd. under the signed MoU.
- EIA studies were carried out for the mining of atomic minerals in the Neendakara-Kayamkulam belt, Chavara, Kollam. Two projects of IREL have been accorded Environmental Clearance and one project of Kerala Minerals and Metals Ltd has accorded recommendation for Environmental Clearance based on our report.
- Testing facility for Biodegradability analysis of alternative single-use plastic and biodegradable items for MSMEs.
- Industrie 4.0 for smart manufacturing in metal casting foundries to attain high quality, safety and robustness in conjunction with reduced energy consumption, wastage and environmental impact.

## Quorum Quenching Mediated Biofilm Control

Interfering the chemical signaling of microorganisms (both intraspecies and interspecies) is a new approach to inhibit adverse biofilm formation. In this approach, natural (microbial or plant origin) and synthetic molecules (analogues) interfering (Quorum quenching) the normal functioning of microbial communication (Quorum sensing) molecules like AHL (Acyl Homoserin Lactone), Auto Inducer I, II, etc. will be applied. At NIIST environmental technology division, several bacterial strains exhibiting QQ property were isolated and

screened. One of the prominent strains was *Bacillus velezensis (PM7),* Genbank ID-MZ234152 (Fig. 1). The QQ property of the novel strain was validated through testing against *S. marcescens*, *P.aerugenosa, Chromobacterium violaceum* and CV 07 (mutant).

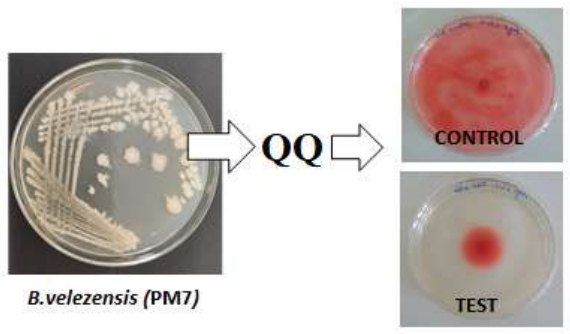



Figure 1. The marginal decline in swarming motility of S. marcescens by the cell-free extracts of newly isolated bacterial strain PM7.

A high throughput screening method for identifying quorum quenching bacteria using the biosensor strain *Chromobacterium violaceum* CV026 was developed with the aid of the QQ strain isolated. Effect of PM7 on biofilm formation against surfaces like polystyrene, Borosilicate glass and RO membrane were studied. The factor responsible for the quorum quenching activity of PM7 is under investigation, and preliminary results pointing towards the enzymatic/proteinaceous nature of the QQ factors. Since the factors are extracellularly secreted, its efficient use in biofouling mitigation is highly anticipated.

## Status update on Perchlorate contamination and remediation measures:

Perchlorate ($ClO_4^-$) salts are used extensively in the space R&D, and strategic sectors. However, this toxic anion is a well-known persistent, micro-pollutant known to interfere with human Thyroid gland function. CSIR-NIIST is the pioneering lab in India involved in the environmental monitoring, and developing bio-remediation technology for perchlorate. In 2012, NIIST flagged heavy contamination of perchlorate in drinking water sources around places (like space R&D units) where it is handled in bulk (Keezhmad in Ernakulam). NIIST was continuously monitoring the status of contamination in the area (Fig. 2) , and in 2021, after nine years in 2021, the level of contamination is still above permissible limits as per international guidelines (15 µg/L). The status of perchlorate in the heavily contaminated community wells (PW1, PW2 and PW3) is presented in Table 1.


Figure 2. Community wells from where samples were collected

Table 1. Perchlorate level in the community wells in Keezhmad during 2015 to 2021

| Sample No. | Distance from APEP (M) | Perchlorate concentration (mg/l) | | |
|---|---|---|---|---|
| | | 2015 | 2018 | 2021 |
| 1 (PW1) | 350 | 43 | 13.2 | 1.5 |
| 2 (PW2) | 450 | 23 | 6.8 | 2.85 |
| 3 (PW3) | 550 | 7.5 | 1.34 | 0.23 |

Meanwhile, our recent analysis also revealed well water contamination of perchlorate up to 2 km away from the perchlorate production unit (APEP) in Keezhmad. Therefore, most probably the contaminated ground water may be getting diluted, and spreading to more areas. This finding warrants regular monitoring of perchlorate contamination in the area.

The ongoing research on remediation measures, NIIST is presently involved in the development of a low-cost Bio-barrier system for decontaminating underground plumes, and contaminated streams/canals. In this system, the bio-barrier will be installed in the line of containment flow (as in-situ treatment), and while the containment flow through the system, the special microbial system under defined conditions will decontaminate perchlorate. This will help in stoppage of further spreading of the contaminant.

## Setting up of Major Analytical Facility

## Continuous Flow Analyser for simultaneous multi-parameter analysis of water and wastewater

Figure 3. Continuous Flow Analyzer for simultaneous multi-parameter analysis

The automation of analytical instruments is the key to improve the sample throughput, reduce manual errors, time of analysis and to increase the productivity of the testing laboratories. A state of the art continuous flow analyser(CFA) was procured (Make: M/s. Skalar Instruments Pvt Ltd) for the simultaneous analysis of multiple parameters such as ammonia, Total Kjeldahl Nitrogen, orthophosphate, total phosphate, nitrite, nitrate, total phenol and total sulphide in water and wastewater samples. The instrument (Fig. 3) would support the ongoing process/technology development programmes on effluent treatment and provide fast and cheap analytical services to MSMEs.

### Total Organic Carbon Analyser for water, wastewater, solid waste, and biomass testing

The instrument (Fig. 4) will be extremely useful for the simultaneous analysis of parameters such as Total carbon, Total organic carbon (liquid & solid), and total bound nitrogen (liquid) in environmental, plastics, and biodegradable plastic samples. It is essential to test the biodegradability of new plastic materials in the market in view of banning single-use plastics in Kerala for regulatory purposes. In addition, the facility will be required for the routine water, wastewater, solid waste sample analysis, and treatment process developments in the division.

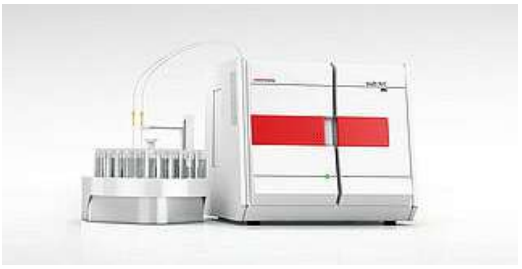


Figure 4. Total Organic Carbon Analyzer

### Heavy metal analysis in Ayurvedic formulations/ ingredients/ final products using Inductively Coupled Plasma Mass Spectrometry Facility (ICPMS)

As per the Ayurvedic Pharmacopeia of India published by the Ayush Department, Government of India, all Ayurvedic Drugs (Single/Compound formulation) must comply with the limits for Heavy Metals prescribed in individual Monograph and wherever limit is not given then they must comply with the limits given in WHO publication "Quality Control Methods for Medicinal Plants and Material". CSIR- NIIST has signed a Memorandum of Understanding with M/s. Pankajakasthuri Pvt Ltd, a leading traditional ayurvedic medical college and drug manufacturer based in Kerala, founded by Padmashree Dr. J. Hareendran Nair for carrying out the regulatory compliance monitoring of toxic heavy metal contents in ayurvedic drug formulations/ ingredients and finished products. A state-of-the-art Inductively Coupled Plasma - Mass Spectrometry (ICP- MS) installed at CSIR- NIIST (Fig. 5) has been employed for the unequivocal ultra-trace level quantification of toxic heavy metals such

as arsenic, lead, cadmium and mercury in 550 samples submitted by M/s. Pankaja Kasthuri Herbals (India) Pvt Ltd.

In addition, the institute facility has been extensively utilized for meeting the requirement of several R & D programs/ EIA/ Consultancy projects in various divisions of the institute and for other academic/research organizations in Kerala. The revenue generated from the facility during 2020- 21 accounts for more than Rs. 25 Lakhs. Some state/Central government agencies and R & D institutes like Groundwater department, Kerala water authority and SCTIMST have availed the services.

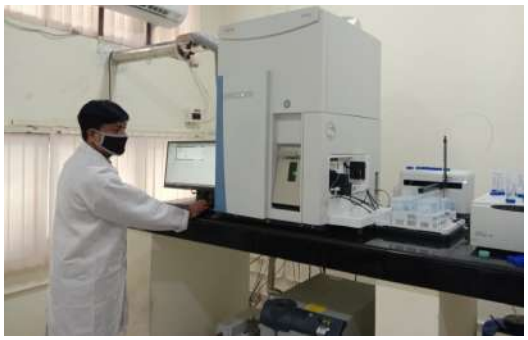


Figure 5. Inductively Coupled Plasma Mass Spectrometer (ICPMS) Facility

## Dioxin Research & Monitoring

The transition assessment of NABL accreditation from ISO/IEC 17025: 2005 to 2017 version has been completed by December 2020 and MoEF & CC recommended dioxin research facility has been extensively utilized by various national and regional R &D/ regulatory / export/ academic and legal bodies in the year 2020-21. Being a unique national facility, NIIST has extended its expertise and service for various important organizations and issue of great importance at war footing. We have received work orders worth Rs. 25 Lakhs during the period 2020-21

The major projects undertaken are ongoing.

- Bhabha Atomic Research Institute (BARC), Mumbai, has awarded a work order for carrying out dioxins and furans quantification in stack samples collected from their process development of a pilot scale industrial plasma gasifier for solid waste treatment.
- Multiple R & D programs of CSIR- NEERI on (a) Sampling, analytical method development, and evaluation of dioxin emission from sanitary pad incinerator (Green Dispo) (b) Rapid carbonization unit – Sanchar for sanitary pad destruction and (c) Testing and analysis of dioxins in soil and ambient air from plastic industries as per the requirement of National Green Tribunal (NGT)
- Analysis of export quality fish and shrimp samples for Marine Product Export Development Authority (MPEDA), Kochi, and regulatory reporting

- A collaborative project led by CSIR-NIIST has been awarded by the CSIR- Mission on Advanced Technology Leads for Assuring Safety of Food (ATLAS) for the development of affordable methods for the confirmatory analysis of dioxins and PCBs in animal origin food samples and its human risk prediction. The method validation in fish and fish products is progressing and the compliance of fish samples collected from Eloor- Edayar region (Fig. 6) was undertaken during the period. Hindustan Insecticides Limited (World's only manufacturer of DDT), FACT, Petrochemical, and leather industries are located in the area. The Maximum Level (ML) of PCDD/Fs in fish/ fish products (as per EU regulation 644/2017) IS 3.5 pg/g wet weight TEQ and a few of the samples exceeded/borderline of the ML (Table 2).

Figure 6. Eloor- Edayar Industrial Area, Kochi

Table 2. PCDD/Fs levels of collected fish and sediment samples

| Sample analyzed | Sampling stations | | | | | |
|---|---|---|---|---|---|---|
| | SP1 | SP2 | SP3 | SP4 | SP5 | SP6 |
| Sediment (pg TEQ/g dry weight) | 23.14 | 9.25 | 6.78 | 29.76 | 12.13 | 35.27 |
| Fish sample analysis (pg TEQ/ g wet weight) | | | | | | |
| Green Chromide | 2.10 | 1.70 | 1.30 | 3.00 | 1.81 | 3.45 |
| Grey Mullet | 3.16 | 2.72 | 1.16 | 3.12 | 2.89 | 4.12 |
| Cat fish | 2.20 | 1.30 | 0.83 | 2.40 | 1.50 | 1.96 |
| Tilapia | 0.72 | 0.58 | 0.52 | 0.90 | 0.72 | 0.96 |

NIIST has also conducted the emission levels of dioxins

from the chlorinator plant of Kerala Minerals and Metals Ltd, Chavara, Kollam, which matched the default emission factors mentioned in the UNEP toolkit (Table 3). Further studies on the levels of dioxins and PCBs in the egg and milk samples collected from the plant's buffer zone are ongoing.

Table 3. Dioxin Emission Analysis of Residues from Titanium Industry

| SL. No | Sample Type | PCDD/Fs &DL-PCBs (µg TEQ /ton) |
|---|---|---|
| 1 | Exempt waste Solid | 0.23 |
| 2 | Cyclone Solid | 1.92 |
| 3 | Scrubber Liquid | 0.02 |
| 4 | ETP Sludge | 9.5 |

## Addressing the emissions from MSME sector

Currently NIIST is in the process of generating emission factor of unintentional POPs in the MSME sector involving a large number of small incinerators and medium scale incinerators which is operated without meeting the mandatory conditions specified for waste incinerators. The majority of such small/medium scale incinerators are manufactured and operated by the informal sector, which falls in the category of MSMEs. Such small incinerators are used for various purposes and centers like sanitary pad/ safety mask burning, food processing industries, restaurants, packaging industries, hotels, villa projects, apartments, community centers, dispensaries, laboratories, etc. The outbreak of the COVID-19 pandemic has resulted in a huge quantity of biomedical waste materials and plastic wastes such as safety masks, PPE kits, gloves, etc. It has led to an unprecedented increase in the waste load in existing incinerators, and the numbers of units have multiplied several-fold. However, many of the on-site incinerator facilities available in India are 1st generation type which does not incorporate any fuels or air pollution control system and are not meeting the mandatory combustion efficiencies, primary & secondary chambers, specified temperature ranges and the emission standards.

As NIIST has strong expertise in generating emission factors through simulated combustion studies, we have fabricated a medium scale single chamber incinerator to conduct waste combustion studies. It will help us understand the emission levels under various combustion practices and evolve at the optimum conditions to minimize the emission of dioxins and furans. The photograph of the fabricated incinerator and preliminary emission test with isokinetic sampler set up is shown in Fig. 7. The studies are ongoing, and it is expected to complete by 2022.

Figure 7. Photograph of incinerator prototype unit

## Biodegradability Testing for Alternative Single-Use Plastic Items and biodegradable items

As per the G.O. No. 128/2019/ENVT, Govt. of Kerala, Environment Department, identified CSIR NIIST as the Nodal lab for Certifying the Biodegradability of single-use plastics items in Kerala. In this regards aerobic and anaerobic facility has been developed to assess the biodegradability of alternative materials against single-use plastic materials. This facility is helping various MSMEs in this sector. CSIR-NIIST has expertise in method standardization, protocol and methodology

development for determination of biodegradability of alternative plastic materials and different kind of biodegradable items as mentioned below:

- Ultimate aerobic biodegradability study of sample is performing under controlled composting conditions as per ISO 14855-2:2018.
- Ultimate anaerobic biodegradation and disintegration study is performing as per ISO 15985:2004.
- Eco-Toxicity/ leaching study is performing as per the standard ASTM D3987-12.

Environmental regulatory authority (i.e., KSPCB) and various MSMEs (i.e., Sprout Pvt. Ltd., West Cost paper Mills etc.) in paper, packaging, and biodegradable items are benefiting by this facility.

## Environmental Impact Assessment

### EIA Study for renewal of KMML Block III mining lease and enhancement of production; Client: KMML, Kollam

Kerala Minerals and Metals Ltd. (KMML) has appointed CSIR-NIIST to evaluate the environmental aspects and their possible associated impacts that would arise due to the proposed heavy mineral sand mining operations and to work out environmental management plans and environmental monitoring programme to prevent, control, minimize/eliminate the adverse environmental impacts envisaged from the mining activity. Kerala Minerals and Metals Ltd. (KMML) are mining atomic minerals of strategic importance to the Government. This project's main objective is to renew the mining lease and enhance mineral sand production from 2,50,000 TPA to 7,50,000 TPA in Block III and physical separation of minerals at the Mineral Separation Plant (MSP). The spatial extent of this project is 88.119 Ha..Natural and Community Resource Augmentation (NCRAP) study was further recommended as additional study. The Project is now recommended for Environmental Clearance.

### EIA for NK block IV of IREL (India) Ltd.

IREL has been granted renewal of mining lease to collect heavy mineral sand from NK Block IV (Panmana and Karunagapally) in Kollam district for an area of 40.566 Ha respectively. For obtaining EC for mining activities, IREL entrusted NIIST to carry out the EIA studies. Based on the study and project presentation, the project has accorded Environmental Clearance.

### Expansion of mining quantity from 2,37,150 TPA to 7,50,000 TPA (ROM) in IV EE

Total mine lease area is 180 hects ( Block IV EE ). This project has a EC based on the study done by NIIST in 2011. But now the project proponent wishes to go for expansion and to increase the production capacity from 2,37,150 TPA to 7,50,000 TPA (ROM). CSIR-NIIST has carried out the study and the project has accorded Environmental Clearance from the Central government (MoEF&CC)

### EIA Study for renewal of mining lease for KMML Block I

This project proposal deals with the Environmental Impact Assessment (EIA) study of KMML NK Block I. The project is for the renewal of the mine lease. The spatial extent of the mine lease is 34.285 Ha. The proposed renewal is for inland mining only. The mining plan for the first two years is 2,00,000 TPA, and for the next two years is 2,50,000 TPA, and 3,00,000 TPA for the last year. Studies were carried out in order to determine the effect of mining on various environmental ecosystems, and mitigation measures were suggested to reduce the impact of mining. An environmental Management Plan was also suggested for the above project. The Public was very supportive which was reflected in public hearing conducted at site.

### EIA study for NK block- II EE of IREL (India) Ltd.

NK block II EE is an extension to IRE NK block II and the area is of 67Ha.This block will be mined only by DWUP (inland mining). IRE has awarded the job of carrying out the EIA study to us. We have completed the Public hearing and now based on the presentation to State EIA committee, the project is recommended for Environmental Clearance to SEIAA.

### NCRAP Study for KMML Block – III operating under violation and regularization of Environmental Clearance

NCRAP (Natural and Community Resource Augmentation Plan) studies were conducted as per the Notification S.O 804(E) dated 14.03.17, and regularization of this project which is under violation. NCRAP refers to the estimation of ecosystem damages and their monetary equivalents. The total mine lease area of KMML Block-III is 88.119 Ha. In this project, the equivalent cost for ecosystem damages was worked out, and mitigation measures were suggested for the reclamation of land. The significant impact envisaged is on the land environment

and coastal erosion followed by hydrogeology, air, noise, socio-economic and occupational health, and safety. NIIST has also carried out studies through Remote sensing and Geographical Information System (GIS) to measure the status of erosion and accretion happening 5 km upstream and 5 km Downstream of the project site. The change detection study enabled us to work out the net erosion / accretion that has happened due to beach washing and other activity. The project is now recommended for Environmental Clearance.

## EIA Study for the stability of TS Canal and Impact on Aquatic Fauna

Environmental clearance for IREL Block IV EE (Eastern Extension) was granted based on our EIA report to IREL (INDIA) Ltd. for a capacity of 2,37,150 TPA with certain compliance conditions. One of the compliance conditions (Specific condition no (iii)) was "50 meters all along the canal shall be maintained as a buffer and shall not be disturbed at all". For amendment of EC condition NIIST carried out a study considering the hydrostatic pressure up to 3 m depth from the sand. A ecological survey was also carried out to identify if there are any rare or endangered species. Based on the report submitted by NIIST, the committee recommended the mining on both sides of TS canal, leaving 10m buffer zone on both sides of TS canal. The outcome of the study enabled the company to collect highly concentrated sand from the banks of the canal and to increase the production capacity of these rare earths.

## Land Use Land Cover (LULC) studies for Jamnagar, Gujarat Industrial Area

In this project, Land Use land cover (LULC) analysis of Jamnagar Gujarat Industrial Area is done with the help of high resolution satellite imagery and state of the art GIS software. Land use refers to "man-made or anthropogenic" activities and various uses which are carried on land. Land cover refers to "natural vegetation, water bodies, rock/soil, artificial cover and other resulting due to transformation". The LULC analysis helped to identify the extent of land in the project area into various categories viz. built up area, barren land, mining area, agriculture, waterbodies, etc. and changes over a period of time.

## Assessment of plastic contaminated soil vis-à-vis recommendations for its reuse

CSIR-NIIST choked out the detailed methodology to conduct the sampling and collect the samples from the plastic contaminated site (Fig. 8). The samples were collected by employing the coning and quartering method. All the samples were sun-dried and analyzed for moisture content, percentage retained for various sieve/mesh sizes, fixed solids (FS) and volatile solids (VS), heavy metals concentration (mg/Kg), maximum leachable heavy metals concentration (mg/L), etc. Based upon the detailed characterization of the waste and existing regulations/guidelines, a techno-economic, and environmentally sustainable measure was recommended to reuse plastic contaminated sites.

Figure 8. Collection of sample from a plastic contaminated site.

## IIoT (Industrial Internet of Things) implementation for smart manufacturing of metal castings

The as-cast model, created by tooling and methods design followed by simulation of mold filling and metal solidification using AutoCAST XI software, is the input to the sand casting process. The sub-units of the system are sensorized IoT machines for pattern making, mold preparation, melting and pouring and thermal reclamation of sand for re-cycling. Wireless data connectivity enables the IoT generated data to stream to the edge device and the private cloud server located at NIIST. Process monitoring and real-time analytics shown on dynamic dashboards help visualize the key parameters of active projects. The analytics transforms data into actionable insights giving warnings, alarms and reporting emergency situations. The data logs and reports are used for offline analytics by machine learning models for qualitative and optimization studies (Fig. 9).

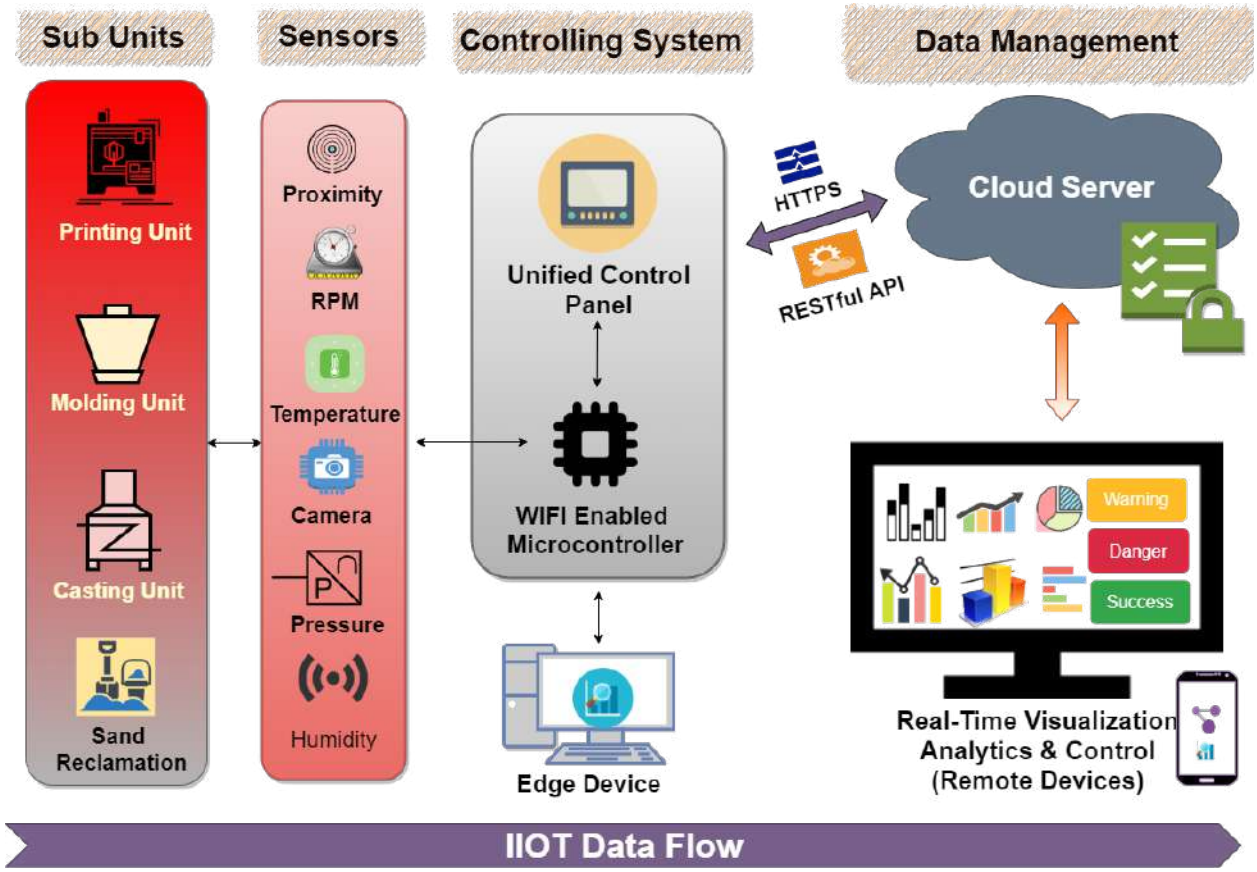


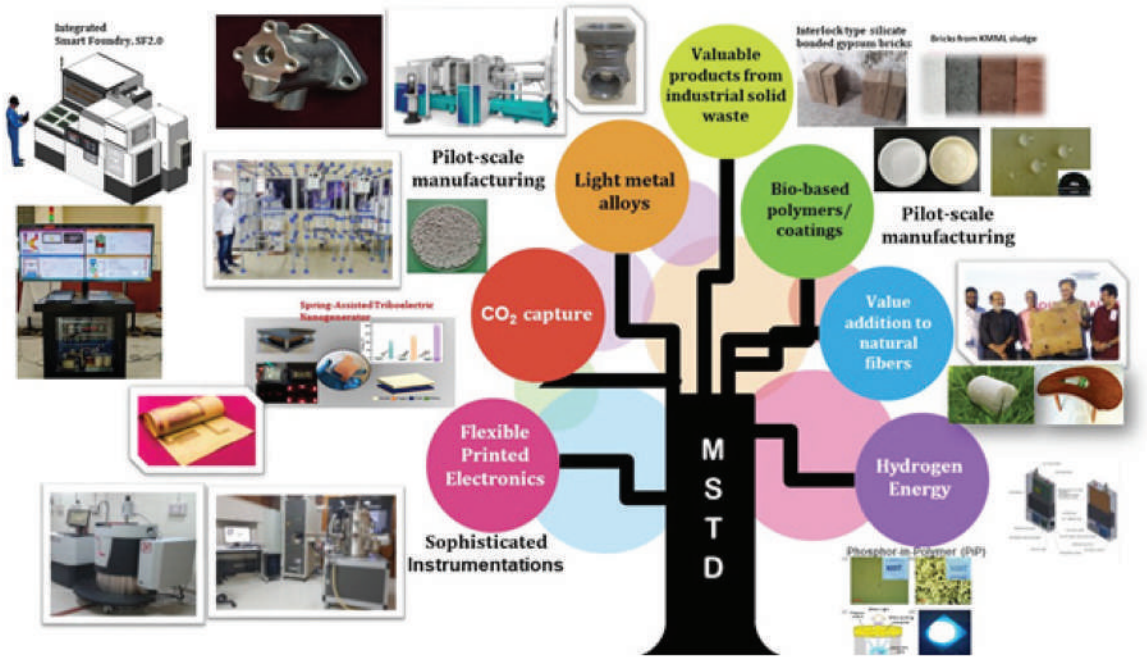

Figure 9. Smart Foundry deployed at CMTI, Bangalore for production of small, intricate metal castings

### Sampling and analysis of water quality parameters at Pothundi and Kanjirapuzha river basins in Palakkad and Thrissur Districts of Kerala

Kerala State Remote Sensing & Environment Centre (KSREC) has awarded CSIR- NIIST the work to carry out the sampling and general water quality parameter analysis including heavy metals in the Pothundi irrigation project and Kanjirapuzha irrigation project river basins. The scope of work included the sampling of river water from the ayacut area of the two selected irrigation project basins in one season (pre-monsoon), at locations identified by KSREC and the analysis of the sampled river water for various quality parameters. The analysis helps to evaluate the suitability of the river water for irrigation.

# DIVISIONAL DETAILS

| | |
|---|---|
| Name | Materials Science & Technology Division (MSTD) |
| Expertise | Light weight metallic materials<br>Electronic Materials & Devices<br>Nanomaterials for energy and environment<br>Functional Polymers & composites<br>Value added products from lean grade ores & industrial slags |
| Number of scientists | 22 |
| Number of Technical staff | 4 |
| Number of students | 99 |
| Facilities | |
| No. of ongoing projects during 20-21 (GAP, SSP, CNP,TSP, In-house) | 54 |
| No. of publications (SCI+non SCI) during 20-21 | 88+ 5 book chapters |
| No. of Ph. D. awarded during 20-21 | 11 |



# सामग्री विज्ञान और प्रौद्योगिकी प्रभाग

**पदार्थ विज्ञान और प्रौद्योगिकी प्रभाग (एमएसटीडी)**

एमएसटीडी में वैज्ञानिक अंतरिक्ष, सामरिक अनुप्रयोगों, रक्षा और अन्य औद्योगिक क्षेत्रों के लिए उपयोग की जाने वाली धातुओं और अन्य सामग्रियों के लिए अत्याधुनिक तकनीकों को विकसित करने में लगे हुए हैं। प्रभाग में 20 वैज्ञानिक, 5 तकनीकी अधिकारी और लगभग 106 शोध छात्र/प्रोजेक्ट फेलो शामिल हैं। हमारे पास लगभग 35 अनुदान सहायता सरकारी वित्त परियोजनाएं, 5 सीएसआईआर परियोजनाएं, 9 औद्योगिक रूप से समर्थित परियोजनाएं और एक अंतरराष्ट्रीय उद्योग वित्त परियोजना हैं। हमारे कुछ शोध प्रयासों और उपलब्धियों को नीचे प्रस्तुत किया गया है।

**अनुसंधान एवं विकास गतिविधियों की कुछ मुख्य विशेषताएं:-**

- स्वचालित वायु संपीडक अनुप्रयोगों के लिए हलका एल्यूमीनियम आधारित क्रैंक कोष्ठ
- वर्चुअल कास्टिंग सॉल्वर प्रौद्योगिकी का व्यावसायीकरण विवरण
- जंग संरक्षण के लिए स्मार्ट नैनोकंटेनर-आधारित एंटीकोर्सिव बायो-कोटिंग्स
- रोगाणुरोधी कोटिंग्स के लिए नीम के अर्क के बायोजेनिक एजी नैनोपार्टिकल्स
- जैव चिकित्सा अनुप्रयोगों के लिए एमजी मिश्र धातुओं पर सेरियम फॉस्फेट रासायनिक रूपांतरण कोटिंग
- ऊर्जा कुशल इमारतों के लिए बीआईवीओ4-ज़ेडएनओ जटिल अकार्बनिक वर्णक
- जंग संरक्षण के लिए टिकाऊ जल विरोधी कोटिंग
- स्टील पर प्लांट एक्सट्रेक्ट आधारित हाइब्रिड एंटीकोर्सिव कोटिंग
- अल्कोहल ऑक्सीकरण प्रतिक्रिया के लिए एक कुशल इलेक्ट्रो-उत्प्रेरक के रूप में पीडी संशोधित एनआई नैनोवायर
- उच्च तापमान सीओ2 कैप्चर के लिए क्षार सिलिकेट आधारित सिरेमिक ग्रेन्यूल्स
- पर्सल्फेट सक्रियण के माध्यम से जलीय घोल से एज़ो प्रतिक्रियाशील रंगों को हटाना
- रेयर अर्थ सिरेमिक से कार्यात्मक ग्लेज़ कोटिंग्स
- लचीले प्रकाश अनुप्रयोगों के लिए लाल-नारंगी उत्सर्जक फॉस्फोर-आधारित कंपोजिट
- कठोर स्थिति माइक्रोवेव परिरक्षण के लिए एलए0. 5एसआर0. 5सीओओ3- फोम का संचालन करना
- रेयर अर्थ पर्कोव्साइट्स पीआर 2एफ़ईएमएनओ 6 और एसएम 2 सी आरएमएन ओ 6 में चुंबकत्व का उलटा संकेत
- स्वचालित और ऊर्जा उत्पादन के लिए एमएन आधारित आरई-मुक्त स्थायी चुंबक का विकास
- कमरे के तापमान चुंबकीय प्रशीतन अनुप्रयोगों के लिए मैग्नेटोकैलोरिक सामग्री का विकास
- स्पिंट्रोनिक्स अनुप्रयोगों के लिए अर्ध-धातु फेरोमैग्नेट्स का विकास कैंसर कोशिकाओं के उपचार में उपयोग किए जाने वाले अतिताप चिकित्सा के लिए जैव-संगत चुंबकीय नैनोकणों का विकास
- प्रिंट करने योग्य पदानुक्रमित निकल नैनोवायर आधारित संवेदक
- शहरी खनन कचरे से कीमती धातुओं का संवर्धन
- अपशिष्ट जल उपचार के लिए अपशिष्ट कॉयर पिथ को सक्रिय कार्बन में बदलना
- बहुलक /कॉयर कंपोजिट: आधुनिक खेती के लिए जैव निम्ननीय कॉयर मल्चिंग मैट और शीट
- निर्माण उद्योग के लिए कम घनत्व वाली ध्वनिक सामग्री
- कटाव नियंत्रण के लिए रोट-प्रतिरोधी कॉयर भूवस्त्र
- पॉलिमर नैनोकंपोजिट्स: पॉली (एल-लैक्टाइड) के उन्नत गुणों के लिए टिकाऊ बहुआयामी नैनोफिलर
- सुपरमॉलेक्यूलर दृष्टिकोण के माध्यम से ब्लॉक सहबहुलक डोमेन के भीतर कार्यात्मक दाता-स्वीकर्ता अणुओं की सह-संयोजन

# Materials Science and Technology Division

In the MSTD, the scientists are engaged in developing the cutting edge technologies for the metals and other materials used for the space, strategic applications, defence and other industrial sectors. The division has a work force consisting of 20 Scientists, 5 Technical officers, and about 106 research students/project fellows. We have around 35 Grant-in-aid government funded projects, 5 CSIR projects, 9 industrially supported projects, and one international industry funded projects. Some of our research endeavours and achievements are highlighted below.

## Highlights of some of the R&D activities

- Lightweight aluminum based crankcase for automotive air compressor applications
- Commercialization details of the Virtual Casting Solver Technology
- Smart nanocontainer-based anticorrosive bio-coatings for corrosion protection
- Biogenic Ag nanoparticles of neem extract for antimicrobial coatings
- Cerium phosphate chemical conversion coating on Mg alloys for biomedical applications
- $BiVO_4$–ZnO complex inorganic pigment for energy efficient buildings
- Durable hydrophobic coating for corrosion protection
- Plant extract based hybrid anticorrosive coating on steel
- Pd modified Ni nanowire as an efficient electro-catalyst for alcohol oxidation reaction
- Alkali silicate based ceramic granules for high temperature $CO_2$ capture
- Removal of azo reactive dyes from aqueous solutions via persulfate activation
- Functional Glaze coatings from Rare Earths Ceramics
- Red-orange emitting phosphor-based composites for flexible lighting applications
- Conducting $La_{0.5}Sr_{0.5}CoO_{3-\delta}$ foams for harsh condition microwave shielding
- Sign reversal of magnetization in rare earth perovskites $Pr_2FeMnO_6$ and $Sm_2CrMnO_6$
- Development of Mn based RE-free permanent magnets for automotive and energy generation
- Development of magnetocaloric materials for room temperature magnetic refrigeration applications
- Development of Half-metallic Ferromagnets for spintronics applications development of biocompatible magnetic nanoparticles for hyperthermia therapy used in treating the cancerous cells
- Printable hierarchical nickel nanowire based sensors
- Enrichment of precious metals from urban mining wastes
- Conversion of waste coir pith into activated carbon for wastewater treatment
- Development of Coir/ Polymer Composites for Furniture, Acoustic and Electrical Insulation Applications
- Development of disposable plates and packaging materials using coconut husk
- Development of Nanoporous Crystalline Aerogels of Syndiotactic Polystyrene for Thermal and Acoustic Insulation
- Stereocomplexation of Enantiomeric Star-Shaped Poly (lactide)s (Biodegradable Polymers)
- Block Copolymer-based Supramolecular Assemblies and their Hierarchical Assemblies

## New Facility being created Pilot Scale Aluminium Alloy Squeeze Casting Facility atCSIR-NIIST, Thiruvananthapuram

The concern about the depletion of natural resources and the environmental needs necessitate high strength and lighter aluminium alloys for the aerospace, automotive, defence, and energy sectors processed

through innovative methods. The conventional casting processes like sand casting, gravity die casting (GDC) and high pressure die casting (HPDC) are employed by various industries to make large quantities of complex shaped components for their requirements. These high volume casting processes contribute to higher productivity but associated with the castings of lower quality caused by the gas entrapment during the die filling and solidification shrinkages leading to defects and large scale rejection. Increasing demand for high quality thin wall products with reduced defects have led to the development of squeeze casting process.

## Squeeze Casting (SQC) Technology

Squeeze casting is a novel high yield and energy efficient process developed from the conventional die casting for producing the near net shaped castings with an excellent dimensional accuracy and improved material characteristics. Squeeze casting is a liquid state process to produce components with high mechanical performances, comparable with forgings due to the application of a very high pressure (above 100 MPa) in the liquid state. In the squeeze casting, the applied pressure enhances the heat transfer between the mould and the component due to the better contact during the metal solidification which increases the cooling rate. As a consequence, a very fine grain size is obtained in the component, thus leading to higher mechanical strength as well as ductility.

The SQC is primarily classified as the direct and the indirect squeeze casting based on the different approaches of the liquid metal movement during die filling. In the case of direct squeeze casting process, the molten metal is poured directly into an open die and the hydraulic ram is moved down into the melt for applying the required pressure; whereas, in the indirect squeeze casting, a near-net shaped die is filled with a liquid metal flow that can be controlled by the injection speed of a plunger rod, and an intense pressure can be applied when the die is completely filled. Due to this advantage, the indirect squeeze casting process has more potential for the commercial manufacturing than the direct squeeze casting process favouring high quality products with the reduced processing energy and cost. The MSTD has also been engaged in developing aluminium alloy products for the various industrial applications. After a detailed analysis and realizing the need for an advanced facility to manufacture high quality Al-alloy products, a pilot scale SQC facility has been established in CSIR-NIIST, Thiruvananthapuram.

## Pilot Scale SQC Facility at CSIR-NIIST, Thiruvananthapuram

CSIR, New Delhi has funded Rs. 5.70 Crores for establishing this national facility under the Facility Creation Scheme. The project took an year for its establishment and to scale-up the squeeze casting technology for the production of components for the automotive and aerospace applications which is further being funded by the government agencies and the industries for the successful implementation of the facility for the product manufacturing. The following organizations have shown keen interest in the technology development through the strong financial and technical support by signing the NDA and MOU.

- Department of Science & technology (DST), New Delhi
- Atlas Copco, Belgium
- NFTDC, Hyderabad
- Sri Kaliswari Metal Powders Pvt. Ltd, Sivakasi
- Roots cast P Ltd., Coimbatore
- GTRE-DRDO, Bengaluru

Some of the key features of the squeeze casting facility are:

- BUHLER Evolution 34 compact - die casting machine designed, manufactured and supplied by Bühler Group, Switzerland integrated with 200 kg aluminium melting furnace and auto ladler for automatic melt transfer.
- The machine is capable of performing Squeeze Pressure and High Pressure die casting with a maximum locking force of 3400 kN to make maximum ~5 Kg weight components of aluminium and zinc alloys.
- This is one of its kind machine where the whole casting process parameters can be adjusted precisely in real time for the components to be manufactured and to suit their required material properties.

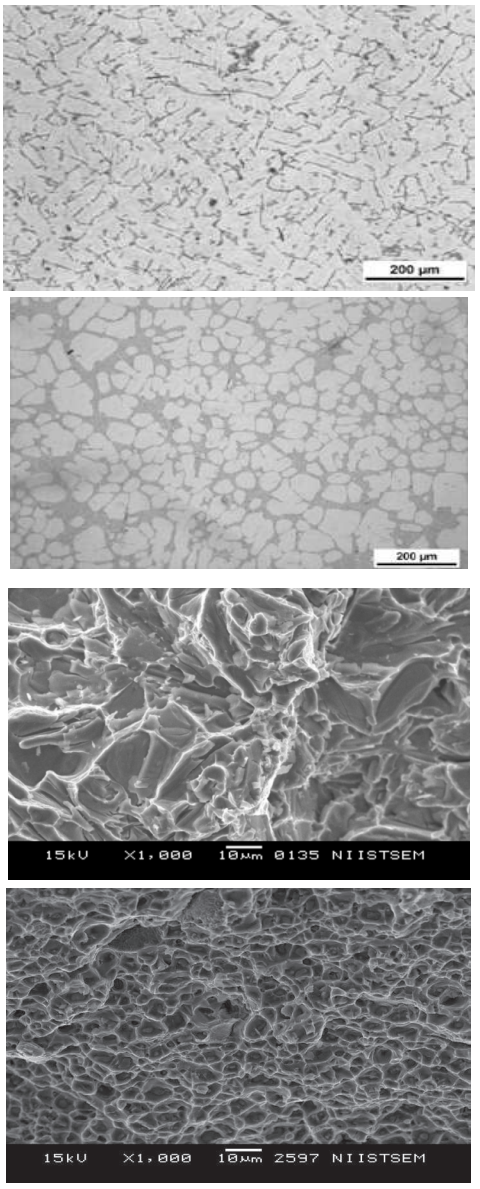
AutoCAST X1 – functionalities

## Novelty and Benefits

- This squeeze casting technology will be first of its kind in the country. Adoption of this technology to the main stream manufacturing will contribute for the nation's economy by creating new skilled jobs in the aerospace, automotive, defence, energy and industrial machineries sectors.
- High quality and long-life components indigenously made for the various section by the squeeze casting technology will reduce the import needs of sensitive components and products and enable global export to various developing and developed countries.
- The SQC technology enables weight saving by improving the material property of the same metal cast by the conventional processing leading to lower raw material cost, lightweight, and high quality products with the less material wastage.

**Photographs of few components, which would be developed using this process, are exhibited below.**

Aluminium Alloy Piston, Flange, LF Housing, Connecting Rod and Scroll Compressor Plate



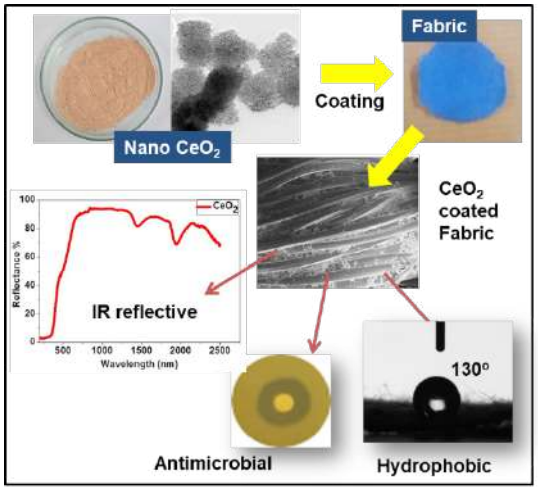

Gravity die cast alloy, Squeeze cast alloy
The microstructure and the fractured surface details of Squeeze Casting Process compared to the Gravity Die Casting process

## Important R&D Outputs

### 1.Nano $CeO_2$ based Near IR reflective, hydrophobic antimicrobial coatings

Emulsion-combustion reaction was performed using the cerous carbonate-urea emulsion prepared in hexane/water medium by using the mechanical milling with CTAB surfactant. The prolonged exposure of urea-cerous carbonate emulsion mixture at 90°C undergoes slow and steady flameless *'smouldering'* that caused localized micro-thermal heating. Ultimately simultaneous decomposition of cerous carbonate and

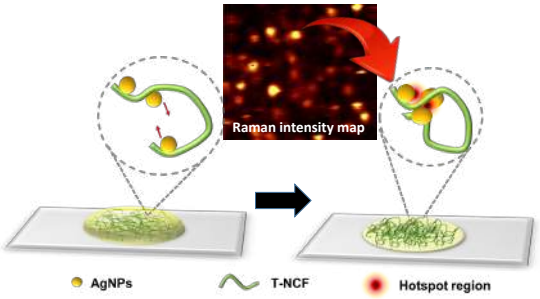
urea occurred which finally produced crystalline, soft ceria agglomerates consisting of fluorite $CeO_2$ particles. Ceria, thus, obtained was studied for the optical reflectance within the wavelength range of 700-2400 nm to understand the total solar reflectance quality [TSR]. The product was also systematically characterized for phase purity, morphology, UV absorbance, band-gap energy as well as surface chemistry using the XPS analysis. The Near IR reflectance data confirms 94% reflectance in the IR region. An antimicrobial study was also conducted against Escherichia coli, Staphylococcus aureus, Klebsiella, Candida albicans, and Aspergillus Niger. Subsequently, this IR reflective, antimicrobial ceria was dispersed in an acrylic-sodium silicate hybrid dispersant cum binder system for forming the ceria spray coatings on the fabrics commonly used for making the face masks. The IR reflectance and hydrophobic properties of ceria coated masks were examined. The ceria modification enhanced the IR reflectance up to 80% with the hydrophobic water contact angle above 130°. This study explored the beneficial properties of IR reflective, antimicrobial, hydrophobic $CeO_2$ for the processing of surface engineered, multifunctional textiles for the medical sector.




Nano $CeO_2$ modified multifunctional fabrics

## 2.Nanocellulose-silver ensembles for ultrasensitive SERS: An investigation on the role of nanocellulose fibers for the generation of high-density hotspots

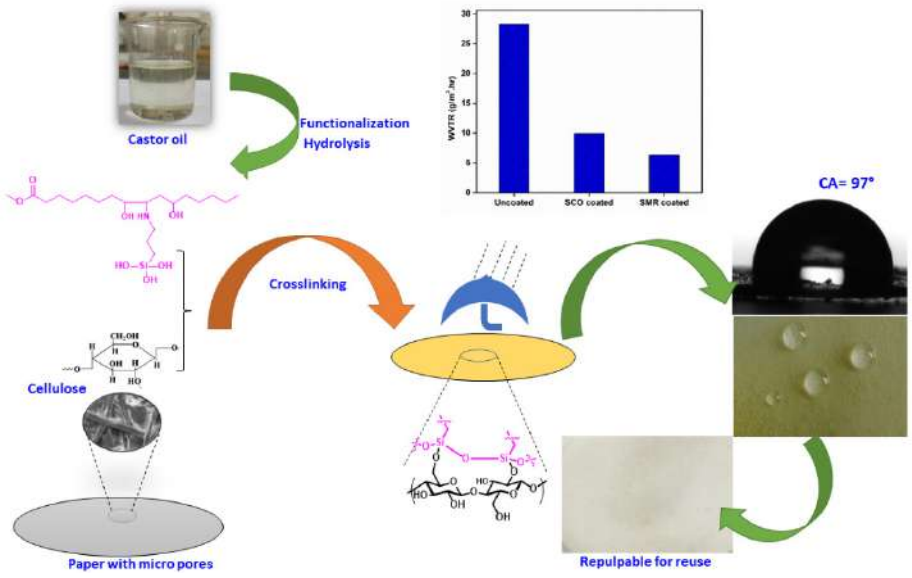
Nanocellulose-based systems have been utilized as ultra-sensitive surface enhanced Raman scattering (SERS) platforms for the trace level detection of various Raman active molecules including environmental pollutants. Large scale hotspot engineering is a significant approach for the development of highly efficient SERS platforms. TEMPO-oxidized nanocellulose fiber (T-NCF) serves as a labyrinth for developing highly sensitive and stable silver (Ag)-based SERS platform enabling single molecular level SERS detection of analytes. The SERS activity of 4- methylbenzenethiol (4-MBT) in silver nanoconstructs with dissimilar size and shape (denoted as Ag/NCF-I and Ag/NCF-II systems) synthesized by varying T-NCF to $Ag^+$ ratio, exhibited femtomolar sensitivity regardless of their structural variation. A detailed investigation of the SERS performance of both systems with 4-MBT at extremely low concentration ($10^{-15}$ M) is carried out with the help of large-area Raman intensity mapping in order to evaluate the role of T-NCF in Raman signal enhancement. The analytical enhancement factors (AEFs) for Ag/NCF-I and Ag/NCF-II are calculated to be $1.4 \times 10^{12}$ and $4.8 \times 10^{11}$ respectively. A mechanism of local enrichment of analytes is postulated anticipating the ability of flexible nanocellulose fibers to congregate AgNPs resulting in induced plasmonic coupling of local electromagnetic fields and high-intensity hotspot generation. The reported synthesis strategy resulted in Ag colloids with long-term stability (over two years) and can be easily scaled-up with excellent shelf-life. This investigation ascertains the potential of nanocellulose fibers in the development of a robust lithography-free SERS sensing platform with single molecule level sensitivity. Further, this study can be extended to other functional nanostructures with tailored plasmonic properties for a broad range of applications. (Ref: Applied Materials Today, 20, 100672, 2020)




Cartoon showing the role of nanocellulose fibers enabling ultrasensitive SERS platforms with longer shelf-life (>2 years)

## 3. Hydrophobic, moisture resistant and biorenewable paper coating derived from castor oil based epoxy methyl ricinoleate with repulpable potential

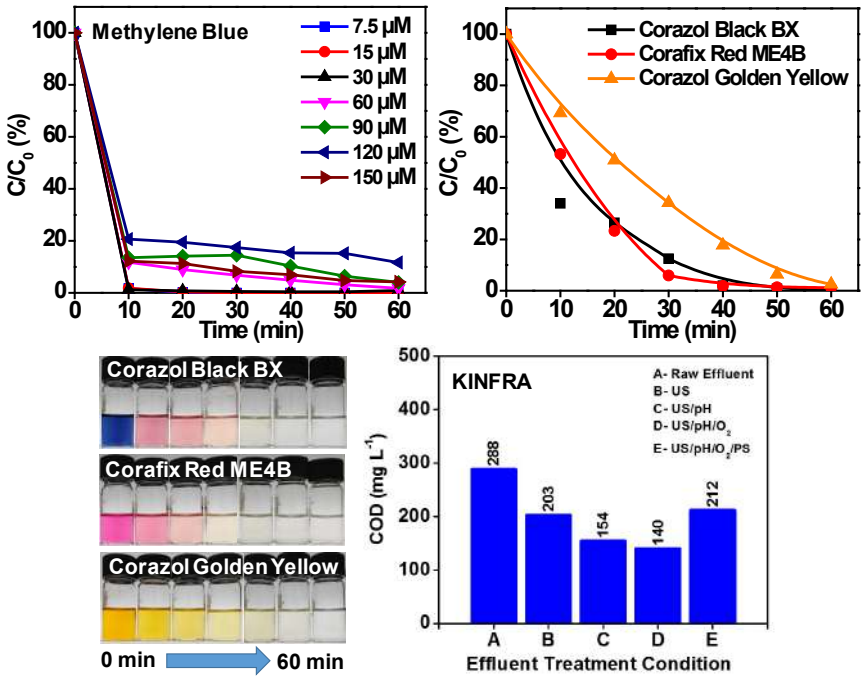
After ban on single-use plastics, completely bio-based coating on paper is in great demand to replace the plastics liner and other organic-inorganic hybrid coating. To resolve the issues like moisture, hydrophilicty and repulpability after use, a green, sustainable and hydrophobic bio-coating material for paper substrate has been developed. Silanized castor oil (SCO) and silanized methyl ricinoleate (SMR) bio-resins have been synthesized via the structural modifications of epoxidized castor oil through transesterification and silanization process, Subsequently, the silylated bio-resins have been hydrolysed and subjected to crosslinking with cellulosic paper substrate through condensation process. The coated papers exhibit hydrophobicity with water contact angle (WCA) up to 97° and strong moisture resistance (moisture content of 2-3%). The SEM and EDX analyses confirm the uniform coating of SMR resin with better texture and higher degree of silane grafting. The water vapour transmission rate (WVTR) has been observed to be decreased by 77.5% after the coating because of blockage of pores and strong bonding with the cellulosic fibers. Further, the coated papers show adequate thermal stability and better tensile strength for commercial packaging. These coatings have been removed via exposure to strong alkali solution at 90°C and the recyclability potential of paper has been confirmed for the reuse. These renewable resourced and eco-friendly coating materials have been found to be suitable alternative for paper packaging and other coating applications with circular economy approach.




## 4. Removal of methylene blue and azo reactive dyes from aqueous solution via modified pulse low frequency ultrasound cavitation process

Organic dyes in the aqueous solutions and textile effluents cause severe environmental pollution due to their carcinogenic and mutagenic nature. Ultrasound (US) cavitation is one of the promising advanced oxidation process (AOP) to remove the organic dyes from the aqueous solutions and textile effluents. Nevertheless, the conventional low frequency US cavitation process exhibits very low efficiency in the dye removal process and demands effective modification to improve its dye removal performance. In this investigation, the conventional pulsed low frequency (22±2 kHz) US cavitation process has been modified by varying the US power, initial solution pH, and $O_2$ flow rate to enhance the decomposition of cationic methylene blue (MB) dye in the aqueous solution. The operation of classic Haber-Weiss reaction, both in the forward and backward directions, and the ozone effect have been observed under the modified US cavitation process as confirmed

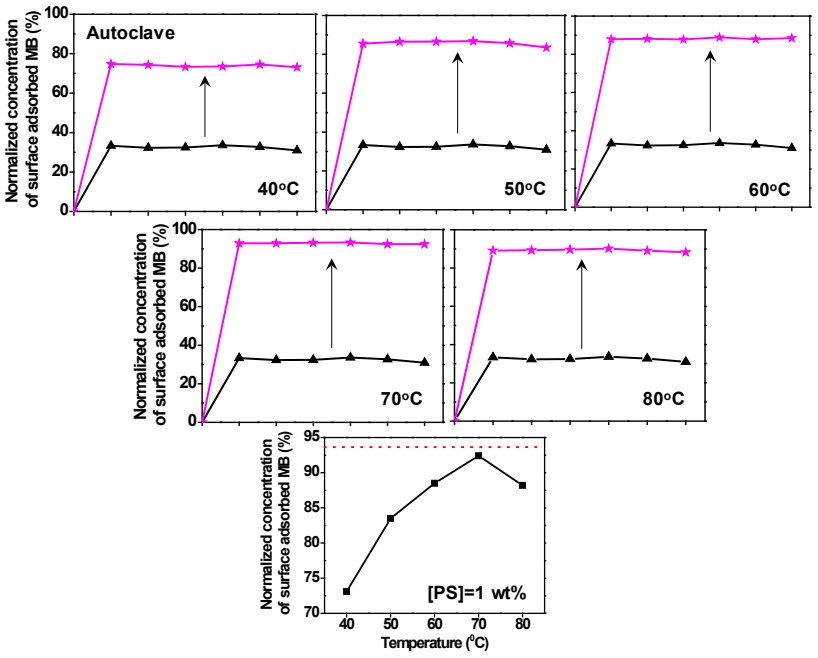
via the systematically conducted radical trapping experiments. Moreover, the hydrothermally synthesized hydrogen titanate ($H_2Ti_3O_7$) nanotubes (HTN) have been utilized as sonocatalyst for obtaining 100% dye removal with their effective regeneration obtained via the in-situ thermal activation of persulfate (PS, $S_2O_8^{2-}$). The decomposition of industrial azo reactive dyes in the aqueous solution as well as in the textile effluent has also been demonstrated by using the modified US cavitation process involving the thermal activation of PS which justifies its suitability for the commercial application.




## 5. Using Thermal Activation of Persulfate for Regeneration and Recycling of Hydrogen Titanate Nanotubes as Dye Adsorbent Catalyst

Adsorption is one of the physical techniques effective in the removal of organic dyes from the aqueous solutions. Various types of adsorbents such as the orange peel, rice husk, coconut shell, fly ash, clay, activated carbon, carbon nanotubes, and graphene / graphene oxides have been reported in the literature for the removal of varieties of organic dyes from the aqueous solutions. However, the regeneration and recycling of adsorbents in the dye removal application remains a major challenge. Different techniques such as the thermal decomposition, pH adjustment, and activation of strong oxidants such as the hydrogen peroxide ($H_2O_2$) have been reported in the literature for the regeneration of adsorbents. Recently, hydrogen titanate nanotubes (HTN), synthesized via the hydrothermal method, have been reported as excellent adsorbent for the basic dyes due to their high specific surface-area and easily adjustable zeta potential. Although the regeneration of HTN via the activation of $H_2O_2$ has been reported, there are no other alternative methods available in the literature, for this purpose, to replace the costlier and hazardous $H_2O_2$ based method. Hence, we synthesized the HTN via the hydrothermal process and utilized them to adsorb the methylene blue (MB), a cationic dye, from the aqueous solution via the adsorption mechanism. The regeneration of HTN has been demonstrated via the thermal activation of persulfate anion (PS, $S_2O_8^{2-}$) by varying its initial concentration and the regeneration temperature within the range of 0.27-1 wt% and 40-80°C respectively under the thermal conditions set by the autoclave and US cavitation process which have been utilized as the heating techniques. Both of these heat generation techniques have the advantage of providing fine control over the heating rates and final temperatures to be achieved compared with the conventional use of hot plate technique. The as synthesized HTN exhibits the MB adsorption of 93% in the first cycle for the initial MB concentration of 90 µM. Under the autoclave condition, the best combination of initial PS concentration and

temperature for the regeneration of HTN have been observed to be 1 wt% and 70°C with the maximum MB adsorption of 92%; while, the corresponding values under the US cavitation conditions have been noted to be 1 wt%, 80°C, and 91% respectively. Hence, the successful regeneration and recycling of HTN has been obtained via the thermal activation of PS under both the autoclave and US cavitation conditions.



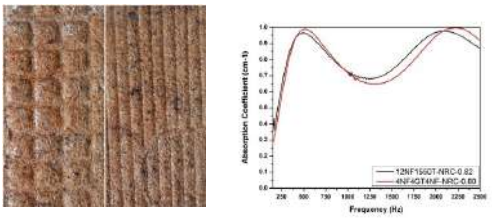

## 6. Development of Coir/Polymer Composites for Furniture, Acoustic and Electrical Insulation Applications

Natural fiber-reinforced composites offer high specific strength and good mechanical properties being lightweight and eco-friendly. The development of renewable and biodegradable materials has attracted significant attention in terms of meeting the growing demand for the sustainable development, given an increase in the environmental awareness. Various polymers such as phenol-formaldehyde resin, polyester, polylactides, and polyethylene for the fabrication of furniture products were explored. Keeping the recycling option in mind, we have used several thermoplastics as well. No additional treatment has been done on the coir fibre. We have developed processes for the fabrication of both thermoplastic and thermoset-based furniture products by using coir as reinforcement materials. Polymers exhibit a variety of electrical properties reflecting their structures and molecular motion. Most polymers are highly insulating dielectrics. In the ongoing NCRMI project, we have developed polymer-coir composites for electrical insulation applications.

Furniture products developed in collaboration with NCRMI, Government of Kerala

Natural fibers especially coir fibers, which possess high hardness, large diameter, large bulk density, are sustainable and non-toxic. They can be utilized as a suitable replacement for mineral fibers for obtaining good sound absorption coefficient particularly at mid to low frequencies. We have developed a process for making low density acoustic panels from coir/epoxy

composites by using different layers of hybrid coir mats, which are flame resistant and have good sound absorption properties at low frequencies with the noise reduction coefficient @0.8. These hybrid coir composites produced with tailor-made sound absorption and physical properties show prospects as the cost-effective acoustic panels for noise control. PLA/ Coir composites.



Acoustic hybrid panels of coir/polymer composites (b) Absorption coefficient vs frequency in geotextile(GT)/needle felt (NF) hybrid composites in comparison to needle felt coir composite (Produced at Neyyattinkara Coir Cluster Development Society, Thiruvananthapuram).

Synthesized green acoustic panels also from coir/ poly (lactic acid) composite which shows good sound absorption coefficient with noise reduction coefficient 0.6-0.7, with self-extinguishing nature. The present composites show biodegradation also within 120 days under the soil burial conditions. Current results indicate the prospects for applications of these composites as green acoustic paneling in automobiles, house hold items and in room acoustics control.

### 7. Development of disposable plates and packaging materials using coconut husk

Coconut husk is a renewable resource material obtained after extraction of the coconut kernels for edible purpose. The material predominantly serves as a source of coir fiber used in ropes, mats and beds. In recent years, new developments have been reported in making value-added products by using the coconut husk. Coconut husk contains lignin hemicellulose and cellulose. The leftover material after extraction of coir fiber is termed coconut pith which forms nearly 70% of husk. The coir pith is a waste material and currently ends up in landfill/growth medium for plants and available freely. The project was intended to develop a natural alternative to plastic containers; and thereby, to reduce the discarded plastic waste. It was suggested as an alternative material to make plastic containers and reduce the use of petrochemical-derived plastics in packaging.

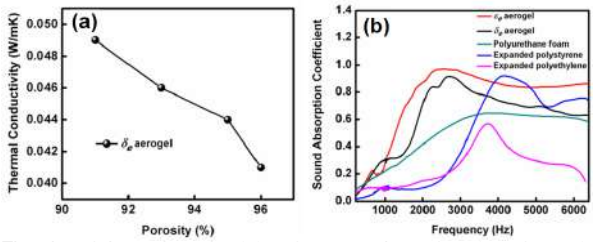
The main objective of the project is to establish the technical parameters for the production of plates/ trays using the coconut husk as a cost-effective, non-polluting and environmentally safe packaging material. The laboratory level process development including technical parameters and performance testing has been carried out. A moulded product with good mechanical properties and finish has been obtained under the suitable processing conditions. The process is expected to result in new applications for coir husk; thus, increasing the scope for value addition to the coconut husk, an important agricultural residue. Value-added products from waste materials like coir husk would enhance the potential of coir products industry and improve the income and living standards of many local populations. The developed process can be used to make plates from coconut husk without the addition of any costly chemicals.

Coconut husk plate

### 8. Development of nanoporous crystalline aerogels of syndiotactic polystyrene for thermal and acoustic insulation

Hierarchically porous crystalline-nanoporous aerogels of syndiotactic polystyrene (sPS) received much attention because of their unique nanoporous structures along with meso and macro porosity. Depending on the difference in the packing of polymer chains within the crystal lattice, sPS has two nanoporous crystalline forms, namely $\delta$ and $\varepsilon$ forms ($\delta_e$ and $\varepsilon_e$). In this study, we have prepared high purity nanoporous $\delta$ and $\varepsilon$ forms of sPS aerogels from their respective gels using a solvent exchange strategy followed by an environment-friendly freeze-drying technique. Using these highly porous aerogels, the phase transition behavior of sPS at higher temperatures was investigated. The $\delta_e$ form showed a complex phase transition behavior on heating; and at a higher temperature, the $\gamma$ form (obtained through an intermediate helical phase) transformed to the mixture of $\alpha$ and $\beta$ forms. On the other hand, the $\varepsilon_e$ form transformed directly to the $\gamma$ form; and on further heating, the $\gamma$ form transformed exclusively to the $\alpha$ form. The dielectric, thermal and acoustic properties of $\delta\varepsilon$ and $\varepsilon_e$ aerogels were promising with ultralow dielectric constant (1.02 ± 0.02), thermal conductivity ($\lambda$) as low as 0.04 W $m^{-1} K^{-1}$ and high sound absorption coefficient (close to 1). Moreover, these aerogels exhibited excellent oleophilicity which has been demonstrated in oil/organic solvent separation experiments. These

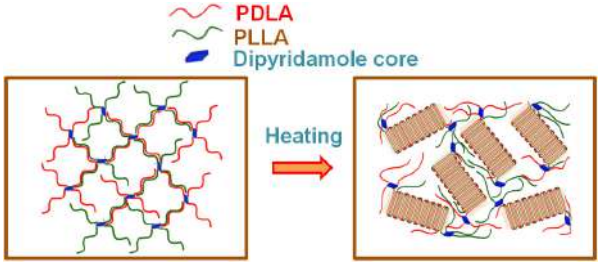
multifunctional aerogels of sPS can, therefore, find a multitude of applications especially in the thermal and acoustic insulation and molecular sorption of oil/ organic solvents.




The plot of thermal conductivity of $\delta_e$ aerogel as a function of porosity, and (c) normal incident sound absorption coefficients of $\delta_e$ and $\varepsilon_e$ aerogels measured in the frequency range 300-6400 Hz and compared with other commercially available sound insulation materials.

## 9. Stereocomplexation of enantiomeric star-shaped poly(lactide)s (biodegradable polymers)

Thermally stable biodegradable polymers attracted the attention of researchers and industries to replace single-use plastics. We have prepared the blends of star-shaped poly(D-lactide) (SSPLLA) and star-shaped poly(L-lactide) (SSPDLA) with equimolar composition. The influence of cooling rate from the melt on stereocomplex formation of equimolar blends of enantiomeric star-shaped poly(lactide)s with a dipyridamole core has been investigated. As evidenced by the differential scanning calorimetry, wide-angle X-ray scattering and Fourier-transform infrared spectroscopy, melt cooling of equimolar blends of SSPLLA and SSPDLA result in the non-crystalline state. A careful analysis of WAXS and FTIR data revealed that the slow cooled sample (10 °C/min) exhibits the amorphous phase and the fast cooled sample (50 °C/min) results in the mesophase. On subsequent heating, the slow cooled sample remains in the amorphous phase; whereas, the fast cooled sample crystallized (cold crystallization) exclusively into the stereocomplex at ~90°C. The aging of slow cooled sample at room temperature and subsequent heating leads to the formation of stereocomplex. The photoluminescence studies revealed that the cooling rate from the melt has a strong influence on the core molecule (dipyridamole) aggregation and it determines the geometry of interactions between the branches of SSPLLA and SSPDLA. Based on these results, we propose antiparallel chain packing in the fast cooled SSPLLA/SSPDLA blends because of the non-aggregation of dipyridamole core molecules and this geometry favores the formation of exclusive stereocomplex. On the other hand, due to the possible aggregation of dipyridamole molecules, the slow cooled sample led to the topological constraints and geometric constraints where the interactions between SSPLLA and SSPDLA chains prevent the crystallization. The present findings could open new avenues for the design of a variety of macromolecular architectures for a better understanding of the stereocomplex formation mechanism of chiral

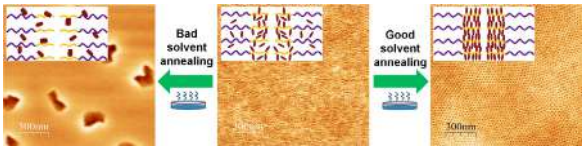



Stereocomplex formation in equimolar blends of SSPLLA and SSPDLA

## 10. Block copolymer-based supramolecular assemblies and their hierarchical assemblies

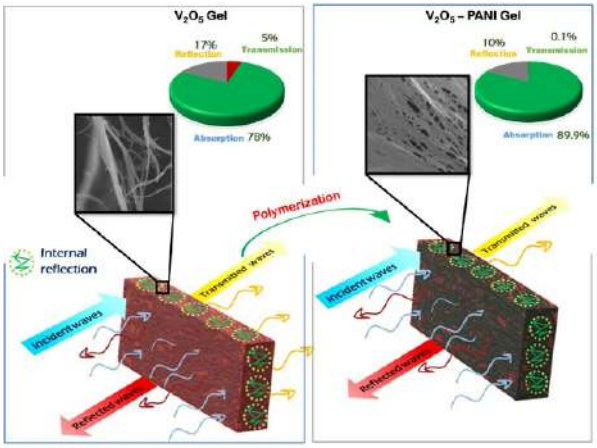
The factors that control the formation of supramolecular assemblies (SMAs) by hydrogen bonding using polystyrene-block-poly(4-vinyl pyridine) (PS-b-P4VP) and biphenyl systems containing different functionalities have been investigated both in bulk as well as in thin films. 4-Hydroxybiphenyl (4HB) (hydroxyl functionalized), biphenyl-4-carboxylic acid (BPCA) (carboxyl functionalized) and 4′-hydroxy-4-biphenylcarboxylic acid (HBCA) (with both hydroxyl and carboxyl functionalities) have been chosen as small molecules. Phase behavior of SMAs in bulk has been studied by temperature-dependent wide-angle and small-angle X-ray scattering. All the SMAs show the macrophase separation of small molecules in solvent-casted samples. Heating or annealing above the glass transition temperature of block copolymers turns out to be a crucial factor in the effective formation of SMAs in the case of 4HB. On the other hand, SMAs formation has not been that effective in the case of carboxylic group-containing small molecules (BPCA and HBCA). Heating or annealing of as-cast films above the melting temperature of small molecules lead to the homogeneous dispersion of BPCA and HBCA in SMAs due to the breakage of hydrogen bonds. In thin films, SMAs formation by solvent vapor annealing has been sensitive to the selectivity of solvents to constituted blocks and small molecules. the breaking of self-association of small molecules by heating above the melting temperature of small molecules or annealing in a good solvent for both block copolymers and the small molecules is a key factor in the formation of SMAs in bulk and thin films. The present study provides a

guideline for the basic design of effective SMAs using different kinds of small molecules, block copolymers and annealing conditions. (*Mater. Today Commun.*, 2020, 25, 101147)




Atomic force microscopy images of block copolymer supramolecules before (middle) and after annealing in good and bad solvent vapors. Schematic illustrations of the hierarchical assembly of small molecules within the block copolymer microdomains are shown in the insets.

## 11. $V_2O_5$-Polyaniline composite aerogels for green electromagnetic interference shielding




Schematic representation of electromagnetic wave attenuation mechanism in $V_2O_5$-PANI aerogels

Smart and portable electronic gadgets are ubiquitous in modern times. Densely packed electronics in these devices operating in mobile communication, radio broadcasting, television and radio communication generate spurious electromagnetic (EM) waves. These harmful EM waves can largely interfere the functioning of electronic devices, resulting in issues like data losses, information insecurity and critical system failures. On top of this, the electromagnetic interference (EMI) can cause health issues ranging from insomnia, headache, fertility problems and even cancer as well. So, it is imperative to develop efficient, lightweight electromagnetic shields that can solve electromagnetic interference. Green EMI shielding materials are the most promising among the EM wave attenuating solutions because of their less environmental hazard resulting from the efficiently attenuating spurious waves with minimal secondary reflection.

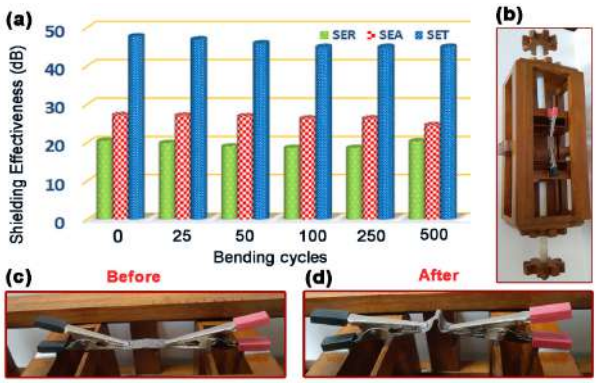
Against this background, NIIST team has proposed a facile strategy for developing green and ultra-lightweight aerogels-based EM wave absorbers with low carbon content. Herein, we realized a peculiar 3D nanoarchitectured aerogel using the nanowires of a layered oxide $V_2O_5$, which has been further reinforced by a conducting polymer such as polyaniline (PANI). The structure, morphology, formation of gel, and the EMI shielding properties of $V_2O_5$-PANI composite aerogel have been investigated in detail. The mesoporous aerogel has a very low density of ~0.02 g $cm^{-3}$ with the maximum EMI shielding efficiency (EMI SE) of 34 dB in X band, with an impressive specific shielding efficiency of 1662.2 dB $cm^3$ $g^{-1}$. Green index ($g_s$) has been found to be one of the highest so far (~2.91). The excellent show of EMI SE has been ascribed to the multiple internal reflections inside the layered structure of $V_2O_5$ and intrinsic conducting properties of polyaniline. Ours is the first-ever report of an eco-friendly, lightweight EMI shielding solution employing inorganic $V_2O_5$ nanowires forming robust EMI attenuating aerogel, which are free of carbonaceous fillers like carbon nanotubes, graphene or even MXene.

## 12. Nickel electrodeposited textiles as wearable radar invisible fabrics

In general, highly conductive metallic materials or highly permeable magnetic materials are proven microwave shields used in the defense applications. However, there are domains where high density and rigid nature of metals can be constrained in applications such as wearable and portable shields. For example, radio frequency (RF) shielding tents, curtains and screens are used for customized mobile laboratories and workstations. Further, shielded mobile phones and laptop pouches are highly handy for the domestic as well as police, military and security services around the globe. Especially, in the defense sector, a microwave absorbing attire designed for a remotely located soldier will be useful, since it can make him 'radar invisible' to the surveillance radars of the enemy. Against this background, the research on the conductive textile materials as EMI shields is strategically important. Ideally, the wearable shields should combine the flexibility, breathability and conformability of a textile fabric, with the RF electrical properties of metals like ultra-low surface resistivity and excellent shielding effectiveness.

The NIIST team qualified a few wearable fabrics

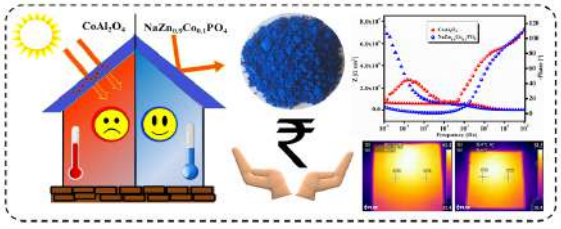
electrodeposited with nickel, as efficient absorbents of microwaves in X band. Here two samples of fabrics - a natural fiber based linen and an artificial fiber based nylon fabrics has been chosen for electrodeposition. Prior to this, the surface activation of the fabric has been carried out through sputtering of platinum, followed by electrodeposition of nickel using Watts bath solution. Interestingly, the two step process has transformed the fabric from an electromagnetic (EM) transparent material to an excellent electromagnetic interference (EMI) attenuator, retaining its flexibility and breathability. Microstructural analysis of electrodeposited fabrics shows much thicker and broader Ni deposits for linen than nylon fabric due to the availability of more bundle of fibers. Further, the abundance of lint in linen provide more surface to deposit Ni, which helps in achieving better shielding values. Metallic and ferromagnetic characteristics of Ni deposited fabric structures have also been investigated. The high conductivity and high permeability of Ni also play a pivotal role in the current system to lower the skin depth of the shield, along with the more inter-connected coating structure, which are advantageous for better shielding. The electrodeposited linen, even after 500 bending cycles could retain up to 94% of total shielding efficiency ($SE_T$) of the unbent state, indicating its outstanding durability and flexibility. Exceptional EMI shielding efficiency of 45-52 dB has been achieved for the Ni deposited linen, which means 99.999% of attenuation has been attained. The outcome of this research can lead to the development of lightweight, wearable and flexible 'radar invisible fabrics', which has wide range of applicability in defense and healthcare sectors.




(a) EMI shielding performance of nickel coated linen fabric after different bending cycles (from 0 to 180 degree). (b) Photograph of set-up for performing bending test. (c) & (d) Photographs of electrofabric taken before and after the bending in the bending set-up.

## 13. A cost-effective intense blue colour inorganic pigment for multifunctional cool roof and anticorrosive coatings

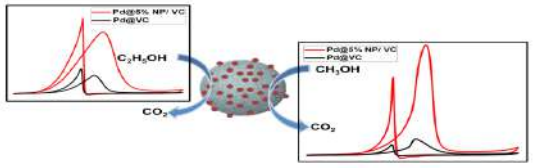
An enormous attention has been paid to the cobalt aluminate ($CoAl_2O_4$) blue pigments owing to their significant hue of blue colour. Nevertheless, several serious disadvantages, such as high cost due to the high cobalt consumption and poor solar reflectance, are associated with this pigment. Therefore, the development of cost effective and sustainable blue pigments with the reduced Co content and improved solar reflectivity has been a major focused area in the pigment research. Herein, a new series of multifunctional blue coloured inorganic pigments with low cobalt content has been prepared via the solid-state method. The structural and spectroscopic evaluations has indicated that the strong blue colour could be generated because of the distorted tetrahedrally organized cobalt chromophore. This structural distortion of the chromophore geometry has been linked to the covalency and electron affinity factors. The colour (b* = -59.21) and solar reflectance (R* = 64%) measurements of optimized composition ($NaZn_{0.9}Co_{0.1}PO_4$) has been observed to be superior than the commercially available $CoAl_2O_4$ blue pigment. The optimized pigment loaded epoxy coated steel substrate in marine medium exhibits an impressive corrosion resistance properties. The anticorrosive mechanism, further established through the XPS results, validates that the phosphatized inhibitive film serves as the barrier for corrosion. The estimated Co content in $NaZn_{0.9}Co_{0.1}PO_4$ has been found to be around 10 times lower than the $CoAl_2O_4$ blue pigment indicating the cost-effective nature. The optimized pigment has been able to retain its optical properties in the prepared acrylic coatings on Al sheet and concrete block. Further, the temperature shielding studies ensure a reduction of ~4°C in comparison with $CoAl_2O_4$ coatings.




Multifunction inorganic blue pigment

## 14. Nickel phosphate modified carbon supported pd catalyst for enhanced alcohol electro oxidation

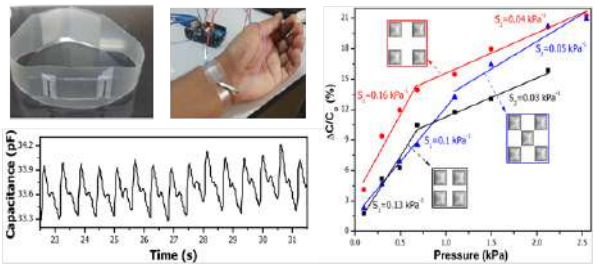
Transition metal phosphates are emerging as a novel class of material for many potential electrochemical applications owing their several advantages like abundance, environmental friendliness and low cost. Herein, we explore the excellent electro chemical property of nickel phosphate (NP) as an electrocatalyst for alcohol oxidation. Novel vulcan carbon supported Pd@NP has been synthesized through a very simple method at room temperature. In the presence of NP well dispersed homogeneous Pd particles having reduced size have been observed. Approximately, seven-fold increments in the catalytic efficiency towards methanol oxidation and three fold increments towards ethanol oxidation than vulcan carbon supported pure Pd were achieved. The improved electrochemical property and increased surface area by the combination of Pd with nickel phosphorous compound and supporting carbon material imparted an excellent catalytic efficiency to the synthesized catalyst.




Alcohol electro oxidation on modified carbon supported Pd catalyst.

## 15. Wearable capacitive pressure sensors using polydimethylsiloxane micro-pyramids for bio-signal monitoring

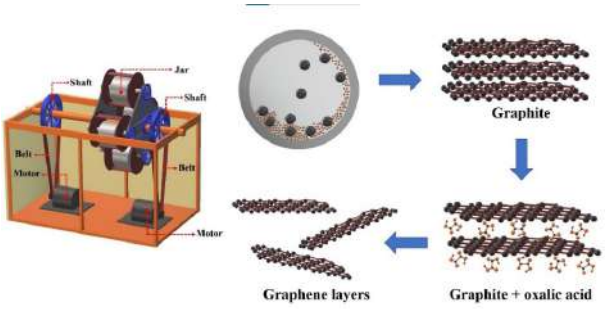
Recently, microstructured PDMS based pressure sensors have been explored as the potential candidates in bio-signal monitoring and electronic-skin applications. Here, we have fabricated capacitive pressure sensors based on the micro-pyramidal PDMS dielectric thin film structures and studied the influence of surface coverage and arrangement of these structures on the sensitivity of pressure sensor devices. Pressure sensor with periodically arranged pyramids (surface coverage: 36.7%) exhibits sensitivity of 0.16 $kPa^{-1}$ in <1 kPa and 0.04 $kPa^{-1}$ in 0.75-2.5 kPa pressure ranges, whereas the pressure sensor with diagonally arranged pyramids (surface coverage: 45.2%) exhibits sensitivity of 0.1 kPa-1 in <1 kPa and 0.05 kPa-1 in 0.75- 2.5 kPa pressure ranges respectively. Despite having large surface coverage, pressure sensor with diagonally arranged pyramids exhibits high sensitivity (0.05 kPa- 1) in 1-2.5 kPa pressure range than periodically arranged pyramids owing to the large displacement and increase in effective permittivity of diagonally arranged pyramids. Simulation studies on the developed pressure sensor structures using finite element analysis software also confirm relatively large displacement and $\Delta C/C_0$ in diagonally arranged pyramids compared to the periodically arranged pyramids. Experimental results and simulations demonstrate that the sensitivity of these kinds of pressure sensors can also be tuned by arrangement of pyramids. Also, the developed flexible capacitive pressure sensor has been demonstrated for in-vivo, real-time pulse wave form recording. [Sensors and Actuators A: Physical, 314, 112251 (2020)].




Photograph and output performance of micro patterned PDMS based wearable pressure sensor for pulse monitoring.

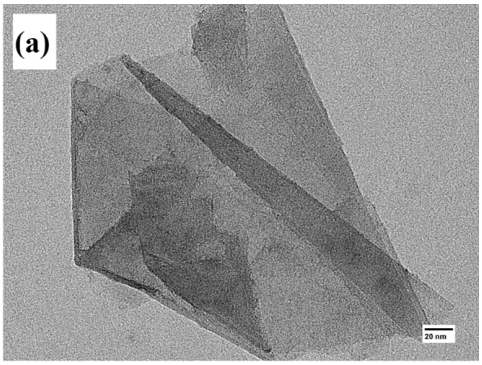
## 16. Scalable preparation of graphene oxide from graphite ore via mechano-chemical ball milling

Mechanical exfoliation can generate graphene, but a consistent and scalable preparation of few-layer graphene oxide (FLGO) continues to be a challenge. We employed a mechanochemical milling technique to achieve maximum shear and frictional force by dual drive mode operation for preparation of FLGO directly from the graphite ore. Natural graphite ore has been obtained from M/s Chotanagpur Industries, Jharkhand.




The low-grade graphite which contained 9.07% fixed carbon was upgraded to 91.32% by using a newly

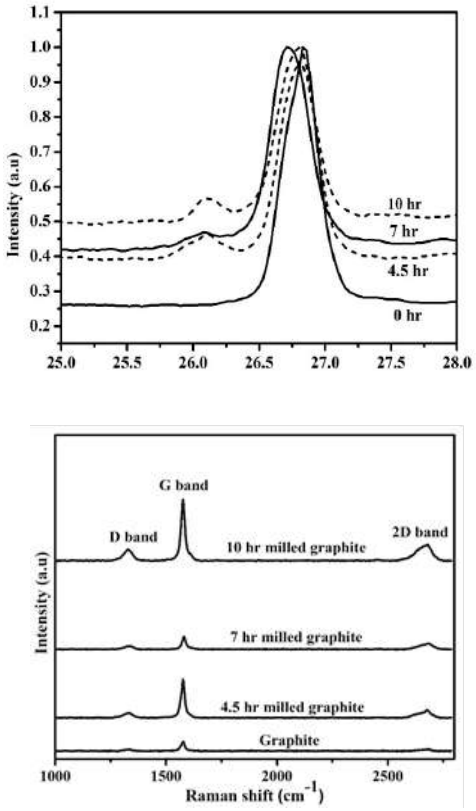
developed eco-friendly floatation reagent from the natural source. A high pure graphite could be obtained with a combined two-step process of flotation followed by leaching from a very lean grade ore. The X-ray diffraction study reveals the change in the crystallinity of sample which is due to the acid treatment which occurred along with high purity. The degree of exfoliation which occurred during the ball milling has been evaluated via TEM images and the selected-area electron diffraction (SAED) pattern reveals the crystal structure of sample. The graphene flakes or sheets obtained via the ball milling (10 h) has been found to be transparent and sheet-like structure in the TEM image. The sample shows hexagonal pattern and has been found to be polycrystalline in nature. A carbon purity of 98.16% could be obtained without incorporating any addition pressure or extreme temperature or using hazardous chemicals. Further to its value addition, an effective and low-cost process for the mass producing high-quality graphene from graphite (50 g per batch) has been demonstrated. The graphene, thus, obtained has been found to vary in size from a few layers to multilayers, signaling that the successful exfoliation occurs during the ball milling process.




TEM images of graphene (Milled Graphite or Graphene)

## 17. Plasma arc melting of Garnet mineral for recovery of iron metal and alumina rich slag

Garnet is a mineral abrasive produced from the naturally occurring Almandine garnet. Garnet have been crushed and size graded for the use as abrasive, cutting and filter media. They are used in water jet cutting, sand blasting, sand paper, water filtration, and a number of other uses. Almandine is the hardest garnet and also the most abundant. Here, a material which has resistance to temperature is called the refractory material. In this work, we are focussing on the synthesis of such a refractory material mullite from the garnet mineral. Garnet al.so contains 31% $SiO_2$ and 17% $Al_2O_3$ along with the presence of $Fe_2O_3$ and MgO. No other beach minerals have the components $Al_2O_3$ and $SiO_2$ other than sillimanite. Even though there are unwanted components like $Fe_2O_3$ and MgO, due to the characteristics of garnet it is also used for the synthesis of Mullite. The main problem in using the Garnet mineral is that it has less amount of $Al_2O_3$ content and higher amount of $Fe_2O_3$. Smelting studies have been carried out in a 40 kW DC extended transferred arc plasma reactor to remove the iron by carbothermic reduction technique. The reactor is basically a pot type reactor with the graphite crucible as the furnace hearth which is thermally insulated. Graphite electrodes are arranged in a vertical configuration. The bottom electrode (anode) is kept stationary and top one (cathode) with an axial hole for passing the plasma forming Argon gas is actuated by rack and pinion mechanism for the arc stabilization. The flow of argon gas has been regulated at 1.0 L $min^{-1}$ throughout the period of experiment. An average arc voltage of 50 V and 250 Amp current have been maintained during the experiment. Temperature observed in the plasma reactor has been in the range of 1400-1600$^0$C. At optimized




XRD and Raman spectra of graphene at different milling time

condition, 90% of iron has been recovered in a metallic form. Alumina content has been enriched from 17% to 45% in the slag which can be further enriched by adding $Al_2O_3$ rich mineral precursor (Silimanite/Alumina) for making mullite refractories.

Plasma arc furnace Iron metal

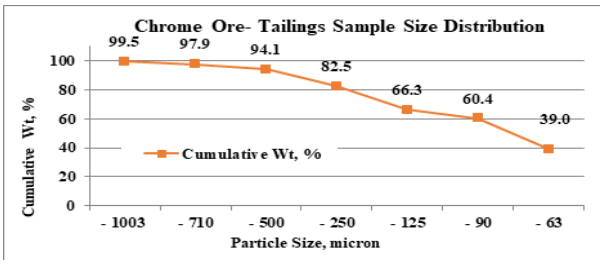
## 18. Low temperature reduction roasting of chromite ore tailings to increase Cr/Fe ratio

Chromite ore is the source for making ferrochrome metal, chrome based chemicals and refractories. Mostly, these ores usability depends on the Cr/Fe ratio besides the Cr content. XRF analysis of Chrome ore tailings collected from Orissa region has been done to know the chemical composition of as received samples. It is found that Cr/Fe ratio for the chrome ore tailings is 0.59. Due to the lowest Cr/Fe ratio and low $Cr_2O_3$ of ~28% which is not suitable for any metallurgical use as it is. Sieve analysis for chrome ore tailings reveals that the sample size is less than 1mm and -250 micron is ~83%. The objective of the study is to increase the Cr/Fe ratio to more than 2 which is desired for the production of low-carbon Ferro chrome.

*Characterization of Chrome ores*

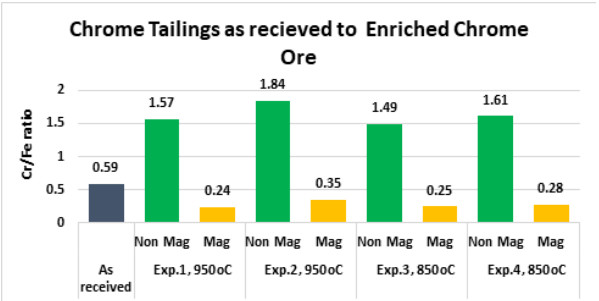
| | $Cr_2O_3$ | $Fe_2O_3$ | MgO | $Al_2O_3$ | $SiO_2$ | Cr(T)* | Fe(T)* | Cr/Fe* |
|---|---|---|---|---|---|---|---|---|
| Chrome Ore Tailings | 28.12 | 46 | 2.1 | 11.7 | 8.87 | 19.23 | 33.2 | 0.59 |

Reduction studies were carried out for chrome ore tailings with low grade coal (FC ~45%) at 850°C and 950°C for 3 hours in horizontal tubular furnace at Argon atmosphere throughout the experiment to avoid re-oxidation of iron. 20% excess stoichiometric carbon is used in the study. Each experimental conditions are repeated twice to evade the experimental errors. After the experiment, weight loss has been noted and magnetic separation with permanent hand magnets has been done. Obtained Mag and Non-mag samples are weighed and XRF analysis has been carried out. Around 55% of feed recovery achieved in non-mag portion and minimum recovery of 77% of $Cr_2O_3$ has been attained. The ratio of Cr/Fe has found to be increased to minimum of ~1.5 to maximum of ~1.8.




*Size Distribution of Chrome ore tailings*

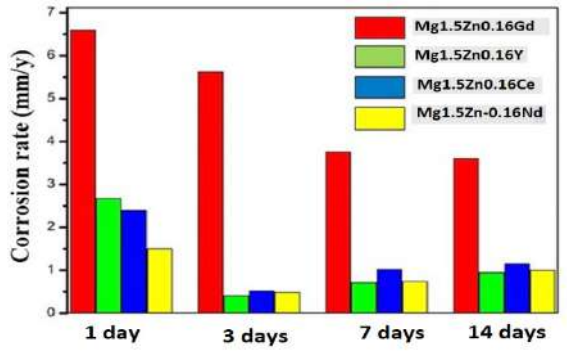
*Experimental Results for Chrome ore tailings*




## 19. Role of rare earth elements on the corrosion behavior of Mg-Zn-RE alloys (RE = Gd, Y, Ce, Nd)

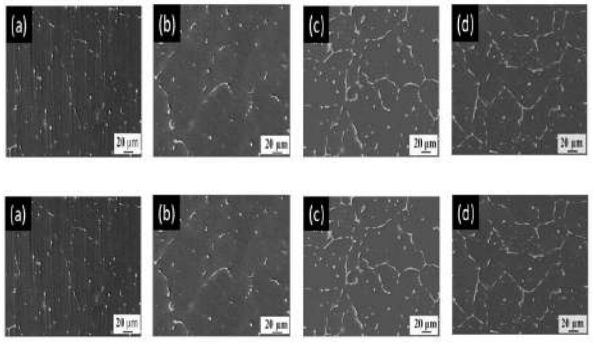
Recently, the combination of RE and Zn in Mg alloys has drawn a special attention due to the enhanced mechanical properties as well as corrosion resistance. Moreover, ZE41 (Mg-4Zn-1RE, wt.%) alloy already finds potential applications ranging from the aerospace to biomedical industries. In early stage of development, La based misch metal (MM) have been added to Mg-Zn to prepare ZE alloys. Later, MM has been replaced with Nd for the better mechanical properties. As observed in Mg-RE binary alloys, the corrosion rate of Mg-Zn-RE alloys has been influenced by the RE elements as different elements introduce different secondary phases with different electrochemical behaviours. However, a study devoted to establish the influence of different REs on the corrosion behaviour of Mg-Zn-RE alloys has not been

reported. Given this background, four different Mg-Zn-RE alloys having same atomic% of RE and Zn, to replicate ZE41 alloys with the compositions of Mg-1.52Zn-0.16Gd, Mg-1.52Zn-0.16Y, Mg-1.52Zn-0.16Ce and Mg-1.52Zn-0.16Nd (at.%, hereinafter referred to as GZ, YZ, CZ and NZ respectively) have been prepared and the effects of these REs on the microstructure and corrosion behaviour of these alloys have been investigated. Their corrosion behaviour has been studied by using the polarization, impedance measurement, hydrogen evolution method and weight loss method. The corrosion layers formed on the surface of alloys have been characterized via the XPS. Followings are some of the observations from the study.




Corrosion rate of alloys calculated from the weight-loss measurement of samples immersed in 1 wt% NaCl at different immersion times

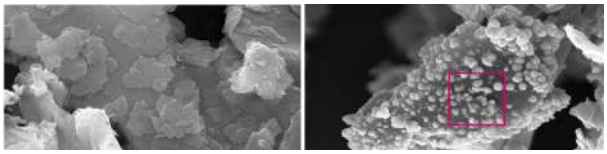
The discontinuously distributed secondary phases accelerated the corrosion in Mg-1.52Zn-0.16Gd alloy. On the other hand, the low corrosion potential of second phases and the presence of $Y_2O_3$ in the corrosion layer have been attributed to the better corrosion resistance in Mg-1.52Zn-0.16Y alloy. In spite of higher cathodic activity of second phases, the network morphology as well as the presence of $Nd_2O_3$ in the corrosion layer significantly improve the corrosion resistance of Mg-1 .52Zn-0.16Nd alloy.




Micrographs of (a) Mg1.5Zn0.16Gd, (b) Mg1.5Zn0.16Y showing discrete second phases whereas (c) Mg1.5Zn0.16CeCZ and (d) MG1.5Zn0.16Nd showing continuous network of second phases.

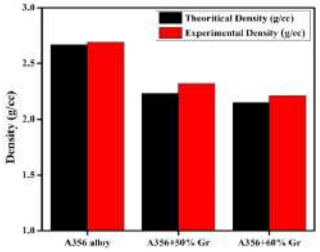
## 20. Squeeze infiltration processing and structural characteristics of lightweight aluminum-carbon metal matrix composites

Natural Graphite flakes are attractive carbon-based reinforcements due to its layered structure providing self-lubrication, improved thermal properties, low cost, and ease of machinability. High volume fractions of graphite-reinforced aluminium A356 metal matrix composites by liquid metal squeeze infiltration technique has been studied. The interface between the matrix and reinforcement plays a vital role in determining the properties of metal matrix composites (MMC). The presence of oxide layer on the surface of molten metal and the adsorbed contaminant on the reinforcement surface generally leads to non-wetting of the reinforcement with molten metal. To avoid interfacial reactions and improper wetting between the Graphite reinforcement and the matrix, the graphite particles were properly surface treated and coated with copper. Porous graphite preforms of varying volume fractions and pore densities have been prepared through cold pressing followed by vacuum sintering. The sintered porous graphite preforms have been infiltrated with liquid aluminium alloy (A356) at 760°C under the squeeze infiltration pressure of 40 MPa. The microstructures of Al A356-Graphite infiltrated composites of varying volume fraction have shown uniform distribution of graphite particles in the matrix. The graphite particle addition had led to 14 and 18% reduction in the density for 50% and 60% volume fractions of graphite reinforced aluminum composites leading to light weighting of the material. The SEM analysis of copper-coated graphite particles shows that there is an uniform dispersion of copper which covers the whole surface of each graphite particle and the coating thickness is approximately 3 μm. The coated copper has spherical morphology deposited on the surface of graphite particles. The thermal conductivity value of 60% volume fraction of uncoated graphite composite has been 52 W/m K obtained at the temperature of 102°C which is higher than the conductivity value obtained for 50% volume fraction. From the thermal conductivity measurements, it has been observed that the thermal conductivity increases with an increase in the volume fraction of graphite particles.

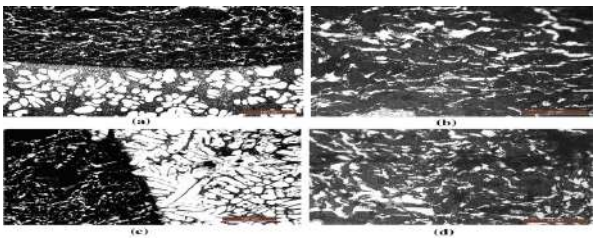


| Element | Weight% | Atomic% |
|---|---|---|
| C K | 27.76 | 65.99 |
| O K | 1.16 | 2.07 |
| Cu K | 71.07 | 31.93 |

SEM morphologies of (a) uncoated graphite flakes and (b) Cu coated graphite (c). EDS of Cu coated graphite and (d) surface composition of coated graphite



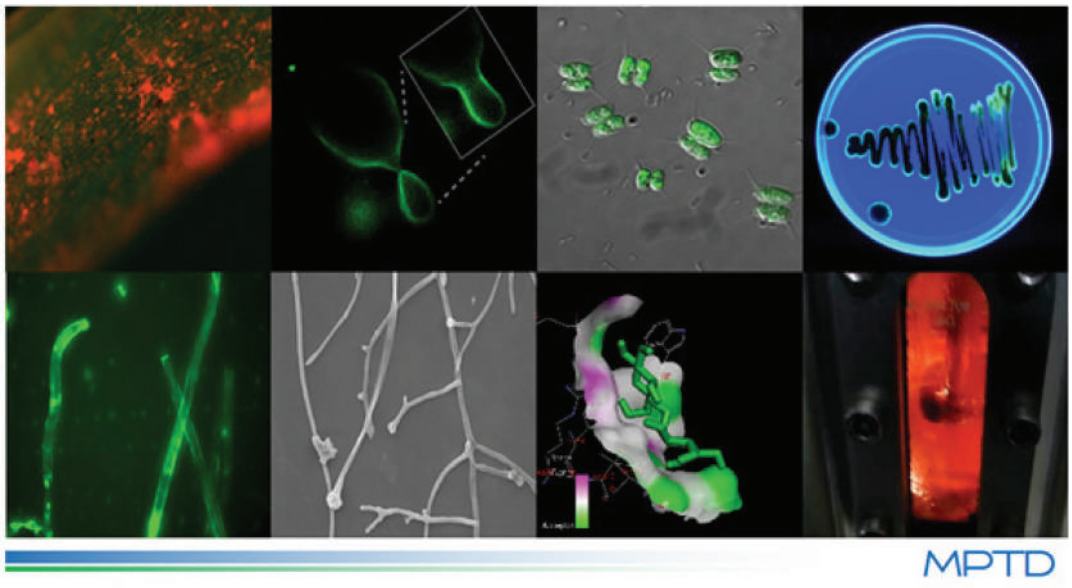

Density measurements of 356 aluminum alloy, Al-50%Gr and Al-60% Gr Graphite reinforced composites



Optical micrographs of graphite infiltrated A356 aluminium composite (a) interface region of 50% vol. fraction (b) Al 356 infiltrated graphite region of 50% vol. fraction

# DIVISIONAL DETAILS

| | |
|---|---|
| Name | Microbial Processes and Technology (MPTD) |
| Expertise | Microbial Biotechnology<br>Bioprocesses and Fermentation<br>Biofuels and Biorefineries<br>Molecular Biology and Omics Sciences<br>Plant Microbe Interactions<br>Algal Biotechnology<br>Biological Phenomena |
| Number of Scientists | 10 |
| Number of Technical Staff | 1 |
| Number of Students | 45 |
| Facilities | Lignocellulosic Ethanol Pilot Plant<br>Solid State Fermentation Pilot Plant (Koji Room)<br>DNA Sequencing Facility<br>Fermentation Facility (0.5-150L fermenters and allied equipment)<br>PCR, qPCR<br>Ultracentrifuge, High Speed Centrifuges<br>Advanced analytical instrumentation (HPLCs, GCs, GC-MS, HPTLC, Particle Size Analyzer, FTIR) |
| No. of ongoing projects during 20-21 (GAP, SSP, CNP,TSP, In-house) | 22 |
| No. of publications (SCI+Non SCI) during 20-21 | 51 |
| No. of Ph. D. awarded during 20-21 | 2 |



# सूक्ष्म प्रक्रियाओं और प्रौद्योगिकी प्रभाग

**मिक्रोबियल प्रक्रिया और प्रौद्योगिकी प्रभाग**

मिक्रोबियल प्रक्रिया और प्रौद्योगिकी प्रभाग (एमपीटीडी) का अधिदेश जैव प्रौद्योगिकी के विशिष्ट सीमांत क्षेत्रों में उच्च गुणवत्ता वाले अनुसंधान एवं विकास का संचालन करना है। पर्यावरणीय स्थिरता सुनिश्चित करते हुए क्षेत्रीय जैव संसाधनों की खोज और मूल्यवर्धन पर महत्वपूर्ण जोर दिया जाता है। यह प्रभाग सूक्ष्मजीव संसाधनों की खोज और दोहन करके जैव प्रक्रियाओं और उत्पादों के विकास के लिए केंद्रित क्षेत्रों में अनुसंधान में सक्रिय रूप से शामिल है। अनुसंधान का वर्तमान केंद्र बिन्दु i) औद्योगिक एंजाइम और मूल्य वर्धित रसायन ii) जैव ईंधन और बायोरिफाइनरी (iii) जैवसक्रिय अणुओं iv) स्वास्थ्य और जीनोमिक्स (v) प्लांट माइक्रोब अंतःक्रिया और (vi) प्रोबायोटिक और अल्गल न्यूट्रास्युटिकल्स के क्षेत्रों में हैं। दूसरी पीढ़ी के बायोएथेनॉल पर विशेष अनुसंधान एवं विकास के लिए प्रभाग ने "जैव ईंधन केंद्र" समर्पित किया है। लिग्नोसेल्यूलोसिक बायोएथेनॉल के उत्पादन के लिए प्रायोगिक संयंत्र को अब साइट पर ठोस अवस्था किण्वन उत्पादन प्रायोगिक संयंत्र द्वारा समर्थित किया गया है, जो बेहतर प्रभावी लागत और प्रबंधन के अवसर लाता है। यह प्रभाग विभिन्न सूक्ष्मजीव बायोप्रोसेस विकसित करने पर अनुसंधान एवं विकास में शामिल है और किण्वन प्रौद्योगिकी, प्रोबायोटिक के लिए सूक्ष्मजीव निरूपण, जैव कीटनाशकों और जैव उर्वरक आदि पर काम करने के लिए मजबूत उद्योग संबंध हैं।

**झलकियाँ**

**i.** एस्परगिलस अनगुइस एनआईआई 08123 से ग्लूकोज टॉलरेंट बीटा ग्लूकोसिडेज जीन को क्लोन किया गया और पिचिया पास्टोरिस में व्यक्त किया गया। यह ग्लूकोज सहिष्णुता के आणविक कारणों पर अध्ययन को सक्षम करने की उम्मीद रखती है।

**ii.** स्यूडोमोनास ग्वारिकोनेंसिस के बाहरी झिल्ली लाइपेस जीन को कूटलेखन करने वाले एस्टा जीन को ई कोलाई में क्लोन किया गया था

**iii.** बायोपॉलीमर पॉली हाइड्रॉक्सी ब्यूटाइरेट-को-वेलरेट (PHBV) संश्लेषण के रूप में एक नया मैंग्रोव आइसोलेट स्थापित किया गया है। PHBV नैनोकणों और स्कैफल्ड को संश्लेषित किया गया था।

**iv.** बायोमास व्युत्पन्न शर्करा का एफडीसीए में रूपांतरण करने के लिए अत्यधिक एचएमएफ सहिष्णु (240 मिमी तक) बायोकेटलिस्ट, रोडोकोकस किंगशेंगी सी 27 का उपयोग करके हरित रसायन संचालन के साथ पहली बार रिपोर्ट किया गया।

**v.** शैवाल युक्त तेल से पॉलीअनसेचुरेटेड फैटी एसिड का पृथक्करण शुद्धता के करीब प्राप्त हुआ।

**vi.** झींगा सीप के कचरे से बायो-चिटिन उत्पादन के लिए लैब स्केल प्रक्रिया विकसित की गई।

**vii.** तटीय लवणीय सहिष्णु दो चावल किस्मों (पोक्कली और कग्गा) के जड़ से जुड़े माइक्रोबायोम को पहली बार समझा गया है। इस विश्लेषण से पता चला कि पर्यावरणीय शरीरक्रियात्मक स्थितियों को प्रमुख हानिकारक कारक माना जाता है। प्रजातियों की समृद्धि राइजोस्फीयर की तुलना में जड़ों में अधिक पाई गई। इसके अलावा, ओटीयू के उच्च प्रतिशत अवर्गीकृत हैं जो संभावित नव जीवाणु का संकेत देता हैं।

**viii.** असंस्कृत टाकसा के अंतर्गत आती एक नई पौधा जीवाणु टाकसा की खोज और पहचान की गई है: पोक्कली चावल से वेरुकोमाइक्रोबिया। यह फाइलम वेरुकोमाइक्रोबिया का भारतीय मिट्टी से सुसंस्कृत पहली प्रतिनिधि मानी जाती है।

**ix.** कोर्यन जीवाणु से अद्वितीय सॉर्टेज एंजाइम के गतिक गुण स्थापित किया गया।

**x.** पी. जैन्थिनेलम एनसीआईएम 1366 के जीनोम और ट्रांसक्रिप्टोम विश्लेषण ने बड़ी संख्या में सीएज़ाइम और अद्वितीय नियामक कारकों की पहचान की जो इसकी बेहतर बायोमास हाइड्रोलिसिस क्षमता के कारणों को समझाने में मदद कर सकते हैं।

**xi.** गतिविधि और हाइड्रोलिसिस क्षमता के लिए वाणिज्यिक सेल्युलस की रूपरेखा यह पहचानती है कि एक विशेष घटक एंजाइम का उच्च अनुमापांक हाइड्रोलिसिस को बेहतर बनाने में सहायक नहीं हो सकता है और सहक्रियाएँ एक महत्वपूर्ण भूमिका निभा सकती हैं।

**xii.** पेन्टोज शर्करा का उपयोग करके जाइलोनिक एसिड उत्पादन के लिए प्रक्रिया को अनुकूलित किया गया।

# Microbial Processes and Technology Division

The mandate of the Microbial processes and Technology Division (MPTD) division is to conduct high quality R &D in specific frontier areas of Biotechnology. Significant emphasis is put in exploration and value addition of regional bioresources while ensuring environmental sustainability. The division is actively involved in research in the focussed areas for bioprocesses and products development by exploring and exploiting the microbial resources. The current focus of research are in the areas of i) Industrial enzymes and value added chemicals ii) Biofuels and biorefinary (iii) bioactive molecules iv) Health and genomics (v) plant microbe interactions and (vi) probiotic and algal nutraceuticals. The Division has a dedicated "Centre for Biofuels" for exclusive R&D on 2nd generation bioethanol. The pilot plant for the production of lignocellulosic bioethanol is now supported by on-site solid-state fermentation enzymes production pilot plant, bringing better cost-effective and handling opportunities. The Division is involved in R & D on developing different microbial bioprocess and has strong industry linkages to work on fermentation technology, microbial formulation for probiotic, biopesticides and biofertilizers etc.

## Highlights

- Glucose tolerant beta glucosidase gene from *Aspergillus unguis* NII 08123 was cloned and expressed in *Pichia pastoris*. This is expected to enable studies on the molecular reasons for glucose tolerance
- EstA gene encoding the outer membrane lipase gene of *Pseudomonas guariconensis* was cloned in *E coli*
- Biopolymer poly hydroxy butyrate-co-valerate (PHBV) synthesis form a new mangrove isolate is established. PHBV nanoparticles and scaffold was synthesized.
- Reported for the first time, conversion of biomass derived sugars to FDCA using a novel highly HMF tolerant (up to 240 mM) biocatalyst, *Rhodococcus qingshengii* C27 with promising green chemistry operations
- Near purity separation of polyunsaturated fatty acids from algal oil achieved
- Lab scale process for bio-chitin production from prawn shell waste developed.
- Root associated microbiome of coastal saline tolerant two rice varieties (pokkali and Kagga) is deciphered for the first time. This analysis showed that environmental physiological conditions considered as the major detrimental factor. Species richness was found to be higher in the roots compared to rhizosphere. Also, higher percentages of the OTUs are unclassified indicating potential novel bacterial taxa.
- Discovered and identified a novel plant beneficial bacterial taxa belongs to the uncultured taxa; *Verrucomicrobia* from pokkali rice. This is considered to be the first cultured representative of phylum *Verrucomicrobia* from an Indian soil.
- Kinetic properties of the unique sortase enzyme from *Corynebacterium* established.
- Genome and transcriptome analyses of *P. janthinellum* NCIM 1366 identified high number of CAZymes and unique regulatory factors that may help to explain the reasons for its superior biomass hydrolysis potential.
- Profiling of commercial cellulases for activity and hydrolysis potential identifies that higher titre of a particular component enzyme may not be helpful to improve the hydrolysis and synergisms may play an important role.
- Process for xylonic acid production using pentose sugars optimized.

## 1. Brief report of the R &D activities

### I. Bioprocesses and Products

### 1. Industrial Enzymes

#### 1.1. Enzymatic transglycosylation for organic synthesis

Glycans are important in different areas including Pharma and methods for their efficient synthesis is in high demand. Chemical synthesis is multistep involving protection and de-protection steps, and enzymatic methods involving glycosyl transferase (GT), are hindered due to their cost and in their requirement of complex nucleotide phosphate sugars they use as donor substrate. Alternative to using GT is the possibility of using glycosyl

hydrolases with transglycosylation activity, whose substrates are cheap. Studies at NIIST has identified beta glucosidase activities from fungus *Aspergillus niger* NII 08121, which has transglycosylation activity. An FBR project was initiated to develop process for production of Ascorbic Acid 2 glucosidase (AA2G), a stable derivative of vitamin C (Ascorbic Acid) where the C2 hydroxyl group is protected by glucose. AA2G retains all physiological activities of the vitamin and is important in cosmetic and pharmaceutical industry. Chemical synthesis of AA2G is tedious and involves complicated multistep reactions and a single step enzymatic synthesis is highly beneficial. We have demonstrated that a tranglycosylating crude culture filtrate enriched in beta glucosidase (BGL) enzyme from *A. niger* is capable of performing the same reaction with the advantage of using cheaper maltose as glycosyl donor instead of cyclodextrin in the case of Cyclodextrin glucanotransferase, the enzyme currently employed for the same purpose.

Process development for production of the enzyme and for AA2G are being developed. Also studies are on for identifying the actual enzyme. Production process optimization of trans-glycosylating enzyme showed that xylan and CMC as probable better carbon sources. One percent xylan supported the highest AA2G synthetic activity followed by 1% wheat bran (Fig 1)

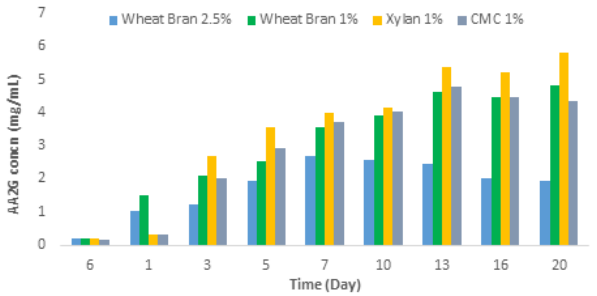



Fig 1: Screening of C sources for enhanced production of AA2G synthetic activity

The effect of different media components and process parameters like inoculum, surfactant addition and incubation time were also estimated following a Placket & Burman, statistical design of experiment (Fig 2)

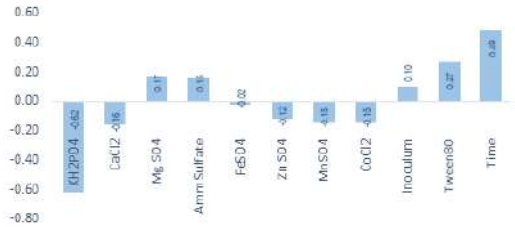
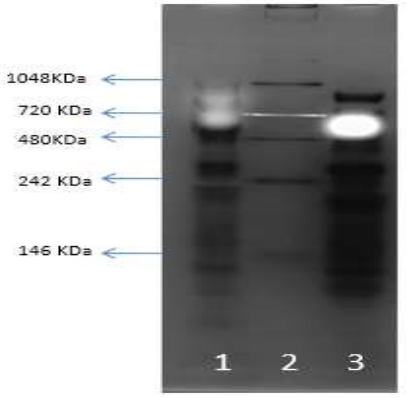



Fig 2: Effect estimate showing role of media components on AA2G production

Transglycosylation assay was optimised using Box-Behnken design and the optimum pH, temperature, acceptor donor ratio and incubation time was found to be 5, 60°C, 1:5 and 24 h respectively, yielding a maximum of 4.5 g/l (13 mM) of AA2G. Protein purification studies and zymogram analysis helped in the identification of three isoforms of BGL with the ability to synthesize AA2G (Fig 3). LC-MS analysis indicated the probability of 5 GH enzymes in catalyzing transglycosylation like, beta glucosidase, alpha glucosidase, invertase, beta galactosidase and xylosidase (Table 1).




Overlapped images of Native PAGE and zymogram analysis fofr fractions with transglycosylation activity
1) 70-90
2) Marker
3) 60-70

| Sample | AA2G yield (g/L) |
|---|---|
| 70-90 upper band (b/w 1048 kDa and 720 kDa) | 0.96 |
| 70-90 lower band (b/w 720 kDa and 480 kDa) | 0.91 |
| 60-70 upper band (b/w 720 kDa and 480 kDa) | 1.47 |
| 60-70 lower band (b/w 242 kDa and 146 kDa) | 0.14 |

Lanes

1: 70-90 Fraction
2: Marker
3: 60-70 fraction

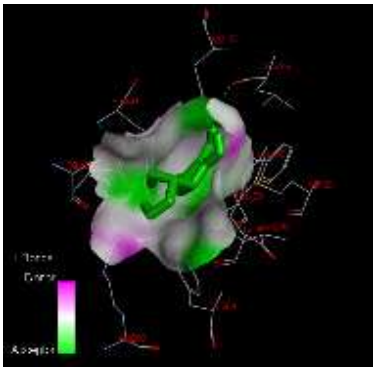
Fig 3. Overlapped images of native PAGE and zymogram analysis for fractions with transglycosylation activity

Table 1: Theoretical analysis of enzymes identified from protein fraction with glucosidase activity, which can catalyze AA2G synthesis

| Accession no | Name | BE with AA/H bonds | BE with Mal/H bonds |
|---|---|---|---|
| A2RAL4 Extracellular beta glucosidase | | -6.3/5 | -7.7/7 |
| A0A117DZ97 | Alpha glucosidase | -5.3/1 | -6.1/4 |
| A0A10017V3 | Alpha glucosidase | -5.2/6 | -6.7/6 |
| A0A3F3Q2F6 | Alpha glucosidase | -5.9/2 | -6.9/6 |
| A2QAN3 (5IFP) | Beta Galactosidase | -5.7/3 | -7.4/4 |
| A2QTU5 (6DRU) | Alpha Xylosidase | -5.1/6 | -7.3/6 |
| Q0ZR37 | Extracellular invertase | -5.2/3 | -6.8/3 |

*In-silico* docking analysis of extracellular BGL showed the highest binding energy of -6.3 and -7.7 KCal towards ascorbic acid and maltose respectively, when compared to the other enzymes (Fig 4A & B)

A: BGL docking with AA



B: BGL docking with maltose

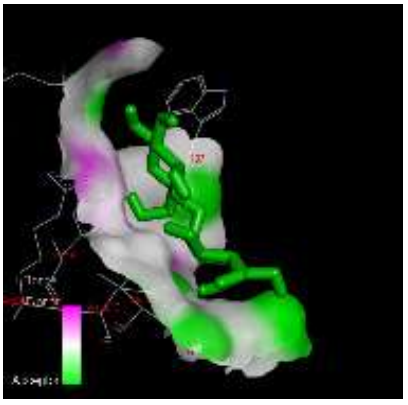


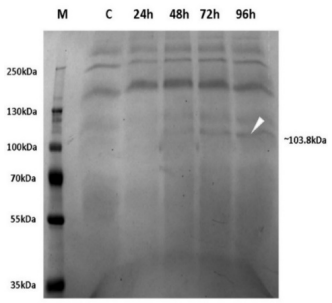
Fig 5: Docking analysis of BGL with substrate (AA) and glycoside donor (Maltose)

## 1.2. Molecular cloning and expression of glucose tolerant beta glucosidase (GT-BGL)

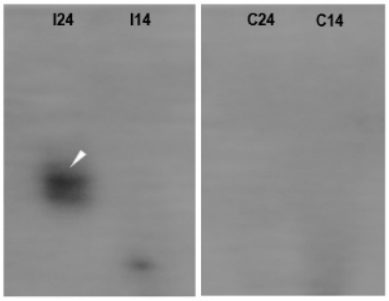
Glucose tolerant beta glucosidases (GT-BGLs) are very important enzymes for biorefineries as they can improve the efficiency of biomass hydrolyzing enzyme cocktails by preventing feedback inhibition from product-glucose and therefore achieve high sugar concentration on hydrolysis of biomass. NIIST had identified a potent GT-BGL from fungus- *Aspergillus unguis* NII 08123, but the organism produced the enzyme in low titres. Previous attempts to clone the enzyme for over production and to enable studies on the molecular reasons for glucose tolerance were unsuccessful.

The current study targeted the molecular cloning and expression of GT-BGL of *Aspergillus unguis* NII 08123. The full-length GT-BGL was identified from whole genome sequence of *A. unguis*, using partial sequence of the protein obtained through MALDI-MS analysis performed one of the earlier studies from the lab (Rajasree, 2013) for a complementarity-based detection. The full-length intron-free cDNA sequence of GT-BGL was identified from the transcriptome data and was used for cloning and expression in *Pichia pastoris* X33. The full-length cDNA contained an ORF of 2595 nucleotides which encode 864 amino acids.

The presence of recombinant GT-BGL was identified through SDS-PAGE analysis of the culture supernatants of induced recombinant *Pichia pastoris* at different time intervals. SDS-PAGE analysis indicated that the recombinant protein has a mol. wt. of ~103.8 kDa (Fig.5a). The un-induced culture supernatant of clone 24 was used as a control for the SDS-PAGE analysis. There was no GT-BGL protein band in the control supernatant. GT-BGL band intensity increased gradually with increase in incubation time with the maximum band intensity obtained in the culture supernatant of 96 h sample.




M) Native Mark™ Unstained Protein Standard, C) Uninduced culture supernatant (Control), 24 h - 96 h Induced culture supernatant at different time intervals



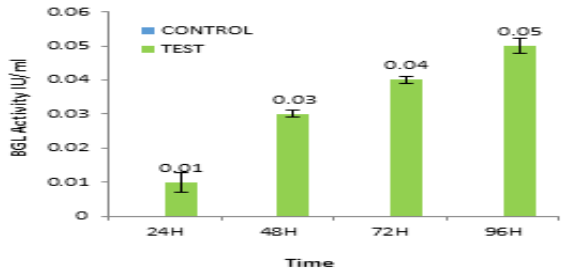

I24, I14 Induced culture supernatants (96 h) showing activity in gel (Only clone I24 culture supernatant showed activity band), C24, C14 Control experiment, no activity band observed (Clone 24 and Clone 14 supernatant (96 h) used without induction)

Fig 5: Confirmation of recombinant GT-BGL production in *P. pastoris* by SDS PAGE (A) and zymogram (B) analyses

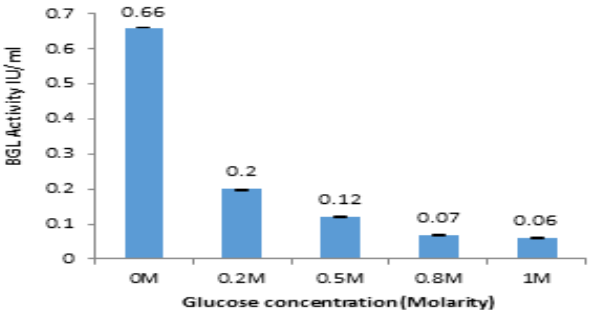
The 96-h sample supernatant of two induced positive clones (I14, I24) and their un-induced controls (C14, C24) were used for zymogram analysis. The two positive clones were induced initially with 0.5% methanol (24 h) and then increased to 1% methanol (48-96 h).

Zymogram analysis for secretion of extracellular GT-BGL by recombinant *P. pastoris* clones was performed using gel-based activity staining method with MUG as a substrate. The culture supernatant from clone I24 showed a fluorescent band when the gel was with MUG (Fig.5b). However, there were no fluorescent bands in other lanes, confirming recombinant beta-glucosidase production and secretion by the clone I24.

The levels of BGL secreted by the recombinant protein was estimated using the crude clone I24 supernatant, following the pNPG assay, and the maximum activity of 0.05 IU/ml was observed at the 4$^{th}$ day of induction (Fig.6a). For the glucose tolerance assay, concentrated 96 h culture supernatant with an activity of 0.66 IU/ml was used. The recombinant beta-glucosidase was found to be active even at higher glucose concentrations (1.0 M) and retained an activity of 0.12 IU/ml at 0.5 M glucose concentration (Fig.6b).




A. BGL secretion by methanol induced clone I24 (Control did not possess any activity)




B. Glucose tolerance of secreted BGL from recombinant *P. pastoris* clone I24

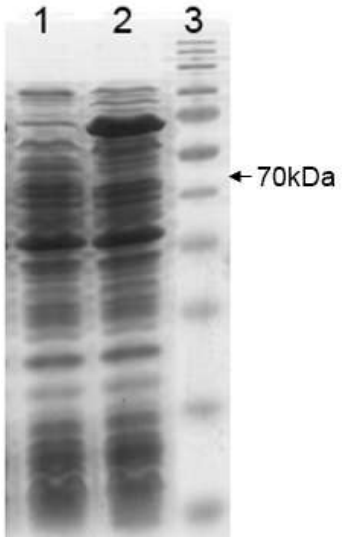
Fig 6: Activity and glucose tolerance of the recombinant GT-BGL produced by *P. pastoris*

The expressed recombinant protein was assayed using cellobiose as substrate to confirm BGL activity when it gave 5.76 mg/ml (16.8 mM) of glucose from cellobiose. The recombinant protein production of *A. unguis* GH3 family GT-BGL in *Pichia pastoris* was successfully established under AOX1 promoter control. Confirmation of the cloning and secreted expression of the protein were made by different methods including SDS-PAGE analysis, Zymogram analysis, BGL assay, and cellobiose hydrolysis test. The molecular weight of the protein was determined by SDS-PAGE analysis. The recombinant protein was stable and active even in 1 M of glucose. The recombinant GT-BGL could serve as a model for further studies on understanding the mechanism of tolerance to product inhibition in GH3 beta-glucosidase.

### 1.3. Cloning and expression of Outer membrane lipase gene of *Pseudomonas guariconensis*

Esterases and lipases from microorganisms have attracted attention for their potential applications in the pharmaceutical, food, biochemical, and biological interests. EstA is an autotransporter (AT) protein that belongs to the GDSL family (equivalent to the classical GXSXG motif of lipases/esterases produced and recreated by gram negative bacteria. This protein exposes its catalytically active lipase/ esterase domain containing nucleophilic serine on the cell surface. They share a common architecture, such as a signal peptide, passenger domain with a specific function, and translocation domain that forms a β-barrel and anchors the protein to the bacterial outer membrane. The potential applications of ATs include the surface display and extracellular expression of recombinant proteins. The *Est*A gene, which encodes a novel outer membrane lipase/esterase (OML) gene of *Pseudomonas*

*guariconensis,* a NIIST isolate, *was* cloned and expressed in BL21 DE3 cells (Fig 7). The gene has an open reading frame of 1863 bp and encodes the 621-amino acids, which contains an autotransporter (AT) domain (350–621 amino acids). The whole gene was amplified and ligated into the pET-28a vector. Recombinant plasmids were transformed into *E. coli* BL21 (DE3) cells for expression studies and the SDS-PAGE results showed that the recombinant proteins appeared mostly as inclusion bodies which needs further optimization for proper refolding to make the protein in active confirmation




Lane Information

1) pET28a control
2) Recombinant OM lipase
3) Marker

Fig. 7. Expression of OM lipase of *Pseudomonas guariconensis* in *E.coli* BL21 DE3

## 2. Biopolymers, Bio-surfactants and Microbial Metabolites

### 2.1. Production of Polyhydroxy butyrate-co-valerate (PHBV) by a novel halotolerant mangrove isolate for various application

In an attempt to improve the physical properties of PHB, we screened for PHB copolymer i.e. PHBV producing microorganism. PHBV producing microorganism was isolated from mangroves. The polymer was produced by propionic acid dependent pathway and extracted and characterized by GPC, HNMR, TGA, DSC and FTIR. The PHBV yield from glucose was estimated to be 73% of biomass weight with 2.02g/L at 48h and a high 3-hydroxyvalerate fraction of 48 mol%. Thereafter, spherical homogenous PHBV nanoparticles of ~164 nm size (Fig 8) were prepared for future applications. Electrospinning of PHBV nanofibers were synthesised with porosity of 60-70% and size of nanofibers were found to be <200nm. Applications of PHBV polymer as scaffolds has great impact in field of biomedical industry.

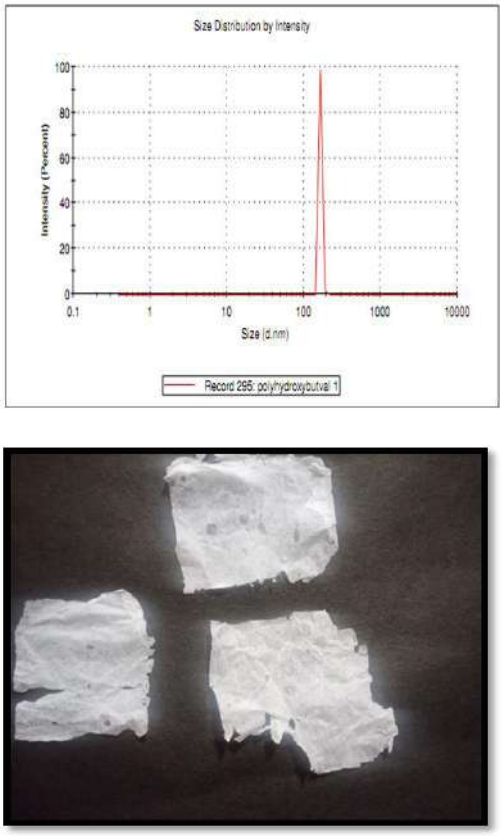



Fig. 8. DLS analysis of PHBV nanoparticle (A) and PHBV scaffold synthesised by electrospinning (B)

### 2.2. Development of an integrated approach for the production of 2,5-furan dicarboxylic acid from sorghum syrup derived fructose by chemo-catalytic dehydration and whole-cell biocatalytic oxidation

This study aims to develop an integrated chemo and biocatalytic approach for the conversion of sorghum syrup derived fructose to 2,5-furandicarboxylic acid (FDCA). Sucrose in the sorghum syrup was chemo-catalytically hydrolysed to glucose and fructose using seralite SRC120 (cationic resin) as heterogeneous solid acid catalyst followed by the subsequent dehydration of fructose to 5-hydroxymethyl furfural (HMF) with the same (Fig 9). The biocatalysis of HMF to FDCA was carried out using newly isolated whole cells of *Rhodococcus qingshengii* C27 through three consecutive oxidation reactions. The chemocatalytic dehydration of fructose derived from sorghum syrup rendered 65% conversion of fructose with 66% selectivity to HMF. In addition, glucose (from hydrolysed sucrose) was used as major

carbon source for cell enrichment, which resulted the complete utilization of carbohydrates from the sorghum plant extract. The whole cell biocatalysis resulted 94% FDCA yield with complete HMF conversion (8 mM). This is the first report on the conversion of biomass derived sugars to FDCA using a novel highly HMF tolerant (up to 240 mM) biocatalyst, *Rhodococcus qingshengii* C27 with promising green chemistry operations. The present process is a novel approach for FDCA production from biomass and it can be further improvised by design of new, robust and selective catalyst. The process can be scaled-up for further industrial exploitation.

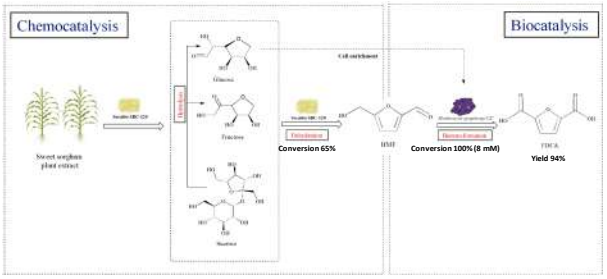



Fig 9: Process flow for the conversion of biomass derived sugars to FDCA through integrated chemo and biocatalytic approach

Biological oxidation of HMF to FDCA was studied on resting and growing cells. Based on the findings, resting cells showed (Fig. 10) maximum catalytically favourable substrate oxidation towards FDCA synthesis. In the presence of glucose and glycerol (1% each), the strain could utilize complete HMF within 15h and oxidised to HMFCA (60% and 50% respectively). It was found that compared to control (without glucose or glycerol), the FDCA production was very unsatisfactory in the presence of glucose and glycerol (9% and 12%). Perhaps, it is because of the presence of other carbon source than HMF which will initiate the cell metabolism.

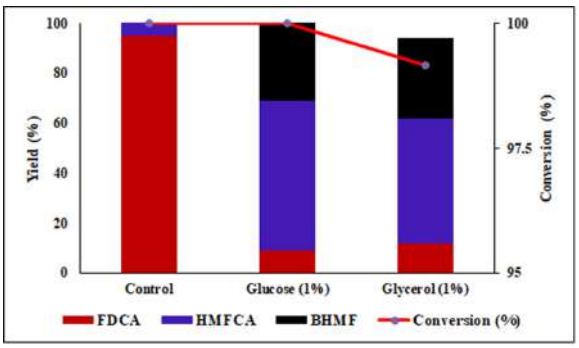



Fig 10: Effect of glucose and glycerol on FDCA and HMF derivatives synthesis. Reaction conditions for glucose and glycerol: 8 mM HMF, 25 mg mL–1 microbial cells, 50 mL MSM (pH 7.0), 200 rpm, 30 °C temperature, 72 h reaction time, glucose (1%) and glycerol (1%). Control: same reaction condition without glucose and glycerol.

Simultaneously the cellular stress got decreased by the HMF derivatives formation such as 5-hydroxymethyl-2-furancarboxylic acid (HMFCA) and 2,5-bis (hydroxymethyl)furan (BHMF) respectively.

Fig. 11 shows the HMF utilization and yield of HMF derivatives including FDCA. The yield was maximum (94%) when the HMF concentration was 8 mM. At this concentration there is no substrate inhibition towards the strain. However, there was 29% of decrement in FDCA yield when doubled the HMF concentration (16 mM). It is evident that continuous oxidations could not take place when increasing the substrate concentration. It might be overcome by increasing the cell concentration. As shown in Fig. 6, the BHMF yield was increased when substrate concentration was high in order to reduce the substrate toxicity by converting it into a less toxic alcohol. Nonetheless, product yield was pretty low while substrate concentration was 32 mM. Though, substrate conversion was 54% and there were 23% of FDCA and 22% of BHMF in the reaction mixture.

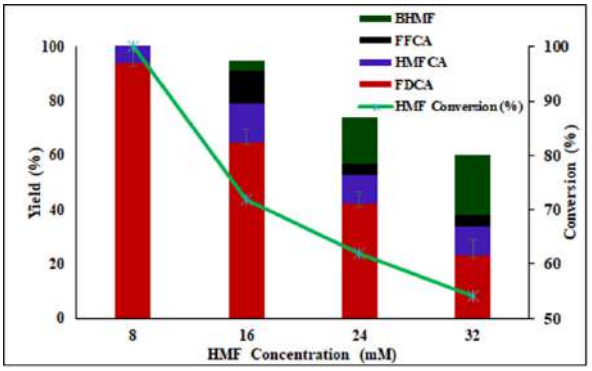



Figure 11: Effect of substrate concentration on FDCA and HMF derivatives synthesis. Reaction conditions: 25 mg mL–1 microbial cells, 50 mL MSM (pH 7.0), 200 rpm, 30 °C temperature, 96 h with HMF concentration ranging from 8 mM to 32 m

Further in this study, it is proposed that by immobilization or continuous biotransformation, FDCA yield can be increased by increasing substrate concentration. Findings suggest that metabolic engineering of the strain may increase the FDCA yield by knocking out gene(s) responsible for HMF reduction to BHMF, also over expressing the gene(s) involved in the HMFCA to FDCA pathway which envisage an industrially sound biocatalyst. Hence an integrated chemical and biocatalytic method with sustainable resources is envisaged as a promising approach for the production of industrially relevant FDCA in benign and environment friendly manner.

## 2.3. Utilization of agricultural and industrial biomass for 2,3-butanediol production

The valorization of agricultural and industrial wastes for fuel and chemical production has a beneficial impact on environmental sustainability. 2,3-Butanediol is a value-added platform chemical covering a wide area of industrial applications. This study aims to find an improved bioprocess for the production of 2,3-butanediol from agricultural and industrial residues consequently ending up with a low $CO_2$ emission bioprocess. Evaluation of the efficacy of different biomass from agricultural and industrial streams for 2,3-butanediol fermentation was performed. Screening of 13 different biomass samples for hydrolyzable sugars has been done and oat hull and spruce bark biomass with maximum hydrolyzable sugars were selected for submerged fermentation studies. After 96 hours of fermentation, results show that 37.59 and 26.74 g/L 2,3-Butanediol was obtained with oat hull and spruce bark biomass respectively. The results were found to be promising, showing the potential of waste biomass residues as a low-cost substrate for 2,3-Butanediol production (Fig 12).

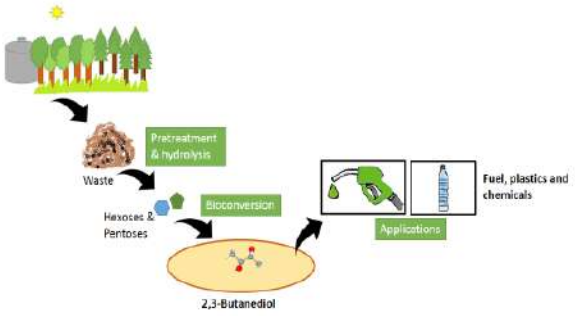



Figure 12: Schematic representation of the process for the conversion of lignocellulosic biomass to 2,3-butanediol

2,3-BDO fermentation was initiated by the inoculation of *Enterobacter cloacae* SG1 into the hydrolysate medium. HPLC analysis reveals the individual concentration of major products during 2,3-BDO fermentation. Apart from 2,3-BDO, acetate and acetoin were produced predominantly. After 24 hours of fermentation 37.59g/L 2,3-BDO was found to produce in oat hull hydrolysate in batch fermentation. 20.72g/L acetoin was also found to be co-produced with 2,3-BDO. 26.74g/L 2,3-BDO was produced in spruce bark biomass along with 20.36g/L acetoin. Since the reaction between 2,3-BDO and acetoin are reversible it was clear from the figure that from 24hours 2,3-BDO concentration decreases and accordingly acetoin concentration was found to increases. 0.39g/L of acetate was present initially in the hydrolysate after pretreatment in oat hydrolysate. Acetate concentration gradually increased and reached at maximum of 2.005g/L in 48hours of fermentation (Fig 13).

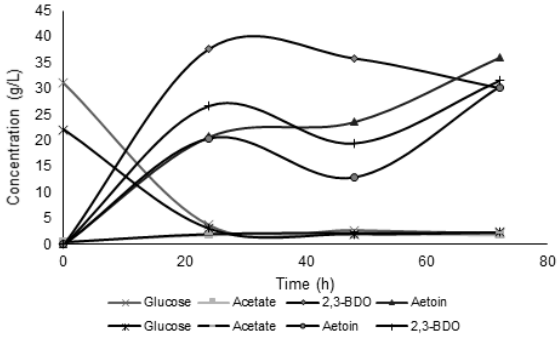



Figure 13: Fermentative production of 2,3-butanediol using oat hull hydrolysate

## 2.4. Metabolic engineering of *Pichia pastoris* for enhanced flux towards squalene production

Linear polyunsaturated triterpene squalene exists in all organisms with immense application in food, pharmaceutical and cosmetic industries. New applications of squalene as an enhancer are ever increasing ensuing in its growing demand. Till date, the chief source of squalene remains shark liver, despite the sharp decrease in shark community and marine wildlife regulations. Annually, 2.7 million sharks are killed for application of squalene in cosmetic industries and 500,000 sharks may have to be sacrificed to meet the global COVID vaccine supply. Such an ecological imbalance has invigorated researchers worldwide to recognize a sustainable route for biosynthesis of squalene. Enormous progress in synthetic biology has paved the way for refinement of microbes and plants for enhanced synthesis of squalene. Alternative to shark liver squalene (1 ton squalene from 3000 sharks), plants, fungi and yeasts were found to be attractive host. However, considering factors like ease of genetic manipulation, accumulation volume per gram Dry Cell weight (DCW) yeasts were identified as suitable host. In general yeast accumulate 0.04-70.32 mg/g DCW of squalene as compared to fungi that accumulate up to 0.3mg/g DCW of squalene. In this study, industrial host *Pichia pastoris* which is well established for recombinant protein production

will be exploited for the metabolite squalene production. Squalene is an important precursor of mevalonate pathway in yeast and essential sterols of the cell are synthesized from it.

Development of a *Pichia* model with accelerated Farnesyl diphosphate (FPP) precursor flux towards squalene and reduced squalene drain towards ergosterol would be tested in this study (Figure). Lipid droplets provide extra space for accumulation of squalene in cytoplasm. Following the overexpression of mevalonate pathway genes, lipid biogenesis and downregulation of squalene epoxidase gene, fermentation experiments would be conducted to confirm the squalene yield and thereby optimize the process parameters and inhibitor concentration to further augment the production of squalene. Bioprocess optimization and gene overexpression studies are currently under progress.

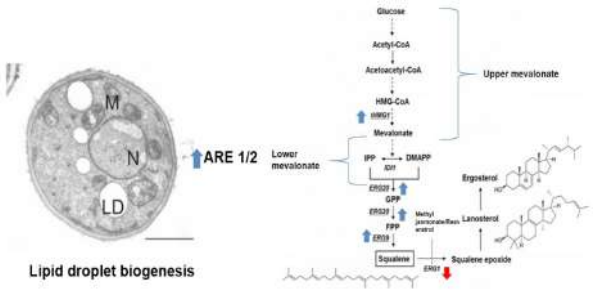



Figure 14 : A Schematic illustration of squalene production through pathway engineering in *Pichia pastoris*

## 3. Probiotics and Nutraceuticals

### 3.1. Exploring the Glycosyltransferases of Exopolysaccharide Production in Lactic Acid Bacteria

The genetic overview of the EPS production by LAB is an auxiliary area of interest as the process and the biosynthetic pathway involves numerous genes and their proteins. Glycosyltransferases (gtfs) are the key enzymes that comes into picture without which the EPS biosynthesis and production cannot happen. Current knowledge of gtfs of LAB and its manipulation is limited and yet to be explored in a wide sense. The EPS producing lactic acid bacteria contain many glycosyltransferase genes in the EPS biosynthetic pathway as they play a vital role in the transfer of sugar units from the high energy sugar nucleotides and thus help in the polymerization and formation of exopolysaccharides.

From the whole genome data, gtf genes of *Lactobacillus plantarum* BR2 (NIIST Strain) were identified (Table 2). Specific primers were made and amplification of the gtf genes from our indigenous LAB isolates were done. *L. plantarum* BR2-GTF gene annotated as (Exopolysaccharide biosynthesis glycosyltransferase) was cloned into pNZ81848 and pET28a vector and transformed into *E. coli* MC1061 and *E. coli* DH5$\alpha$ cells respectively for over-expression and enzyme characterization studies (Fig 15). The approach can be further explored to study the importance of such genes to enhance the EPS production and properties

Table 2. Glycosyltransferase genes of L. *plantarum* BR2 (NIIST isolate)

| Sl. No | Name | START | STOP | Strand | Gene Size |
|---|---|---|---|---|---|
| 1 | glycosyltransferase | 891333 | 890599 | - | 734 |
| 2 | Putative glycosyltransferase | 949008 | 947680 | - | 1328 |
| 3 | glycosyltransferase (putative) | 1404538 | 1403234 | - | 1304 |
| 4 | Glycosyltransferase | 1584955 | 1586307 | + | 1352 |
| 5 | Exopolysaccharide biosynthesis glycosyltransferase EpsF (EC 2.4.1.) | 1621419 | 1622510 | + | 1091 |
| 6 | glycosyltransferase | 1622526 | 1623554 | + | 1028 |
| 7 | glycosyltransferase | 1624810 | 1625778 | + | 968 |
| 8 | Uncharacterized glycosyltransferase YkoT | 2032565 | 2031570 | - | 995 |
| 9 | Glycosyltransferase LafB, Responsible for the formation of Gal-Glc-DAG | 2222844 | 2221822 | - | 1022 |
| 10 | Glycosyltransferase | 2271823 | 2271047 | - | 776 |
| 11 | Glycosyltransferase | 2280007 | 2279114 | - | 893 |
| 12 | Glycosyltransferase | 2284953 | 2284219 | - | 734 |

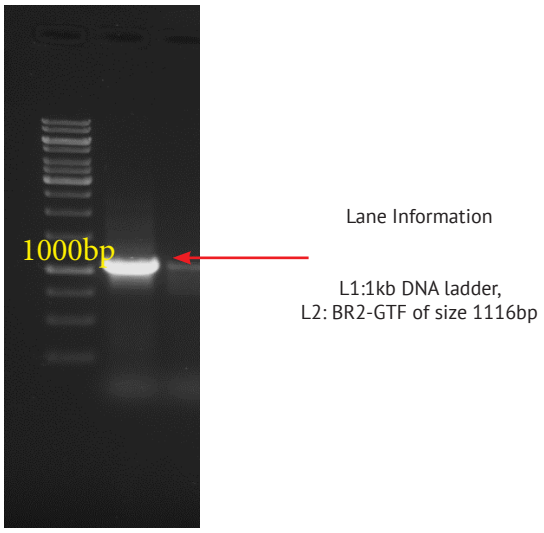



Fig 15. Gel picture showing the BR2-GTF gene (~1116 bp) amplified from *L. plantarum* BR2 genomic DNA

### 3.2. Omega-3 fatty acid-PUFA from edible microalga and its applications

#### A. Near purity separation of PUFA

Urea complexation is the most efficient and cost-effective method to separate polyunsaturated fatty acids (PUFAs) from mixed oils. The ability of urea to form complexes with SFA and MUFAs were used to successfully separate PUFAs. The long chain PUFAs obtained in the non-urea complexing liquid fraction. Temperature plays an important role in crystallization process and depends on the type of fatty acid to be purified. Urea complexation was done at different complexing temperatures and effective temperature for the separation was found to be 25°C. PUFAs like EPA (C20:5- 59%), Arachidonic acid (C20: 4, 16%) and Linoleic acid (C18:2- 12%) were successfully able to purify using urea complexation method (Fig. 16). The purified PUFAs can be used for nutraceutical and pharmaceutical applications.

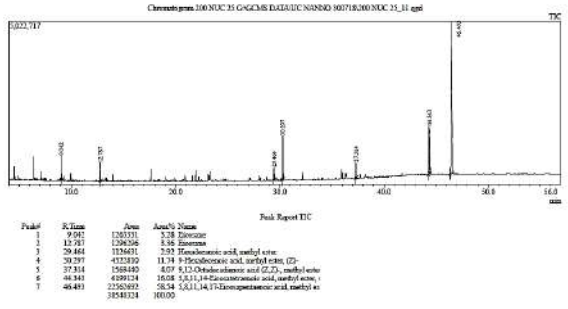


Fig. 16. Near purity separation of PUFA from other fatty acids from edible microalga

#### B. Potential application as preventive agent against neurodegenerative diseases

Omega 3 long-chain PUFA, including EPA and DHA, are dietary fats with an array of health benefits. Role of omega 3 fatty acid enriched microalgae on the cell viability of neuronal cell line (SHSY5Y neuroblastoma cells) and as a preventive measure of neurodegenerative diseases was analysed (Alzheimer's). Cell viability studies were conducted after treatment with different concentrations of DHA and EPA (Sigma Aldrich), aqueous extract and lipid fraction from microalgae enriched with EPA. All the treatments showed cell proliferative effects and minimum cell death, which proves that these compounds are not toxic to the cells (Fig. 17). In summary it suggests that microalga extract or purified PUFA are non-toxic to the cells however, more experiments needs to be performed to preventive the preventive effect of microalga derived PUFA towards are in progress to establish the neurodegenerative diseases (Alzheimer's).

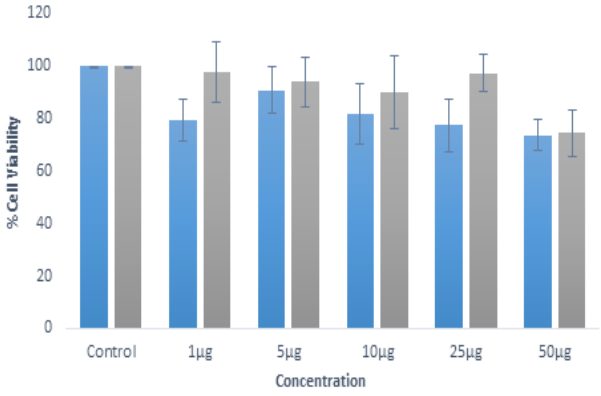



Fig. 17. SHSY5Y cells were treated with different concentrations of microalga extract [(Filled bar) 1,5,10,25 and 50µg] and total lipid extract [(Open bar) 1,5,10,25 and 50µg) and incubated for 48 hours and c) 72 hours. Cell viability was determined using MTT assay (*Courtesy: Dr. KK Maiti, CSTD*)

### 3.3. Bioavailability, Toxicity and Antioxidant property of the trace nutrient - Organic selenium (Arumugam & Reshma, 2020 Patented bioprocess)

Organic Selenium enriched microalga *Nanochloropsis oceanica* CASA CC201 was found to be non-toxic and promoted the growth of the experimental animals (Mice) significantly. Further, (i) it helped in reducing cholesterol and LDL when compared to control (ii) a significant accumulation of selenium was observed in the serum and tissues of organic selenium fed experimental groups (iii) Accumulation of Se in liver was found to be less in organic Se fed group when compared to inorganic Se fed group (iv) level of oxidative stress marker MDA was

found to be significantly low in 0.3 mg/Kg organic Se fed group when compared to control and oxidative stress induced group fed with normal diet and it was comparable to the oxidative stress induced group fed with known antioxidant. In conclusion, Organic selenium enriched *N. oceanica* CASA CC201 can be considered as a safe organic Se supplement in food or feed.

## 4. Microbial processes and waste valorization through biological route

### 4.1.Biosynthesis and characterization of nanoparticles:

Biosynthesized an instantaneous and ecofriendly multiphase Fe nanoparticle for diverse applications using *Syzigium aromaticum* (Fig. 18). The nanoparticles are found to be predominantly in spherical shape with very small mean diameter. The magnetic analysis indicates the superparamagnetic-like behavior of Iron but with frustration of surface spins and thereby lead into a cluster glass-like behavior. Also, through the phyto organic molecules associated with the surface of nanoparticles the surface chemistry can be tuned by subsequent functionalization. It has scope for various industrial applications like ion exchanges, gas sensors, bio separation and hyperthermia (Jebakumar et al., 2020).

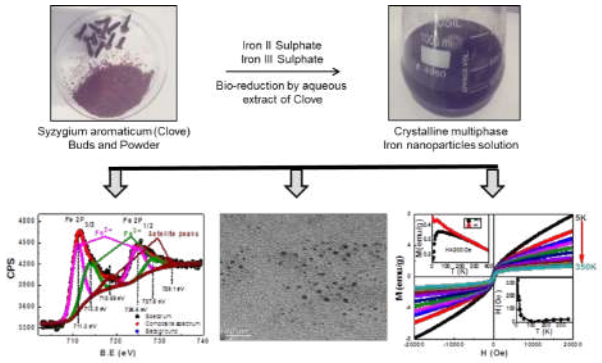



Fig. 18. Biosynthesis and characterization of multiphase Fe nanoparticle using *S. aromaticum*.

An extracellular simple and efficient biosynthetic process was used for the preparation of Au, Ag, and Au-Ag nanoparticles using aqueous extract of dried biomass of newly identified fresh water green alga, *Chlorella acidophile*. The spectroscopic and microscopic analysis of the Au, Ag and Au-Ag NPs confirmed the formation of monometallic and bimetallic core–shell nanostructures (Fig. 19). An enhanced Raman spectrum of the Au-Ag nanoparticle in comparison to the individual Au nanoparticle is indication of the improved properties, which can be used in sensors for industrial applications (Thangaswamy et al., 2021).

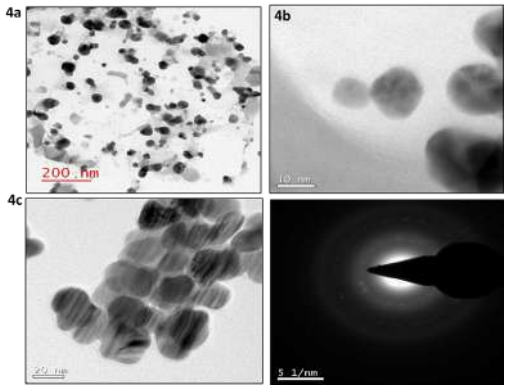



Fig. 19. TEM images of (a)Ag NPs (b) Au NPs (c) Au-Ag NPs and SAED pattern of Au-Ag NPs

### 4.2. Valorization of Food and Kitchen waste: An integrated approach for the production of biopolymer, biofuels, enzymes and chemicals

Food and kitchen waste is being investigated as a suitable feed stock for the production of biopolymer, biofuels, enzymes and chemicals. Media engineering improved poly-3-hydroxybutyrate (PHB) production from 0.91 g/L to 5.132 g/L. There is a five-fold increase in PHB production. The food and kitchen waste were also evaluated for the production of biofuels, chemicals and enzymes. *Saccharomyces cerevisiae* produced 0.316 g of ethanol, *Bacillus sonorensis* MPTD1 produced 2.47 IU/ml of pectinase and *Enterobacter cloacae* SG1 produced 3 g/L of 2, 3-butanediol with a productivity of 0.03 g/L/h using food and kitchen waste as carbon source. Targeting on multiple value-added products is expected to improve the overall process economics. The PHB matrix was found suitable as a supporting matrix for cell culture.

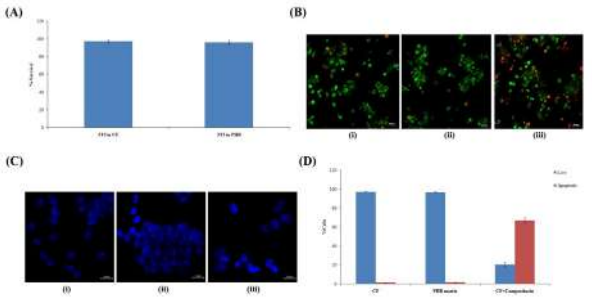



Fig. 20 (A) Cytotoxicity analysis of PHB matrix towards 3T3 cells (B). LIVE/DEAD assay of 3T3 cells grown on PHB matrix (I) 3T3 cells in culture flask (CF) (II) 3T3 cells

in PHB matrix (III) 3T3 cells in CF treated with hydrogen peroxide. Hydrogen peroxide treated cells grown in CF served as positive control (C). DNA fragmentation analysis by Hoechst 33258 staining.(I) 3T3 cells in culture flask (CF) (II) 3T3 cells in PHB matrix (III) 3T3 cells in CF treated with hydrogen peroxide (D) Apoptosis analysis of cells grown on PHB matrix. Camptothecin treated cells served as positive control

### 4.3. Prawn shell waste management and valorization by biotechnological conversion to chitin and other value added products

Prawn shell wastes from *Penaeus vannamei* were tested for bioconversion using *B. megaterium* and *Bacillus subtilis* cultures (isolated from prawn shell wastes) either alone or in combination at pH 6.5 using tap water. Maximum chitin yield (40.57%) with was obtained using *B. megaterium* cultured in 0.1% glucose (Fig 21).

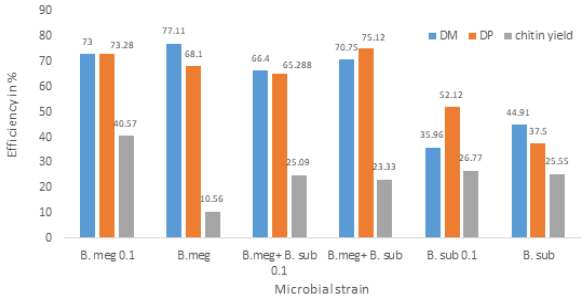



Fig. 21. Demineralization and Deproteination efficiency and chitin yield of bio-fermented prawn shell wastes

FTIR analyses indicated that the biochitin derived through microbial fermentations were comparable with

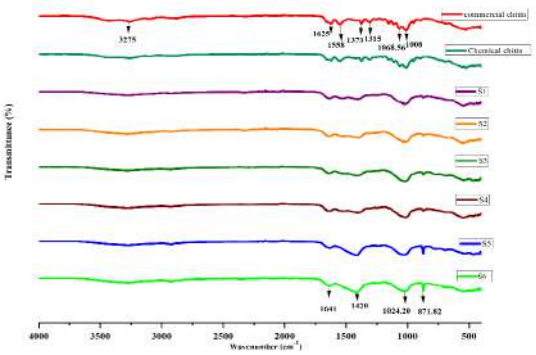



Fig 22: FTIR spectra of the biofermented chitin samples, chemical chitin and commercial chitin.
S1: *B. megaterium* 0.1 % glucose; S2: *B. megaterium*; S3: *B. megaterium* + *B.subtilis* (1:1) 0.1% glucose;
S4: *B. megaterium* + *B.subtilis* (1:1); S5: *B. subtilis* 0.1% glucose, S6: *B. subtilis*

The protein hydrolysates derived by microbial conversion contained essential amino acids like tryphtophan, valine, arginine and methionine (by HPLC) ( Table 3) and metals like Ca, Mg, Fe, Cu, Zn, Sr, etc. (ICP-MS) (Table 4) and hence, could be used for the development of aquatic feed, after optimization of the fermentation conditions.

Table 3. Amino acid analysis of bio-fermented PSW protein hydrolysates

| Protein hydrolysates | Tryptophan (mg $mL^{-1}$) | Ornithine (mg $mL^{-1}$) | Valine (mg $mL^{-1}$) | Arginine (mg $mL^{-1}$) | Methionine (mg $mL^{-1}$) |
|---|---|---|---|---|---|
| S1 | ND | ND | 93.79 | ND | ND |
| S2 | ND | ND | 95.05 | ND | ND |
| S3 | 5.50 | ND | 160.06 | ND | 71.25 |
| S4 | 6.68 | 56.33 | 263.92 | 60.77 | 73.69 |
| S5 | 17.33 | 47.15 | 53.56 | 76.22 | ND |
| S6 | 20.14 | 38.00 | 66.27 | 46.57 | ND |

Table 4. ICP-MS analysis of the protein hydrolysates obtained by bio-fermentation.

| Protein hydrolysates | Ca(ppm) | Mg(ppm) | Fe(ppm) | Mn(ppm) | Cu(ppm) | Zn (ppm) | Sr (ppm) |
|---|---|---|---|---|---|---|---|
| S1 | 75.477 | 53.593 | 3.511 | 0.304 | 3.767 | 3.240 | 9.631 |
| S2 | 6.261 | 9.586 | 0.602 | 0.045 | 1.240 | 1.094 | 0.580 |
| S3 | 20.448 | 30.700 | 1.924 | 0.048 | 2.434 | 1.080 | 2.286 |
| S4 | 34.792 | 53.280 | 1.293 | 0.053 | 2.898 | 1.198 | 4.521 |
| S5 | 15.087 | 26.249 | 1.586 | 0.042 | 2.768 | 0.882 | 1.720 |
| S6 | 11.244 | 22.937 | 1.322 | 0.064 | 3.468 | 0.984 | 1.207 |
| With $H_20$ | 10.0 | 38.248 | 1.014 | 0.062 | 3.458 | 0.890 | 1.006 |
| With $HNO_3$ | 27.543 | 57.596 | 1.307 | 0.062 | 2.832 | 0.923 | 3.287 |

## 5. Plant Microbe Interaction

### 5.1. Molecular rhizosphere ecology: microbiome, diversity, taxonomy, genome and function of root-associated bacteria

#### A) Microbiome of Indian brackish rice varieties – Pokkali and Kaippad

Salinity is a major factor that limits the crop productivity in coastal agricultural farming. Exploring the microbiota of crops cultivated in brackish flooded agricultural fields can increase the knowledge for the development of sustainable approaches for overcoming salinity stress. However, the information on the microbiome inhabiting the rhizosphere or roots of crops cultivated in brackish ecosystem remains largely elusive. Therefore, we metagenomically traced the microbiome of brackish rice varieties (Pokkali and Kaipad) of South India (Kerala). The bacterial communities associated with these rice are expected to possess host-beneficial and brackish adaptive traits. Hence, we are trying to uncover the rhizobacterial communities of the rhizosphere and root regions of Pokkali and Kaipad rice varieties through 16S rRNA amplicon sequencing.

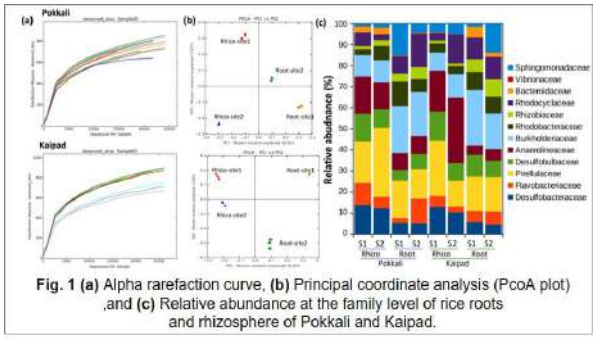



**Fig. 1 (a)** Alpha rarefaction curve, **(b)** Principal coordinate analysis (PcoA plot) ,and **(c)** Relative abundance at the family level of rice roots and rhizosphere of Pokkali and Kaipad.

Fig 22 a) Alpha rarefaction curve b) Principal coordinate analysis (PcoA plot) and c) Relative abundance at the family level of rice roots and rhizosphere of Pokkali and Kaipad

The 16S rRNA amplicon sequencing targeting V3-V4 region of 16S rRNA gene generated a total of 1,850,460 raw reads from 12 samples (both Pokkali and Kaipad). Finally, 967,388 contigs were clustered with >97% sequence identity which resulted in 2673 microbial OTUs. The alpha rarefaction analysis showed a saturated curve indicating that the samples attained sufficient sequencing depth to capture the rhizobacterial diversity (Fig. 22a). From the diversity analysis, the root samples showed a higher genus-level richness compared to the rhizosphere. It may be because, the microbes prefer to colonize endophytically due to the salinity stress in the external environment. A principal coordinate analysis (PCoA) between the samples displayed a close clustering for the replicates of the samples and showed differences according to the sample type. This suggests that there is no variation between the replicates, but has a significant variation between the root and rhizosphere samples of different rice varieties (Fig. 22b). From the microbial composition analysis, *Proteobacteria* was the most dominant phylum in all the samples. The second dominant phylum was *Bacteroidetes* followed by *Patescibacteria* and *Planctomycetes*. We did not find much difference in the microbiome composition at the phylum level. Hence we analyzed the microbiome composition at the family level to understand the distribution at lower taxonomic levels (Fig. 22c). The families which are enriched in the root compared to the rhizosphere include *Burkholderiaceae, Flavobacteriaceae, Rhodobacteraceae, Rhodocyclaceae* and *Rhizobiaceae* whereas the families which are depleted in the root include *Desulfobacteraceae, Desulfobulbaceae, Anaerolineaceae* and *Pirellulaceae*. From the OTU level analysis, the top 10 most abundant OTUs in the rice roots were assigned to the class *Bacteroidia* whereas, the rhizosphere samples were mostly assigned to the class *Deltaproteobacteria*. Most of the abundant OTUs are from the uncultured class and do not have any closest strain with >97 % sequence similarity in the public database suggesting the presence of novel taxa in samples. This data gave us an initial lead that pokkali is a reservoir of diverse and potential microbiome which forced us to culture diverse and novel strains through unique isolation strategies

#### B) Potential and diverse siderophore producing strains with anti-microbial activity from pokkali rhizosphere

Iron limitation marks as one of the constraints that delimits the cultivation and productivity of crops. The ability of certain microbes to enhance plant growth and check disease incidence by the release of an iron chelator referred as 'Siderophore' under this condition can be of great promise. To obtain agriculturally relevant bio-stimulants, we targeted under-explored ecosystem such as Pokkali fields, where the probability of isolating novel siderophore producing microbes would be relatively higher. We isolated 1010 microbes from the rhizosphere of pokkali rice plant which were further screened for siderophore activity using microplate based CAS assay which resulted in ~200 potential siderophore producing strains (Fig. 23).

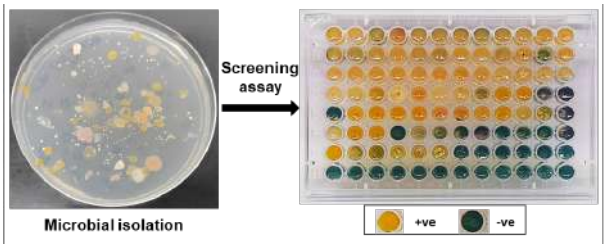



Fig 23: Screening the cultures isolated from the rhizosphere of Pokkali plant to determine siderophore production capacity

Among these, 36 were morphologically diverse strains with siderophore production under broth condition. Moreover, the siderophore production was enhanced for these strains under iron starved condition, by amending 75µM of strong chemical iron chelator - 2, 2 dipyridyl to the broth media (Fig. 24).

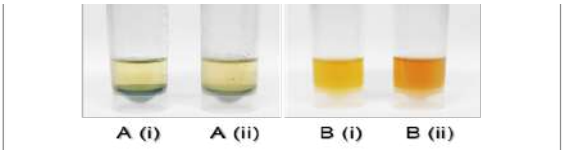



Fig 24: Assay to determine siderophore production
A-Control, B-Test (Orange = siderophore production)
(i) Iron Limited (ii) iron starved (1,2, dipyridyl)

TTable 5: Inhibitory effect of siderophore producing microbes towards phytopathogens.

| Sl. No. | Strains ID. No. | Zone of inhibition towards *Macrophomina phaseolina* (Fungus) | Inhibition towards *Xanthomonas* and *Staphylococcus aureus* (Bacteria) |
|---|---|---|---|
| 1 | NRK-SFe-1 | 2 mm | Both *Xanthomonas* and *S.aureus* |
| 2 | NRK-SFe-2 | 2 mm | Both *Xanthomonas* and *S.aureus* |
| 3 | NRK-SFe-7 | 8 mm | Both *Xanthomonas* and *S.aureus* |
| 4 | NRK-SFe-8 | 4 mm | Both *Xanthomonas* and *S.aureus* |
| 5 | NRK-SFe-17 | 2 mm | Both *Xanthomonas* and *S.aureus* |
| 6 | NRK-SFe-20 | 12 mm | Both *Xanthomonas* and *S.aureus* |
| 7 | NRK-SFe-23 | 4 mm | Towards *S.aureus* |

This further increased the significance of these cultures to be used as potential candidates for future studies. The 16S rRNA gene based phylogeny indicated that siderophore producing strains belonged to the following genus groups - *Pseudomonas, Enterobacter, Klebsiella, Peanibacillus* etc. Among this 7 strains possessed inhibitory property towards fungus and bacteria which further adds on to their potential (Table 5). Studies are underway to determine the role of the culture filtrate of these siderophore producing strains in plant growth promotion. Future plan includes the extraction of these siderophores to determine its novelty and mode of action.

**C) First cultured & novel *Verrucomicrobia* from India with host-plant association**

*Verrucomicrobia* is regarded as one among the tough-to-cultivate bacterial phyla and this limit the possibility of studying their physiology and host-interaction. During the metagenomic investigation to trace the microbiome of Indian brackish rice varieties (Pokkali and Kaippad), we identified the presence of *Verrucomicrobia* members in the rhizosphere and root regions (Fig. 25a). Most importantly, *Opitutaceae* family was observed to be enriched in the root compared to rhizosphere (Fig. 25b). Based on this lead, we proceeded for a *Verrucomicrobia* phylum targeted isolation strategy using root enrichment method where we could isolate a slow growing strain designated NRK V7 (Fig. 26).

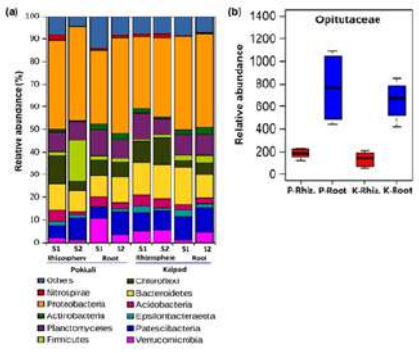



Fig 25: (a) Phylum level distribution of microbiome in Pokkali and Kaipad (rhizopshere & root) rice varities (b) Relative abundance of Opitutaceae family in rhiozospehere & root regions of Pokkali and Kaipad

Fig 26: First cultured *Verrucomicrobia* strain (NRK V7) from India, grown in R2A3 Agar

16S rRNA gene based phylogeny indicated the strain to be a novel genus under sub-division 4 of *Verrucomicrobia* phylum with a sequence identity<93% with its nearest

reference strains (Fig. 27). Also, we could identify NRK V7 similar OTUs (operational taxonomic units) from the metagenome datasets of brackish rice varieites which alligned with the 16S rRNA gene sequence of NRK V7 strain (Fig. 27).

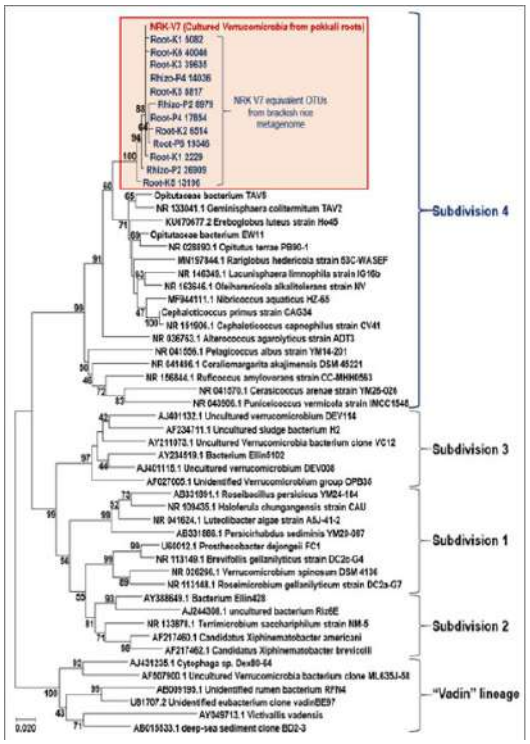



Fig 27: 16S rRNA gene phylogenetic tree showing the phylogenetic position of NRK V7 strain in Verrucomicrobia phylum, and its equivalent OTUs from metagenomic datasets of brackish rice varieties

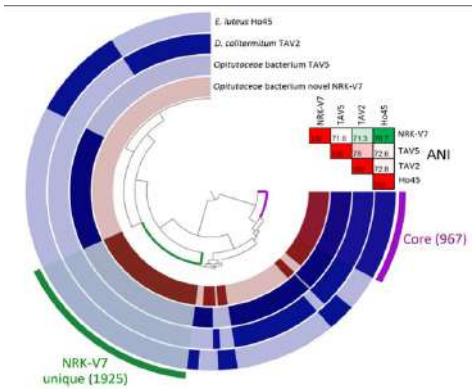



Fig 28: Pan-genome map of NRK V7 and its reference strains shpwing unique genes and core genes

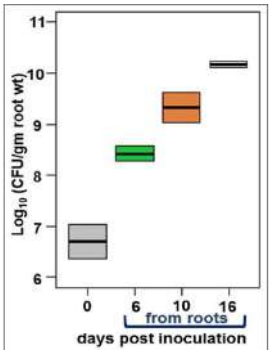



Fig 29: Box plot representing host colonization of NRK V7

The complete genome sequence of NRK V7 revelaled important genetic factors complementing their host-association and eco-adaptation. The pan-genome analysis with closest reference strains revealed some unique genes that reflect their plant-associated lifestyle (Fig. 28). More importantly, NRK V7 harbored entire *NifH* gene cluster which is expected to provide nitrogen-fixation to its host. In addition, genes/gene clusters for motility & chemotaxis, carbohydrate degradation, iron acquisition and saline-stress tolerance were coded in the genome of NRK V7. Interestingly, we could also identify around 14 genes under the category of eukaryotic like proteins which is assumed to play a major role in mediating host-interaction. Further, to confirm the host-association ability of NRK V7 strain, a binary-association experiment was performed which showed that NRK V7 cells proliferated along the host seedling roots which increased from ~$10^6$ on $0^{th}$ day post-inoculation to ~$10^{10}$ $log_{10}$ (CFU/gm root wt) on $16^{th}$ day post-inoculation (Fig. 29). All these result confirm the association of NRK V7 strain with its host, pokkali. Further studies are underway in determining their host-beneficial properties at the molecular level. The metagenomic presence of *Verrucomicrobia* phylum supported with a cultured isolate is the first report of its kind from an India origin which marks another major uniqueness of this research study.

## 5.2. Molecular plant-beneficial bacteria interactions under brackish conditions using *Pokkalibacter plantistimulans* (L1E11$^T$) and pokkali as model system

A) L1E11$^T$ – pokkali root colonization

*Pokkaliibacter plantistimulans* (L1E11$^T$) was isolated from rice cultivated in saline affected costal agro-ecosystems of Kerala, India. The novel strain was positive for many

properties that are beneficial to plant growth including ACC deaminase, biofilm formation, siderophore production, phosphate solubilisation, utilization of plant derived compounds and ability to colonize host roots which indicates its plant-associated life style. The major objective of this research work was to identify how brackish conditions (seawater) influence the movement of L1E11$^T$ towards pokkali to colonize and establish a dynamic interaction with the host. During the course of the study, we found that presence of seawater positively influenced the motility and colonization of L1E11$^T$. To validate this observation, we performed a plant root colonization assay in the presence and absence of seawater. Plant root colonization studies of L1E11$^T$ with pokkali seedlings confirmed that attachment and colonization of L1E11$^T$ was higher in the presence of seawater. We used three different systems for the in-planta colonization studies. Firstly, we performed an L1E11$^T$ colonization experiment in hydroponic system under controlled conditions where L1E11$^T$ tagged with GFP and scarlet were inoculated separately to the 4-day old seedlings in the presence and absence of sea water (Fig. 30). The bacterial colonization of L1E11$^T$ was effectively tracked on 1,3,5,7,9,14 and 24$^{th}$ dpi. To implicate the colonization efficiency of L1E11$^T$ in nature we did an experiment by mimicking the environmental condition where pokkalii seeds were grown in (a) vermiculite quart sand mixture and in (b) garden soil under non-sterile conditions. When L1E11$^T$ was inoculated directly to the soil we found that the colonization was observed in primary roots, lateral root junctions and root hairs after 1$^{st}$ day of inoculation (Fig. 31).

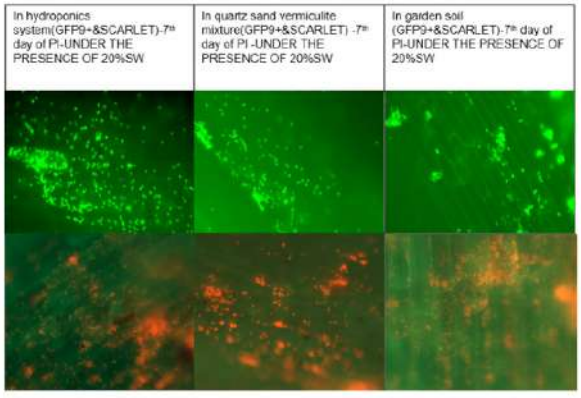
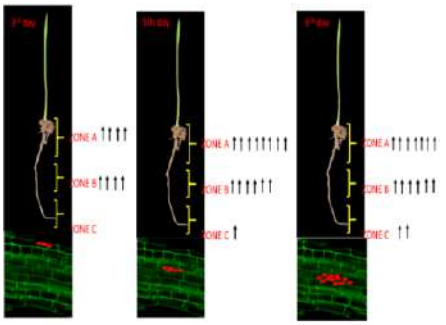



Fig 30: Plat root coloniztion assay (3- systems with GFP9+SCRALET) -7th dpi-under 40X




.2Fig 31: Soil inoculum (Pokkaali rice root with different zones-each arrow indicating the nymber of cells present

After 5th dpi, the bacteria were majorly observed in inner sections of primary roots (inner cellular spaces and root hair junctions (Fig. 32).

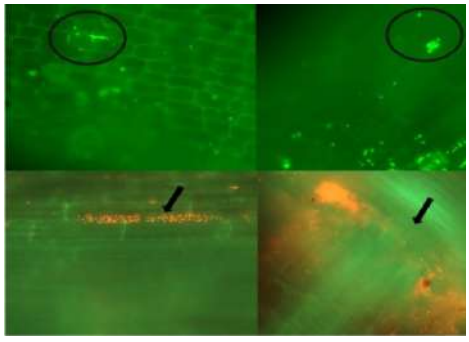


Fig 32: Detection of cells at the inner cellular spaces and lateral root junctions (under 40X)

L1E11$^T$ was completely established along the root surface after 9dpi (Fig. 33). When L1E11$^T$ was inoculated with the seeds, we found that the bacteria moved along the growing seedling roots (Fig. 34) and they remained stable in the roots up to 24$^{th}$ dpi. These experiments helped us to document the colonization of L1E11$^T$ from early stage of seedling development influenced by seawater and thus remain tightly bound to the pokkali roots as a robust host plant colonizer.

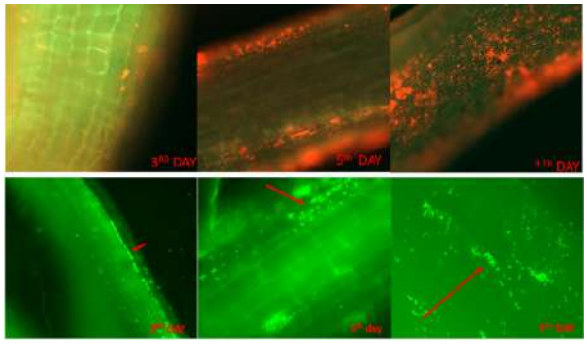


Fig 33: Soil inoculum- Microscopic observation of GFP9+SCARLET- primary root ZONE A – 40X

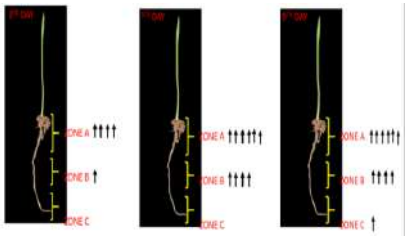


Fig 34: Seed inoculum- Both GFP9 +& SCARLET moving along with the roots

## B) L1E11$^T$ Type VI secretion system (T6SS) – Rhizosphere competition and genome analysis

Plant, microbe and environment are intricate network of cross talk. Plants constantly interact with its surrounding bacterial community as a friend or as foe by holding beneficial microbes and eliminating pathogens. This interaction is highly influenced by surrounding abiotic factors that constantly alter the plant physiology. The root microbiome plays a pivotal role in responding to the environmental stress by promoting plant growth and development. The soil microbes are in constant competition to dominate its environmental niche outcompeting the neighboring community. *Pokkallibacter plantistimulans* (L1E11$^T$) is one among the plant beneficial bacteria which is highly enriched in the roots of pokkali. The tight relation of this bacteria with the plant roots evoked our insights in to explore the fitness of L1E11$^T$ in rhizosphere competition and thus to learn how this bacterium compete with the existing microbiota and establish a stable interaction with the host. We did an in-vitro competitive killing experiment in LB agar medium to check the competitive ability of L1E11$^T$ and we found almost 4-fold decrease in the recovery of prey species (Fig. 35). The killing was prominent in prokaryotes, pathogens and eukaryotes that were used as prey's (Fig. 35). The killing efficiency was enriched in iron deficient condition whereas temperature didn't influence the killing. To study the dynamics of L1E11$^T$ in plant rhizosphere competition, we performed an in-planta competition experiment where 4-day old pokkali seedling roots were inoculated with pokkali field soil solution followed by inoculation of L1E11$^T$. The L1E11$^T$ population increased rapidly from 4$^{th}$ to 7$^{th}$ dpi (Fig. 36) and gained its colonization dominance till 14$^{th}$ dpi. This data confirms that L1E11$^T$ colonized the roots effectively by competing with the soil bacteria to establish a stable interaction with its host plant. These findings strengthened our attempts to unravel the mechanism through which L1E11$^T$ interact with host, pokkali.

We did an extensive genome analysis of L1E11$^T$ using bioinformatics tools to find key players for the rhizosphere combat. From the in-silico analysis, we identified a 34 kb single cluster of

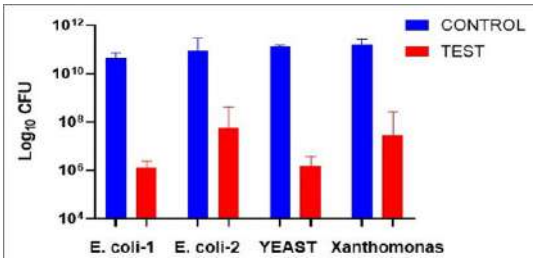



Fig 35: recovery of prey from L1E11 contact dependent killing assay

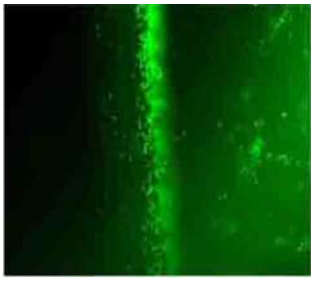


Fig 36: L1E11 GFP9+ on the roots, 7 day post inoculation visualized by fluorescent microscopy

T6SS comprising all the genes essential for the active functioning of this secretion system. T6SS is a nano injectisome which inject toxic proteins called effectors when in contact with the prey organism by a cell puncturing mechanism. It is also known for inter-bacterial competition complementing host colonization and fitness of the organism. Our aim is to study the role of T6SS of L1E11$^T$ in inter-bacterial competition in a poly-microbial niche for a stable plant-microbe interaction. The key genes and the regulators of T6SS have been identified through genome mining. The effectors proteins are the key proteins that cause toxicity in the prey bacteria. We have identified around 9 effector proteins which includes methyl transferases, Pyosin nuclease proteins, Phospholipase, Colicins, Amidase, DNase and 2 un identified toxins through which the lethality is caused. The amidase effector in L1E11$^T$ is highly similar to the *Pseudomonas aeruginosa* T6SS Amidase effector (Tse1) which degrade peptidoglycan cell wall and cause cell lysis. From our analysis we found that L1E11$^T$ harness a battery of effector proteins to power the type six secretion. These effectors have to be experimentally validated for their functional role in L1E11$^T$ - pokkali interaction.

## 6. Understanding Biological Processes and Molecular Biology of Industrial Microorganisms

### 6.1. Engineering of bio-mimicking membrane shapes in giant vesicles for synthetic biology applications

Self-organization via membrane shape changes is a hallmark property of living cells that plays a crucial role in cell functions ranging from signaling for control over molecular events to cell division. Consequently, mimicking highly-curved membrane structures is an exciting goal from a synthetic biology perspective and will play an essential role in understanding molecular organization in living systems.

Giant unilamellar vesicles (GUV's) have been the model of choice to understand, control, and mimic such cellular membrane shapes. We demonstrate large cell-like membrane deformations triggered by bacterial glycolipids self-assembled in vesicles in a robust manner. Firstly, Inverse-phase precursor film assembly using hydrogel-assisted technology is employed for stable and asymmetric glycolipid (LPS) reconstitution in vesicles for membrane deformation studies. Then, defined highly-curved morphology is engineered by controlling membrane tension via application of step-wise osmotic stress. Robust curved membrane structures are reported, ranging from a bud, tubulation, and 'daughter' vesicles interconnected via membrane neck and networks of nano-tubes. In our study, the length of nano-tubes connecting daughter vesicles ranges from 12 µm to 200 µm, diameter of buds or daughter vesicles ranged from 600 nm to 6 µm covering diverse range of curvatures generated in a single synthetic system. Most importantly we demonstrate spatial organisation of model protein in the nano-necks of the engineered structures. We provide here membrane scaffolds closely mimicking cellular lipid composition for understanding the segregation of proteins. Our system offers appealing possibilities for the rational design of curved morphologies imparting spatial organization for bottom-up biology and bio-nanomaterial applications.

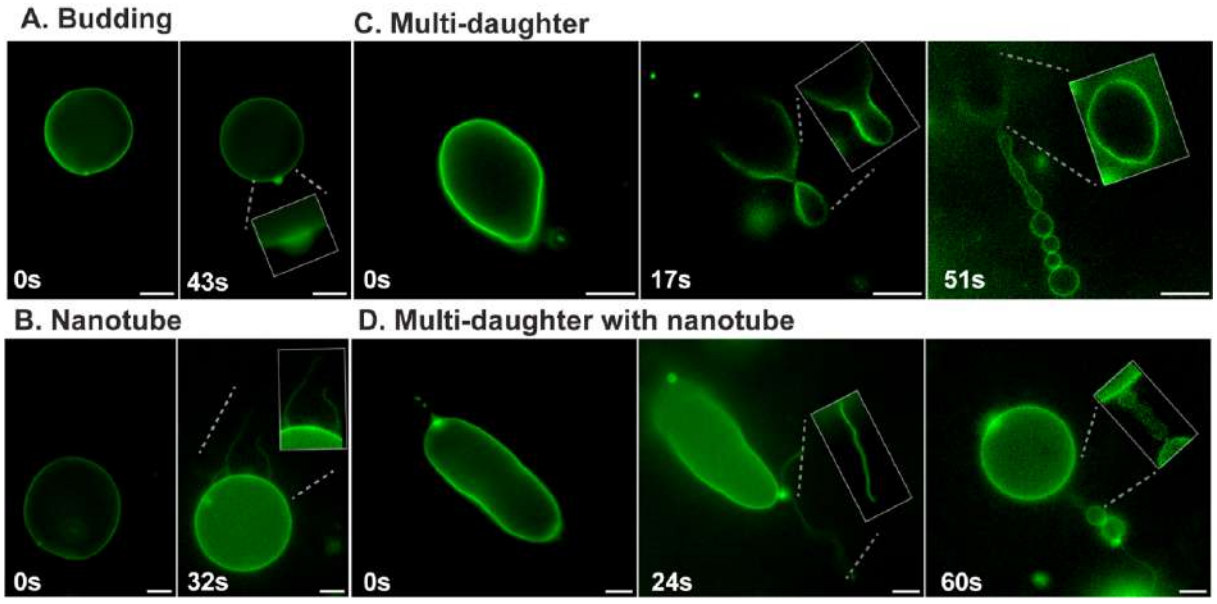



Fig. 37. Real-time membrane remodeling in glycolipid vesicles – Deformations in flaccid LPS vesicles, leading to various membrane morphologies. Snaps from time-series for a vesicle displaying A. Budding where at 0s vesicle is flaccid with membrane fluctuation and 43s the bud is formed, B. Nanotube formation 0s the vesicle is flaccid and 32s short nano-tubes are formed, C. Multi-daughter morphology at 0s vesicle has changed shape, constriction occurs at 17s, inset shows the transformation just before constriction, at 51s mother vesicle in inset splits into multiple-daughter vesicles, Scale bar: 10 µm for A and C panels, B and D panels are 5 µm, Conditions- FITC-LPS:GN lipid extract (1:6) with 0.5 mol% ATTO-488 DOPE, false color represents ATTO dye, 0s in all structures represent a relative time and not the actual time of addition of hyper-tonic solutions. The brightness/contrast is adjusted in FIJI for best representation and visibility of membrane structures.

## 6.2. Kinetic characterization of Sortase E (Cg-SrtE ) of *Corynebacterium glutamicum* ATCC 13032

Most Gram-positive bacteria contain a membrane-bound transpeptidase known as sortase which covalently incorporates the surface proteins on to the cell wall. The sortase-displayed protein structures are involved in cell attachment, nutrient uptake and aerial hyphae formation.

In order to determine the kinetic parameters of Cg-SrtE with Abz-LAHTG-Dap(Dnp) and Abz-LAETG-Dap(Dnp) peptides, kinetic analysis of sortase-catalyzed transpeptidation reaction was performed. Varying concentrations (2.5, 5, 7.5, 10, 15, 20, 25, 30, 35, 40, 45, 50 μM) of each peptide were incubated with 5 μM Cg-SrtE and the reaction was monitored in every 10 min interval for a period of 6 h. The level of cleavage observed for Abz-LAETG-Dap(Dnp) peptide was too low to facilitate the kinetic analysis (data not shown). On the other hand, initial velocities (V) obtained from the progress curves was able to plot against the varying concentration of Abz-LAHTG-Dap(Dnp) (Figure 38a). Thus, with Abz-LAHTG-Dap(Dnp) substrate, calculated an apparent *Km* of 12 ± 1 μM and an apparent *Vmax* of 1.3 ± 0.04 RFU/sec for Cg-SrtE (Figure 38b).

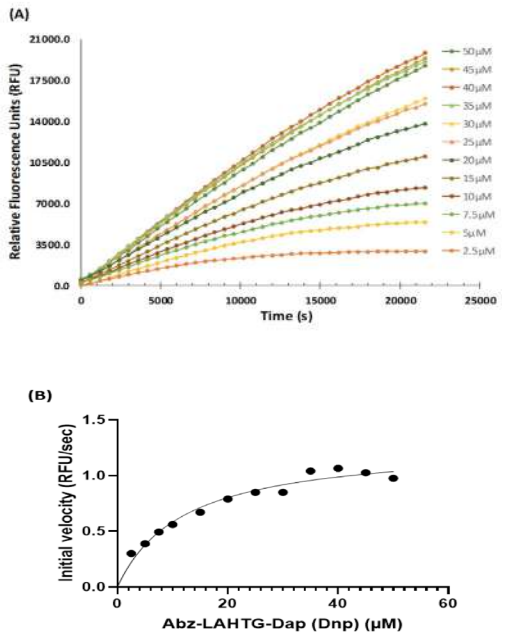



Fig 38. Determination of the kinetic parameters of sortase

## 6.3.Genome analysis and CAZyme characterization of the cellulase hyper-producer *Penicillium janthinellum* NCIM 1366

Microorganisms, especially soft-rot fungi like *Aspergillus*, *Penicillium* and *Trichoderma* that rely on biomass degradation for their survival, can produce a repertoire of cellulases containing several kinds exoglucanases, endoglucanases, beta-glucosidases and nearly 25 known supplementary enzymes that can effectively convert cellulose to glucose. However, natural enzyme systems are not equipped to meet the high substrate conc. encountered in industrial reactors, and the commercial applicability of these cocktails is limited by several factors including low productivity of certain cellulase-components, low specificity and substrate inhibition.

In the last 20 years, the ascomycete *Penicillium* has emerged as a viable producer of cellulases which perform better at biomass hydrolysis as compared to *T. reesei* cellulases. Studies at NIIST using *P. janthinellum* NCIM 1366 (PJ-1366) and its mutants showed that *P. janthinellum* cellulases are very capable of hydrolyzing biomass, including the highly recalcitrant cotton stalks at low enzyme loadings. Profiling of the enzyme activities also revealed higher amounts of endoglucanases and β-glucosidases (BGL) per milliliter of the enzyme as compared to the industrial standard of cellulase production- *Trichoderma reesei* RUT-C30. In view of the increased importance of green energy technologies in the present scenario, it was considered worthwhile to further explore and fine-tune the biomass-degrading enzymes of this fungus, which will aid tremendously in attaining economical biofuel production.

### A. Comparison with other *Penicillium* genomes, and identification of closely related species

The genome of PJ-1366 is among the largest genomes of all sequenced *Penicillium* species, though there are other species that encode more proteins. The presence of large regions of non-coding DNA can possibly result in tighter regulation of gene expression in response to varying environmental conditions and chemicals, mediated by non-coding RNAs (ncRNAs), including regulatory small RNAs (sRNAs) and long non-coding RNAs (lncRNAs). ncRNAs have been shown to be essential for regulating diverse cellular mechanisms associated with transcriptional and posttranscriptional regulation, protein translation, and chromatin modification, among others.

## B. Identification of secreted proteins using SignalP

From the SignalP analysis, it was observed that 8.5 % (1007 proteins) of the predicted proteins of PJ-1366 are extracellular. On comparing with data available for other fungi in FunSecKB2, it was observed that the no. of predicted extracellular proteins of PJ-1366 is nearly 1.5 times that of other *Penicillium* species (Table 6). In comparison to PJ-1366, fungi with higher numbers of secreted proteins belonged to the genus *Aspergillus*. These fungal species are known for their larger genome sizes (~ 40 Mbp) and robust protein secretion which has cemented their usefulness in industrial protein production.

Table 6. Comparison of extracellular proteins with other species using FunSecKB2

| Fungus | Secreted Proteins | Fungus | Secreted Proteins |
|---|---|---|---|
| *Penicillium chrysogenum* | 649 | *Aspergillus niger* | 1261 |
| *Penicillium digitatum* | 687 | *Aspergillus oryzae* | 1464 |
| *Penicillium marneffei* | 484 | *Aspergillus terreus* | 649 |
| *Aspergillus clavatus* | 471 | *Emericella nidulans* | 687 |
| *Aspergillus flavus* | 825 | *Hypocrea atroviridis* | 700 |
| *Aspergillus kawachii* | 732 | *Hypocrea virens* | 748 |

From the KEGG analysis, it was seen that the no. of proteins involved in carbohydrate metabolism was much higher for PJ-1366 as compared to either *T. reesei* RUT-C30 or the closest phylogenetic species *P. rolfsii*- an indication of its better potential for biomass hydrolysis (Fig 39).

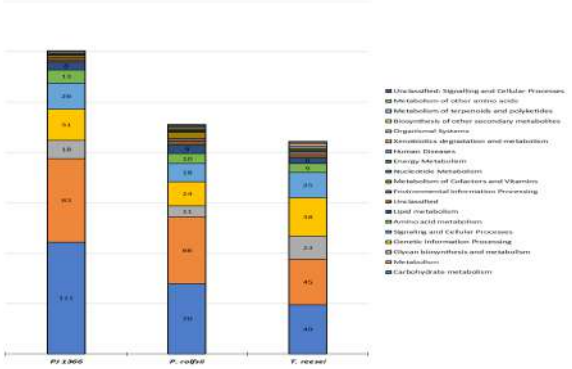


Fig. 39. KEGG analysis of proteins with SignalP

Interestingly, *T. reesei* had more proteins which are involved in glycan biosynthesis and metabolism. This included proteins that are involved in metabolism of chitins and other related structures, and those involved in protein glycosylation. This contributes to protein stability, secretion, and localization.

## C. Identification and analysis of secreted CAZymes and proteases

From the 165 secreted GHs of PJ-1366, 40 sequences were identified which belonged to putative cellulase families GH12, GH131, GH2, GH3, GH30, GH5, GH6 and GH7. BLAST-P analysis of these sequences revealed that 19 of them are potential cellulases- 4 cellobiohydrolases, 6 endoglucanases and 9 betaglucosidases.

Further, using the available UniProt annotation, 71 sequences were flagged as probable hemicellulases. The most common were xylanases/xylosidases (18 sequences), followed by galactanases/galactosidases (16 sequences), mannosidases (14 sequences), arabinases (9 sequences), rhamnosidases (2 sequences) and galacturonidases (2 sequences). Ten sequences encoding polygalacturonases were also present, which, together with pectin lyases (PL1), are known to be involved in the breakdown of pectin

## D. Comparison of genome size, no. of predicted proteins, and no. of predicted CAZymes with other cellulolytic fungi

Data on genome size and predicted proteins were extracted from NCBI Datasets, and CAZymes were predicted using dBCAN server. For all the fungi studied, the sizes of the genomes varied from 23 Mbp (*P. decumbens*) to 49 Mbp (*F. oxysporum*). However, on an average, 2-4 % of all predicted proteins were CAZymes. The organism in which a higher percentage of the encoded proteins are CAZymes was *T. cellulolyticus*, while the fungus with the smallest percentage of CAZymes was *P. decumbens*. In comparison to *T. reesei*, *P. janthinellum* employs almost 1.5 times the share of its proteins in carbohydrate metabolism.

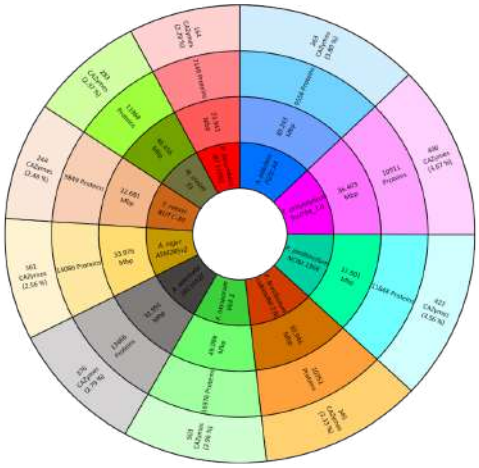


Fig 40. Genome size, no. of predicted proteins and no. of predicted CAZymes for different cellulolytic fungi

The percentage of predicted CAZymes were at the higher end of the spectrum for *P. brasilianum*, *P. janthinellum*, *T. cellulolyticus* and *A. nidulans*. Interestingly, these 3 fungi belong to the *Trichocomaceae* family. Members of this family are characterized by their ability to adapt to extreme environmental conditions. They are also commonly associated with decaying plant/food material (Fig 40).

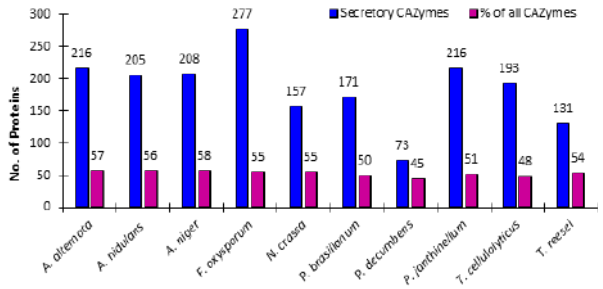



Fig 41. CAZymes with predicted secretory nature

From SignalP analysis of the predicted CAZymes, it was observed that 45-58 % of the predicted CAZymes are extracellular, implying potential roles in biomass deconstruction (Fig 41). The diversity of CAZymes were also high for *P. janthinellum* with it having 116 classes of CAZYmes second only to *Fusarium oxysporum*, a plant pathogen among the fungal genomes analyzed (Fig 42). Among the *Penicilli*, *P. janthinellum* has more secretory lignocellulases, and a more diverse set of CAZymes compared to other fungi with similar CAZyme profiles, which might explain the superiority of its crude enzyme complex in hydrolyzing biomass.

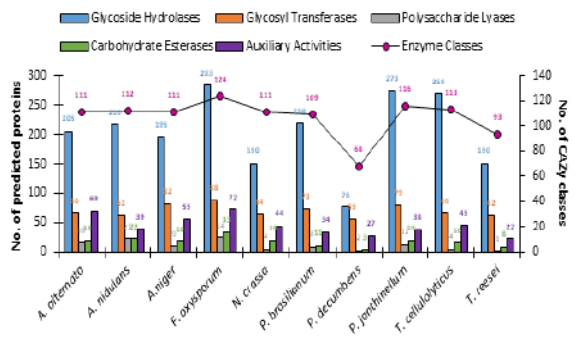



Fig 42. Distribution of CAZy classes in selected cellulolytic fungi

## E. Time scale analysis of the effect of various carbon sources on total protein and cellulase secretion

Mandels and Weber medium containing 1% carbon source was inoculated with 1 x $10^7$ spores/mL from *P. janthinellum* NCIM 1366 cultures maintained on PDA slants. After inoculation, the cultures were incubated at 30 °C and 200 rpm agitation. Secreted proteins in the culture were detected by a modified Bradford's method. The maximum protein secretion (0.86 mg/mL) was obtained in the cellulose + wheat-bran (CW) medium. The protein secretion increased exponentially after 24 h, and plateaued from 5-15 days (Fig 43a). Comparatively higher protein secretion was also observed in the presence of cellulose; in this case only, exponential increase was observed, possibly implying a lower growth rate of the fungus.

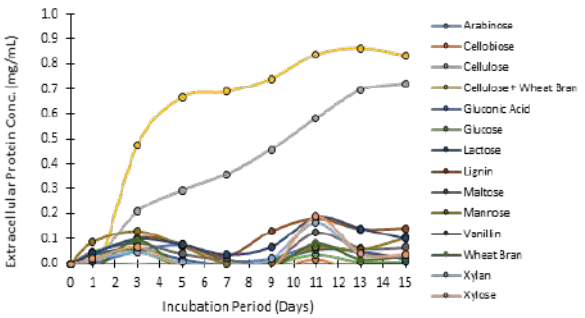



Fig. 43A. Total protein secretion

Total cellulase activity was determined in terms of the glucose released from 50 mg of Whatman® 1 filter paper, as per IUPAC protocol for filter paper assay. The glucose released was measured by the DNS method.

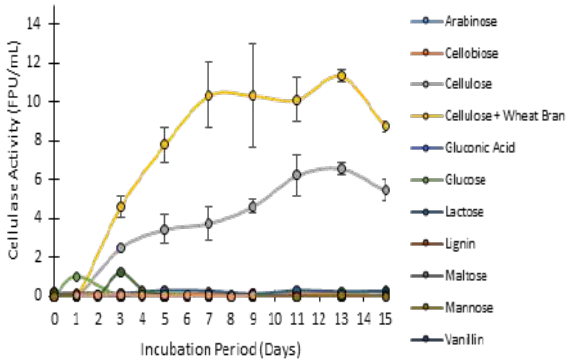



Fig. 43B. Total cellulase activity with different carbon sources

Here again, cellulase activity was only detected in CW and cellulose media, with the maximum glucose release being obtained in CW medium at 13 days. It is noteworthy that even though trace amounts of cellulase activity could be detected in glucose and wheat bran media, these could not be sustained further.

Since detectable levels of cellulase activities were only observed after 24 h of induction, it was of interest to study the transcriptional response to induction. By

RT-PCR analysis, six cellulases- 3 EGs and 3 BGLs, were found to respond within 1 h to cellulose induction (Fig 44). From these, only 2 were secretory.

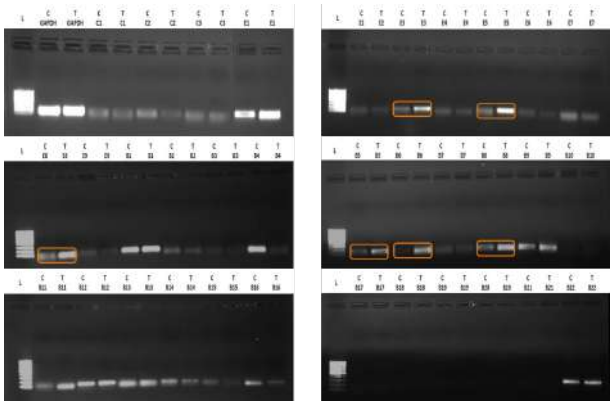


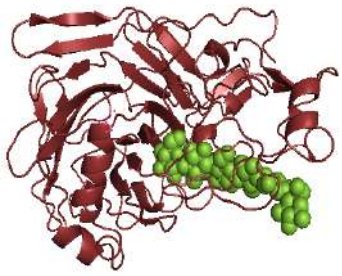
Fig 44. *P. janthinellum* cellulase genes amplified from cDNA 1h post induction
C-glucose-grown control, T - test cultures induced by cellulose/wheat bran.
GAPDH gene was used as the internal control

Comparison by *blastp* with *T. reesei* RUT-C30 cellulases, which are highly efficient in biomass deconstruction, revealed that the endoglucanase (EG-3) was similar to EG I of *T. reesei*. GH7 endoglucanases are quite remarkable in that, at least in some fungi, these enzymes have excellent pH adaptability, good thermo-stability and broad substrate specificity. Therefore, it is conceivable that the fungus might employ such a non-specific, adaptable enzyme in order to initiate cellulolysis in a foreign environment.

## F. *In-silico* analysis of the enzyme efficiencies: docking of highly inducible PJ-1366 cellulases with their respective substrates

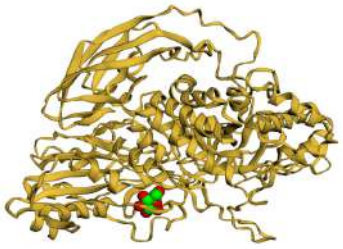
Enzyme affinity towards the substrate can provide information about its efficiencies and affinity can be determined by measuring the binding energies. Selected cellulase sequences - EG-3 (ctg7180000014428.g38), BGL-6 (ctg7180000015125.g119) were used for generating homology models, which were then used for docking analyses using their corresponding substrates/analogues to determine their binding energies. The secreted GH3 BGL (BGL-6) had no equivalent *T. reesei* counterpart. Docking analysis with possible substrates predicted that BGL-6 has distinct binding sites for both known cellulase inducers- cellobiose and sophorose (Fig 45). While BGLs are known to be competitively inhibited by the product glucose, the presence of dual binding pockets may be a possible adaptation to overcome this inhibition. Further secretome and transcriptome analyses are ongoing to further characterize the fungal response to cellulose induction.

Binding energy: -44.63 kcal/mol



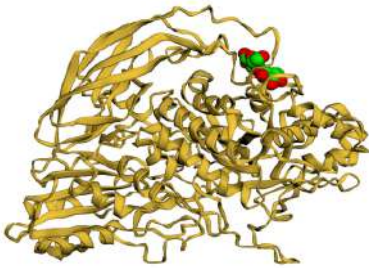
EG-3 (ctg7180000014428.g38) with cellohexaose

Binding energy: -29.26 kcal/mol



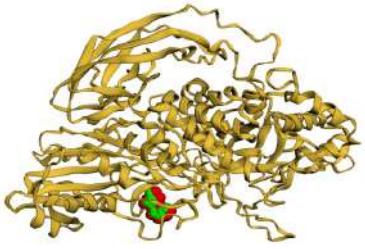
BGL-6 (ctg7180000015125.g119) with glucose

Binding energy: -41.41 kcal/mol



BGL-6 (ctg7180000015125.g119) with cellobiose

Binding energy: -55.42 kcal/mol



BGL-6 (ctg7180000015125.g119) with sophorose

Fig 45: Docking of selected cellulases of *P.janthinellum* with respective substrates/analogues

## 6.4. Understanding the regulation of cellulases in *Penicillium janthinellum* NCIM1366 and its modulation for enhancing production of the enzymes

To screen for the candidate regulators of cellulase expression in *P. janthinellum*, a comparative analysis of the transcriptome of *P. janthinellum* on cellulose and glucose as carbon sources were done. From the transcriptome data, 482 transcription factors which showed differential expression on induction with cellulose were identified. This included 8 genes which are homologs of known regulators of cellulase expression (AraR, LaeA, XlnR, CreA, ClrB, BrlA, PacC and Ace1) (Fig 46). Three among the uncharacterized regulators with highest differential expression were analyzed for domain information using Prosite. The protein corresponding to gene g8937 showed a major facilitator superfamily domain which is characteristic of transporter proteins along with a Zn(2)-C6 fungal-type DNA-binding domain typical of transcription factors indicating its dual functionality (Table 7). It is interesting that such a protein can have role in cellulose signaling pathway along with a transcription factor function. Further studies are expected to reveal the precise role of this protein in cellulase regulation.


Fig.46. Difference in expression of known cellulase regulators detected from transcriptome data

Table.7. Uncharacterized transcription factors with highest changes in expression

| Unigene ID | Gene ID | Interpro ID | Domain description | log(FC) |
|---|---|---|---|---|
| DN9813_c0_g1_i2 | g8937_t1 | IPR001138 IPR020846 | Zn(2)-C6 fungal-type DNA-binding domain. Major facilitator superfamily domain | 10.2 |
| DN9286_c0_g1_i1 | g5822_t1 | IPR001138 | Zn(2)-C6 fungal-type DNA-binding domain | 7.7 |
| DN9767_c0_g1_i27 | g2815_t1 | IPR007219 IPR001138 | Transcription factor domain, fungi Zn(2)-C6 fungal-type DNA-binding domain | -10.9 |

From the genes of known transcription factors, homologs of two known regulators namely Xln R and CreA were selected for studying their role in *P. janthinellum*, besides the three uncharacterized transcription factors with high fold change in expression. Differential expression was confirmed by real- time PCR as the transcriptome data was from a single time point. One endoglucanase (g4919) and one cellobiohydrolase (g243) was selected as model genes for differential expression for the real time PCR. Both genes showed higher fold change in expression consistent with the transcriptome data and a significant fold change was observed as early as 2h post induction (Table 8).

Table 8. Difference in expression of selected transcription factors after induction with cellulose analyzed through real time PCR.

| Gene | log(FC) at 4h (Transcriptome analysis) | log(FC) (RT PCR) | | | |
|---|---|---|---|---|---|
| | | 0h | 2h | 4h | 6h |
| EG(g4919) | 8.46 | -0.42 | 7.48 | 8.85 | 8.05 |
| CBH(g243) | 8.31 | -0.23 | 12.55 | 13.28 | 9.64 |
| g8937 | 10.2 | -0.89 | 3.48 | 0.30 | -0.28 |
| XlnR (g8827) | 3.84 | 0.80 | 4.22 | 5.65 | 8.12 |
| CreA( g1055) | 1.6 | 0.08 | 1.19 | 1.47 | 4.01 |
| g2815 | -10.9 | -0.31 | -7.95 | -2 | -0.62 |
| g5822 | 7.73 | 1.01 | 2.39 | 5.06 | 5.26 |

XlnR gene showed a positive fold change at 2h (log (FC) =4.22) and showed an increasing trend up to 6h. CreA gene also started showing up regulation at 2h and the fold change increased to 4.01 at 6h. The pattern of expression of both XlnR and CreA were similar to the cellulase genes analyzed, suggesting their roles in cellulase gene expression. The gene g8937 showed maximum fold change (log (FC) =3.48) at 2h, inconsistent from the transcriptome data where it showed a very high up regulation at 4h (log (FC) =10.2). Among the five candidate regulators which were selected according to the transcriptome data, most showed consistent fold change in the time scale gene expression analysis confirming the transcriptome results. Even though some

of them showed a difference from the transcriptome data, they have showed either up/down regulation at a different time point. The results indicated potential roles of these transcription factors in regulating cellulase expression. Further validation of their role is planned through knockout/overexpression studies

## II. Biofuels and Biorefineries

### 7. Facilitating Biorefineries: technologies and products

### 7.1. Evaluation of cellulases/cellulase blends available in Indian market for biorefineries

Efficient conversion of lignocellulose to bioethanol requires a highly robust enzyme cocktail that can breakdown complex carbohydrates into soluble sugars. Cellulase from Novozymes serves as one of the most efficient enzyme cocktail for biomass hydrolysis, but at the same time there could be cheap and efficient alternatives in the Indian market for which the biomass hydrolysis potential was never estimated. A survey of the market indicated that there are several manufacturers/ vendors of cellulases used in textile applications. These enzymes may have potential uses for biomass hydrolysis, either alone or by creating blends. This would enable local production of this high demand enzyme at lower cost and may aid in self-reliance on the costliest consumable for biorefineries. Hence cellulase enzymes available in Indian market were procured and were evaluated for their composition as well efficiency in hydrolysis of alkali pretreated rice straw to glucose and xylose. Cellic CTec 2 from Novozymes that produced about 54g/L of glucose at 24h of saccharification was used as the benchmark. Best saccharification efficiency was obtained for Saccharizeb® biomass hydorlyzing enzyme cocktail from Advanced Enzymes (37.8 g/L) followed by cellulases from Kaypeeyes Biotech Pvt Ltd (34.8g/L) and Biolaxi (34 g/L) respectively (Fig 47).

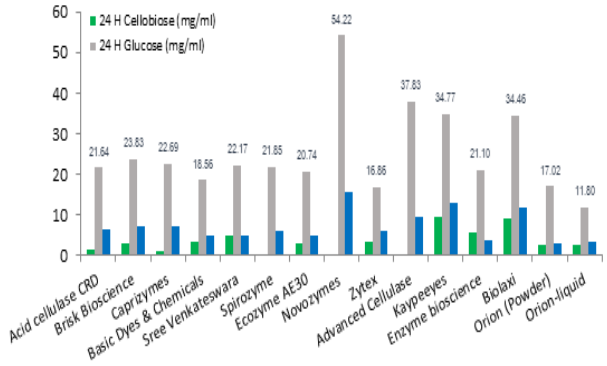



Fig 47. Saccharification of alkali pretreated rice-straw by different commercial cellulases

The reason behind the difference in performance of these enzymes can be attributed to its component enzymes which dictate the course of saccharification. Cellulase cocktail is a complex mixture of different enzymes including cellobiohydrolase, endoglucanase and beta-glucosidase, xylanase, xylosidase, lytic polysaccharide mono oxygenases and several accessory enzymes. A synergistic action of all these results in efficient degradation of lignocellulose. Profiling of these cellulases for major component enzymes revealed that Novozymes had a higher beta-glucosidase and xylanase loading of 7318 IU/mL and 10063 IU/mL respectively (Table 9).

Table 9. Enzyme activity profile of commercial cellulases

| Sl No. | Enzyme Name | Company Name | Protein (mg/mL) | FPUs/mL | BGL (IU/mL) | CMCase (IU/mL) | Xylanase (IU/mL) |
|---|---|---|---|---|---|---|---|
| 1 | Acid cellulase CRD | OM Biosciences | 84.6 ± 1.0 | 100.9 ± 2.4 | 955 ± 7.3 | 21498 ± 220 | 681 ± 9 |
| 2 | BB/ACL/015 | Brisk Bioscience | 49.2 ± 5.3 | 101.9 ± 6.8 | 219 ± 1.8 | 8299 ± 387 | 581 ± 27 |
| 3 | Caprizymes | | 86.6 ± 2.9 | 89.4 ± 2.1 | 983 ± 3.7 | 17548 ± 117 | 717 ± 69 |
| 4 | Code 001 | Basic Dyes & Chemicals | 9.5 ± 2.0 | 46.4 ± 3.9 | 38.8 ± 0.6 | 2282 ± 30 | 233 ± 12 |
| 5 | Code 002 | SVC | 5.6 ± 0.1 | 30.8 ± 0.1 | 18.9 ± 0.0 | 2428 ± 87 | 156 ± 31 |
| 6 | Spirozyme C8 | Spiro Specialties | 6.5 ± 0.6 | 3.75 ± 0.4 | 69.29 ± 2.9 | 2072 ± 49 | 17 ± 1.2 |
| 7 | Ecozyme AE30 | Ecostar | 3.0 ± 0.1 | 3.9 ± 0.1 | 5.9 ± 0.1 | 952 ± 32 | 13 ± 0.6 |
| 8 | Code 003 | Orion Enterprises (Leo Chemicals) | 12.5 ± 0.4 | 0.91 | 19.8 ± 0.2 | 312 ± 79 | 11 ± 0.4 |
| 9 | Novozymes Cellulase | Sigma | 69.7 ± 3.7 | 219.5 ± 12 | 7318 ± 18.8 | 5121 ± 105 | 10063 ± 53 |
| 10 | Supercut | Zytex | 30.5 ± 3.1 | 86 ± 4.6 | 43.9 ± 0.3 | 6447 ± 191 | 424 ± 77 |
| 11 | Saccahriseb | Advanced Enzymes | 32.4 ± 1.3 | 50.2 ± 2.3 | 591 ± 14.7 | 4429 ± 163 | 2838 ± 53 |
| 12 | Code 004 | Orion Enterprises' (Leo Chemicals) | 5.8 ± 0.9 | 0.16 | 12.98 ± 0.1 | 216 ± 22 | 38 ± 4.8 |
| 13 | B190618 | Kaypeeyes | 9.4 ± 0.5 | 28.2 ± 0.7 | 199.8 ± 7.3 | 495 ± 15 | 13875 ± 35 |
| 14 | EAC010120 | Enzyme Bioscience | 8.0 ± 0.5 | 21 ± 3.5 | 16.06 ± 0.1 | 1781 ± 39 | 106 ± 22 |
| 15 | Acid Cellulase Powder | Biolaxi | 2.3 ± 0.1 | 3.3 ± 0.7 | 13.73 ± 0.0 | 235 ± 51 | 676 ± 30 |

Similarly, Advanced cellulase and cellulase from Kaypeeyes had beta-glucosidase activities of 591 IU/

ml and 199 IU/mL respectively. A higher xylanase load may degrade hemicellulose more making larger pores enabling better access of cellulase through the lignocellulose structure to attack cellulose and finally digesting it to release glucose and a higher BGL ensures complete conversion of cellulose to glucose as it prevents cellobiose from accumulating that can inhibit hydrolysis reaction of cellulase. These being the current knowledge on cellulase performance, the study indicated that higher activities of a component enzyme needn't necessarily correlate with the saccharification efficiency. Synergies between component enzymes as well as the peculiarities of them improving their suitability for a particular substrate or for the conditions of hydrolysis may be in play. Further studies to look at their protein profile through Mass spectrometry and expanded hydrolysis profile by using more diverse substrates is being undertaken.

## 8.Non-biofuel products and by-product valorization for biorefineries

### 8.1. Use of metabolically engineered Corynebacterium glutamicum as the cell factory for the production of value added products from lignocellulosic derived sugars

#### A. Xylonic acid production from lignocellulose using engineered Corynebacterium glutamicum

In bacterial system, direct conversion of xylose to xylonic acid is mediated through NAD-dependent xylose dehydrogenase (*xylB*) and xylonolactonase (*xylC*) genes. Heterologous expression of these genes from *Caulobacter crescentus* into recombinant *Corynebacterium glutamicum* ATCC 13032 and *C. glutamicum* ATCC 31831 (with an innate pentose transporter, *araE)* resulted in an efficient bioconversion process to produce xylonic acid from xylose. Initially, media Engineering was carried out through Response Surface Methodology (RSM). To start with 8 factors (media components) were selected for optimization using Plackett Burman Design. Out of which four factors (xylose, urea, $(NH_4)_2SO_4$ and inoculum) showed positive influence on xylonic acid production. Further optimization of the parameters was carried out using Box-Behnken Design. Influence of important parameters is given in Fig 48. Maximum xylonic acid of 56.32 g/L from 60 g/L xylose, i.e. about 76.67% of the maximum theoretical yield was obtained after 120 h fermentation from pure xylose with recombinant *C. glutamicum* ATCC 31831.

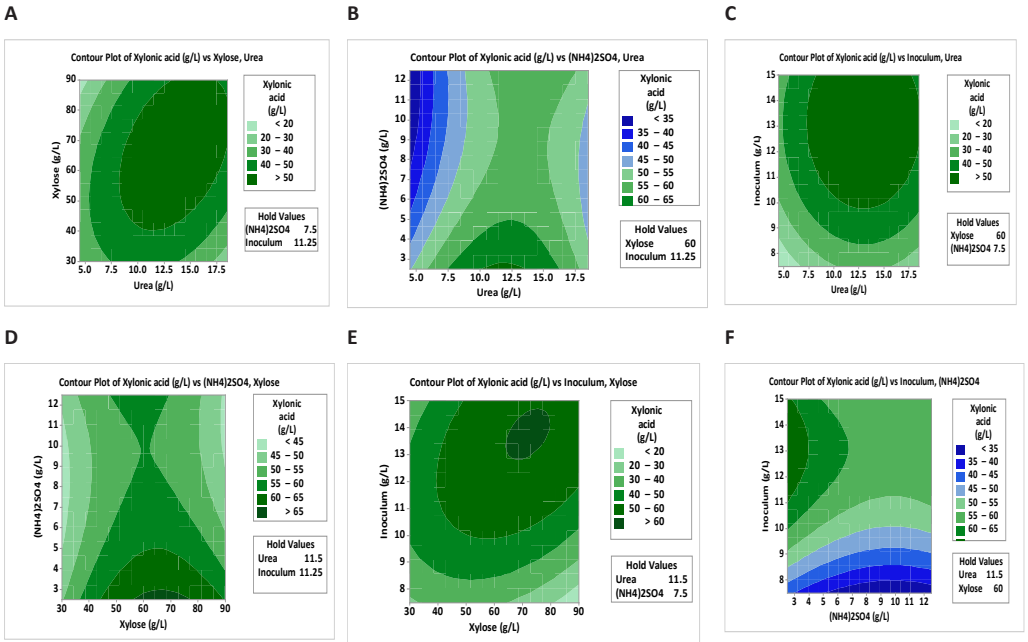



Fig 48. Response Surface Methodology-contour plots showing the effect of various parameters on xylonic acid production by *C. glutamicum* ATCC 31831. (a) Effect of xylose and urea (b) Effect of $(NH_4)_2SO_4$ and urea (c) Effect of inoculum and urea (d) Effect of $(NH_4)_2SO_4$ and urea (e) Effect of inoculum and xylose (f) Effect of inoculum and $(NH_4)_2SO_4$

### B. Direct utilization of Rice Straw Hydrolysate by Engineered *Corynebacterium glutamicum* for the production of 5-Amino Valeric acid and Putrescine

The non-proteinogenic amino acid 5-amino valeric acid (5-AVA) and the diamineputrescine are potential building blocks in the bio-polyamide industry. The production of 5-AVA and putrescine using engineered *Corynebacterium glutamicum (*AVA Xyl and Put Xyl) , by the co-consumption of biomass-derived sugars (glucose and xylose) is an attractive strategy and an alternative to their petrochemical synthesis. Even though, the pure glucose (40 g $L^{-1}$ )gave the maximum product yield by both the strains, the simultaneous utilization of different combinations of pure xylose and glucose by AVA Xyl and PUT Xyl in CGXII synthetic medium was initially validated. A blend of 25 g $L^{-1}$ of glucose and 15 g $L^{-1}$ of xylose in CGXII medium yielded 109.43 ± 2.11 mg $L^{-1}$putrescine and 874.43 ± 0.98 mg $L^{-1}$ 5-AVA after 72h of fermentation. Subsequently, to demonstrate the utilization of biomass-derived sugars, the alkali (NaOH) pretreated-enzyme hydrolyzed rice straw containing a mixture of glucose (23.7 g $L^{-1}$) and xylose (13.6 g $L^{-1}$) was fermented by PUT Xyl and AVA Xyl to yield 91.00 ± 2.58 mg $L^{-1}$putrescine and 260.33 ± 2.47 mg $L^{-1}$ 5-AVA respectively, after 72 h of fermentation. To the best of our knowledge, this is the first proof of concept report on the production of 5-AVA and putrescine using rice straw hydrolysate (RSH) as the raw material (Fig.49)

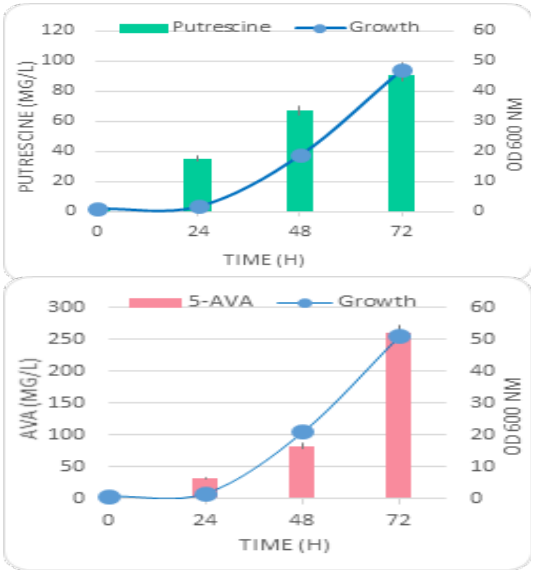



Fig 49. Production of Putrescine and 5-AVA by engineered *C. glutamicum* strains from Rice straw hydrolysate (RSH)

### C. Integrated biorefinery for converting paper mill waste into Lysine using Corynebacteium glutamicum

Paper and pulp industry is one of the biggest industries that generate waste material and waste water. Conversion of the industrial waste to renewable products through green process is one of the recent trends for the production of renewable fuels and other industrially important bioproducts. Lysine is an essential, economically important amino acid used as food and feed supplement. It has also some pharmaceutical applications in the formulation of diets with balanced amino acid composition and in amino acid infusions. L-Lysine has a huge demand as a feed supplement in the pig and poultry industries. Considering the importance and growing worldwide market of lysine, there is constant effort made to improve the entire production process—fermentation processes, optimizing the media conditions, and downstream processes to obtain the final product. Recent progress in this project includes the exploitation of the possibility of using paper rejects hydrolysate for lysine production. under the experimental conditions, after the autoclaving and membrane filtration, the amount of glucose present in the hydrolysate - based medium was determined to be 33 ± 0.9 g/L and from that the maximum lysine titre was 26g/L under optimum conditions (Fig 50 ).

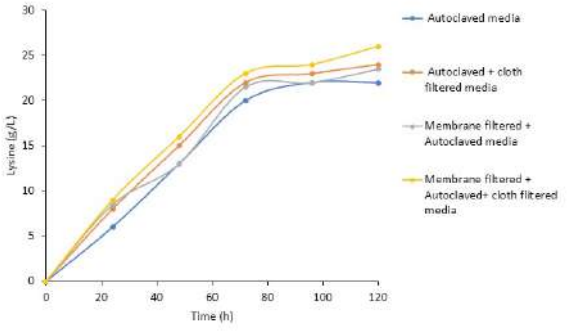



Fig. 50 Lysine production by of *C. glutamicum* DM1729 using paper reject hydrolysate

### 8.2. Development of lignin based wood-adhesive using glyoxal.

Phenol-formaldehyde resin is most common and commercially used wood adhesive. Resin has a huge global demand as reflected by the increase in the phenolic resin market which is projected to reach USD 15.01 billion by 2021. However, environmental

concerns on formaldehyde emission limit the growth of the phenolic resin market. In addition to that both phenol and formaldehyde are chemicals obtained from petroleum industry and hence the price of phenolic resin keeps fluctuating based on the availability of petroleum resource. Hence development of alternative adhesive involving safe and lucrative chemicals is envisaged. The study focused on the replacement of phenol and toxic formaldehyde with phenolic lignin and glyoxal respectively. Lignins were isolated from differentially pretreated sugarcane bagasse (acid and alkali). Lignins derived from above methods were subjected to enzymatic oxidation using Lacasse. Oxidized and unoxidized lignin were further characterized and evaluated for its suitability in the synthesis of lignin based glyoxal resin.

Lignin based glyoxal resin were tested for its physical properties in term of viscosity, % alkalinity, gel time, and total solid content. It was observed that lignin obtained from the enzymatic residue of acid pretreated sugarcane bagasse exhibited better adhesive properties. The resin was further tested for its mechanical performance as wood adhesive (Fig 51). It was observed that purity, polydispersity and molecular weight of lignin largely affect the mechanical performance of the resin as wood adhesive.

Fig. 51. Mechanical testing of formulated lignin-glyoxal adhesive by lap shear method.

# अनुसंधान योजना और व्यवसाय विकास प्रभाग

अनुसंधान योजना और व्यापार विकास प्रभाग (आर पी बी डी) साइंटिस्ट्स और एडमिनिस्ट्रेशन के अलग-अलग विंग्स के बीच लेन-देन करता है जिसमें सीएसआईआर, हेडक्वार्टर और अन्य प्रायोजन एजेंसियां भी शामिल हैं। आर पी बी डी कार्यक्रम समन्वय, परियोजना निगरानी और मूल्यांकन, समीक्षा और रिपोर्टिंग, सीएसआईआर और अन्य बाहरी स्रोतों से प्राप्त वित्तीय संसाधनों के प्रबंधन, प्रौद्योगिकी हस्तांतरण और व्यावसायीकरण में शामिल है। डिवीजन आविष्कार और आईपी / पेटेंट संरक्षण से संबंधित एसएंडटी समर्थन गतिविधि में शामिल है।

विभाजन विशेष रूप से बुनियादी ढांचे और एसएंडटी प्रबंधन आवश्यकताओं के संदर्भ में समय पर कार्रवाई के लिए वार्षिक बजट तैयार करने में शामिल है। उपरोक्त के अलावा, सी एस आई आर के आर & डी कार्यक्रमों की भी निगरानी की जाती है और समीक्षा रिपोर्ट समय-समय पर सी एस आई आर को भेजी जाती हैं। समूह प्रयोगशाला में धन के आवंटन और उपयोग के संबंध में निगरानी अभ्यास भी करता है।

प्रभाग अनुसंधान परिषद और प्रबंधन परिषद दस्तावेजों को तैयार करने में मदद करता है, सी ए जी और सीएसआईआर ऑडिट टीम द्वारा उठाए गए परियोजनाओं से संबंधित ऑडिट पैरा यदि कोई हो तो परियोजना के नेताओं, परियोजना समन्वयकों और संबंधित वर्गों के प्रमुख के साथ समन्वय करके उत्तर प्रदान करता है।

आर पी बी डी ने 2020-21 में 148 बाह्य वित्त पोषित परियोजनाओं और सी एस आई आर से 32 परियोजनाओं के सफल निष्पादन की सुविधा प्रदान की। आरपीबीडी ने छह प्रौद्योगिकी हस्तांतरण और कई निजी उद्योगों के साथ अनुसंधान एवं विकास सहयोग किया। समूह वार्षिक रिपोर्ट 2019-20 और संस्थान के द्विभाषी समाचार पत्र एन आई आई एस टी समाचार और ब्रोशर के प्रकाशन के साथ-साथ प्रयोगशाला को पेश करने के हिस्से के रूप में विभिन्न प्रदर्शनियों का आयोजन करने में शामिल था। इस समूह ने सहयोगी अनुसंधान और विकास के लिए विभिन्न उद्योगों के साथ गठबंधन करने के लिए एक आर एंड डी उद्योग बैठक का आयोजन किया है।

# Research Planning and Business Development

The Research Planning and Business Development Group (RPBD) liaises between the Scientists and different wings of administration including accounts and also with the CSIR Headquarters and other sponsoring agencies. RPBD is involved in the programme coordination, project monitoring and evaluation, reviewing and reporting, management of financial resources received from CSIR and other external sources, technology transfer and commercialization. The division is involved in S&T support activity relating to inventions and IP/Patent Protection.

The division is involved in the preparation of annual budget for timely action particularly with reference to infrastructure and S&T Management requirements. In addition to the above, R&D programmes of CSIR are also monitored and the review reports are periodically sent to CSIR. The group also does the monitoring exercise with respect to allocation and utilization of funds in the laboratory.

The division helps in the preparation of Research Council and Management Council documents, providing reply to Audit para raised by CAG and CSIR Audit team if any, related to projects in consultation with project leaders, project coordinators and Head of the respective sections.

RPBD facilitated the successful execution of 148 externally funded projects and 32 projects from CSIR 2020-21. RPBD catalyzed six technology transfers and R & D collaboration with a good number of private industries. The group was involved in bringing out the Annual Report 2019-20 and Publication of Institute's Bilingual Newsletter NIIST SAMACHAR and brochures as well as conducting various exhibitions as part of projecting the laboratory. The group has organized a R&D Industry Meet, to forge alliance with various industries for collaborative Research and Development.

# Research Planning and Business Development
# Contract Research Projects 2020-21

| PROJECT TITLE | CLIENT | PROJECT LEADER |
|---|---|---|
| **AGRO PROCESSING & TECHNOLOGY DIVISION** | | |
| Analytical, chemical, spectral and cytotoxocity studies of Zingi Vir-H | M/s Pankajakasthuri Herbal Foundation | Dr P Nisha |
| Bio processing of two coded anti-diabetic medicinal plants based on ethno medical leads- A molecular pharmacological approach | Department of Biotechnology (DBT) | Dr P Jayamurthy |
| Design and development of an eco-friendly post-harvest technology for simultaneous dehydration and disinfection of agro crops | Department of Science & Technology (DST) | Mr T Venkatesh |
| Development of analytical protocols for detection of vegetable oil adulteration | M/s KLF Nirmal Industries Pvt Ltd | Mr V V Venugopal |
| Development of biflavonoid based lead molecule (NIIST -OBT-2) from Garcinia travancorica for non-alcoholic fatty liver disease | Dept. of Health Research, New Delhi | Dr G Sindhu |
| Development of guar gum nano particle based mitochondrial antioxidants for cardiac hyper trophy | Dept. of Health Research, New Delhi | Dr R S Soumya |
| Development of instant rice and broken wheat porridge | M/s Manjilas Food Tech Pvt Ltd | Dr P Nisha |
| Development of novel leads for anti-obesity from North East traditional system through chemistry biology interphase | Department of Biotechnology (DBT) | Dr K G Raghu |
| Enhancement of the stability & acceptability for newly developed products | M/s Pankajakasturi Herbals India Ltd, TVM | Mr V V Venugopal |
| Evaluating the medicinal properties (weight reducing, immunomodulation and lipid lowering property) of KLFs virgin coconut oil | M/s KLF Nirmal Industries Pvt Ltd | Dr K G Raghu |
| Evaluation of beneficial effect of Boeravinone-B from Boerhaavia diffusa against diabetic cardiomyopathy through mitochondria mediated pathway in H9c2 cardiomyoblast and heart for development of nutraceuticals | Dept. of Health Research, New Delhi | Mr Salin Raj |
| Identification of proprotein convertase subtilisin kexin-9 (PCSK-9) inhibitors from Garcinia cambogia | Dept. of Health Research, New Delhi | Dr G L Shyni |

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| Investigation of resveratrol based compounds from Dipterocarpaceae family for their anti-diabetic potential | *Kerala State Council for Science, Technology and Environment* (*KSCSTE*) | Dr P Jayamurthy |
| Modernization of jaggery production units -initiative towards energy efficient hygienic jaggery production | Department of Science & Technology (DST) | Mr T Venkatesh |
| Novel antibacterial compounds from marine streptomyees strains associated with four mangrove species from selected regions of Kerala coast for curbing resistant acquired pathogens with special reference to methicillin resistant staphylococcus aureus | *Ministry of Earth Sciences* (*MoES*) | Dr B S Dileepkumar |
| Phytochemical evaluation of pre-treated samples | M/s Pankajakasthuri Herbal Foundation, Kattakada | Dr P Nisha |
| Post-harvest operations for value addition of indigenous fruits and vegetables | Dept. of Agriculture , Government of Kerala | Dr P Nisha |
| Process development for oil/fat to powder by encapsulation for food and nutritional application | Department of Science & Technology (DST) | Dr P Nisha |
| Product development and stability for milk based herbal extract formulation | M/s Arya Vaidya Pharmacy | Mr V V Venugopal |
| Setting up processing unit for dehydrated fruits and vegetables | Horticorp, Thiruvananthapuram | Dr P Nisha |
| Setting up processing unit for dehydrated fruits and vegetables | Horticorp, Thiruvananthapuram | Dr P Nisha |
| Significance of mitochondria associated ER membrane (MAM) in the genesis of diabetic cardiomyopathy | Dept. of Health Research, New Delhi | Ms Anupama Nair |
| Spice essential oil based nanoencapsulates as natural preservatives | Spices Board | Dr P Nisha |
| Technological solutions to normalize the quality parametres during refining and to fractionate the fatty acids | M/s KSE Ltd | Dr V V Venugopal |
| Technology development & incubation activities for processing of traditional millets & herbs | Directorate of Agriculture | Mr V V Venugopal |
| Technology development for value addition/preservation of coconut water | Coconut Development Board | Mr V V Venugopal |
| Valorization of spent turmeric/amla: Process development for antioxidant dietary fibre enriched products as metabolic enhancers | Biotechnology Industry Research Assistance Council (BIRAC) | Dr P Nisha |

| CHEMICAL SCIENCES & TECHNOLOGY DIVISION | | |
|---|---|---|
| Activity guided screening of phospho diestrease inhibitors from Indian medicinal plants to treat erectile dysfunction | Indian Council of Medical Research (ICMR) | Dr A Kumaran |
| Biocompatible combined polymer polysaccharide core-shell VEGF-Targeted Nano-Carrier for sustained Intraocular pharmacotherapy towards diabetic retinopathy | Department of Biotechnology | Dr K K Maiti |
| Design and development of bio-based novel liquid crystalline conductive electrodes and electrolytes for high performing flexi-energy storage devices | Department of Science & Technology (DST) | Dr Saju Pillai |
| Design and development of efficient , stable and cost effective organic dyes for application in dye-sensitized solar cells | Science and Engineering Research Board (SERB) | Dr A Ajayaghosh |
| Design and processing of nano structured hybrid composite materials for electro chemical energy storage | Department of Science & Technology (DST) | Dr K Narayanan Unni |
| Design and synthesis of novel iminosugar variants and their cationic amphiphiles as antiviral therapeutics against Dengue Virus (DENV) | Department of Biotechnology (DBT) | Dr L Ravishankar |
| Development of advanced thermoelectric modules with superior performance in TEG and TEC modes | M/s GAIL(India) Ltd | Dr Biswapriya Deb |
| Development of Knowledge base on pharmaceutical formulations | Kerala State Drugs Pharmaceuticals Limited (KSDPL) | Dr A Kumaran |
| Development of multiplexing detection platform of breast cancer biomakers by non-invasive Surface Enhanced Raman Scattering (SERS)- Nanoprobe | Department of Science & Technology (DST) | Dr K K Maiti |
| Development of novel NIR absorbing sensitizers and their nano-conjugates for the multi model cancer imaging and therapy | Department of Biotechnology (DBT) | Dr Joshy Joseph |
| Development of quantum chemical descriptor (QCD) based method for screening | Science and Engineering Research Board (SERB) | Dr C H Suresh |
| Digitally connected tribal colonies | Medical Electronics & Health Informatics Division | Dr Yoosaf Karuvath |
| Dynamic molecular, supramolecular and surface chemistry for spatiotemporal modulation of smart advanced functional materials | Science and Engineering Research Board (SERB) | Dr Sreejith Shankar Pooppannal |

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| Dynamic molecular, supramolecular and surface chemistry for spatiotemporal modulation of smart advanced functional materials | Department of Science & Technology (DST) | Dr Sreejith Shankar Pooppannal |
| Engineering intelligent theranostic nanocarrier for targeted therapy and diagnosis of Cancer | Science and Engineering Research Board (SERB) | Dr.K K Maiti |
| Engineering Nanostructured surfaces for Developing SERS Sensing Platform | Department of Biotechnology (DBT) | Dr.Yoosaf Karuvath |
| Experimental and theorectical investigation on lead free perovskites for opto electronic applications | Science and Engineering Research Board (SERB) | Dr C Vijayakumar |
| Exploration of the structures and bioactivities of semi-synthetic and glycoside derivatives of abundant natural products from the Western Ghats of India and East Java, Indonesia | Science and Engineering Research Board (SERB) | Dr L Ravishankar |
| Fabrication of portable (Handheld) SERS system for explosive chemicals detection and unique identification | Defence Research and Development Organisation (DRDO) | Dr.Yoosaf Karuvath |
| Fluorescent molecules and assemblies for sensing and imaging (J C Bose Fellowship) | Department of Science & Technology (DST) | Dr A Ajayaghosh |
| Indigenous development of Semi-automatic equipments for large area dye-sensitized solar module fabrication | Ministry of Science & Technology, DST | Dr K Narayanan Unni |
| Large area opto-electronics for Australia and India : From materials to advanced devices | Department of Science & Technology (DST) | Dr A Ajayaghosh |
| Mechanical stimulation induced microscopic crystalline structure changes in molecular materials: Implications on drug formulation and mechanochromic behavior | Science and Engineering Research Board (SERB) | Dr Sunil Vargheese |
| Microfluidic two-photon lithography Raman Spectroscopy (μTPL-RS) system for 3D printing functional microdevices | Department of Science & Technology (DST) | Dr Yoosaf Karuvath |
| Nanomechanical response in organic crystals: Molecular basis of mechanically induced structural transformations | Science and Engineering Research Board (SERB) | Dr Sunil Varughese |
| Nature Inspired chemical entities for healthcare applications | Science and Engineering Research Board (SERB) | Dr B S Sasidhar |

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| New therapeutics agains SARS Cov2: analyzing small molecule chemical libraries by establishing targeted cell based assays for inhibitors of viral entry & viral protease | Department of Biotechnology (DBT) | Dr L Ravishankar |
| Novel strategies for the generation of long lived photo induced charge separated states in donor-acceptor systems | Science and Engineering Research Board (SERB) | Dr K R Gopidas/ Dr Karunakaran Venugopal |
| Probing interfacial device dynamics in highly efficient copper electrolyte based dye-sensitized solar cells for indoor photovoltaics | Science and Engineering Research Board (SERB) | Dr Suraj Soman |
| Revealing the interaction mechanism of the protein with lipids in the apoptosis process: electronic, vibrational and confirmational relaxation dynamics of the heme in the liposomes | Department of Biotechnology (DBT) | Dr. Karunakaran V |
| Screening and characterization of some selected phytomedicines in Homeopathy | Government Homeopathic Medical Collage, Thiruvananthapuram | Dr K V Radhakrishnan |
| Sustainable utilization of abundant natural resources: Synthetic transformations of zerumbone and germacrone towards chemically diverse sesquiterpenoid architectures | Science and Engineering Research Board (SERB) | Dr K V Radhakrishnan |
| Synthesis of a novel lipid-linked oligosaccharride and its evaluation as vaccine adjuvant | Science and Engineering Research Board (SERB) | Dr L Ravishankar |
| Towards cost-effective fabrication of white OLEDS for solid-state lighting: How to address process complexity and optimal usage of materials | Science and Engineering Research Board (SERB) | Dr K Narayanan Unni |
| **ENVIRONMENTAL TECHNOLOGY DIVISION** | | |
| Common research and technology development- Hub for environmental intervention in the MSME Sector | Science and Engineering Research Board (SERB) | Dr K P Prathish |
| Development and field demonstration of waste management systems for a medium scale industry | M/s Jai Hari Food Products, Pathanamthitta | Dr B Krishnakumar |
| Field demonstration and performance evaluation of integrated bio-physical system for generating drinking water from perchlorate contaminated ground water | *Kerala State Council for Science, Technology and Environment* (*KSCSTE*) | Mrs Jasmine G Russel |
| Installation of 50kg/D biogas plant at campus TVM | Reserve Bank of India, Thiruvananthapuram | Dr B Krishnakumar |

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| Novel hybrid nanostructured surface modified electrodes for sensors and biosensors | Department of Science & Technology (DST) | Dr K P Prathish |
| Water characterization for pond renovation | Government Engineering College, Thiruvananthapuram | Dr Abdul Haleem |
| **MATERIALS SCIENCE & TECHNOLOGY DIVISION** | | |
| Adsorbents for gas and vapour molecules. Rational design of materials , porous nano structures and surface chemistry | Noritake, Japan | Dr U S Hareesh |
| Bleaching studies of Kaolin mineral resource in Karnataka State Region | Karnataka State Minerals Corporation Ltd | Dr S Ananthakumar |
| Centre of Excellence for light weight material technologies | M/s WABCO India Ltd | Dr T P D Rajan |
| CFD and kinetic modelling of CVD reactor for TiO2 deposition on float glass at atmospheric pressure | M/s Asahi India Glass Ltd, Mumbai | Dr Adersh Asok |
| Chemical functionalization of Si with 2D structures: Anode materials for lithium ion battery with significantly improved volumetric capacity | Department of Science & Technology (DST) | Dr Saju Pillai |
| Dark-catalytic and planar solar-concentrator based reactors for removal of organic pollutants from textile effluents | Department of Science & Technology (DST) | Dr Satyajit V Shukla |
| Design and development of bioactive and biodegradable rare earth free Mg based alloys and coatings for third generation bio-implant application | Department of Science & Technology (DST) ASEAN | Dr A Srinivasan |
| Design and development of near net shape manufacturing process for light weight high strength aluminium composite and engineering components by squeeze infiltration technique for automotive and aerospace applications | Indo German Science And Technology Centre (IGSTC) | Dr T P D Rajan |
| Development of wearable electronic -skin patch for real -time monitoring of human health parameters and tactile sensing | Department of Science & Technology (DST) | Dr Achu Chandran |
| Development and evaluation of materials for the selective removal of carbon dioxide from flue gases and natural gas streams | ONGC | Dr U S Hareesh |
| Development and in-vitro Characterization of magnesium alloys for biocompatible and biodegradable implant applications | Science and Engineering Research Board (SERB) | Dr A Srinivasan |

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| Development and invitro characterization of rare earth phosphate coatings for biodegradable and biocompatible magnesium based temporary implants | Indian Council of Medical Research (ICMR) | Dr A Srinivasan |
| Development of a miniaturized and portable laser induced breakdown spectroscopy LIBS set up for fast identification and sorting of different plastic classes | Department of Science & Technology (DST) | Dr E Bhoje Gowd |
| Development of binder less coir boards: A greener alternative product to wood panels for building applications | National Coir Research & Management Institute (*NCRMI*) | Dr Sushanta Kumar Sahoo |
| Development of Biodegradable mulching mats using coir-polymer systems | National Coir Research & Management Institute (*NCRMI*) | Dr Saju Pillai |
| Development of ceramic membranes and setting up of a pre-pilot plant manufacturing facility | Department of Science & Technology (DST) (TSDP) | Dr U S Hareesh |
| Development of disposable plates using coconut husk | Mr T P Aboobacker Sundus Villa, Sripushkaram P O, | Dr K I Suresh |
| Development of graphene based membranes from graphite ore for desalination | Ministry of Mines | Dr S S Sreejakumari |
| Development of Iridium coating over carbon-carbon composites for space applications | Indian Space Research Organisation (ISRO), Thiruvananthapuram | Dr S S Sreejakumari |
| Development of iron aluminide coated high performance steels | Department of Science & Technology (DST) | Dr K Jayasankar |
| Development of light weight functionally graded metal- ceramic composite armour materials for defence applications | ARMREB, New Delhi | Dr T P D Rajan |
| Development of Light weight near net shape aluminium composite substrates for thermal management in electronic and avionic packaging systems | Department of Science & Technology (DST) | Dr T P D Rajan |
| Development of Lightweight Aluminum based Crankcase for Automotive Air Compressor Brake Systems | M/s WABCO India Ltd | Dr T P D Rajan |
| Development of magnetically modulated therapeutically active layered double hydroxide(LDH) as a nanomedicine with hyperthermia potential for cancer theranostics | Science and Engineering Research Board (SERB) | Dr Manoj Raama Varma |
| Development of polymer coir composites for electrical insulation | National Coir Research & Management Institute (*NCRMI*) | Dr Bhoje Gowd |

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| Development of sustainable pressure sensitive adhesives from bio-sourced pre-polymers: A green alternative for semi-structural applications | Science and Engineering Research Board (SERB) | Dr Sushanta Kumar Sahoo |
| Development of ZrB2-SiC-HfC and ZrC-SiC-HfC Super strong materials by thermal plasma process for temperatures exceeding 2000 degree celsius | Indian Space Research Organisation (ISRO), Thiruvananthapuram | Dr K Jayasankar |
| Green Synthesis of Warm White Light Emitting Single Phase Oxyfluoride Phosphors for Thermally Stable, Energy Efficient, and Elevated color Rendering LED Lamps. | Science and Engineering Research Board (SERB) | Dr Subrata Das |
| Improvement of Flux Pinning in Bi-based superconductor Tapes | Science and Engineering Research Board (SERB) | Dr Manoj Raama Varma |
| Investigation of Zintl phases as efficient thermoelectric materials for energy conversion | Science and Engineering Research Board (SERB) | Dr Manoj Raama Varma |
| Large-Scale Production of Coir/Polymer Composites for Acoustic Applications | National Coir Research & Management Institute (*NCRMI*) | Dr V S Prasad |
| Nanowire white LEDs based on innovative nano phosphors | Department of Science & Technology (DST) | Dr Subrata Das |
| Pilot scale manufacturing of innovative building materials from industrial solid wastes | M/s Star Clays | Dr S Ananthakumar |
| Pilot scale processing of high Strength Al-Si-Cu-Mg-Sr alloy and prototype flange, suspension arm and knuckle component manufacturing by squeeze casting | M/s Sri Kaliswari Metal Powders Pvt Ltd | Dr M Ravi |
| Pilot scale squeeze casting technology development of high strength aluminium alloy products for strategic and automotive applications | Ministry of Science & Technology | Dr M Ravi |
| Process development for precision planar optics patterning in the float glass surface via hot forming | Asahi India Glass Ltd, Mumbai | Dr Adersh Asok |
| Processing of CeO2 Nanoparticles for energy saving glaze coatings and cool textiles | Indian Rare Earths *Limited, Kollam* | Dr S Ananthakumar |
| Production of polymer/coir composites for furniture Application | National Coir Research & Management Institute (*NCRMI*) | Mr M Brahmakumar |
| Quantitative assessment of hot tearing characteristics of aerospace magnesium alloys using instrumented constrained rod casting (CRC) technique | Aeronautical Research and Development Board | Dr A Srinivasan |

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| Recovery of Scandium , TiO2 and Iron from red mud wastes of aluminum industries | Science and Engineering Research Board (SERB) | Dr K Jayasankar |
| Recovery of scandium metal from acid leach liquor from titanium mineral industries | Ministry of Mines | Dr M Sundararajan |
| Self-powered electro-optical memory devices for next generation display and data storage application | Science and Engineering Research Board (SERB) | Dr Achu Chandran |
| SMART FOUNDARY (SMART= Sustainable Metal casting using Advanced Research and Technology | Department of Science & Technology (DST) | Dr S Savithri |
| Synthesis and characterization of broad spectrum ultraviolet filter with visible light emission and antioxidant activity: A potential multifunctional active ingredient with multitude of applications | Department of Science & Technology (DST) | Dr Adersh Asok |
| Technical support to flow + solver code of Autocast XI | M/s 3D Foundry Tech Pvt Ltd | Dr S Savithri |
| X-ray photoelectron spectroscopy (XPS) of metallic powder samples of VSSC, Thumba, Trivandrum | Vikram Sarabhai Space Center (VSSC), Thiruvananthapuram | Dr Saju Pillai |
| **MICROBIAL PROCESSES AND TECHNOLOGY DIVISION** | | |
| Characterization, recombinant expression, process scale up validation of selected hydrolases from native action bacteria for commercial exploitation | Department of Biotechnology (DBT) | Dr Rajeev K Sukumaran |
| Deciphering interacting partners of PAMPs / Effectors of collechotrichium falcatum that trigger innate immunity in sugarcane | Department of Biotechnology (DBT) | Dr Rajeev K Sukumaran |
| Development of a bioprocess for the commercial production of the plant growth stimulant Gibberellic acid GA3 | Biotechnology Industry Research Assistance Council (BIRAC) | Dr Madhavan Nampoothiri |
| Development of a gene expression platform for heterologous protein production in the filamentous fungus Aspergillus unguis | Department of Biotechnology (DBT) | Dr Rajeev K Sukumaran |
| Development of a sustainable process for the production of poly-3-hydroxybutyrate using kitchen and food waste | Department of Science & Technology (DST) | Dr R Sindhu |
| Direct utilization of agro residual biomass for the production of $\alpha,\omega$-diamines as well as $\alpha,\omega$–amino acids: strain and process development using Corynebacterium glutamicum | Department of Biotechnology (DBT) | Dr Madhavan Nampoothiri |
| Holistic processes and practices for clean energy in strengthening bio economic strategies | Department of Science & Technology (DST) | Dr P Binod |

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| Integrated bio refinery for converting paper mill waste into chemical wealth | Department of Biotechnology (DBT) | Dr P Binod |
| Investigation of the dynamics & mechanism of flocculation by polymers and biopolymers for separation of solid particles of high rate thickeners in mineral processing industries | Ministry of Mines | Dr.Rakesh Kumar Yasarla |
| Investigation on identification and biochemical validation of selenoproteins from Nannochloropsis oceanica CASA CC201 as functional food/ feed supplements | Science and Engineering Research Board (SERB) | Dr Muthu Arumugham |
| Microbiome analysis of saline tolerant Pokkali rice varieties of coastal agri saline fields(Pokkali and Kaippad tract) of Kerala and evaluating their core endophyte beneficial rhizobacteria for enhancing rice growth under saline conditions | Department of Biotechnology (DBT) | Dr N Rameshkumar |
| Molecular and functional characterization of active saline adapted nitrogen fixing plant growth promoting bacteria of native grown coastal saline tolerant rice varieties (Pokkali) of Kerala | Science and Engineering Research Board (SERB) | Dr N Rameshkumar |
| Quantification of substrate across membrane proteins | Department of Biotechnology (DBT) | Dr Harsha Bajaj |
| Quantifying molecular transport in membrane proteins using novel optofluidic assay | Department of Biotechnology (DBT) | Dr Harsha Bajaj |
| Study on chemo-enzymatic transformation of lignin derived from lignocellulosic biomass for potential application as adhesives | Department of Science & Technology (DST) | Dr Leena Perumal |
| Technical Consultancy to Greenisle Solutions Pvt Ltd | M/s Greenisle Solutions Pvt Ltd | Dr Madhavan Nampoothiri |
| Validation of the bioprocess for phytase production | M/s Tata Chemicals Limited | Dr Madhavan Nampoothiri |

# Consultancy Programmes

| Sl No | CLIENT | PROJECT TITLE | PROJECT LEADER |
|---|---|---|---|
| | M/s Aura Exim, Ernakulam | Wheat Bran Waste Processing | Dr Anjineyalu |
| | M/s Samurdhi, BLFO | Setting up processing unit vegetable processing unit | Dr P Nisha |
| | M/s Avisa Biotech Pvt Ltd, Mumbai | Fermentation and scale up trials melanin production at 150L scale | Mr M Kiran Kumar |
| | M/s Avisa Biotech Pvt Ltd, Mumbai | Fermentation and scale up trials melanin production at 150L scale | Mr M Kiran Kumar |
| | M/s CML Biotech Pvt Ltd, Ernakulam | Pre commercial feasibility studies on flocculent based disinfection systems and modifications of the process | Dr A Ajayaghosh |
| | M/s Marikar Green Earth Pvt Ltd, Thiruvananthapuram | Manufacturing of biodegradable tableware using rice bran and rice husk | Dr Saju Pillai |
| | Indian Rare Earth Ltd., Kollam | EIA and EMP study for IREL NK Block-II & NK Block-II EE | Dr J Ansari |
| | Kerala Minerals and Metals Ltd. (KMML), Kollam | EIA study for KMML I V VII Phase II | Dr J Ansari |
| | M/s Pankajakasthuri Herbals India Pvt. Ltd., Thiruvananthapuram | Analysis and interpretation of Arsenic lead , cadmium and Mercury in ayurvedic formulation | Dr K P Prathish |
| | Kerala State Remote Sensing and Environment Centre *(KSREC)* | Sampling and quality analysis of water from Kanjirapuzha and Pothundi rivers | Mr Abdul Haleem |
| | CSIR-NEERI, Nagpur | Study on dioxins and furans emissions in air, ash/soil samples in small incinerators | Dr K P Prathish |
| | MG University, Kottayam | Study on dioxins, furan and dioxin-like PCB levels in sediment samples | Dr K P Prathish |
| | M/s Cella Space Ltd, Ernakulam | Assessment of plastic contaminated soil vis-à-vis recommendations for its reuse at Cella Space Ltd | Mr Akshay Shende |
| | Indian Rare Earth Ltd., Kollam | Impact assessment studies for carrying out mining of Beach sand minerals on either side along the TS canal situated in IREL Block IV EE, Chavara, Kollam | Mr Saurabh Sakhre |
| | CSIR-NEERI, Nagpur | Study on dioxins, furan emission levels from Sanchar Unit | Dr K P Prathish |
| | Kerala State Pollution Control Board | Inventory of Electrical and Electronic Equipment's(EEE) waste under Guidelines on implementation of E waste Management | Mr Saurabh Sakhre |
| | M/s Marine Products Exports Development Authority | Study on dioxins, furan and dioxin-like PCBs in fish samples | Dr K P Prathish |
| | SCTIMST, Poojappura | Method development and analysis of heavy metals in tissues | Dr K P Prathish |

# Technology transfer agreements during the period 2020-21

| Sl No | Title | Name of the firm/firms with whom the MoU / Agreement is entered into | Project leader |
|---|---|---|---|
| 1 | Knowhow for making Trikatu syrup | Trivandrum district palm products development cooperative federation Ltd, Neyyattinkara | Dr M V Reshma |
| 2 | Knowhow for automatic hand sanitizer | M/s Tachlog Pvt Ltd., Thiruvananthapuram | Dr Achu Chandran |
| 3 | Knowhow for automatic Air sanitizer | M/s Ecocure technologies Thiruvananthapuram | Dr B Krishnakumar |
| 4 | Knowhow for automatic hand sanitizer | M/s Cabeio Technologies, Thiruvananthapuram | Dr J Ansari |
| 5 | Know how for NIIST air sanitizer | Mr Mohanan, Malappuram | Dr B Krishnakumar |
| 6 | Licensing fee for NIIST UV-Clean disinfecting unit | M/s Panchtatva technologists and services, Ambernath (E) | Dr Partha Kundu |
| 7 | Licensing of know-how for aerodynamically designed reusable stopgap facemask (SFM) | Mr Varun Kumar K V, M/s AVK Toolings, Thiruvananthapuram | Dr Adersh Asok |
| 8 | A system and a method for onsite wastewater treatment and resource recovery | Mr Ahmed Bilal, S/o Mohammed Pareri, Pareri House, Paivalike P O, Kasargod-671 348 | Dr B Krishnakumar |
| 9 | Setting up an industrial unit to manufacture eco-friendly & biodegradable products | M/s Marikar Motors Limited, Thiruvananthapuram | Dr Saju Pillai |
| 10 | Agreement for technology transfer and subsequent consultancy for setting up of plant for agro waste processing | M/s Marikar Motors Limited, Thiruvananthapuram | Dr Anjineyalu |
| 11 | Know how for novel raw nendran banana grit and combo of nendran and green gram | M/s Moza Organic Pvt Ltd, Ernakulam | Dr M V Reshma |
| 12 | "Wheat bran based cutleries" | M/s Aura Exim, Ernakulam | Dr Anjineyalu |
| 13 | Knowhow for making of invisible fluorescent dyes and pigments | M/s Huebright Colors Private Limited, Bangalore | Dr C Vijayakumar |

# Other MoUs/ Agreements Signed

| Sl No | Title | Nature of the MoU | Name of the firm/firms with whom the MoU/Agreement is entered into | Project leader |
|---|---|---|---|---|
| 1 | Development of instant rice porridge, instant rice porridge with legumes & instant wheat broken | Agreement for Sponsored Research | M/s Manjilas Food Tech Pvt Ltd. 3/49/1, Sasthri Road, Nellikkunnu, Thrissur-5 | Dr P Nisha |
| 2 | Flocculent based disinfection system for pathogenic medical waste diposal | Mutual Non Disclosure Agreement | M/s CML Biotech (P) Ltd., 4/434 B, Karukutty , Angamaly-683576 | Dr U S Hareesh |
| 3 | Superhydrophobic and antimicrobial materials, formulations and coatings | Mutual Non Disclosure Agreement | M/s Aerofil Filters India Private Limited, House No 58C, 34 Choice Village Nadama, Tripunithura, Ernakulam-682 301 | Dr U S Hareesh |
| 4 | Analysis and interpretation of Arsenic lead , cadmium and Mercury in ayurvedic formulation | Deed of Variation | M/s Pankajakasthuri Herbals India Pvt Ltd, Poovachal, Thiruvananthapuram | Dr K P Prathish |
| 5 | Analytical, chemical, spectral and cytotoxocity studies of Zingi Vir-H | Agreement for Sponsored Research | M/s Pankajakasthuri Herbals Research Foundation, Ayurvda medical college, Kattakada, Thiruvananthapuram | Dr P Nisha |
| 6 | Agreement with GTRE | Non Disclosure Agreement | Gas Turbine Research Establishment, Bangalore | Dr T P D Rajan |
| 7 | Development of disposable plates using coconut husk | Agreement for Sponsored Research | Mr T P Aboobacker Sundus Villa, Sripushkaram P O, Panjal, Cheruthuruthy, Thrissur-679531 | Dr K I Suresh |
| 8 | Development of polymer coir composites for electrical insulation | Agreement for Sponsored Research | NCRMI, Kudappanakkunu P O, Thiruvananthapuram | Dr E Bhoje Gowd |
| 9 | Development of binderless coir boards: A greener alternative product to wood panels for building applications | Agreement for Sponsored Research | NCRMI, Kudappanakkunu P O, Thiruvananthapuram | Dr Sushanta Kumar Sahoo |
| 10 | Evaluating the sensory acceptability of the banana grit and banana powder samples | Material Transfer & Confidentiality Agreement | Ms Leena V, Aswathy, Karippur, Malayinkil P O, Trivandrum | Dr M V Reshma |
| 11 | Development of organic based fluorescent pigments for currency and security applications | MoU | Security Printing and Minting Corporation of India Ltd, Ministry of Finance, New Delhi | Dr C Vijayakumar |
| 12 | Establishing an incubation centre for light weight material technologies | Research and Development Collaboration Agreement | WABCO India Limited,Plot. No.Third Main Road,Ambattur Indutrial Estate,Chennai-600058 | Dr T P D Rajan |
| 13 | Validation of the bioprocess for phytase production | Agreement for Sponsored Research | M/s TataChemicals, Bombay House, 24, Homi Modi Street, Fort, Mumbai | Dr Madhavan Nampoothiri |

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|---|---|---|---|---|
| 14 | Phytochemical evaluation of pretreated samples | Agreement for Sponsored Research | M/s Pankajakasthuri Herbals Research Foundation, Ayurvda medical college, Kattakada, TVM | Dr P Nisha |
| 15 | Indigenous fabrication of trasparent conductiong oxide (TCO) coatings by spray pyrolysis for dye sensitized solar cell applications | MoU | Delgado Coating & Technology Solutions Pvt Ltd, Kochi | Dr Suraj Soman |
| 16 | Scentific and technical cooperation in the area of building integrated photovoltaics (BIPV) | MoU | University of Applied Sciences & Arts of Southern Switzerland (SUPSI), Swiss Confederation | Dr Adersh Asok |
| 17 | Customized portable Raman Spectrophotometric device for multiplex detection of brest cancer of biomarkers | MoU | M/s Vinvish technologies Ltd, Thejeswani Buildings, Technopark , Thiruvanathapuram | Dr Yoosaf Karuvath |
| 18 | Development and valuation of materials for selective removal of carbon dioxide from flue gases and natural gas streams | MoU | ONGC ENERGY Centre Trust, 8th floor, Core 3 &4, Scope Minar, Laxmi Nagar, New Delhi-110092 | Dr U S Hareesh |
| 19 | E waste Inventory in the Kerala State | MoU | Kerala State Pollution Control Board | Mr Saurabh Sakhre |
| 20 | Manufacture of edible & biodegradable products from wide range of agro residues | Mutual Non Disclosure Agreement Technology Transfer & Consultancy | M/s Greennovate Eco Solutions Private Limited, Godown In Kh No 1093, 39-B, Groun Floor, Aya Nagar, New Delhi-110047 | Dr Anjineyalu |
| 21 | Development of Knowledge base on pharmaceutical formulations | MoU | Kerala State Drugs and Pharmaceuticals Ltd, Kalavoor, Alappuzha | Dr A Kumaran |
| 22 | Pre Commercial feasibility studies on flocculent based disinfection systems and modifications of the process | MoU | CML Biotech Pvt Ltd, 4/434B, Karukutty P O, Angamaly, Ernakulam-683576 | Dr Sreejith Shankar |
| 23 | Wheat bran based cutleries | Deed of Variation | M/s Aura Exim 11/916-B, Gokulam, Thuthiyoor Road, Rajeev Gandhi Junction, Behind Special Economic Zone, Ernakulam | Dr AnjIneyalu |
| 24 | Computational modelling and simulation for Chemical Vapour Deposition (CVD) of TiO2 on float glass | MoU | M/s Asahi India Glass Ltd, 2nd floor, Tribhuwan Cxomplex, Ishwar Nagar, Mathura Road, New delhi 110065 | Dr Adersh Asok |
| 25 | MoU with Autokast Ltd | MoU | M/s Autokast Ltd, SN Puram P O, Cherthala, Alappuzha | Dr S Ananthakumar |
| 26 | Knowhow for making of invisible fluorescent dyes and pigments | Deed of Variation | M/s Huebright Colors Private Limited, No.223 AB, Classic Orchards, 4th Main 7th Cross, behind Meenakshi Temple, Bannerghatta Road, Bangalore | Dr C Vijayakumar |

# Patents

## Granted in India

| Patent No | Title | Grant Date | Inventors |
|---|---|---|---|
| 353011 | Fluorescent material for self-erasable writing, authentic security labeling, currency counterfeit prevention and processes for the preparation thereof | 04-Dec-20 | Ayyappanpillai Ajayaghosh, Rajasekaran Thirumalai Kumaran |
| 357742 | Lanthanum phosphate based coatings and monoliths as non-reactive surfaces for molten metals | 03-Feb-21 | Sankar Sashidharan, Rajesh Komban, Abdul Azeez Peer Mohamed, Solaiappan Ananthakumar, Unnikrishnan Nair Saraswathy Hareesh, Krishna Gopakumar Warrier |
| 358637 | A method for anaerobic process coupled separation and refining of plant materials | 15-Feb-21 | Vattackatt Balakrishnan Manilal, Ajit Hardas |

## Granted abroad

| Patent No | Title | Grant Date | Inventors |
|---|---|---|---|
| 6700200 | New Inorganic Blue pigments from Cobalt doped Magnesium having Transition Element Oxides and a Process for the preparing the same | 07-May-20 | Padala Prabhakar Rao, Saraswathy Divya |
| 1066126 | Semiconductor-oxides nanotubes-based composite particles useful for dye-removal and process thereof | 26-May-20 | Shukla Satyajit Vishnu, Padinhattayil Hareesh, Narayani Harsha, Jose Manu, Karunakaran Remya |
| BR 112012021846-8 | Process for the production of violacein and its derivatives containing bioactive pigment from chromobacterium sp. Niist-ckk-01 | 08-Dec-20 | Krishnakumar Bhaskaran |

## Filed in India

| Title | Inventors | File No | Filing Date |
|---|---|---|---|
| Organic selenium enriched edible marine microalgal biomass | Muthu Arumugam, Ragini Reshma | 202011028987 | 08-Jul-20 |
| Electrochromic bi-layered devices for dynamic light throughput control and a process for the preparation thereof | Deb Biswapriya, Prabhu Thulichal Ganesh Prabhu Gayathri, Venugopal Ranjana | 202011034413 | 11-Aug-20 |
| A diagnostic screening kit for simultaneous detection of clinically relevant biomakers from breast cancer tissue samples using surface enhanced raman scattering platform and process for the preparation thereof | Maiti Kaustabh Kumar, Kunjuraman Sujathan, Murali Vishnu Priya, Karunakaran Varsha, Selvakumar Deepika, Murali Madhukrishnan, Valliamma Neelakantapillai Saritha, Lekshmi Asha | 202011034768 | 11-Aug-20 |
| A thermoresponsive self-assembled organic material as photonic ink and a process of making thereof | Ayyappanpillai Ajayaghosh, Cherumukkil Sandeep, Chakkooth Vijayakumar | 202011038507 | 05-Sep-20 |

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|---|---|---|---|
| Flocculant based disinfection process for pathogenic medical waste disposal | Shankar Pooppanal Sreejith, Unnikrishnan Nair Saraswathy Hareesh, Parameswaran Binod, Sukumaran Rajeev Kumar, Ayyappanpillai Ajayaghosh | 202011039050 | 08-Sep-20 |
| A Superhydrophobic Composite and Multifunctional Applications Thereof | Shankar Pooppanal Sreejith, Nirmala Anjali, Unnikrishnan Nair Saraswathy Hareesh, Ayyappanpillai Ajayaghosh | 202011038721 | 08-Sep-20 |
| A system and method for onsite wastewater treatment and resource recovery | Bhaskaran Krishnakumar | 202011054437 | 14-Dec-20 |
| Isoprenyl natural scaffold against mdr staphylococcus aureus and synergistic compositions thereof | Kokkuvayil Vasu Radhakrishnan, Murugan Thulasi Meenu, Sidharth Chopra, Grace Kaul, Manjulika Shukla | 202111015503 | 31-Mar-21 |
| Sustained release liquid dosage form for steam inhalation | Alaganandam Kumaran, Anand Ganapathy Aravind Kumar, Vijaykumari Mahadevan Hari Priya, Chulliparambil Alisha Valsan | 202111015511 | 31-Mar-21 |
| Antibacterial Multi-Charged Metal Complexes and Coatings with Metal Nanoparticles Thereof | Shankar Pooppanal Sreejith, Nirmala Anjali, Unnikrishnan Nair Saraswathy Hareesh, Pottath Suja, Vijayan Visakh, Pillai Saju, Sukumaran Rajeev Kumar, Ayyappanpillai Ajayaghosh | 202111015509 | 31-Mar-21 |

## Filed Abroad

| Title | Inventors | File No | Filing Date |
|---|---|---|---|
| Thermoelectric materials and a process for the preparation thereof | Deb Biswapriya, Chakkooth Vijayakumar, Ignatious Vijitha, Meshram Manoj Ramakrishna, Singh Jaivinder, Tanjore Puli Yuvaraj | 19787476.10 | 13-May-20 |
| Thermoelectric materials and a process for the preparation thereof | Deb Biswapriya, Chakkooth Vijayakumar, Ignatious Vijitha, Meshram Manoj Ramakrishna, Singh Jaivinder, Tanjore Puli Yuvaraj | 2020-536874 | 26-Jun-20 |
| Thermoelectric materials and a process for the preparation thereof | Deb Biswapriya, Chakkooth Vijayakumar, Ignatious Vijitha, Meshram Manoj Ramakrishna, Singh Jaivinder, Tanjore Puli Yuvaraj | 201980006164.60 | 02-Jun-20 |
| Thermoelectric materials and a process for the preparation thereof | Deb Biswapriya, Chakkooth Vijayakumar, Ignatious Vijitha, Meshram Manoj Ramakrishna, Singh Jaivinder, Tanjore Puli Yuvaraj | BR 1120200156647 | 31-Jul-20 |
| Process for the preparation of pyrylium salts | Sasidhar Balappa Somappa, Chettiyal Thodi Fathimath Salfeena, Ayyappanpillai Ajayaghosh | 18904834.10 | 03-Aug-20 |
| Process for the preparation of pyrylium salts | Sasidhar Balappa Somappa, Chettiyal Thodi Fathimath Salfeena, Ayyappanpillai Ajayaghosh | 16/967613 | 05-Aug-20 |
| Process for the preparation of pyrylium salts | Sasidhar Balappa Somappa, Chettiyal Thodi Fathimath Salfeena, Ayyappanpillai Ajayaghosh | 2020-542442 | 05-Aug-20 |
| A process for the preparation of functionalized weather-resistant and slow-decaying geotextiles | Vadakkethonippuathu Sivankuttynair Prasad, Padinjareveetil Anju, Methalayil Brahmakumar, Das Anitha Ravindranath, Sebastian Sumy | 16/999551 | 21-Aug-20 |

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|---|---|---|---|
| A process for the preparation of functionalized weather-resistant and slow-decaying geotextiles | Vadakkethonippuathu Sivankuttynair Prasad, Padinjareveetil Anju, Methalayil Brahmakumar, Das Anitha Ravindranath, Sebastian Sumy | 20192226.70 | 21-Aug-20 |
| Thermoelectric materials and a process for the preparation thereof | Deb Biswapriya, Chakkooth Vijayakumar, Ignatious Vijitha, Meshram Manoj Ramakrishna, Singh Jaivinder, Tanjore Puli Yuvaraj | 10-2020-7024850 | 27-Aug-20 |
| Thermoelectric materials and a process for the preparation thereof | Deb Biswapriya, Chakkooth Vijayakumar, Ignatious Vijitha, Meshram Manoj Ramakrishna, Singh Jaivinder, Tanjore Puli Yuvaraj | 16/979019 | 08-Sep-20 |
| Screening kit for detection of precancerous lesions of cervix and process for the preparation thereof | Kaustabh Kumar Maiti, Varsha Karunakaran, Kunjuraman Sujathan | 17/046183 | 08-Oct-20 |
| Screening kit for detection of precancerous lesions of cervix and process for the preparation thereof | Kaustabh Kumar Maiti, Varsha Karunakaran, Kunjuraman Sujathan | GB2016080.0 | 09-Oct-20 |
| Thermo-responsive molecules for controlled heat and light transmission windows and applications thereof | Ayyappanpillai Ajayaghosh, Das Satyajit, Soman Suraj, Asok Adersh, Shankar Pooppanal Sreejith | PCT/IN2020/050884 | 16-Oct-20 |
| Screening kit for detection of precancerous lesions of cervix and process for the preparation thereof | Kaustabh Kumar Maiti, Varsha Karunakaran, Kunjuraman Sujathan | --- | 13-Jan-21 |
| Flocculant based disinfection process for pathogenic medical waste disposal | Shankar Pooppanal Sreejith, Unnikrishnan Nair Saraswathy Hareesh, Parameswaran Binod, Sukumaran Rajeev Kumar, Ayyappanpillai Ajayaghosh | PCT/IN2021/050032 | 13-Jan-21 |
| A transparent gel electrolyte system and fast switching electrochromic devices thereof | Deb Biswapriya, Ayyappanpillai Ajayaghosh, Venugopal Ranjana, Prabhu Thulichal Ganesh Prabhu Gayathri, Shankar Pooppanal Sreejith | PCT/IN2021/050143 | 15-Feb-21 |

# Knowledge Resource Centre

## Knowledge Resource Centre

The Knowledge Resource Centre has carried out a broad spectrum of activities to cater to the information needs and information technology requirements of the scientific community.

## Information resources & services

KRC enriched its collection with online as well as print resources, including books, journals, technical reports, standards, patents, theses, and other resources, including academic databases. KRC acquired 120 new books in 2020-21, including 56 books that were received as gifts.

As a member of the National Knowledge Resource Consortium (NKRC), the KRC has continued to have full-text articles from the American Chemical Society, Royal Society of Chemistry, American Institute of Physics, Institute of Physics, Springer Nature, Oxford University Press, Taylor & Francis, etc., as well as the subscription to specialized databases including SciFinder discovery services, Web of Science, ASTM Standards and Qpat, in addition to the e-journals that are subscribed directly. The library automation software Koha and institutional repository software Dspace were updated to the latest version. The home page of the online public access catalog was also updated.

The software iThenticate was subscribed by KRC, and it is the most widely used tool for researchers and professional writers to examine their original works for plagiarism. Subscription to the research writing support tool Grammarly premium was also continued for ensuring error-free manuscripts. The works are being started for upgrading the KRC security with Radio Frequency Identification System (RFID).

KRC also maintains and updates the institute website, Social media pages, VIDWAN database, and Institutional Repository (IR). There are now 2714 journal papers, 356 Ph.D. theses, and 250 news items in the IR. KRC regularly provided training on Sci-Finder discovery services, Grammarly premium, Web of Science, reference management software, literature searches, prior art searches, open access etc.

## Information Technology Infrastructure and Enabled Services

IT Lab of CSIR NIIST is continuously envisaging the information needs of the laboratory and setting up efficient and reliable infrastructure for the smooth functioning, speed and security of the communication network. The laboratory is linked with two internet leased lines of 100 mbps and 28 mbps respectively to fulfil the internet requirements of the laboratory. All the buildings are interconnected through gigabit fiber optic backbone. During the reporting period, 22 internet ports were added to the existing network making the total internet connections to 1150+ through wired and wireless network. Separate VLANs have been maintained to improve the network performance. Server grade antivirus is deployed for virus free network environment.

IT lab also maintains a data center comprising of servers, storage and network devices. IT lab also takes care of all the maintenance of hardware and software of all the IT assets. We have implemented an online portal for recruiting scientists and other permanent positions of CSIR NIIST and we have also developed and installed a separate Online Portal for recruiting the Project Assistants. The modification and revamping of the Institute website as per the Government of India guidelines have been started.

IT lab manages the smooth functioning of AADHAR enabled biometric attendance system installed at eight different locations in the laboratory. The center has also installed Face Recognition devices for secured access to the main building. The center issues institutional identify cards for the staff members, research scholars and pensioners. Digital Display system is also maintained in seven locations inside the laboratory for exhibiting research outcomes, notices etc. Printing and Scanning facility is provided to the end users through a wide range of Heavy Duty Color Laser Printers and A3/A4 Scanners.

# List of Publications

**Publications :236** **Avg. Impact Factor: 5.082**

**SCI Journals: 205** **non-SCI journals: 18** **Book Chapters: 13**

**High Impact factor papers:**

1. Praveen (V K), Vedhanarayanan (B), Mal (A), Mishra (R K), Ajayaghosh (A). 'Self-Assembled Extended p-Systems for Sensing and Security Applications.'Accounts of Chemical Research, 2020, 53(2):496-507 IF-22.384
2. Bhattacharya (B), Roy (D), Dey (S), Puthuvakkal (A), Bhunia (S), Mondal (S), Chowdhury (R), Bhattacharya (M), Mandal (M), Manoj (K), Mandal (P K), Reddy (C M). 'Mechanical Bending Induced Fluorescence Enhancement in Plastically Flexible Crystals of a GFP Chromophore Analogue.'Angewandte Chemie-International Edition, 2020, doi.org/10.1002/anie.202007760 IF-15.336
3. Salikolimi (K), Praveen (V K), Sudhakar (A A), Yamada (K), Horimoto (N N), Ishida (Y). 'Helical Supramolecular Polymers With Rationally Designed Binding Sites for Chiral Guest Recognition. 'Nature Communications, 2020, 11(1) IF:14.919
4. Joseph (M M), Ramya (A N), Vijayan (V M), Nair (J B), Bastian (B T), Pillai (R K), Therakathinal (S T), Maiti (K K). 'Targeted Theranostic Nano Vehicle Endorsed with Self-Destruction and Immunostimulatory Features to Circumvent Drug Resistance and Wipe-Out Tumor Reinitiating Cancer Stem Cells. 'Small, 2020, 2003309 IF:13.281
5. Sreelekshmy (B R), Basheer (R), Sivaraman (S), Vasudevan (V), Elias (L), Shibli (S M A). 'Sustainable Electric Power Generation From Live Anaerobic Digestion of Sugar Industry Effluents Using Microbial Fuel Cells. 'Journal of Materials Chemistry A, 2020, 8(12):6041-6056 IF:12.732
6. Pandiselvam (R), Kaavya (R), Jayanath (Y), Veenuttranon (K), Lueprasitsakul (P), Divya (V), Kothakota (A), Ramesh (S V). 'Ozone as a novel emerging technology for the dissipation of pesticide residues in foods-a review. 'Trends in Food Science & Technology, 2020, 97(38-54) 10.1016/j.tifs.2019.12.017 IF:12.563
7. Pandiselvam (R), Mayookha (V P), Kothakota (A), Ramesh (S V), Thirumdas (R), Juvvi (P). 'Biospeckle laser technique - A novel non-destructive approach for food quality and safety detection. 'Trends in Food Science & Technology, 2020, 10.1016/j.tifs.2019.12.028 IF:12.563
8. Nabeela (K), Thomas (R T), Mohamed (A T), Pillai (S). 'Nanocellulose-silver Ensembles for Ultrasensitive Sers: an Investigation on the Role of Nanocellulose Fibers in the Generation of High-density Hotspots. Applied Materials Today, 2020, 20:100672 IF:10.041

1. ABRAHAM (A), MATHEW ANIL (K), PARK (H), CHOI (O), SINDHU (R), BINOD (P), PANDEY (A), PARK (J H), SANG (B I) 'Pretreatment Strategies for Enhanced Biogas Production From Lignocellulosic Biomass'Bioresource Technology; 301:122725; 2020

2. ABRAHAM (A), MOIDEEN (S K), MATHEW (A K), RAJ (S R A), SINDHU (R), PANDEY (A), SANG (B I), SUKUMARAN (R K) 'Fumaric acid production from sugarcane trash hydrolysate using Rhizopus oryzae NIIST 1 'Indian Journal of Experimental Biology; 58(8):548-556; 2020

3. ABRAHAM (B), RESHMITHA (T R), NAVAMI (M M), GEORGE (L), VENUGOPALAN (V V), NISHA (P) 'Phytochemical Rich Extract From the Spent Material Generated From Industrial Dashamoola Preparation (a Medicinal Ayurvedic Decoction) With Antioxidant, Antidiabetic and Anti-inflammatory Potential 'Industrial Crops and Products; 151:112451; 2020

4. ADAR (T), LANKALAPALLI (R S), BITTMAN (R), ILAN (Y) 'The assembly of glycosphingolipid determines their immunomodulatory effect: A novel method for structure-based design of immunotherapy 'Cellular Immunology; 355:104157; 2020

5. AGARWAL (P B), SHARMA (R), MISHRA (D), THAKUR (N K), AGARWAL (A), AJAYAGHOSH (A) 'Silicon Shadow Mask Technology for Aligning and In Situ Sorting of Semiconducting SWNTs for Sensitivity Enhancement: A Case Study of NO2 Gas Sensor 'ACS Applied Materials & Interfaces; 12(36):40901–40909; 2020

6. AJAY KUMAR (P), ROHATGI (P), WEISS (D), RAJAN (T P D), PAI (B C), MONDAL (D P), DAS (S) 'Cast metal matrix composites over last 50 years and future opportunities in India 'Indian Foundry Journal; 66(10):17-27; 2020

7. AKHIL, DEVENDRA (L P), SUKUMARAN (R K) 'Comparative Evaluation of Laccase Mediated Oxidized and Unoxidized Lignin of Sugarcane Bagasse for the Synthesis of Lignin-based Formaldehyde Resin 'Industrial Crops and Products; 150:112385; 2020

8. AKHTAR (A), SENTHILMURUGAN (S), MOHANTY (K), SUNDAR (R), UNNIKRISHNAN (R), HAREESH (U S) 'Sugarcane Juice Clarification by Lanthanum Phosphate Nanofibril Coated Ceramic Ultrafiltration Membrane: PPO Removal in Absence of Lime Pre-treatment, Fouling and Cleaning Studies 'Separation and Purification Technology; Page : 117157; 2020

9. AMRUTHA (S), GIRI (L), SEETHALEKSHMI (S), VARUGHESE (S) 'Enhanced Aqueous Solubility of the Solid Forms of a BCS Class-II Anti-Tuberculosis Drug, Prothionamide 'Crystal Growth and Design; 20(8):5086–5096; 2020

10. ANAGA (N), BASAVARAJA (D), ABRAHAM (B), NISHA (P), VARUGHESE (S), JAYAMURTHY (P), SASIDHAR (B S) 'Advanced glycation end-products (AGE) trapping agents: Design and synthesis of nature inspired indeno[2,1-c] pyridinones 'Bioorganic Chemistry; 105:104375; 2020

11. ANANJANA (K), SWETHA (S), PRAKASH (P), NISHAD (K V), KOMATH (M), NAIR (B N), SAILAJA (G S) 'Amino acid inspired tunable superparamagnetic iron oxide (SPION) nanostructures with high magnetic hyperthermia potential for biofunctional applications 'New Journal of Chemistry; 44(5):1962-1970; 2020

12. ANITHA (J K), JOSEPH (S), REJITH (R G), SUNDARARAJAN (M) 'Monazite chemistry and its distribution along the coast of Neendakara–Kayamkulam belt, Kerala, India 'SN Applied Sciences; 2(5); 2020

13. ANJALY (B A), SURESH (C H) 'Absorption and Emission Properties of 5-phenyl Tris(8-hydroxyquinolinato) M(Iii) Complexes (M = Al, Ga, in) and Correlations With Molecular Electrostatic Potential 'Journal of Computational Chemistry; 41(16):1497-1508; 2020

14. ANJU (P), PRASAD (V S) 'Functionalization-Induced Self-Assembly of Polystyrene/Kaolinite in Situ Nanocomposites into Giant Vesicles 'Langmuir; 36(7):1761-1767; 2020

15. ARUN (K B), DHANYA (R), CHANDRAN (J), ABRAHAM (B), SATYAN (S), NISHA (P) 'A comparative study to elucidate the biological activities of crude extracts from rice bran and wheat bran in cell line models 'Journal of Food Science and Technology - Mysore; https://doi.org/10.1007/s13197-020-04353-1; 2020

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## 1 अप्रैल 2020 से 31 मार्च 2021 तक सम्मानित पी.एच.डी.

| एसीएसआईआर, सीएसआईआर-एनआईआईएसटी | | | | |
|---|---|---|---|---|
| क्रम सं. | नाम | शोध का शीर्षक | पर्यवेक्षक और सह पर्यवेक्षक | पुरस्कार की तिथी |
| | सुश्री. सूजिता बी एस | सीनडेसमस क्वाड्रि-कॉडा सीएएसए सीसी202 में नाइट्रोजन तनाव मध्यस्थता लिपिड संचय का जैव रासायनिक और आणविक लक्षण वर्णन | डॉ. एम. आरुमुगम | 28.05.2020 |
| | सुश्री. सीजिला रोसली सी वी | पॉली (एल-लैक्टाइड)/ बोरॉन नाइट्राइड नैनोकंपोजिट्स की संरचना और गुण | डॉ. ई. भोजे गौड़ | 28.05.2020 |
| | सुश्री. लक्ष्मी डी आर | मैग्नेटोडी-इलेक्ट्रिक और मैग्नेटोइलेक्ट्रिक अनुप्रयोगों के लिए बहुपरतीय मिश्रण | डॉ. के.पी. सुरेन्द्रन | 10.06.2020 |
| | सुश्री. नबीला कल्लई | कार्यात्मक संकर सामग्री और उनके अनुप्रयोगों के लिए हरित मंच के रूप में नैनोसेल्यूलोज फाइबर | डॉ. सजू पिल्लै | 30.06.2020 |
| | सुश्री. राजी वी नायर | पर्यावरण प्रदूषकों के अल्ट्रासेंसिटिव अभिज्ञान के लिए संवेदन मंच के रूप में वैकल्पिक रूप से ट्यून किए गए ग्राफीन क्वांटम डॉट्स का संश्लेषण और निर्माण | डॉ. सजू पिल्लै | 15.07.2020 |
| | श्री. अभिलाष विश्वनाथ | कम दबाव कास्टिंग प्रक्रिया का अभिकलनात्मक मॉडलिंग: प्रायोगिक सत्यापन और समानता विश्लेषण | डॉ एस सावित्री | 27.07.2020 |
| | सुश्री. गायत्री प्रभु टी जी | ऊर्जा प्रबंधन और विनियमन के लिए टंगस्टन ऑक्साइड आधारित इलेक्ट्रोक्रोमिक उपकरण | डॉ बिसवाप्रिय डेब | 31.07.2020 |
| | सुश्री. अश्वती उदयन | आवश्यक ओमेगा -3 फैटी एसिड उत्पादन और नॉनोक्लोरोप्सिस ओशिका सीएएसए सीसी201 से इसके अनुप्रयोगों पर संयंत्र विकास नियामकों के प्रभाव पर जांच | डॉ. एम. आरुमुगम | 14.08.2020 |
| | श्री. विपिन वी वी | जैव-प्रेरित संरचनात्मक रंग: कोलाइडल फोटोनिक क्रिस्टल और अनुप्रयोगों में फोटोनिक बैंड गैप ट्यूनिंग | डॉ. सजू पिल्लै | 14.08.2020 |
| | सुश्री. आन्नरोज़ सन्नी | हाइपरथर्मिया थेरेपी के लिए एक आसान संश्लेषण का उपयोग कर बायोकंपैटिबल स्पिनल फेराइट नैनोपार्टिकल्स का विकास | डॉ एम वसुंधरा | 02.09.2020 |
| | श्री. सूजई पी टी | प्रभावी कैंसर प्रबंधन के लिए एसईआरएस निर्देशित नैनोथेरानोस्टिक जांच का डिजाइन, निर्माण और जैविक मूल्यांकन | डॉ कौस्तभ कुमार मैत्ती | 09.09.2020 |
| | सुश्री. वर्षा करुणाकरन | कैंसर और अल्जाइमर रोग के लिए सतही वर्धित रामन बिखराव आधारित नैदानिक मंच का विकास | डॉ कौस्तभ कुमार मैत्ती /डॉ के जी रघु | 16.10.2020 |

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|---|---|---|---|---|
| | श्री. जुबि जेकब | कृषि और औषधीय उपयोग के लिए एक्टिनोमाइसेट्स और उनके मेटाबोलाइट्स की जांच | डॉ बी एस दिलीप कुमार | 29.10.2020 |
| | श्री. रेजित आर जी | हाइपरस्पेक्ट्रल सुदूर संवेदन का उपयोग करते हुए वर्कला कोवलम तट, पश्चिम- दक्षिण भारत के साथ सामरिक खनिज भंडार का भू-अन्वेषण | एम सुंदरराजन | 22.10.2020 |
| | श्री. सालिन राज पी | हाइपरग्लाइकेमिया मध्यस्थता माइटोकॉन्ड्रियल डिसफंक्शन और हृदय से संबंधित जटिलताओं का स्पष्टीकरण और फेरुलिक एसिड का मूल्यांकन | डॉ के जी रघु | 20.11.2020 |
| | सुश्री. शरण्या गिरिधरन | कैंसर के निदान और उपचार के लिए नए आणविक जांच पर डिजाइन, संश्लेषण और अध्ययन | डॉ ए अजयघोष/ डॉ कौस्तभ कुमार मैती | 02.12.2020 |
| | श्री. चिन्नादूरई एम | हाइब्रिड पेरोसाइट नैनोक्रिस्टल: संश्लेषण, ऑप्टोइलेक्ट्रॉनिक गुण और अनुप्रयोग | डॉ विजयकुमार सी | 19.01.2021 |
| | सुश्री. शरतना पी | केरल के पश्चिमी घाट से कुछ चुनिंदा औषधीय पौधों की बायोप्रोस्पेक्टिंग | डॉ के वी राधाकृष्णन | 22.02.2021 |
| | सुश्री. चिंजू गोविंद एम वी | फेमटोसेकंड पंप-जांच स्पेक्ट्रोस्कोपी से हीम मॉडल यौगिकों और प्रोटीन के अल्ट्राफास्ट इलेक्ट्रॉनिक, कंपन और गठनात्मक विश्राम गतिकी का उपयोग करना। | डॉ वी करुणाकरन | 01.03.2021 |
| | सुश्री. रेमया जी एस | संक्रमण धातु परिसरों की प्रतिक्रियाशीलता को ट्यून करने के लिए प्रतिस्थापन प्रभावों और लिगैंड संशोधनों की मात्रा का ठहराव पर डीएफटी अध्ययन | डॉ सुरेश सी एच | 10.03.2021 |
| | सुश्री. वीणा के एस | ज़िंगिबेरासी परिवार के प्रकंदों की चयनित प्रजातियों से प्रचुर मात्रा में जैव सक्रिय पदार्थों का अलगाव और अर्ध-संश्लेषण | डॉ रवि शंकर लंकलापल्ली | 10.03.2021 |

# Ph D Awarded

| AcSIR, CSIR-NIIST | | | |
|---|---|---|---|
| **Name** | **Thesis Title** | **Supervisor and Co. Supervisor** | **Date of Award** |
| Sujitha B. S. | Biochemical and molecular characterization of nitrogen stress mediated lipid accumulation in Scenedesmus quadri- cauda CASA CC202 | Dr. M. Arumugam | 28.05.2020 |
| Sijla Rosely C. V. | Structure and properties of poly (L-lactide)/boron nitride nanocomposites | Dr. E. Bhoje Gowd | 28.05.2020 |
| Lekshmi D. R. | Multilayer composites for magnetodi-electric and magnetoelectric applications | Dr. K.P. Surendran | 10.06.2020 |
| Nabeela Kallayi | Nanocellulose fibers as green platform for functional hybrid materials and their applications | Dr. Saju Pillai | 30.06.2020 |
| Raji V. Nair | Synthesis and fabrication of optically tuned graphene quantum dots as sensing platforms for ultrasensitive detection of environmental pollutants | Dr. Saju Pillai | 15.07.2020 |
| Abhilash Viswanath | Computational modelling of the low pressure casting process: Experimental validation and similitude analysis | Dr. S. Savithri | 27.07.2020 |
| Gayathri Prabhu T. G. | Tungsten oxide based electrochromic devices for energy management and regulation | Dr. Biswapriya Deb | 31.07.2020 |
| Aswathy Udayan | Investigation on the effect of plant growth regulators on essential omega-3 fatty acid production and its applications from Nonnochloropsis oceanica CASA CC201 | Dr. M. Arumugam | 14.08.2020 |
| Vipin V. V. | Bio-inspired structural colors: Photonic band gap tuning in colloidal photonic crystals and applications | Dr. Saju Pillai | 14.08.2020 |
| Annrose Sunny | Development of biocompatible spinel ferrite nanoparticles using a facile synthesis for hyperthermia therapy | Dr. M. Vasundhara | 02.09.2020 |
| Sujai P. T. | Design, fabrication and biological assessment of SERS guided nanotheranostic probes for effective cancer management | Dr. Kaustabh Kumar Maiti | 09.09.2020 |
| Varsha Karunakaran | Development of surface enhanced Raman scattering based diagnostic platform for Cancer and Alzheimer's Disease | Dr. Kaustabh Kumar Maiti/Dr. K. G. Raghu | 16.10.2020 |
| Jubi Jacob | Probing actinomycetes and their metabolites for agricultural and medicinal use | Dr. B. S. Dileep Kumar | 29.10.2020 |

| | | | |
|---|---|---|---|
| Rejith R. G. | Geo-exploration of strategic mineral deposits along Varkala Kovalam coast, South-West India using hyperspectral remote sensing | Dr M. Sundararajan | 22.10.2020 |
| Salin Raj P. | Elucidation of hyperglycaemia mediated mitochondrial dysfunction and associated complications in heart and evaluation of ferulic acid against the same | Dr. K. G. Raghu | 20.11.2020 |
| Saranya Giridharan | Design, synthesis and studies on new molecular probes for diagnosis and treatment of cancer | Dr. A. Ajayaghosh / Dr. Kaustabh Kumar Maiti | 02.12.2020 |
| Chinnadurai M. | Hybrid perovskite nanocrystals: Synthesis, optoelectronic properties and applications | Dr. Vijayakumar .C | 19.01.2021 |
| Sharathna P. | Bioprospecting of some selected medicinal plants from Western Ghats of Kerala | Dr. K. V. Radhakrishnan | 22.02.2021 |
| Chinju Govind M. V. | Ultrafast electronic, vibrational and conformational relaxation dynamics of heme model compounds and proteins in various environments using femtosecond pump-probe spectroscopy | Dr. V. Karunakaran | 01.03.2021 |
| Remya G. S. | DFT studies on quantification of substituent effects and ligand modifications to tune the reactivity of transition metal complexes | Dr. Suresh C. H. | 10.03.2021 |
| Veena K.S | Isolation and semi-synthesis of abundant bioactives from selected species of rhizomes of Zingiberaceae family | Dr. Ravi Shankar Lankalapalli | 10.03.2021 |

## Testing and analytical services Cell

The Testing and Analytical Service Cell activity of CSIR-NIIST has migrated to the AnalytiCSIR portal of CSIR. All major equipment support has been uploaded on this portal and the in-house and external sample processing is now online. There are now more than 350 users availing these facilities. The status of analysis can now be ascertained online and the results uploaded can be accessed from any part of the world by the user This facility is one of the best of its kind in the southern part of the Country and is being extensively utilized generating a steady flow of revenue for the Lab. The external sample analysis is carried out on payment basis.

During the period of the report students from various educational institutes and universities, R&D institutions and several major Industries had utilized this facility generating revenue of Rs.21.85 lakhs. There is a continuous demand as in previous years for XPS, NMR, XRD, SEM and TEM from external Clients.

With the introduction of AnalytiCSIR portal, the instrumentation booking process has become a seamless experience and with minimal intervention the procedure for availing analytical support is completed. The usage statistics data, revenue generated, availability of equipments etc., can now be monitored online.

# प्रबंधन परिषद्

**01/01/2018 से 31/12/2020 की अवधि केलिए**

**अध्यक्ष**

**निदेशक, सीएसआईआर- एनआईआईएसटी**

**सदस्य**

**डॉ अश्विनी कुमार नांगिया**
निदेशक, सीएसआईआर-एनसीएल, पुना

**डॉ एस सावित्री**
मुख्य वैज्ञानिक

**डॉ पी निशि**
प्रमुख, आरपीबीडी

**श्री सी के चंद्रकांत**
प्रधान वैज्ञानिक

**डॉ यू एस हरीश**
वरिष्ठ वैज्ञानिक

**डॉ पी जयमूर्ति**
वैज्ञानिक

**श्री एम ब्रह्मकुमार**
प्रधान तकनीकी अधिकारी
/एफएओ सीओएफ,
एनआईआईएसटी

**सदस्य सचिव**

प्रशासन नियंत्रक/प्रशासन अधिकारी,
एनआईआईएसटी

# प्रबंधन परिषद्

**01/01/2020 से 31/12/2021 की अवधि**

**अध्यक्ष**

**निदेशक, सीएसआईआर- एनआईआईएसटी**

**सदस्य**

**डॉ एन कलईसेल्वी**
निदेशक, सीएसआईआर-सीईसीआरआई, कराईकुडी

**डॉ पी निशि**
प्रमुख, आरपीबीडी

**डॉ एस अनंतकुमार,**
वरिष्ठ प्रधान वैज्ञानिक

**डॉ ए कुमरन**
प्रधान वैज्ञानिक

**डॉ के पी सुरेंद्रन**
प्रधान वैज्ञानिक

**डॉ सूरज सोमन**
वैज्ञानिक

**डॉ बीना जॉय**
प्रधान तकनीकी अधिकारी

वित्त एवं लेखा नियंत्रक/ वित्त एवं लेखा अधिकारी,
एनआईआईएसटी

**सदस्य सचिव**

प्रशासन नियंत्रक/प्रशासन अधिकारी, एनआईआईएसटी

# MANAGEMENT COUNCIL

**Period 01/01/2018 to 31/12/2020**

**CHAIRMAN**

**Director, CSIR-NIIST**

**MEMBERS**

**Dr Ashwini Kumar Nangia**
Director, CSIR-NCL, Pune

**Dr S Savithri**
Chief Scientist, Head, MSTD

**Dr P Nishy**
Head, RPBD & KRC

**Shri C K Chandrakanth**
Principal Scientist

**Dr U S Hareesh**
Senior Scientist

**Dr P Jayamurthy**
Scientist

**Shri M Brahmakumar**
Principal Technical Officer

**CoFA/FAO Member**

MEMBER SECRETARY
CoA / AO, NIIST

# MANAGEMENT COUNCIL

**Period 01/01/2021 to 31/12/2021**

**CHAIRMAN**

**Director, CSIR-NIIST**

**MEMBERS**

**Dr N Kalaiselvi**
Director, CSIR-CECRI, Karaikudi

**Dr P Nishy**
Chief Scientist & Head, RPBD and KRC

**Dr S Ananthakumar**
Senior Principal Scientist

**Dr A Kumaran**
Principal Scientist

**Dr K P Surendran**
Senior Scientist

**Dr Suraj Soman**
Scientist

**Dr Beena Joy**
Principal Technical Officer

**CoFA/FAO Member**

MEMBER SECRETARY
CoA / AO, NIIST

# पदोन्नतियाँ / Promotions

**डॉ. मनोज रामा वर्मा/**
**Dr Manoj Raama Varma**
प्रमुख वैज्ञानिक/
Chief Scientist

**डॉ. जे अंसारी/ Dr J Ansari**
प्रमुख वैज्ञानिक/Chief Scientist

**डॉ. निशि पी/ Dr Nishy P**
प्रमुख वैज्ञानिक/Chief Scientist

**डॉ. एम. रवी**
**Dr M Ravi**
प्रमुख वैज्ञानिक/Chief Scientist

**डॉ. वि.बि मणिलाल**
**Dr V B Manilal**
प्रमुख वैज्ञानिक/Chief Scientist

**डॉ. के एन नारायणन उण्णी/**
**Dr K N Narayanan Unni**
वरिष्ठ प्रधान वैज्ञानिक/
Senior Principal Scientist

**डॉ. टीपीडी राजन/**
**Dr T P D Rajan**
वरिष्ठ प्रधान वैज्ञानिक/
Senior Principal Scientist

**डॉ. के पी सुरेन्द्रन/**
**Dr K P Surendran**
प्रधान वैज्ञानिक/Principal Scientist

**डॉ. जोशी जॉर्ज/**
**Dr Joshy Joseph**
प्रधान वैज्ञानिक/
Principal Scientist

**डॉ. के जयशंकर/**
**Dr K Jayasankar**
प्रधान वैज्ञानिक/
Principal Scientist

**डॉ निशा पी/ Dr Nisha P**
प्रधान वैज्ञानिक/Principal Scientist

**श्री मोनी/Mr Moni V**
प्रधान वैज्ञानिक/Principal Scientist

**डॉ. बिस्वप्रिया डेब/**
**Dr Biswapriya Deb**
प्रधान वैज्ञानिक/
Principal Scientist

**डॉ. के. पि. प्रतीष**
**Dr K P Prathish**
वरिष्ठ वैज्ञानिक/
Senior Scientist

**डॉ. निशांत**
**Dr Nishanth**
वरिष्ठ वैज्ञानिक/
Senior Scientist

**श्री. रोबर्ट फिलिप/**
**Shri Robert Philip**
वरिष्ठ तकनीकी अधिकारी(2)/
Senior Technical Officer(2)

# पदोन्नतियॉ / Promotions

**डॉ. एस रामस्वामी/**
**Dr S Ramaswamy**
वरिष्ठ तकनीकी अधिकारी(2)/
Senior Technical Officer(2)

**डॉ. जोशी जॉर्ज/**
**Dr Joshy George**
वरिष्ठ तकनीकी अधिकारी(2)/
Senior Technical Officer(2)

**श्रीमती सौमिनी मैथ्यू/ Smt Saumini Mathew**
वरिष्ठ तकनीकी अधिकारी(2)/
Senior Technical Officer(2)

**श्री डि आर सोभंकुमार/**
**Mr D R Sobhankumar**
वरिष्ठ तकनीकी अधिकारी(2)/
Senior Technical Officer(2)

**श्रीमती सहरूबा पी एम/**
**Smt. Saharuba P M**
वरिष्ठ तकनीकी अधिकारी(1)/Senior Technical Officer(1)

**श्री एन एस राजू/Mr N S Raju**
वरिष्ठ प्रशासन नियंत्रक/
Senior Controller of Administration

**श्री थॉमस टी के/**
**Sri. Thomas T K**
वरिष्ठ भंडार एवं क्रय नियंत्रक/
Senior Controller of Stores And Purchase

**श्री. हरिक्रिष्णन**
**Mr Harikrishnan**
वित्त एवं लेखा अधिकारी/Finance & Accounts Officer

श्री. जी चंद्रबाबू/
**Mr G Chandrababu**
वरिष्ठ अधीक्षण अभियंता/ Senior Superintending engineer

श्री. बी कार्तिक/
**Mr B Karthik**
सहायक कार्यपालक अभियंता(सिविल)/
Assistant Executive Engineer (Civil)

श्री.पी अरुमुखम/
**Mr P Arumugham**
सहायक अभियंता(सिविल) /
Assistant Engineer (Civil)

श्री. के एस प्रमोद/
**Mr. K. S Pramod**
वरिष्ठ तकनीशियन(1)/
Senior Technician (1)

श्री. के सुरेश कण्णन/
**Mr K Suresh Kannan**
वरिष्ठ तकनीशियन(1)/
Senior Technician (1)

श्री. यू धरणिपति/
**Mr U Dharanipathy**
वरिष्ठ तकनीशियन(1)/
Senior Technician (1)

श्री. विष्णु वी एल/
**Mr Vishnu V L**
वरिष्ठ आशुलिपिक/
Senior Stenographer

श्री.के मधु/
**Mr K Madhu**
लैब सहायक पीएमएल5
Lab Assistant PML 5

श्री. श्रीकुमारन/
**Mr Sreekumaran**
लैब सहायक पीएमएल5
Lab Assistant PML 5

श्री. टी वी सतीश/
**Mr T V Satheesh**
लैब सहायक पीएमएल5
Lab Assistant PML 5

श्री. के उण्णिकृष्णन/
**Mr K Unnikrishnan**
लैब सहायक पीएमएल5
Lab Assistant PML 5

श्री.जी भक्तवत्सलम/
**Mr G Bhaktavalsalam**
लैब सहायक पीएमएल2
Lab Attendant PML 2

श्री पुष्पकुमार के आर नायर/
**Mr Pushpakumar K R Nair**
लैब सहायक पीएमएल 2
Lab Attendant PML 2

## कर्मचारी भर्ती 2020-21
## Staff Recruitement 2020-21

**डॉ. रिजु डेविस**
**Dr Riju Davis**

**डॉ. वसंत राघवन के**
**Dr.Vasanth Ragavan K**

**डॉ.ऐश्वर्या आर नायर**
**Dr.Aiswarya.R.Nair**

**श्री राहुल आर**
**Mr Rahul L R**

## सीएसआईआर-एनआईआईएसटीमें स्थानांतरण
## Transfer to CSIR-NIIST

**श्रीमती प्रीता के/Smt Preetha K**
सहायक अनुभाग अधिकारी(सामा.)/
Assistant Section Officer (G)
सीएफटीआरआई, मैसूर से/
From CFTRI, Mysore

**श्री सजीत पी एस/Mr Sajith P S**
ग्रुप डी (फराश)/Group D (Farrash)
आईआईसीटी, हैदराबाद से/From IICT, Hyderabad

## सीएसआईआर-एनआईआईएसटीमें स्थानांतरण
## Transfer from CSIR-NIIST

**श्री विष्णु गुर्जर/**
**Mr Vishnu Gurjar**
कनिष्ठ आशुलिपिक/
Junior Stenographer
सीएसआईआर-सीरी, पिलानी/
CSIR-CEERI, Pilani

**डॉ इंदु शर्मा/**
**Dr Indu Sharma**
वैज्ञानिक/Scientist
सीएसआईआर-एचआरडीजी/
CSIR-HRDG

## सेवानिवृत्ति/ Retirement

**श्री जी चंद्र बाबू/**
**Mr G Chandra Babu**
वरिष्ठ अधीक्षण अधिकारी/
Senior Superintending Officer
को सेवानिवृत्त/Retired on
30/04/2020

**श्री एम पी वर्की**
**/Mr M P Varkey**
प्रयोगशाला सहायक
/Lab Assistant
को सेवानिवृत्त/Retired on
30/05/2020

**श्रीमती पी एस पद्मिनी/**
**Mrs P S Padmini**
वरिष्ठ आशुलिपिक (एमएसीपी)/
Senior Stenographer(MACP)
को सेवानिवृत्त/Retired on
30/11/2020

**श्री एन एस राजू /**
**Mr N S Raju**
प्रशासन नियंत्रक /
Controller of Administration
को सेवानिवृत्त/Retired on
31/03/2021

## Activities of Vigilance, RTI and Women Cell in CSIR-NIIST

The institute has a full-time vigilance officer who deals with all vigilance matter pertaining to CSIR-NIIST, Thiruvananthapuram. The vigilance officer furnishes certain reports/returns to the Chief Vigilance Officer on regular basis. The vigilance officer is not directly associated in decision making or finalization of tenders/purchase and audit matters. No vigilance case is pending or contemplated against any employees of CSIR-NIIST during 2020-21.

The institute has a Central Public Information Officer (CPIO) who furnishes information under Right to Information Act (RTI) 2005. During the financial year 2020-2021, we have received 89 RTI queries and all these queries have been replied. The institute submitted all the RTI quarterly returns for the year 2020-21 in the central information commission (CIC) RTI annual return information system.

CSIR-NIIST has a women cell constituted for woman welfare and to attend problems/ inconveniences of women employees in CSIR-NIIST which also acts as Internal Complaints Committee (ICC) to deal with Sexual Harassment of Women at Workplace. No complaints were filed to the Women Cell during the year 2020-21.

# पुरस्कार तथा सम्मान/ AWARDS AND HONOURS

## सर्वश्रेष्ठ नवाचार के लिए सीएसआईआर-प्रौद्योगिकी पुरस्कार
## CSIR-Technology Award for the best innovation


प्रकाशिकी, इलेक्ट्रॉनिक्स में नवीन तकनीकी प्रगति और सिग्नल बढ़ाने वाली तकनीकों के आविष्कार ने रामन स्पेक्ट्रोस्कोपी के दायरे को वास्तविक जीवन के अनुप्रयोगों को बढ़ा दिया है। इस संदर्भ में, उपकरण के हैंडहेल्ड संस्करण एक बड़ी क्षमता पाते हैं। वर्तमान में रामन वर्णक्रममापी के लिए सीमित भारतीय निर्माता हैं, और उन्हें अनुसंधान एवं विकास और औद्योगिक उद्देश्यों दोनों के लिए देश में आयात किया जाता है। वाणिज्यिक प्रणालियों की लागत 10 लाख रुपये से लेकर 100 लाख तक है और उनके व्यापक अनुप्रयोगों को बाधित करता है। सीएसआईआर-एनआईआईएसटी ने एक लाख रुपये से कम लागत पर रामन वर्णक्रममापी बनाने की तकनीक हासिल कर ली है, जिससे यह कई श्रेणियों के उपयोगकर्ताओं के लिए सस्ती हो गई है। लागत कारक के अलावा, आयातित प्रणालियों के कुछ अन्य कमियां भी हैं। व्यावसायिक रूप से उपलब्ध आयातित हैंडहेल्ड संस्करण ज्यादातर उत्तेजना स्रोत के रूप में 785 एनएम लेजर डायोड का उपयोग करता हैं। चूंकि सिलिकॉन आधारित सीसीडी डिटेक्टरों की नियर-इन्फ्रा-रेड (एनआईआर) किरण कम संवेदनशील होती है, महंगे आईआर परिष्कृत सीसीडी का उपयोग करना आवश्यक है और अधिकतम रामन स्पेक्ट्रल किरण सीमित होते है। एनआईआईएसटी-द्वारा विकसित सिस्टम उत्तेजना स्रोतों के रूप में या तो 638 एनएम या 532 एनएम लेजर डायोड के साथ काम करता हैं। यह प्रणाली कम खर्चीले सीसीडी डिटेक्टरों से भी सुसज्जित है जो दृश्य सीमा में बेहतर संवेदनशील हैं, जिससे लागत में काफी कमी आती है। इसके अतिरिक्त, यह विस्तारित श्रेणियों में रामन वर्णक्रमीय डेटा एकत्र करने की अनुमति देता है जो नमूने के बारे में अधिक वैज्ञानिक जानकारी प्रदान करता है। हालांकि इन उत्तेजना स्रोतों के साथ अत्याधुनिक प्रणालियां हैं, लेकिन कमियां यंत्र की भारीता और उच्च लागत हैं। एनआईआईएसटी में रूप रेखा की गई सॉफ़्टवेयर सुविधाओं में अंतर्निहित मॉड्यूल हैं और शोर हटाने और पृष्ठभूमि सुधारने के लिए ऑनलाइन सिग्नल संसाधन को सक्षम करता हैं, जिससे उत्पाद को साइट पर अनुप्रयोगों के लिए तैनात किया जा सकता है। वर्तमान नवाचार प्रौद्योगिकी को स्वदेशी बनाना प्रयासों में से एक है, इसी प्रकार यह देश के 'मेक इन इंडिया' और 'आत्मनिर्भर भारत' दृष्टिकोण में योगदान देता है। इन प्रगतियों ने सीएसआईआर- राष्ट्रीय अंतर्विषयी विज्ञान तथा प्रौद्योगिकी संस्थान और केंद्रीय इलेक्ट्रॉनिक्स अभियांत्रिकी अनुसंधान संस्थान के वर्ष 2020 के सर्वश्रेष्ठ नवाचार के लिए सीएसआईआर-प्रौद्योगिकी पुरस्कार प्राप्त किया है। इस टीम में सीएसआईआर-एनआईआईएसटी के डॉ. योसफ करुवथ, डॉ. नारायणन उन्नी, डॉ. कौस्तुभ कुमार मैती, डॉ. एलिजाबेथ जैकब और रॉबर्ट फिलिप और सीएसआईआर-सीरी से डॉ. अजय अग्रवाल और डॉ, ऋषि शर्मा शामिल हैं। वर्तमान आविष्कार का दवाओं के गुणवत्ता परीक्षण, कपटपूर्ण उत्पादों को पता लगाने और बायोमार्कर और रोगजनकों का पता लगाने के माध्यम से रोग निदान हेतु स्वास्थ्य सेवाओं ने औषधीय क्षेत्र में महत्वपूर्ण प्रभाव पड़ा है। इसके अतिरिक्त, इसका उपयोग विस्फोटकों का पता लगाने और शैक्षिक क्षेत्र में शिक्षण सहायता के माध्यम से मातृभूमि की सुरक्षा हेतु रणनीतिक क्षेत्र में किया जा सकता है।

Recent technological advancements in optics, electronics, and the invention of signal enhancing techniques have enhanced the scope of Raman spectroscopy to real-life applications. In this context, handheld versions of the equipment find a huge potential. Presently there are limited Indian manufacturers for Raman spectrometer, and they are imported to the country for both R&D and industrial purposes. The cost of the commercial systems ranges from Rs. 10 lakhs to 100 lakhs and impedes their widespread applications. CSIR-NIIST has acquired know-how in fabricating Raman spectrometers at a cost less than Rupees 1 lakh making it affordable to several categories of end-users. Apart from the cost factor, there are some other drawbacks for the imported systems. The commercially available imported handheld versions mostly utilize 785 nm laser diode as the excitation source. Since silicon based CCD detectors have low sensitivity in the near-infra-red (NIR) range it is necessary to use costly IR enhanced CCD and the maximum Raman spectral range is limited. The NIIST-developed systems work with either 638 nm or 532 nm laser diodes as excitation sources.The system is also equipped with less expensive CCD detectors that show better sensitivity in the visible range, enabling considerable cost reduction. Additionally, this allows for collecting Raman spectral data in extended ranges yielding more scientific information about the sample. Though

there are state of the art systems with these excitation sources, the drawbacks are the bulkiness of the device and the high cost. The software features designed at NIIST have built-in modules and enable online signal processing for noise removal and background correction, enabling the product to be deployed for on-site applications. The present innovation is one of the first attempts to indigenize the technology, thus contributing to 'Make in India' and 'Atmanirbhar Bharat' visions of the country. These developments brought CSIR-Technology Award for the best innovation for the year 2020 to CSIR-National Institute for Interdisciplinary Science and Technology and Central Electronics Engineering Research Institute. The team include Dr. Yoosaf Karuvath, Dr. Narayanan Unni, Dr. Kaustabh Kumar Maiti, Dr. Elizabeth Jacob, and Robert Philip from CSIR-NIIST and Dr. Ajay Agarwal and Dr, Rishi Sharma from CSIR-CEERI. The present invention has significant ramifications in the pharmaceutical sector for quality testing of ingredients of medicines, detection of fraudulent products and healthcare sector for disease diagnosis through detection of biomarkers and pathogens. Additionally, it can be used in the strategic sector for homeland security through the detection of explosives and in the educational sector as a teaching aid.

## सीएसआईआर युवा वैज्ञानिक पुरस्कार/ CSIR Young Scientist Award

**डॉ सूरज सोमन**
**Dr Suraj Soman**

डॉ सूरज सोमन ने रसायन विज्ञान में अर्ध-स्वचालित उपकरण विकसित करने और डाई-सेंसिटाइज़्ड सोलर मॉड्यूल फैब्रिकेशन के लिए सेमी-ऑटोमैटिक उपकरण और प्रक्रिया विकसित करने और वैकल्पिक कॉपर और कोबाल्ट इलेक्ट्रोलाइट्स से जुड़े अनुसंधान के लिए वर्ष 2020 में सीएसआईआर युवा वैज्ञानिक पुरस्कार प्राप्त किया है। 26 सितंबर, 2020 को एक विर्चुयल समारोह में विज्ञान एवं प्रौद्योगिकी मंत्री माननीय डॉ. हर्षवर्धन द्वारा पुरस्कार प्रदान किया गया।

Dr Suraj Soman received CSIR Young Scientist Award for the year 2020 in Chemical Sciences, for developing semi-automatic equipment's and process for dye-sensitized solar module fabrication and for the research involving alternate copper and cobalt electrolytes. Award was presented by Hon. S&T minister Dr. Harsha Vardhan in a virtual function on 26th September, 2020.

## केरल राज्य युवा आइकन पुरस्कार / Kerala State Youth Icon Award

डॉ सूरज सोमन को फोटोवोल्टिक प्रौद्योगिकियों के विकास में योगदान के लिए वर्ष 2020 के लिए विज्ञान में केरल राज्य के युवा आइकन पुरस्कार प्राप्त हुआ है।

Dr Suraj Soman received Kerala State Youth Icon Award in Science for the year 2020 for the contributions in developing new generation photovoltaic technologies

## युवा वैज्ञानिक के लिए इन्सा पदक

**INSA Medal for Young Scientist**

डॉ सूरज सोमन ने वर्ष 2020 को रसायन विज्ञान के क्षेत्र में पृथ्वी की प्रचुर मात्रा में सामग्री को नियोजित करके डाई-संवेदी सौर कोशिकाओं की क्षमता में सुधार लाने और साथ ही उनकी ऑप्टिकल और इलेक्ट्रिकल विशेषताओं को अनुकूलित करने के लिए इन्सा युवा वैज्ञानिक पदक प्राप्त किया है।

Dr Suraj Soman received INSA Medal for Young Scientist in the area of Chemical Science for the year 2020 for improving efficiencies of dye-sensitized solar cells by employing earth abundant materials as well as by optimizing their optical and electrical characteristics

## केरल राज्य युवा वैज्ञानिक पुरस्कार/ Kerala State Young Scientist Award

डॉ. श्रीजीत शंकर को 30 जनवरी 2021 को रासायनिक विज्ञान (केएससीएसटीई, केरल सरकार) में केरल राज्य युवा वैज्ञानिक पुरस्कार से सम्मानित किया गया, जो कि लागू वोल्टेज (इलेक्ट्रोक्रोमिक) या तापमान (थर्मोक्रोमिक) के आधार पर उनके रंग, पारदर्शिता और प्रकाश / गर्मी थ्रूपुट को बदलने वाली लागत प्रभावी और स्केलेबल स्मार्ट सामग्री के विकास के लिए है। इन सामग्रियों का उपयोग ऊर्जा कुशल भवनों के लिए स्मार्ट विंडो घटकों के रूप में किया जा सकता है। इन स्मार्ट सिस्टम को अन्य स्वच्छ ऊर्जा प्रौद्योगिकियों के साथ एकीकृत किया जा सकता है ताकि एक पूर्ण भवन एकीकृत समाधान तक पहुंच प्रदान की जा सके। कम ऊर्जा पदचिह्न वाले ऐसे स्मार्ट विंडो प्रोटोटाइप की कल्पना कुशल ऊर्जा प्रबंधन में योगदान करने के लिए की गई है, जो आवश्यकता-आधारित गोपनीयता सुनिश्चित करने के अलावा, इनडोर प्रकाश व्यवस्था और इनडोर तापमान बनाए रखने के लिए आवश्यक ऊर्जा की मात्रा से सीधा संबंध रखता है।

Dr. Sreejith Shankar was awarded the Kerala State Young Scientist Award in Chemical Sciences (KSCSTE, Government of Kerala) on 30 January 2021, for his work on the development of cost-effective and scalable smart materials that change their colour, transparency and light/heat throughput depending on applied voltage (electrochromic) or temperature (thermochromic). These materials can be used as smart window components for energy efficient buildings. These smart systems can be integrated with other clean energy technologies to provide access to a complete building integrated solution. Such smart window prototypes with low energy footprint are envisioned to contribute to efficient energy management, with direct correlation to the amount of energy required for indoor lighting and maintaining indoor temperature, apart from ensuring need-based privacy.

# 31/03/2021 तक की कर्मचारियों की सूची
# STAFF LIST AS ON 31/03/2021

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प्रमुख वैज्ञानिक और प्रधान/
Chief Scientist & Head

**डॉ (श्रीमती) एलिज़ाबेथ जेकब/ Dr (Mrs )Elizabeth Jacob**
प्रमुख वैज्ञानिक/ Chief Scientist

**डॉ बी कृष्णकुमार/Dr B Krishnakumar**
प्रधान वैज्ञानिक/Principal Scientist

**श्री बी अब्दुल हलीम/Mr B Abdul Haleem**
वरिष्ठ वैज्ञानिक/Senior Scientist

**डॉ पारताकुंडु/Dr Parthakundu**
वरिष्ठ वैज्ञानिक/Senior Scientist

**डॉ के पी प्रतीष/Dr K P Prathish**
वरिष्ठ वैज्ञानिक/Senior Scientist

**श्री सौरभ सखरे/Mr Saurabh Sakhre**
वैज्ञानिक/ Scientist

**श्री धनी बाबू तलाकला/Mr Dhani Babu Talakala**
वैज्ञानिक/ Scientist

**श्री अक्षय दिलीप शिंडे/Mr Akshay Dilip Shende**
वैज्ञानिक/ Scientist

**श्री वी के शाजीकुमार/Mr V K Shajikumar**
वरिष्ठ तकनीकी अधिकारी (2)/Senior Technical Officer (2)

**डॉ जोषी जॉर्ज/Dr Joshy George**
वरिष्ठ तकनीकी अधिकारी (2)/Senior Technical Officer (2)

**श्रीमती पी एम सहरूबा/Mrs P M Saharuba**
वरिष्ठ तकनीकी आधिकारी/ Senior Technical Officer (1)

**पदार्थ विज्ञान तथा प्रौद्योगिकी प्रभाग/ Materials Science & Technology Division**

**डॉ(श्रीमति) एस सावित्री/Dr (Mrs) S Savithri**
प्रमुख वैज्ञानिक और प्रधान/ Chief Scientist & Head

**डॉ मनोज रामा वर्मा/Dr Manoj Raama Varma**
प्रमुख वैज्ञानिक/ Chief Scientist

**डॉ एम रवि/Dr M Ravi**
प्रमुख वैज्ञानिक/ Chief Scientist

**डॉ एस अनंतकुमार/Dr S Ananthakumar**
वरिष्ठ प्रधान वैज्ञानिक/Senior Principal Scientist

**डॉ के आई सुरेश/Dr K I Suresh**
वरिष्ठ प्रधान वैज्ञानिक/Senior Principal Scientist

**डॉ टी पी डी राजन/Dr T P D Rajan**
वरिष्ठ प्रधान वैज्ञानिक/Senior Principal Scientist

**डॉ एस वी शुक्ला/Dr S V Shukla**
प्रधान वैज्ञानिक/Principal Scientist

**डॉ यू एस हरीष/ Dr U S Hareesh**
प्रधान वैज्ञानिक/Principal Scientist

**डॉ ई भोजे गौड़/Dr E Bhoje Gowd**
प्रधान वैज्ञानिक/Principal Scientist

**डॉ के जयशंकर/Dr K Jayasankar**
प्रधान वैज्ञानिक/Principal Scientist

**डॉ ए श्रीनिवासन/Dr A Srinivasan**
प्रधान वैज्ञानिक/Principal Scientist

**डॉ एम सुंदरराजनDr M Sundararajan**
प्रधान वैज्ञानिक/Principal Scientist

**डॉ के पी सुरेंद्रन/Dr K P Surendran**
प्रधान वैज्ञानिक/Principal Scientist

**डॉ सजू पिल्लई/Dr Saju Pillai**
वरिष्ठ वैज्ञानिक/Senior Scientist

**डॉ सुब्रता दास/Dr Subrata Das**
वरिष्ठ वैज्ञानिक/Senior Scientist

**डॉ के जी निशांत/Dr K G Nishanth**
वरिष्ठ वैज्ञानिक/Senior Scientist

**डॉ एस एस श्रीजाकुमारी/Dr S S Sreejakumari**
वरिष्ठ वैज्ञानिक/Senior Scientist

**डॉ सुशांता कुमार साहू/Dr Sushanta Kumar Sahoo**
वैज्ञानिक/ Scientist

**डॉ अच्चू चंद्रन/Dr Achu Chandran**
वैज्ञानिक/ Scientist

**श्री जे वेंकटेशन/Mr J Venkatesan**
वैज्ञानिक/ Scientist

**डॉ वी एस प्रसाद/Dr V S Prasad**
प्रधान तकनीकी आधिकारी/ Principal Technical Officer

**श्री ब्रह्मकुमार/Mr Brahmakumar**
प्रधान तकनीकी आधिकारी/ Principal Technical Officer

**श्री ए पीर मोहम्मद/Mr A Peer Mohammed**
वरिष्ठ तकनीकी अधिकारी (2)/Senior Technical Officer (2)

**डॉ एस रामस्वामी/Dr S Ramaswamy**
वरिष्ठ तकनीकी अधिकारी (2)/Senior Technical Officer (2)

**श्री वी हरीश राज/Mr V Harish Raj**
तकनीकी आधिकारी/ Technical Officer

## मईक्रोबियल प्रक्रिया तथा प्रौद्योगिकी प्रभाग/ Microbial Processes &Technology Division

**डॉ राजीव कुमार सुकुमारन/Dr Rajeev Kumar Sukumaran**
प्रधान वैज्ञानिक व प्रधान/Principal Scientist & Head

**डॉ के माधवन नंपूतीरी/Dr K Madhavan Nampoothiri**
वरिष्ठ प्रधान वैज्ञानिक/Senior Principal Scientist

**डॉ पी बिनोद/Dr P Binod**
वरिष्ठ वैज्ञानिक/Senior Scientist

**डॉ एन रमेश कुमार/Dr N Ramesh Kumar**
वरिष्ठ वैज्ञानिक/Senior Scientist

**डॉ मुत्तु अरुमुगम/Dr Muthu Arumugam**
वरिष्ठ वैज्ञानिक/Senior Scientist

**श्री एम किरण कुमार/Mr M Kiran Kumar**
वरिष्ठ वैज्ञानिक/Senior Scientist

**डॉ एल राकेश कुमार यसरला/Dr L Rakesh Kumar Yasarala**
वैज्ञानिक/ Scientist

**डॉ बी वी तिरुमलेश/Dr B V Thirumalesh**
वैज्ञानिक/ Scientist

**डॉ पी ए बलकुमारन/Dr P A Balakumaran**
वैज्ञानिक/ Scientist

**श्री पी एन शिवनकुट्टी/Mr P N Sivankutty Nair**
वरिष्ठ तकनीशियन(2) /Senior Technician (2)

## एस एवं टी सेवाएं/S & T Services इंजीनियरिंग सेवा प्रभाग/ Engineering Services Division

श्री आर राजीव /**Mr R Rajeev**
वरिष्ठ अधीक्षण अभियंता/Senior Superintending Engineer

श्री चन्द्र शेकर नीलम /**Mr Chandra Shekar Neelam**
सहायक कार्यपालक अभियंता (इलकट्रिकल)/Assistant Executive Engineer (Electrical)

**श्री बी कार्तिक/Mr B Karthik**
सहायक कार्यपालक अभियंता(सिविल) /Assistant Executive Engineer (Civil)

**श्री पी अरुमुगम/Mr P Arumugam**
सहायक अभियंता(सिविल) /Assistant Engineer (Civil)

**एम जयदीप /Mr M Jayadeep**
वरिष्ठ तकनीशियन(1) /Senior Technician(1)

**श्री के एस प्रमोद /Mr K S Pramod**
वरिष्ठ तकनीशियन(1) /Senior Technician(1)

**श्री के सुरेश कन्नन /Mr K Suresh Kannan**
वरिष्ठ तकनीशियन(1) /Senior Technician(1)

**श्री यू धरनीपति /Mr U Dharanipathy**
वरिष्ठ तकनीशियन(1) /Senior Technician(1)

**श्री टी वी सतीश /Mr T V Satheesh**
प्रयोगशाला सहायक /Lab Assistant

**श्री पी एस सजीत /Mr P S Sajith**
ग्रुप डी/ Group D

## ज्ञान संसाधन केंद्र/ Knowledge Resource Centre

**डॉ(श्रीमती) पी निशि/Dr (Mrs) P Nishy**

प्रमुख वैज्ञानिक और केआरसी व आरपीबीडी के प्रधान/
Chief Scientist & Head of KRC & RPBD

**श्री वी मोनी/Mr V Moni**
प्रधान वैज्ञानिक/Principal Scientist

**श्री एस बी रिबिन जोन्स/Mr S B Ribin Jones**
वरिष्ठ वैज्ञानिक/Senior Scientist

श्री राहुल एल आर/**Mr.Rahul L R**
वरिष्ठ तकनीकी आधिकारी(1) / Senior Technical Officer(1)

**श्री एस पुश्किन/Mr S Pushkin**
वरिष्ठ तकनीकी आधिकारी(1)/ SeniorTechnical Officer(1)

**श्री जी नागश्रीनिवासु/Mr G Nagasrinivasu**
वरिष्ठ तकनीशियन(2) /Senior Technician (2)

**श्री पुष्पकुमार के आर नायर/**
**Mr Pushpakumar K R Nair**
प्रयोगशाला सहायक**(2)/ Lab Attendant (2)**

## अनुसंधान योजना और व्यापार विकास/ Research Planning & Business Development

**श्री सी के चंद्रकांत/Mr C K Chandrakanth**
वरिष्ठ प्रधान वैज्ञानिक/Senior Principal Scientist

**श्री आर एस प्रवीण राज/Mr R S Praveen Raj**
प्रधान वैज्ञानिक/Principal Scientist

**डॉ रिजु डेविस/Dr Riju Davis**
प्रधान वैज्ञानिक/Principal Scientist

**डॉ दीपा बालन/Dr Deepa Balan**
वैज्ञानिक/ Scientist

**डॉ राज कुमार/Dr Raj Kumar**
वैज्ञानिक/ Scientist

## प्रशासन/Administration

**श्री एन एस राजू/Mr N S Raju**
प्रशासन नियंत्रक/Controller Of Administration

**श्री के एफ़ जोसफ/Mr K F Joseph**
अनुभाग अधिकारी(सामा.)/Section Officer (G)

**श्री जी पद्मकुमार/Mr G Padmakumar**
अनुभाग अधिकारी(सामा.)/Section Officer (G)

डॉ ऐश्वर्या आर नायर/**Dr Aiswarya R Nair**
चिकित्सा अधिकारी/Medical Officer

**श्री टी जे बाबू/Mr T J Babu**
वरिष्ठ सुरक्षा अधिकारी/Senior Security Officer

**श्री के पी कृष्णन/Mr K P Krishnan**
सहायक अनुभाग अधिकारी/Assistant Section Officer

**श्रीमति मेर्सी जोसफ/Mrs Mercy Joseph**
सहायक अनुभाग अधिकारी/Assistant Section Officer

**श्रीमती के प्रीता/Mrs K Preetha**
सहायक अनुभाग अधिकारी/Assistant Section Officer

**श्रीमती नीतू एस इंदुचूडन/Mrs Neethu S Induchoodan**
सहायक अनुभाग अधिकारी/Assistant Section Officer

**श्री आर के रमेश कुमार/Mr R K Ramesh Kumar**
सहायक अनुभाग अधिकारी/Assistant Section Officer

**श्री ओ वी शशिकुमार/Mr O V Sasikumar**
वरिष्ठ आशुलिपिक(एमएसीपी)/Senior Stenographer (MACP)

**श्री बी सतीश कुमार/Mr B Satheesh Kumar**
वरिष्ठ सचिवालय सहायक(सामा.)/Senior Secretariat Assistant (G)

**श्रीमती ए एल सजिता/Mrs A L Sajitha**
वरिष्ठ सचिवालय सहायक /Senior Secretariat Assistant

**श्री टी एच बशीर/Mr T H Basheer**
वरिष्ठ तकनीशियन(2) /Senior Technician(2)

**श्री प्रवीण कन्नल/Mr Praveen Kannal**
वरिष्ठ तकनीशियन(1) /Senior Technician(1)

**श्री शाना एस नायर/Mrs Shana S Nair**
स्टाफ परिचारिका/Staff Nurse

**श्रीमती एम गीता/ Mrs M Geetha**
प्रयोगशाला सहायक /Lab Assistant

**श्री के उण्णिकृष्णन/Mr K Unnikrishnan**
प्रयोगशाला सहायक /Lab Assistant

**श्री के मधु/Mr K Madhu**
प्रयोगशाला सहायक /Lab Assistant

**शी ए श्रीकुमारन/Mr A Sreekumaran**
प्रयोगशाला सहायक /Lab Assistant

## लेखा एवं वित्त/Finance & Accounts

**डॉ सोमू रॉय/Dr Somu Roy**
वित्त एवं लेखा अधिकारी/Finance & Accounts Officer

**श्री वी हरीकृष्णन/Mr V Harikrishnan**
वित्त एवं लेखा अधिकारी/Finance & Accounts Officer

**श्री संजीव सदानंदन/Mr Sanjeev Sadanandan**
सहायक अनुभाग अधिकारी/Assistant Section Officer

**श्रीमती कोमला सोमन/Mrs Komala Soman**
सहायक अनुभाग अधिकारी/Assistant Section Officer

**श्रीमती जी गीता/Mrs G Geetha**
सहायक अनुभाग अधिकारी/Assistant Section Officer

**श्री वी एल विष्णु/Mr V L Vishnu**
कनिष्ठ आशुलिपिक/Junior Stenographer

**श्री पी रेजित/Mr P Rejith**
ग्रुप सी(एनटी)/Group C (NT)

## भंडार एवं क्रय/ Stores & Purchase

**श्री थॉमस टी कुरियाकोस/Mr Thomas T Kuriakose**
वरिष्ठ भंडार एवं क्रय नियंत्रक/Senior Controller Of Stores & Purchase

**श्री सी एम कृष्णदास/Mr C M Krishnadas**
सहायक अनुभाग अधिकारी(भंडार एवं क्रय)/Assistant Section Officer (S&P)

**श्री एम अनिलकुमार/Mr M Anilkumar**
सहायक अनुभाग अधिकारी (भंडार एवं क्रय) /Assistant Section Officer (S&P)

**श्रीमती शीबा सईतु/Mrs Sheeba Saithu**
वरिष्ठ सचिवालय सहायक(भंडार एवं क्रय)/
Senior Secretariat Assistant (S&P)

**श्रीमती एल लता/Mrs L Latha**
वरिष्ठ तकनीशियन(2) /Senior Technician(2)

**श्री बी अजयकुमार/Mr B Ajayakumar**
वरिष्ठ तकनीशियन(2) /Senior Technician (2)

**श्री टी आर सुरेश कुमार/Mr T R Suresh Kumar**
वरिष्ठ तकनीशियन(2) /Senior Technician (2)

**श्री टी के घोष/Mr T K Ghosh**
ग्रुप सी (एनटी)(एमएसीपी)/Group C (NT) (MACP)

**श्री जी बक्तवल्सलम/Mr G Bhakthavalsalam**
ग्रुप सी (एनटी)/Group C (NT)

# घटनाक्रम और समारोह 2020-21

कोविड महामारी के कारण सभी कार्यक्रम ऑनलाइन मोड माध्यम से आयोजित किए गए।

### राष्ट्रीय प्रौद्योगिकी दिवस

सीएसआईआर-एनआईआईएसटी में 11 मई, 2020 को राष्ट्रीय प्रौद्योगिकी दिवस मनाया गया। डॉ. ए. अजयघोष, निदेशक, सीएसआईआर-एनआईआईएसटी ने स्वागत भाषण दिया और मुख्य अतिथि का परिचय दिया। राष्ट्रीय प्रौद्योगिकी दिवस पर डॉ. शेखर सी. मंडे, महानिदेशक, वैज्ञानिक और औद्योगिक अनुसंधान परिषद, नई दिल्ली द्वारा व्याख्यान दिया गया। मुख्य अतिथि ने कोविड-19 महामारी से निपटने में सीएसआईआर द्वारा उठाए गए कदम पर प्रकाश डाला और नई प्रौद्योगिकियों के विकास की आवश्यकता पर भी बल दिया।

### पीसी रे स्मारक भाषण

आचार्य प्रफुल्ल चंद्र रे स्मृति व्याख्यान (श्रृंखला में चौथा) 03 अगस्त, 2020 को आयोजित किया गया था। डॉ. ए. अजयघोष, निदेशक, सीएसआईआर-एनआईआईएसटी ने स्वागत भाषण दिया और मुख्य अतिथि का परिचय दिया। आचार्य प्रफुल्ल चंद्र रे स्मृति व्याख्यान आईआईएसईआर, कोलकाता के निदेशक प्रोफेसर सौरव पाल ने "आचार्य के दिनों से वर्तमान तक रसायन शास्त्र" विषय पर दिया। डॉ. टी.पी.डी. राजन, अध्यक्ष, शैक्षणिक कार्यक्रम समिति ने धन्यवाद ज्ञापित किया।

### सीएसआईआर स्थापना दिवस

सीएसआईआर-एनआईआईएसटी में 25 सितंबर, 2020 को सीएसआईआर स्थापना दिवस मनाया गया। डॉ. ए. अजयघोष, निदेशक, सीएसआईआर-एनआईआईएसटी ने स्वागत भाषण दिया और मुख्य अतिथि का परिचय दिया। सीएसआईआर स्थापना दिवस में व्याख्यान प्रो. आशुतोष शर्मा, सचिव, विज्ञान और प्रौद्योगिकी विभाग (डीएसटी), भारत सरकार, नई दिल्ली द्वारा दिया गया। डॉ. टी.पी.डी. राजन, अध्यक्ष, शैक्षणिक कार्यक्रम समिति ने धन्यवाद ज्ञापित किया।

### सीएसआईआर-एनआईआईएसटी स्थापना दिवस

सीएसआईआर-एनआईआईएसटी स्थापना दिवस 6 अक्टूबर, 2020 को मनाया गया। डॉ. ए. अजयघोष, निदेशक, सीएसआईआर-एनआईआईएसटी ने स्वागत भाषण दिया और मुख्य अतिथि का परिचय दिया। सीएसआईआर-एनआईआईएसटी स्थापना दिवस में व्याख्यान प्रोफेसर संदीप वर्मा, सचिव, विज्ञान और इंजीनियरी अनुसंधान बोर्ड (एसईआरबी), भारत सरकार, नई दिल्ली द्वारा "पोस्ट-सीओवीआईडी अनुसंधान परिदृश्य: हस्तक्षेप और अवसर" विषय पर दिया गया मुख्य अतिथि द्वारा 2019-2020 की वार्षिक रिपोर्ट का प्रकाशन किया गया। डॉ. टी.पी.डी. राजन, अध्यक्ष, शैक्षणिक कार्यक्रम समिति ने धन्यवाद ज्ञापित किया।

### राष्ट्रीय विज्ञान दिवस

राष्ट्रीय विज्ञान दिवस 1 मार्च, 2021 को मनाया गया। डॉ. ए. अजयघोष, निदेशक, सीएसआईआर-एनआईआईएसटी ने स्वागत भाषण दिया और मुख्य अतिथि का परिचय दिया। राष्ट्रीय प्रौद्योगिकी दिवस को व्याख्यान प्रो गोवर्धन मेहता, विश्वविद्यालय के विशिष्ट प्रोफेसर और डॉ कल्लम अंजी रेड्डी चेयर, स्कूल ऑफ केमिस्ट्री, हैदराबाद विश्वविद्यालय द्वारा दिया गया था। डॉ. टी.पी.डी. राजन, अध्यक्ष, शैक्षणिक कार्यक्रम समिति ने धन्यवाद ज्ञापित किया।

### हिन्दी दिवस

हिंदी दिवस 18 सितंबर 2020 को मनाया गया। डॉ एलिजाबेथ जेकब, मुख्य वैज्ञानिक और अध्यक्ष, हिंदी सप्ताह आयोजन समिति ने स्वागत भाषण दिया। डॉ. इशिता नियोगी, वैज्ञानिक, सीएसआईआर-एनआईआईएसटी द्वारा 'बनारस के इतिहास' पर एक विशेष वार्ता दी गई। श्री. एनएस राजू, प्रशासन नियंत्रक, सीएसआईआर-एनआईआईएसटी ने धन्यवाद ज्ञापित किया।

### सतर्कता जागरूकता सप्ताह

27 अक्टूबर से 2 नवंबर 2020 तक सतर्कता जागरूकता सप्ताह मनाया गया। इस संबंध में संस्थान के कर्मचारियों और छात्रों के लिए निबंध लेखन, नारा लेखन आदि जैसे विभिन्न कार्यक्रम/प्रतियोगिताएं आयोजित की गईं। कार्यक्रम की शुरुआत 27 अक्टूबर 2020 को सभी स्टाफ सदस्यों द्वारा सत्यनिष्ठा प्रतिज्ञा लेते हुए हुई।

समारोहों को चिह्नित करने के लिए, हमारे परिसर के अंदर और बाहर विभिन्न स्थानों पर पोस्टर/बैनर प्रदर्शित किए गए, जिसमें 'सतर्क भारत, समृद्ध भारत' (सतर्क भारत, समृद्ध भारत) विषय को चिह्नित करना सतर्कता जागरूकता का संदेश था।

सतर्कता जागरूकता सप्ताह का समापन समारोह 2 नवंबर 2020 को आयोजित किया गया था। स्वागत भाषण डॉ. जे अंसारी, मुख्य वैज्ञानिक, सीएसआईआर-एनआईआईएसटी ने दिया। समापन भाषण एर. शेफीन अहमद के आईपीएस, पुलिस उप महानिरीक्षक, दक्षिण पश्चिमी रेंज, कोरापुट, ओडिशा द्वारा दिया गया था। श्री. पद्मकुमार जी, अनुभाग अधिकारी (प्रशासन), सीएसआईआर-एनआईआईएसटी ने धन्यवाद ज्ञापित किया।

# Events and Celebrations

Due to COVID pandemic all the events were conducted through online mode.

## National Technology Day

The National Technology Day was celebrated in CSIR-NIIST on May 11, 2020.

Dr. A. Ajayaghosh, Director, CSIR-NIIST delivered the welcome address and introduced the Chief Guest of the day. The National Technology Day Lecture was delivered by Dr. Shekhar C. Mande, Director General, Council of Scientific & Industrial Research, New Delhi. The Chief Guest highlighted the lead taken by CSIR in combatting the COVID-19 Pandemic and also stressed the need for the development of new technologies.

## PC Ray Memorial Lecture

The Acharya Prafulla Chandra Ray Memorial Lecture (4th in the Series) was organized on August 03, 2020. Dr. A. Ajayaghosh, Director, CSIR-NIIST delivered the welcome address and introduced the Chief Guest of the day. The Acharya Prafulla Chandra Ray Memorial Lecture was delivered by Prof. Sourav Pal, Director, IISER, Kolkata in the topic of "Chemistry from the Days of Acharya to the Present". Dr. T.P.D. Rajan, Chairman, Academic Programme Committee proposed the vote of thanks.

## CSIR Foundation Day

The CSIR Foundation Day was celebrated in CSIR-NIIST on September 25, 2020. Dr. A. Ajayaghosh, Director, CSIR-NIIST delivered the welcome address and introduced the Chief Guest of the day. The CSIR Foundation Day Lecture was by delivered by Prof. Ashutosh Sharma, Secretary, Department of Science and Technology (DST), Government of India, New Delhi. Dr. T.P.D. Rajan, Chairman, Academic Programme Committee proposed the vote of thanks.

## CSIR-NIIST Foundation Day

The CSIR-NIIST Foundation Day was celebrated on October 6, 2020. Dr. A. Ajayaghosh, Director, CSIR-NIIST delivered the welcome address and introduced the Chief Guest of the day. The CSIR-NIIST Foundation Day Lecture was delivered by Prof. Sandeep Verma, Secretary, Science and Engineering Research Board (SERB), Government of India, New Delhi in topic of "Post-COVID Research Landscape: Interventions and Opportunities". The Annual Report of 2019-2020 was released by the Chief guest. Dr. T.P.D. Rajan, Chairman, Academic Programme Committee proposed the vote of thanks.

## National Science Day

The National Science Day was celebrated on March 1, 2021. Dr. A. Ajayaghosh, Director, CSIR-NIIST delivered the welcome address and introduced the Chief Guest of the day. The National Technology Day Lecture was delivered by Prof. Goverdhan Mehta, University Distinguished Professor & Dr. Kallam Anji Reddy Chair, School of Chemistry, University of Hyderabad. Dr. T.P.D. Rajan, Chairman, Academic Programme Committee proposed the vote of thanks.

## Hindi Day

Hindi Day was observed on 18th September 2020. Dr. Elizabeth Jacob, Chief Scientist and Chairman, Hindi Week Organizing Committee delivered the Welcome address. Dr. A. Ajayaghosh, Director, CSIR-NIIST delivered the presidential address. A special talk was delivered by Dr. Ishita Neogi, Scientist, CSIR-NIIST on 'History of Banaras'. Sri. N. S. Raju, Controller of Administration, CSIR-NIIST gave the vote of thanks.

## Vigilance Awareness Week

Vigilance Awareness Week was observed from 27th October to 2nd November 2020. In this regard a variety of events/contests like essay writing, slogan writing etc. were conducted for staff and students of this Institute. The programme commenced on 27th October 2020 by taking Integrity Pledge by all the staff members.

To mark the celebrations, posters/ banners were displayed at various locations inside and outside our campus carrying the message of Vigilance Awareness to mark the theme 'Satark Bharat, Samriddh Bharat' (Vigilant India, Prosperous India).

The valedictory function of the Vigilance Awareness Week was conducted on 2nd November 2020. The Welcome address was delivered by Dr. J Ansari, Chief Scientist, CSIR-NIIST. The Valedictory address was given by Er. Shefeen Ahmed K IPS, Deputy Inspector General of Police, South Western Range, Koraput, Odisha. Vote of thanks was proposed by Shri. Padmakumar G, Section Officer (Administration), CSIR-NIIST.

## RESEARCH COUNCIL (upto August 2020)

### CHAIRMAN
**Prof Padmanabhan**
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### SECRETARY
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Chief Scientist, CSIR-NIIST

**Dr K Madhavan Nampoothiri**
Senior Principal Scientist, CSIR-NIIST

## अनुसंधान समिति (अगस्त 2020 तक)

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CSIR-NIIST

# राष्ट्रीय अंतर्विषयी विज्ञान तथा प्रौद्योगिकी संस्थान

(वैज्ञानिक तथा औद्योगिक अनुसंधान परिषद्)

तिरुवनंतपुरम

# National Institute for Interdisciplinary Science & Technology

**(Council of Scientific & Industrial Research)**

Thiruvananthapuram