भाभा परमाणु अनुसंधान केंद्र का आधिकारिक द्विमासिक प्रकाशन
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- Nisargruna - Conceptualisation & Deployment
- Rapid Composting Tech
- Book Review - What Is Life?

कृषि चक्रीय अर्थव्यवस्था, सतत नवाचारों को बढ़ावा देता जैव-विज्ञान

जीवन के लिए आवश्यक तत्वों सहित सभी तत्व जैव-भूरासायनिक चक्रों के माध्यम से जैवमंडल में प्रसारित होते हैं। जैविक एवं अजैविक प्रावस्थाओं के बीच तत्वों की आवर्ती गति के माध्यम से होने वाला जीवन का यह रसायन विज्ञान, चक्रीय अर्थव्यवस्था की अवधारणा को जन्म देता है, जहां कुछ भी अपव्यय/अपशिष्ट नहीं होता। परमाणु ऊर्जा विभाग में, नाभिकीय ऊर्जा के उपयोग की हमारी खोज में भी यही सिद्धांत परिलक्षित होते हैं। यहां हमने न केवल नाभिकीय ईंधन के पुनर्संसाधान बल्कि, सामाजिक लाभ हेतु भी कृषि/जैव-अपशिष्ट के पुनश्चक्रण के लिए बंद चक्र को अपनाया है। इस ग्रह पर जीवन, कुछ और नहीं बल्कि पोषण चक्र ही है। जीवन, तत्वों के क्रम के माध्यम से एक पूर्व-निर्धारित तरीके से आकार लेता है और मृत्यु पश्चात विघटन, जन्म और विकास के अगले चक्र को बढ़ाता है। हालाँकि, शहरी जीवन शैली पर एक सूक्ष्म अध्ययन से पता चलता है कि वर्तमान में संतुलित पोषक चक्र किस प्रकार बाधित हो रहे हैं। शहर की सीमा से सटे कचरे या दीर्घकाय होते कूड़े के ढ़ेर इस बात को प्रमाणित करते हैं। इन तथाकथित "अपशिष्ट" को इनके उपयोगोपरांत प्राकृतिक या मानव निर्मित साधनों से पुनश्चक्रित किया जाना चाहिए था। कम से कम यह तो माना जा सकता है कि ये हरित-गृह गैसें एवं विषाक्त रिसाव का स्रोत बन जाते हैं जो जल निकायों को प्रदूषित कर स्वास्थ्य और सामाजिक आर्थिक खतरे पैदा करते हैं।

पच्चीस वर्ष पूर्व, शहरी अपशिष्ट प्रबंधन को आर्थिक रूप से सुदृढ. साधनों के रूप में संरेखित करने की खोज में, "निसर्ग-ऋण" की अवधारणा अस्तित्व में आई। संस्कृत भाषा से आए इस शब्द का शब्दानुवाद, "प्रकृति का ऋण" है। इसका मुख्य उद्देश्य, यांत्रिक प्रणालियों के माध्यम से सूक्ष्मजीव के चयापचय का उपयोग करके जीवाणुओं को ऊर्जा-समृद्ध ईंधन एवं पोषक तत्वों से भरपूर खाद में परिवर्तित करना था। इस लक्ष्य की प्राप्ति हेतु, हालांकि गोबर का बायोमीथेनेशन उपलब्ध था, अन्य सभी प्रकार के जैव-निम्नीकरणीय अपशिष्ट सरलता से इस प्रक्रिया हेतु अनुकूल नहीं थे। बायोमीथेनेशन पर सूक्ष्म अध्ययन से पता चलता है कि लघु श्रृंखला कार्बनिक अम्ल मीथेन में जैव रूपांतरण के लिए एक अधिमान्य पूर्वगामी हैं। इसे सुविधाजनक बनाने के लिए, निसर्ग-ऋण संयंत्र में अवायवीय कक्ष से पूर्व एक एरोबिक डाइजेस्टर की संकल्पना की गई। यहाँ लंबी श्रृंखला के अणुओं को प्रभावी रूप से लघु श्रृंखला के जैव अम्ल में विभाजित किया गया, जिनका मीथेन गैस बनाने के लिए मीथेनोजन द्वारा अवायवीय परिवर्तन हुआ था। तब से, धीरे-धीरे प्रौद्योगिकी विकसित होती जा रही है और सब्ज़ी बाज़ार के कचरे, बूचड़खानों, नगरपालिकाओं, दुग्ध-उत्पादक केंद्रों, चिड़ियाघरों एवं जल-पान गृहों जैसे विविध स्थान से प्राप्त अपशिष्ट के निस्तारण हेतु इसे देश भर में व्यापक रूप से अपनाया जा रहा है, अब तक इसे लगभग ४०० जगहों पर स्थापित किया गया है। निसर्ग-ऋण संयंत्रों में उत्पादित बायोगैस का उपयोग खाना पकाने के साथ-साथ बिजली उत्पादन के लिए किया जाता है, जबकि उद्यान/कृषि क्षेत्र इसके उत्पादित उच्च गुणवत्ता वाले खाद का तैयार बाज़ार हैं। जैसा कि हमने पद्मश्री डॉ. शरद पी. काले द्वारा आरंभ एवं पोषित किए गए परमाणु ऊर्जा विभाग के एक प्रमुख कार्यक्रम 'निसर्ग-ऋण' नामक आंदोलन की २५ वर्षों की यात्रा पूरी की है, इस चक्रीय अर्थव्यवस्था एवं सतत कार्यपद्धतियों को बढ़ावा देने में भाभा परमाणु अनुसंधान केंद्र द्वारा किए गए उल्लेखनीय योगदानों में से एक के रूप में अनुशंसित है। इन प्रौद्योगिकियों में, द्रुत कम्पोस्टिंग प्रौद्योगिकी, एक मॉड्यूलर में प्रकृति प्रेरित वायुजीवी प्रसंस्करण अपशिष्ट एवं स्केलेबल फैशन में एकल सेल्युलोलाइटिक कवक की सहायता से, ऐसी प्रौद्योगिकियां जो चीनी उद्योग से प्राप्त अपशिष्ट को खनिज समृद्ध फॉस्फेटिक एवं जस्ता उर्वरकों में परिवर्तित करती हैं। कृषि हितैशी रोगाणुओं के गुणात्मक वृद्धि हेतु कृषि अपशिष्ट के विकास के माध्यम के रूप में तथा अपशिष्ट जल उपचार के लिए संकर कणीय अनुक्रमण बैच रिएक्टर आदि शामिल हैं। समुद्री जीवों के अनुपयुक्त चिटिनस सीपी से उत्पादित पादप वृद्धि उत्तेजक "अनुचैतन्य" का सफलतापूर्वक व्यावसायीकरण किया गया और यह अत्यधिक लोकप्रिय हो गया है।

भापअ केंद्र न्यूज़लेटर का यह अंक "अपशिष्ट से उत्कृष्ट" विषय से प्रेरित जैव विज्ञान अनुसंधान एवं विकासात्मक गतिविधियों को प्रदर्शित करता है, जिसका पर्यावरण, जैव-भू-रासायनिक चक्र, कृषि, अर्थव्यवस्था एवं बड़े पैमाने पर जन कल्याण पर अनेक सकारात्मक प्रभाव पड़े हैं। मुझे पूर्ण विश्वास है कि यह संकलन भापअ केंद्र वैज्ञानिक समुदाय के बीच विमर्श का विषय बनकर उभरेगा और कई युवा सह-कर्मियों को प्रेरित करेगा।

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BioScience Fueling Innovations in Agri Circular Economy, Sustainability

All elements, including those essential to life, circulate in the biosphere through biogeochemical cycles. This chemistry of life that occurs through the recurring movement of elements between biotic and abiotic phases gives rise to the concept of circular economy, where there is no waste. The same principles are reflected in our quest to harness nuclear energy at Department of Atomic Energy. Here we have adopted a closed cycle, not only for reprocessing nuclear fuels but also for recycling of agro/bio-waste for societal benefits. Life in this planet, is nothing but a function of nutrient cycling. Life takes shape through the ordering of elements in a predefined way and its disintegration upon death, fuels the next cycle of birth and growth. However, even a casual glance at the urban way of living shows how the balanced nutrient cycles are presently disrupted. This is evidenced in the growing mounds of garbage or refuse at dump sites bordering city limits. This so called “waste” should have undergone recycling at the end of their useful life, either through natural or manmade means. Instead it becomes a source of green house gases and toxic leachates that pollute water bodies posing health and socio economic hazards, to say the least.

Twenty-five years back, in the pursuit of aligning to ecologically sound means of urban waste management, the concept of “Nisargruna” came into being. Its literal translation from Sanskrit means, “Nature's Loan”. At the heart of it was the transformation of the molecules of life into energy rich fuel and nutrient-abundant manure by harnessing microbial metabolism in mechanized systems. To meet this goal, though biomethanation of cow dung was available, all other types of biodegradable waste were not readily amenable to this process. A closer look at biomethanation reveals that short chain organic acids are a preferred precusor for biotransformation to methane. In order to facilitate this, an aerobic digestor preceeding the anaerobic chamber was introduced in the Nisargruna plant. Here long chain molecules were effectively broken down to short chain organic acids which underwent anaerobic transformationby methanogens to form methane gas. Since then, the technology has moved from strength to strength and has been widely adopted across the country for diverse waste such as vegetable market waste, abbatoirs, municipalities, dairy farms, zoos and canteens, totalling to about 400 installations so far. Biogas produced in Nisargruna plants is used for cooking as well as electricity generation, whereas the high-quality compost produced has a ready market in garden/agriculture sector. As we cover a journey of 25 years to commemorate the movement named 'Nisargruna', a flagship program of DAE, initiated and nurtured by Padmashree, Dr Sharad P. Kale, it is apt to appraise few other notable contributions made by BARC in promoting circular economy and sustainable practices. These technologies include, Rapid Composting Technology, a nature inspired aerobic processing of waste aided by a single cellulolytic fungus in a modular and scalable fashion, technologies that convert waste from the sugar industry to mineral rich phosphatic and zinc fertilizers, use of agricultural waste as growth medium for multiplication of agriculturally beneficial microbes and hybrid granular sequencing batch reactor for waste water remediation and so on. The plant growth stimulator “Anuchaitanya” produced from the unconsumed chitinous shells of marine organisms is successfully commercialized and has become very popular. This issue of BARC newsletter showcases the Bioscience research and developmental activities inspired by the theme“best out of waste”, which has had a multitude of positive effects on the environment, biogeochemical cycles, agriculture, economy and human well being at large. I am confident that this compendium will make a good read among the BARC scientific community and inspire many young colleagues.

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‘अपशिष्ट से उत्कृष्ट’

की कार्यनीति को समृद्ध बनाता प्रयोगशाला से कृषि भूमि तक की जैव-प्रौद्योगिकी

सह-संपादक का संदेश

भाभा परमाणु अनुसंधान केंद्र (बीएआरसी) में नाभिकीय कृषि एवं जैव प्रौद्योगिकी प्रभाग (एनएएंडबीटीडी) के पास कृषि अनुसंधान के विविध क्षेत्रों तक एक व्यापक अनुसंधान कार्यक्रम है। एनएएंडबीटीडी का मुख्य दृष्टिकोण, जो कि हमारे राष्ट्रीय लक्ष्य “आत्मनिर्भरता” (स्वाबलंबन) के अनुरूप है, नई जलवायु-समुत्थानशील एवं अधिक उपज देने वाली फसल किस्मों को विकसित करने, फसल सुरक्षा की नई तकनीकों को आगे बढ़ाने और किसानों के खेतों या रसोई-घरों में उत्पन्न होने वाले अपशिष्ट जैव-पदार्थ का प्रभावी ढंग से उपयोग करने के लिए नवीन प्रौद्योगिकियों का निर्माण करने से संबंधित है। ये पहलू सामाजिक लाभ के लिए नाभिकीय ऊर्जा के शांतिपूर्ण उपयोगों को रेखांकित करते हैं। न्यूज़लेटर का यह विशेष अंक भापअ केंद्र की उन अनूठी पहलों पर प्रकाश डालता है, जिन्हें सफलतापूर्वक व्यापक रूप से अपनाई जाने वाली, पर्यावरण-अनुकूल एवं कुशल जैव-अपशिष्ट उपयोग प्रौद्योगिकियों में बदला गया है।

अपशिष्ट प्रबंधन ने वैश्विक महत्व हासिल कर लिया है, क्योंकि दुनिया भर के शहरों में हर दिन भारी मात्रा में अपशिष्ट जमा होता है। उत्पन्न कुल घरेलू अपशिष्ट में से, लगभग आधा प्रकृति में जैव-अपघटनीय होता है और इसमें पर्यावरण की दृष्टि से टिकाऊ तरीके से संसाधित होने की क्षमता होती है। हालाँकि, अपनी जटिल प्रकृति के कारण, रसोई, कैंटीन या खाद्य प्रसंस्करण उद्योग से उत्पन्न अपशिष्ट एक बड़ी चुनौती बनकर उभरा है। इस अपशिष्ट को संसाधित करने की दो प्रमुख प्रौद्योगिकियाँ हैं: बायो-कम्पोस्टिंग और बायो-मीथेनेशन। बायो-मीथेनेशन प्रक्रिया इस अपशिष्ट को अच्छी गुणवत्ता वाले ईंधन में बदलने का एक बेहतरीन तरीका है, जो हमारे देश की ऊर्जा सुरक्षा में महत्वपूर्ण योगदान दे सकता है। इसके अलावा, कम्पोस्टिंग प्रक्रिया के दौरान उत्पन्न जैव-खाद का उपयोग मिट्टी के स्वास्थ्य को बेहतर बनाने और जैविक खेती को बढ़ावा देने के लिए किया जा सकता है।

रसोई घरों, कैंटीन, कृषि उत्पादक बाज़ारों आदि में उत्पन्न होने वाले इस जैव-अपशिष्ट में जटिल जैव-अणु होते हैं, जिन्हें पारंपरिक एकल अवायवीय पाचन-आधारित बायो-मीथेनेशन (बायोगैस) संयंत्रों में प्रभावी ढंग से निम्नीकृत नहीं किया जा सकता। एनएएंडबीटीडी में विकसित प्रमुख प्रौद्योगिकी “निसर्ग-ऋण में अवायवीय पाचन का एक अतिरिक्त चरण शामिल है, जो ऊपर उल्लिखित जैव-अपघटनीय अपशिष्ट को संसाधित करने के लिए एक व्यापक समाधान प्रदान करता है। “रनअराउंड” प्रौद्योगिकी, जिसे पूरे देश में सफलतापूर्वक लागू किया गया है, उपयोगी गैस उत्पन्न करती है जिसका उपयोग सीधे तौर पर खाना पकाने के लिए किया जा सकता है, या सिलेंडरों में भरकर रखा जा सकता है, अथवा बिजली उत्पन्न करने के लिए ईंधन के रूप में इस्तेमाल किया जा सकता है। न्यूज़लेटर का यह अंक ‘निसर्ग-ऋण’ की सफलता से जुड़े कहानियों को विस्तार से बताएगा।

हाल के वर्षों में, यह स्पष्ट हो गया कि प्रभावी अपशिष्ट प्रबंधन के लिए बड़े क्षमता वाले संयंत्रों में अपशिष्टों को प्रक्रमित करने के बजाय, स्रोत पर ही (छोटे हाउसिंग सोसाइटी, होटल आदि में) अपशिष्ट की छोटी मात्रा का प्रबंधन किया जाए। एक छोटी, विकेंद्रीकृत अपशिष्ट प्रबंधन प्रणाली परिवहन एवं आधारभूत ढांचे की लागत में बड़ी बचत कर सकती है। इस उद्देश्य के लिए विशेष रूप से कॉम्पैक्ट मॉड्यूलर ‘शेषा’ तकनीक विकसित की गई। ‘निसर्ग-ऋण’ अवधारणा पर आधारित ‘शेषा’ तकनीक को स्थापित करने के लिए बहुत कम स्थान की आवश्यकता होती है और यह बहुत किफायती भी है। इस तकनीक का पेटेंट कराया गया है (भारतीय पेटेंट संख्या 531960) और इसे विभिन्न स्थानों पर सफलतापूर्वक परिनियोजित किया गया है।

बगीचों, कृषि क्षेत्रों या पवित्र स्थानों पर चढ़ाए जाने वाले फूलों से निकलने वाला बायोमास कचरा मुख्य रूप से सूखे पत्तों, फूलों के अवशेषों एवं अन्य सेल्यूलोज़ पदार्थ से बना होता है। ऐसे अपशिष्ट का प्रबंधन करना कठिन होता है क्योंकि इसके सड़ने में बहुत अधिक समय लगता है। एनएएंडबीटीडी द्वारा विकसित ‘रैपिड कम्पोस्टिंग टेक्नोलॉजी’ (RCT) इस समस्या का प्रभावी ढंग से समाधान करती है। आरसीटी, जिसमें एक एकल सेल्यूलोलिटिक कवक शामिल होता है, इस प्रकार के अपशिष्ट को संसाधित करके उसे उच्च गुणवत्ता वाले जैविक खाद में बदल देता है। उपयोग में आसान इस तकनीक का लाइसेंस कई कंपनियों को दिया गया है, जिन्होंने इसे विभिन्न मंचों के माध्यम से हमारे समाज के एक बड़े वर्ग तक व्यापक रूप से उपलब्ध कराया है। इन सभी प्रक्रियाओं से उत्पन्न खाद मिट्टी के लिए एक बहुत अच्छा ‘कंडीशनर’ (सुधारक) है और इसका उपयोग मिट्टी के स्वास्थ्य को बेहतर बनाने के लिए किया जा सकता है। मिट्टी में मौजूद ‘जैविक कार्बन’ जो मिट्टी की समग्र गुणवत्ता निर्धारित करने वाला एक मुख्य मापदंड है—की नियमित रूप से भरपाई की जानी चाहिए। मिट्टी की गुणवत्ता का मूल्यांकन करने के लिए, एनएएंडबीटीडी ने ‘सॉइल ऑर्गेनिक कार्बन डिटेक्शन किट’ विकसित की है, जिसका उपयोग किसान अपने खेतों की मिट्टी की गुणवत्ता की जांच करने के लिए करते हैं। ‘अपशिष्ट से समृद्धि’ बनाने के एक अन्य उदाहरण के रूप में, इमली प्रसंस्करण इकाइयों से निकलने वाले अपशिष्ट जल को लाभकारी कवक के तेज़ी से विकास के लिए एक कम लागत वाले ‘बड़े पैमाने पर गुणन माध्यम’ में परिवर्तित किया गया है।

जैसा कि इस अंक में विस्तार से बताया गया है, भापअ केंद्र द्वारा विकसित प्रौद्योगिकियों ने समाज पर गहरा प्रभाव डाला है और सतत, पर्यावरण-संतुलित अपशिष्ट प्रबंधन की दिशा में एक मार्ग प्रशस्त किया है। हमें आशा है कि ये और हमारी प्रयोगशालाओं में विकसित की जा रही अन्य तकनीकें ‘अमृत काल’ के दौरान भारत को ‘विकसित भारत’ की ओर अग्रसर करने में महत्वपूर्ण भूमिका निभाएंगी।

डॉ. आनंद डी. बल्लाल
अध्यक्ष
नाभिकीय कृषि एवं जैव प्रौद्योगिकी प्रभाग (एन ए एंड बी टी डी)
जैव विज्ञान वर्ग

Lab-to-Land Biotech Enriching *Wealth from Waste*

ASSOCIATE EDITOR'S *message*

The Nuclear Agriculture and Biotechnology Division (NA&BTD) at the Bhabha Atomic Research Centre (BARC) has a comprehensive research program spanning diverse areas of agricultural research. The chief vision of NA&BTD, which is in line with our national goal of "Aatmanirbharta" (self-reliance), pertains to developing new climate-resilient high-yielding, crop varieties, advancing novel crop protection techniques, and creating innovative technologies for effectively utilizing the waste biomass generated in farmer's field or house-hold kitchens. These aspects underscore the peaceful uses of atomic energy for societal benefits. This thematic issue of the Newsletter highlights the unique initiatives of BARC that have been successfully translated into widely-adopted, Eco-friendly and efficient bio-waste utilization technologies.

Waste management has assumed global significance as huge amount of waste piles up every day in cities across the world. Of the total household waste generated, about half of it is biodegradable in nature and has the potential to be processed in an environmentally sustainable manner. However, due to its complex nature, the waste generated from kitchens, canteens or food processing industry has emerged as major challenge. The two major technologies to process this waste are biocomposting and biomethanation. The biomethanation process is an excellent way to convert this waste into good quality fuel, which can make a vital contribution to the energy security of our country. Furthermore, the bio-manure generated during the composting process can be used to improve the health of soils and give impetus to organic farming. This bio-waste generated in the household kitchens, canteens, agri producer markets etc. comprises of complex biomolecules, which cannot be effectively broken down in conventional single anaerobic digestor-based biomethanation (biogas) plants. "Nisargruna", the premier technology developed at NA&BTD, which has an added step of aerobic digestion, offers a comprehensive solution for processing the above-mentioned biodegradable waste. The Nisargruna technology, which has been successfully deployed throughout the country, generates useful gas that can be directly used or compressed into cylinders for cooking or employed as a fuel to generate electricity. The newsletter issue will highlight 'Nisargruna' success stories in greater detail.

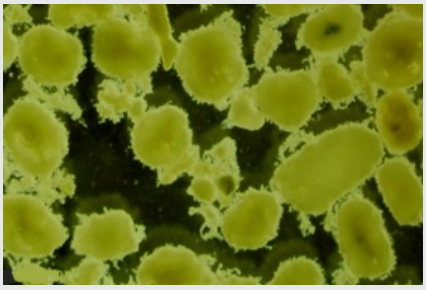
During recent years, it was apparent that managing smaller quantities of waste at the source itself (smaller housing societies, hotels etc.), rather than processing at large capacity plants, was also vital for effective waste management. A smaller, decentralized waste management system would lead to major savings in transportation and infrastructure costs. The compact modular Shesha technology was specifically developed for this purpose. Shesha technology, based on the Nisargruna concept, requires minimum foot print for installation and is also very cost-effective. The technology has been patented (Indian Patent No. 531960) and successfully deployed at different places.

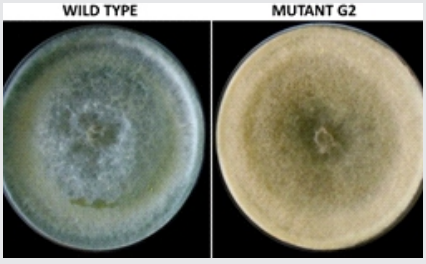
Biomass waste from gardens, agricultural fields or offerings at holy places is primarily made up of dry leaves, flower remains and other cellulosic material. Such waste is difficult to manage as its degradation takes a very long time. The Rapid Composting Technology (RCT) developed by NA&BTD addresses this issue effectively. The RCT, comprising of a single cellulolytic fungus, tackles such type of waste, converting it into high-quality organic manure. This easy to use technology has been licensed to several companies who in turn have made it widely available across different platforms to a broad segment of our society. The manure generated from all these processes is a very good soil 'conditioner' and can be used for improving the soil health. Soil organic carbon, a main parameter that determines the overall quality of soil, needs to replenished on a regular basis. In order to evaluate the soil quality, NA&BTD has developed Soil Organic Carbon Detection Kit, which is used by farmers for testing the soil quality on their field. In another example of 'wealth from waste', solid waste from tamarind processing units has been converted to low cost mass multiplication medium for faster growth of beneficial fungi.

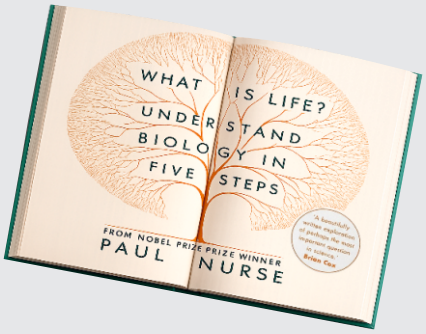
As described in greater details in this issue, technologies developed by BARC have created huge impact on the society and shown a path towards sustainable, environmentally-balanced waste management. We are hopeful that these and other technologies being developed in our laboratories will play a vital role during the 'Amrit Kaal' in advancing India towards 'Viksit Bharat'.

Dr. Anand D. Ballal
Head
Nuclear Agriculture & Biotechnology Division (NA&BTD)
BioScience Group

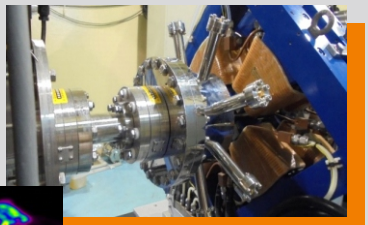
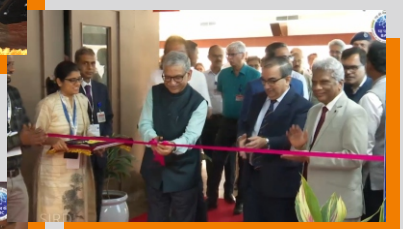
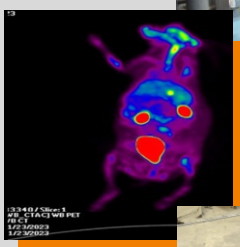
इस अंक में INSIDE



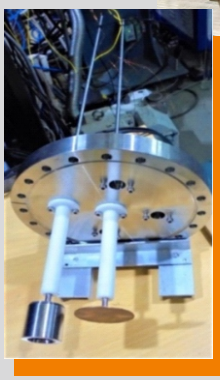




This edition of the BARC Newsletter showcases Bioscience innovations inspired by "Best Out of Waste," with tangible benefits for the environment, agriculture, the economy, and human well-being. It also features a thoughtful review of Nobel Laureate Paul Nurse's popular work - What is Life? Further, this issue also reflects BARC's firm commitment to linguistic diversity - making science accessible across languages to wider audience.





Articles of Forthcoming Issue

R&D outcomes in Accelerator Science & Technology, and Applications

Upgradation of Food Package Irradiator in BARC

Radiation Medicine Centre: Notable developments

BARC abuzz with students on National Science Day 2026

International Women's Day 2026 marked in BARC

निसर्गऋण प्रौद्योगिकी

1

निसर्गऋण : पर्यावरण संतुलन की दिशा में 25 वर्षों की यात्रा

सयाजी मेहेत्रे[1,2*]

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निसर्गऋण-जेएनपीटी

सारांश

भाभा परमाणु अनुसंधान केंद्र, मुंबई ने रसोईघरों, बाज़ारों और बूचड़खानों में उत्पन्न होने वाली जैव अपघटनीय अपशिष्ट संसाधन पदार्थों के प्रसंस्करण के लिए निसर्गऋण प्रौद्योगिकी विकसित की है। यह प्रौद्योगिकी जीवन को बनाए रखने में प्रकृति और धरती मां की भूमिका को स्वीकार करती है और हमें संसाधनों के पर्याप्त रूप से सदुपयोग में अपनी भूमिका निभाने की याद दिलाती है ताकि आने वाली पीढ़ियां भी जीवन की समान गुणवत्ता का आनंद ले सकें। यह एक जैव-मेथैनन प्रक्रिया है जिसमें वायवीय एवं अवायवीय चरण शामिल हैं जो जैव-अपशिष्ट के पूर्ण क्षरण को सुनिश्चित करता है। इससे आयतन में लगभग 90% की कमी होती है। इसके दो उपयोगी उप-उत्पाद हैं- समृद्ध मीथेन के साथ बायोगैस और एक उत्कृष्ट मृदा अनुकूलन के रूप में उच्च गुणवत्ता वाली जैविक खाद। इस प्रौद्योगिकी विकास की यात्रा वर्ष 2001 के दौरान शुरू हुई जब भापअ केंद्र परिसर के भीतर स्थित नर्सरी में पहला प्रायोगिक संयंत्र स्थापित किया गया । इस लेख में निसर्गऋण कार्यान्वयन की वैज्ञानिक एवं तकनीकी यात्रा का अवलोकन शामिल किया गया है।

NISARGRUNA Technology

1

NISARGRUNA: 25 Years Journey Towards Sustainable Environment

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Nisargruna-JNPT

ABSTRACT

Bhabha Atomic Research Centre, Mumbai has developed NISARGRUNA technology for processing of biodegradable waste resource materials originating in kitchens, markets and abattoirs. The technology acknowledges the role of Nature and Mother Earth in sustaining life and reminds us to play our role in resource handling adequately so that future generations also can enjoy the same quality of life. This is a bio-methanation process involving aerobic and anaerobic phases which ensures complete degradation of bio-waste. The volume reduction is about 90%. There are two useful byproducts viz. biogas with enriched methane and high-quality organic manure as an excellent soil conditioner.
The journey of the technology development has started during 2001 when first pilot plant was installed at Nursery, inside BARC campus. Overview of the scientific and technological journey of Nisargruna implementation has been covered throughout this article.

KEYWORDS: *Nisargruna, Biogas, Bio-waste*

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Introduction

A basic tenet that governs the sustainability of our planet is conservation of matter and energy. Continuation of Nature's biogeochemical cycles of various elements is central to this sustainability. The concept of *NISARGRUNA* (which means Nature's loan) is to understand the laws of Nature and, accordingly, play our part as responsible inhabitants of this ecosystem. There is no word called waste in the dictionary of Nature. Viewed in this perspective, waste is not something to be dumped in total disregard to the ecosystem. Wealth contained in waste, in the form of matter and energy, must be recycled and reused.

Unfortunately, waste is associated with a number of negative qualities. Apart from the stink and unsightliness, generation of waste is invariably decentralized. Modern urban societies centralize the collection of waste and, in the process, create problems of mammoth size. Large areas, difficult to find in urban settings, are required to dump our wastes. Dump yards spread stink and ill health and leach toxic substances into ground water. Biodegradable waste materials can reduce the value of dry recyclable waste, when both are mixed. If the biodegradable wastes can be processed separately, subsequent value addition in the remaining waste, mostly recyclable, can lead to economically viable waste management.

Organic matter content of soil is an important component of sustainable agriculture. Though Indian soils have been productive over thousands of years, organic matter in our soils has considerably declined over a period of time. Application of organic manure is a time-tested method to replenish the organic content of soil. Biodegradable wastes generated in kitchens and vegetable markets and agro-wastes generated in agricultural fields are important sources of organic manure. However, these wastes need to be processed before they can be applied as manure. NISARGRUNA technology offers a comprehensive solution to handling biodegradable wastes and is based on the concept of maintaining the elemental balance in nature.

NISARGRUNA plant is designed around the basic concept of safe and environment-friendly treatment of biodegradable wastes, combined with generation of energy in the form of biogas. It offers a decentralized alternative for processing the biodegradable waste generated in human settlements. Basically, it is a biphasic biomethanation plant that can generate about 60-100m^3 of biogas (about 20-30kg of methane) per tonne of waste processed. The gas can be used either for cooking or for electricity generation. Manure, obtained after waste processing, is rich in nitrogen and can be used as an excellent soil conditioner. The carbon to nitrogen ratio of this manure is similar to that of fertile land (12:1). It has good quantities of phosphorous, potassium, iron and magnesium. Moreover, it is weed-free and does not have any offensive smell[1,2].

Principle of Nisargruna Technology

The organically rich bio-degradable portion of solid waste is mixed with water to form slurry. The slurry is then aerobically digested in the predigester, wherein organic matter is converted to organic acids. The predigestion is accelerated by addition of hot water and intermittent aeration. Predigestion reactions are exothermic and the temperature rises to 40^{o}C by itself. Hot water obtained using solar energy is added to raise the temperature to 45^{o}C. Their main role is to digest fats, proteins and low molecular weight carbohydrates to produce organic acids and volatile fatty acids.

The smaller molecules like proteins and simple carbohydrates are degraded during predigestion. The pH of the feed slurry to predigester is around 7.0 - 8.0. The retention time (*Hydraulic time*) in the predigester is 4-5 days. After the predigestion the pH reduces to 4-5. The predigested slurry is further digested under anaerobic conditions for about 25 days. The process of methanogenesis takes place in this digester. Methane and carbon dioxide are the terminal products of this process. Methane is produced from two primary substrates viz. acetate and hydrogen/ carbon dioxide (formate). At this stage the organic acids are converted by consortium of methanogenic bacteria to methane and carbon dioxide.

The undigested lignocelluloses and hemicelluloses then flow out as high quality organic manure slurry. The pH of this slurry ranges from 7.5-8.0.

The three steps of biogas production are as follows: 1) hydrolysis 2) acidification and 3) methanogenesis. Various bacteria are involved in these processes.

Hydrolysis

In this step, the organic matter is hydrolyzed by extra-cellular enzymes (cellulase, amylase, protease and lipase) of microorganisms in the pre-digester tank. Converting solid waste into liquid form in the mixer stimulates this step. Bacteria start decomposing the long chains of the complex carbohydrates, proteins and lipids into shorter parts. Proteins are split into peptides and amino acids. Simple carbohydrates and lipids are degraded completely into organic acids and fatty acids.

Acidification

Acid-producing bacteria involved in the second step convert the intermediates produced in the hydrolysis step into acetic acid (CH_3COOH), hydrogen (H_2) and carbon dioxide (CO_2) in the predigester. These bacteria, of the genus *Bacillus*, are aerobic and facultative anaerobic, and can grow under acidic conditions. An air compressor maintains aerobic conditions in the predigester. To produce acetic acid, the bacteria use the oxygen dissolved in the solution or bonded oxygen. Hereby, the acid-producing bacteria reduce the compounds with a low molecular weight into alcohols, organic acids, amino acids, carbon dioxide, hydrogen sulphide and traces of methane. The pH of the raw slurry falls from 7.5 to about 4.5 to 5.5 in the pre-digester. It appears that in the predigester, various zones are formed and different bacteria dominate these zones.

Addition of hot water helps in eliminating the mesophilic bacteria and selection of thermophilic bacteria. But these thermophilic bacteria can operate at lower temperatures also. Hence hot water added even once a day should be sufficient for maintaining the pure consortium in the predigester. However, if it is possible to maintain the temperature of the predigester in

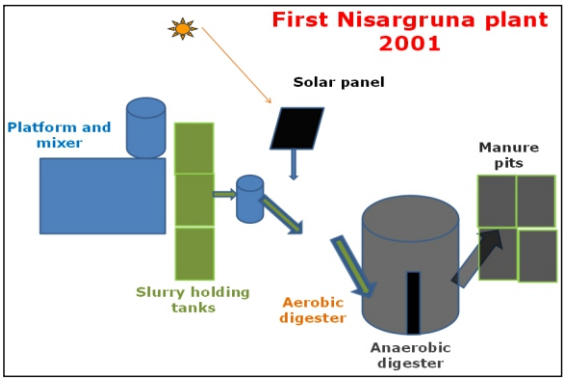

Fig.1: Schematic diagram of the first plant installed at Nursery 2001.

Photo.1: First Nisargruna plant installed at Nursery, BARC 2001.

the range of 50-55°C throughout the day, the performance will definitely be better and the holding time may be further reduced. The hot water helps in hygienization of the slurry by killing the enteric bacteria that may be present in the waste. Some Gram negative enterobacteria and coliform bacteria have been isolated in the raw slurry. However, in the second zone these bacteria are totally eliminated. From the pre-digester tank, the slurry enters the main tank where it undergoes anaerobic degradation by a consortium of methanogenic bacteria belong to the archaebacteria group. These bacteria are naturally present in the alimentary canal of ruminant animals (cattle). They produce methane from the cellulosic materials in the slurry. The undigested lignocellulosic and hemicellulosic materials are then passed on to the settling tank. After about a month, high quality manure can be dug out from the settling tanks. There is no odour in the manure and the organic content is high, which can improve the quality of humus in soil.

Methane Formation

Methane-producing bacteria, involved in the third step, decompose compounds with a low molecular weight. Under natural conditions, methane-producing microorganisms occur wherever anaerobic conditions are provided, for instance under water (in marine sediments), in ruminant stomachs and in marshes. They are anaerobic and very sensitive to environmental changes. In contrast to acidogenic and acetogenic bacteria, methanogenic bacteria belong to the archaebacteria group, a group of bacteria with a very heterogeneous morphology and a number of common biochemical and molecular-biological properties that distinguish them from all other bacterial genera. It is advisable to circulate the generated biogas back into the system using a small compressor. This would enhance the reduction of carbon dioxide to methane and enrichment of methane fraction in the biogas.

The separation of two stages in methane production helps in improving the purity of methane gas, thereby increasing its fuel efficiency. However, the average composition round the year would depend on how effectively predigester temperatures can be maintained. The gas is finally taken through a GI/plastic pipeline to utility points. Drains for condensed water vapor are provided online. The biogas burns with a blue flame and is ideal for cooking. Alternately, it can be used to produce electricity in a dual fuel biogas-diesel engine.

Installation of Nisargruna Technology

First Nisargruna plant was installed during June 2001 at Nursey, opposite to CFB inside BARC campus. The design of the plant is shown in Fig. 1 and Photo 1. The capacity of this plant was 0.5 MT/year. It was the crude prototype with a minimum of infrastructure. It was only an idea which was put into action. After seeing the success of this idea, we were encouraged to develop more plants[1].

The technology got improved over the period of time as per the material available for processing. Important functional modifications were added subsequently. Aeration grid was improved the process was fairly under control. Many gadgets were added in the design of the plant. Over the subsequent years more safety applications and gas utilization aspects were added (Fig. 2)[4].

Utilization of the gas has played significant role in the success of the technology. So gas utilization aspects were added during recent times. This includes electricity generation, gas turbine, community kitchen, vehicle applications etc.

Presently the design given in Fig. no 3 is followed by all the technology licensees. The system includes gas utilization, gas storage, manure enrichment and water cycling etc.

Thus the technology has evolved over the period of time and functioning for the effective management of the biodegradable waste.

Use of Manure as a Soil Conditioner

There is always demand for the manure for soil application, the question is where to get the enormous quantities of organic matter? The concept of bioenergy can provide us both energy and valuable manure. Nature has shown us an excellent way of harvesting solar energy through biological route. Every living cell is an energy power house. Directly or indirectly it uses solar energy. Every bio-molecule is loaded with energy. This route of harvesting energy through NISARGRUNA concept also ensures that we get an energy rich soil conditioner. This will help in replenishing the depleting top soil layer providing us sustainable and dynamic soil matrix to fulfill our food demand. The route also ensures the

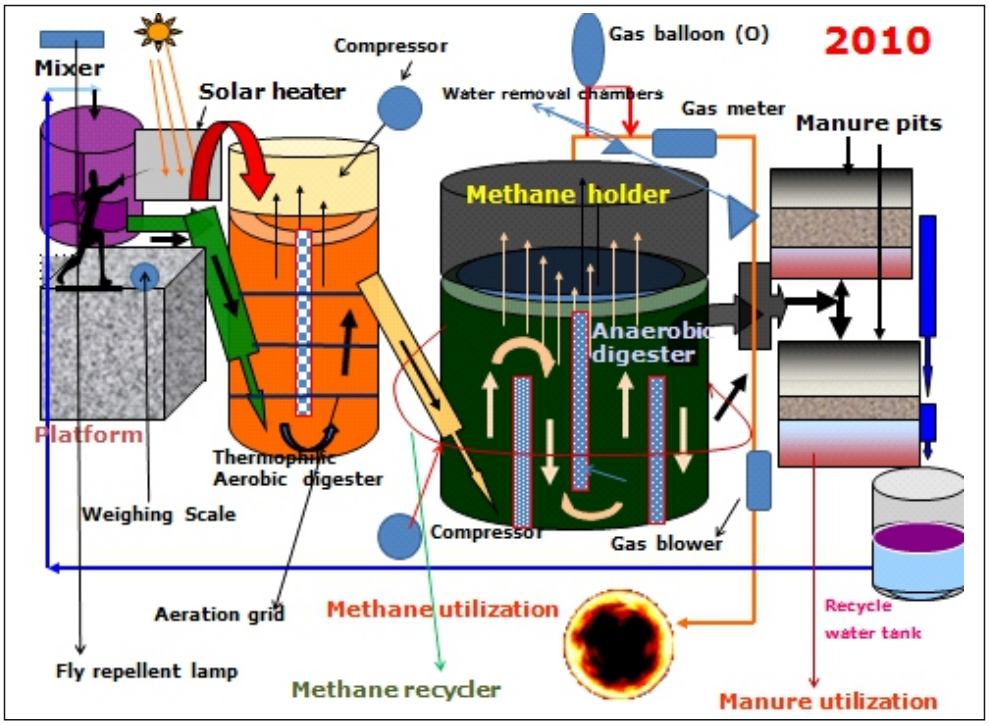

Fig.2: Schematic diagram of the plant.

continuation of biogeochemical cycles of various elements. Indian farmland extends to about 142 million hectares. Each hectare needs about 2-3 MT of good quality organic manure per year. This will also help to reduce substantially the use of chemical fertilizers.

Biogas use, replacing conventional fuels like kerosene or firewood, allows for the conservation of environment. It therefore, increases its own value by the value of saved traditional fuels i.e. forest saved or planted. The price of supplied energy produced by biogas competes with distorted prices on the national or regional level of the energy market. Monopolistic practices, which enable energy suppliers to sell their energy at a price higher than the competition price, still dominate the energy market in many countries including India. A decentralized, economically self-sufficient Nisargruna unit therefore - under competitive conditions - provides its energy without market distortions[3].

Reduction of the Greenhouse Effect

NISARGRUNA technology plays an important role in global struggle against the greenhouse effect. It reduces the release of CO_2 from the burning of fossil fuels in two ways. First, biogas is a direct substitute for liquid petroleum gas (LPG), kerosene or coal for cooking, heating, electricity generation and lighting. Additionally, the reduction in the consumption of artificial fertilizer avoids carbon dioxide emissions that would otherwise come from the fertilizer producing industries. By helping to counter deforestation and degradation caused by overusing ecosystems as sources of firewood and by melioration of soil conditions NISARGRUNA technology reduces CO_2 releases from these processes and sustains the capability of forests and woodlands to act as a carbon sink. Methane, the main component of biogas is itself a greenhouse gas with a much higher "greenhouse potential" than CO_2. Converting methane to carbon dioxide through combustion is another contribution of Nisargruna technology to the mitigation of global warming. This holds true as the material used for biogas generation would otherwise undergo anaerobic decomposition releasing methane to the atmosphere. Of course, burning biogas also releases CO_2. But this, similar to the sustainable use of firewood, does only return carbon dioxide which has been assimilated from the atmosphere by growing plants few year(s) before. There is no net intake of carbon dioxide in the atmosphere from biogas burning as is the case when fossil fuels are burnt[5,6,7].

Advantage of the Technology

- Environmental friendly processing of biodegradable waste is achieved. This waste is completely zeroed and by-products are generated.
- The elemental cycles like nitrogen, carbon, hydrogen, oxygen etc. cycles expect that the biodegradable waste has to go through microbial route for ensuring their availability for future life. Nisargruna achieves this objective fully.
- The processing cost of biodegradable waste is far lesser compared to any other foreign technology.
- Decentralized handling of the waste will reduce the transportation costs, dumping yard needs and assured processing. In long run, it means that dumping yards could be totally eliminated. If proper segregation occurs at the source, then the requirement of land-fill sites can be reduced by 60-70%.

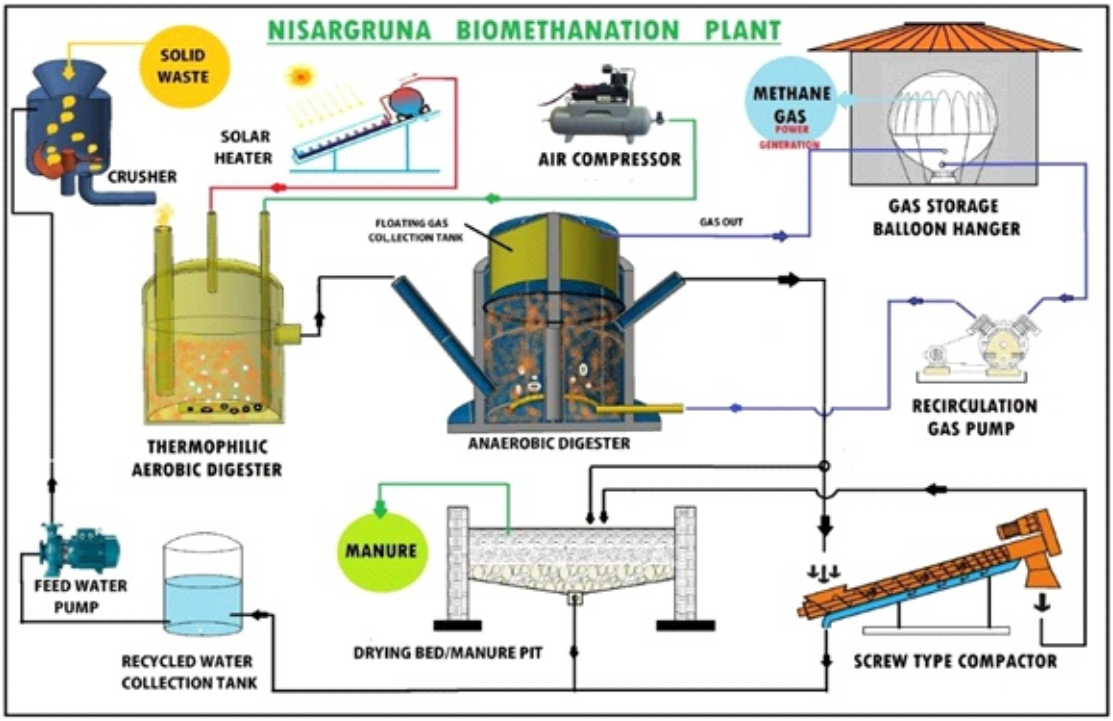

Fig.3: Current design of the Nisargruna technology.

- Transportation of this waste through crowded areas could easily be avoided if decentralized Nisargruna plants are made available.
- By-products like biogas and manure can make the process economically attractive.
- Processing of solid biodegradable waste in this manner would ensure that this material won't be carried to dumping yards and release methane there, in slow and unplanned composting. Since the biogas is trapped to burn, the contamination of environment with a vast quantity of methane will be completely avoided. This would earn carbon credit.
- The use of biogas as fuel will save the classical fuel consumption including petrol, LPG and diesel. This is another reason which will ensure the carbon credit for the process.
- In rural areas where biomass can be made available to run these plants, energy-freedom can easily be achieved. The stand-alone Nisargruna plants can be rural power houses.
- It offers a long-life methodology to treat the biodegradable waste in a very limited space. The continuity of the process makes it possible to treat a large quantity of waste at a single site without any need of adjoining areas.
- The technology is relatively simple and does not involve any imports. The plants can be operated by unskilled workers after training them initially for about 3-4 weeks. It is developed keeping in mind local environment and the types of wastes.
- The manure generated in the process will help in rejuvenating the depleting organic carbon contents in our agricultural soils.

Technological Improvement/Upgradation: Generation of *'Shesha':*

A novel, compact helical shaped digester cum waste converter made of low-cost PVC pipes has been developed and deployed for kitchen waste processing during 2021. The name Shesha (शेष) has been given on the basis of the serpentine shape of this digester (its resemblance to the snake Shesha) as well as Sanskrit name of waste (Fig. 4). The system has been patented with Indian Patent No. 531960[4].

The main advantage of this waste converter includes helical shaped digester made from low-cost PVC pipes which saves major cost of construction and MS dome required for conventional designs. It is suitable for skid mounting on a vehicle or wheels required for processing waste from smaller societies/residential complexes. Also, the design has inbuilt suitability of biogas recycling for methane enrichment and suitable for online monitoring of process parameters. The overall process includes converting organically rich bio-degradable portion of solid waste to slurry by mixing equivalent quantity of water and it is almost the same as occurred in Nisargruna except the plug-flow system. The undigested lignocelluloses and hemicelluloses then flow out as high-quality organic manure slurry. It has been observed that waste is converted into good quality manure and the gas generation is substantial.

The overall process includes converting organically rich bio-degradable portion of solid waste to slurry by mixing equivalent quantity of water. The slurry is then aerobically digested in the predigester, where organic matter is converted to organic acids. The predigestion is accelerated by addition of

Fig.4: Shesha pilot plant installed at Training School Hostel during 2021.

hot water and intermittent aeration. Hot water obtained using heating the gas itself. The smaller molecules like proteins and simple carbohydrates are degraded during predigestion. The pH of the feed slurry to predigester was around 7-8. The retention time (Hydraulic time) in the predigester was 3-4 days. After the predigestion the pH reduced to 4-5. The predigested slurry was further digested under anaerobic conditions for about 25 days. The process of methanogenesis takes place in the digester made up of PVC pipes. At this stage the organic acids are converted by consortium of methanogenic bacteria to methane and carbon dioxide. The undigested lignocelluloses and hemicelluloses then flow out as high-quality organic manure slurry. The pH of this slurry ranges from 7.5-8. It has been observed that waste was converted into good quality manure and the gas generation was substantial. All the microbial and biochemical parameter of the waste was achieved at the end of the process.

Conclusion

Nisargruna technology has matured over the period of time and also proved successful across different sectors of the society. But still there are hurdles in wider application of the technology. These includes

1. Mostly the problem comes when the waste is not segregated properly. The non-degradable material like plastic, iron nails, etc brakes mixer resulting in not functioning plant properly.

2. There are no operational difficulties as far as technology is concerned. Two pilot plants installed at Nursery inside BARC and TSH, Anushaktinagar are working without any major difficulty for last 25 years. During lockdown also plants were working efficiently.

3. Waste management is responsibility of government agencies like municipal corporation, municipal councils, state government so there is delay in implementation of project. Coordination between different agencies is required.

4. Installation and maintenance costs are increasing with time. So government should give some support for its sustainable implementation.

The technology has showed path towards sustainable management of waste and it is our duty to follow all the processes in scientific way for sustained working of the plant.

Acknowledgement

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निसर्गऋण प्रौद्योगिकी

2

निसर्गऋण प्रौद्योगिकी का राष्ट्रव्यापी विकास

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निसर्गरुणा संयंत्र

सारांश

विभिन्न प्रकार के जैव अपघटनीय अपशिष्ट के प्रक्रमण के लिए निसर्गऋण प्रौद्योगिकी विकसित की गई है जो "शून्य अपशिष्ट, शून्य बहि:स्त्राव" का दृष्टिकोण अपनाकर जैव अपघटनीय अपशिष्ट के प्रबंधन के लिए एक व्यापक, विकेंद्रीकृत एवं पर्यावरण के अनुकूल समाधान प्रदान करती है। हालांकि, प्रारंभिक विकास महत्वपूर्ण था, लेकिन संपूर्ण भारत में इसका व्यापक परिनियोजन चुनौतीपूर्ण साबित हुआ है, जिसके लिए देश भर में प्रचालन संयंत्र स्थापित करने के लिए विभिन्न कार्यान्वयन एजेंसियों से व्यापक प्रयासों की आवश्यकता पड़ी । इस प्रौद्योगिकी का परिनियोजन विभिन्न कार्यान्वयन एजेंसियों के सहयोगात्मक प्रयासों के माध्यम से प्राप्त हुआ है, परिणामस्वरूप, पूरे भारत में 400 से अधिक संस्थापन स्थापित किए गए हैं। इस अध्याय में स्रोत पर अपशिष्ट के प्रबंधन में प्रौद्योगिकी की प्रभावशीलता को प्रदर्शित करने वाली प्रमुख सफलता की कहानियों को वर्णित किया गया है।

NISARGRUNA Technology

2

Nationwide Deployment of Nisargruna Technology

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Nisargruna plant

ABSTRACT

Nisargruna technology has been developed for processing different types of biodegradable waste which provides a comprehensive, decentralized, and environment-friendly solution for managing biodegradable waste, by adopting a "zero garbage, zero effluent" approach. While the initial development was significant, its widespread deployment across India proved challenging, requiring extensive efforts from various implementing agencies to establish operational plants nationwide. The deployment of this technology has been achieved through the collaborative efforts of various implementing agencies, resulting in over 400 installations across India. Key success stories demonstrating the technology's effectiveness in managing waste at the source has been narrated in this chapter.

KEYWORDS: *Nisargruna, Biogas, Bio-waste, biodegradable waste*

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Introduction

Achieving a greener future requires changing waste management from simple disposal to proactive reduction, reuse, and recycling, necessitating both individual actions (composting, choosing reusable products) and collective efforts (improved infrastructure, policy support, and community engagement). This comprehensive approach reduces environmental pollution, conserves resources, and supports a sustainable circular economy. Nisargruna technology strongly supports the scientific solution to the society. Success stories of the deployment of the technology has been given below.

Nisargruna Biogas Plant Matheran Hill Station, Karjat, Maharashtra

Matheran being an eco-sensitive zone due to presence of several rare flora and fauna, there are many restrictions imposed by environmental authorities including no vehicle movement and no dumping the waste in open area. Horses are the main mode of transportation which leads in littering the roads with horse dung. There are several hotels and restaurants to cater large number of tourists and such establishments produce several metric tons of biodegradable kitchen wastes.

Mumbai Metropolitan Region Environment Improvement Society (MMR-EIS) signed MoU with Mumbai Municipal Corporation and BARC during 2005 for setting up five-ton capacity plant for processing kitchen waste and horse dung. The plant became functional in February 2007 (Fig. 1). Since then it is functioning in an uninterrupted way till the date. The plant also achieved milestone when it received ISO 9000 certification for its functioning and safety aspects. The plant gave lot of confidence for the technology implementation and successful running for several years.

Organic Solid Waste Management at BARC, Mumbai and Anushaktinagar

Anushaktinagar township, the residential hub for the Department of Atomic Energy (DAE) in Mumbai, houses approximately 40,000 to 50,000 residents. It is a self-contained community covering over 1000 acres, featuring over 9,500 residential flats and 280 buildings. The colony generates 12-15 tons of total waste every day. Out of this, 50% is biodegradable waste. Nisargruna technology has done strong impact on management of the biodegradable waste in the colony. The details f the plants installed at Anushaktinagar is as follows.

First Nisargruna plant was installed during June 2001 at Nursey (Fig.2), opposite to PP inside BARC campus. The design of the plant is shown in Fig. 1. The capacity of this plant was 0.5 MT/year. The plant is running with full capacity over the years and the gas has been given to CFB canteen. The plant was close for 6 months during the Covid pandemic period and was restarted immediately after the normalization of the situation[2].

Second Nisargruna plant was developed at Training School Hostel during 2003 which was developed for processing 2-ton waste per day (Fig 2). The plant is running successfully for last several years. The plant is supplying the gas to the TSH canteen.

Third Nisargruna plant has been installed at BARC hospital site for processing the canteen waste as well as part of the colony waste. The plant has a capacity of 2.5-ton waste processing per day (Fig. 3). The plant has developed during Covid period and started functioning from 2022. Gas has been supplied to the Hospital canteen regularly.

Fourth plant has been installed at BARC Northgate CISF canteen during 2017. The plant has a capacity of 100 kg waste processing per day (Fig. 4). The gas is supplied to the canteen.

Other installations have been done by DCS&EM who is looking after the management of daily waste generated in the colony. DCSEM has installed 6 Nisargruna plants of 500 kg capacity each during 2018. Further the facility was scaled up to processing 3-ton waste plant at Tapti site during 2021 (Fig. 5). Recently another 3-ton capacity plant has been installed at Mandala for processing wet waste. Now all the waste generated in the colony is processed inside the colony only.

NISARGRUNA for Community Kitchen

Kurudampalyam is a small village, 20 Km away from Coimbatore city, with most of the villagers falling below poverty line (BPL), Coimbatore (rural) district authority decided to install a 2 MTPD Nisargruna plant at the village (Fig. 6). In 2014 the plant was completed. Biodegradable waste from the

Fig.1: Nisargruna plant, Matheran and Nisargruna plant at Nursery and the biogas stove at canteen located at 3rd floor of CFB Building.

Fig.2: Nisargruna plant at Trining School Hostel, Anushaktinagar.

Fig.3: Nisargruna plant at BARC Hospital, Anushaktinagar.

adjoining part of Coimbatore city is delivered to the plant every day. The biogas produced at the plant is supplied to a community kitchen across the road. The community kitchen has 12 biogas burners (Fig. 6). Villagers come there with their raw ingredients and cook their meals.

Nisargruna at the Doorsteps of Software Techies

Several corporate houses including Tata Consultancy Services (TCS), WIPRO, Tata Motors, NABARD Bank etc have adopted this technology to make their corporate campuses and premises zero waste facility. TCS has Nisargruna plants at many of their campuses including their largest campus at Chennai. The Chennai campus has a 3 ton plant where the gas is converted to electricity using a biogas generator. TCS, Thane plant is working for more than a decade now (Fig. 7).

Handling Abattoir Waste - Nisargruna gave a Solution

A MoU was signed between BARC and MCGM, Mumbai for processing slaughter house waste (15-ton capacity). Deonar abattoir being the biggest slaughter house in Mumbai was selected for setting up the plant. Slaughterhouse animal wastes like blood, intestines, feathers and hair are generated in huge quantity and used to dumped at the Deonar dumping ground, due to which there was allegations by nearby residents of foul smell and pollution. This was necessitated after the

Fig.4: Nisargruna plant at CISF Headquarter, BARC.

National Green Tribunal had ordered the abattoir to cease slaughter of all animals for export after activities at the slaughterhouse were found to violate environmental norms.

Nisargruna plant was installed during 2016 (Fig. 8) and is running successfully for last 09 years. Substantial amount of electricity has been generated which is used for running Gas turbine.

Use of biogas plant for processing slaughter house waste was done for the first time and it has proved to be very

Fig.5: Nisargruna plant installed at Tapti waste processing site, Anushaktinagar.

Fig.6: Waste collected from the city and processed at the plant to get the gas.

Fig.7: Nisargruna plant at TCS, Thane and Wipro, Kochi.

successful. Plant has been under continuous operation for almost 42 months. Thus the technology has made significant contribution in solving problem of slaughter house waste.

Subsequently the technology was spread to different slaughter houses in Chennai, Rajkot, Bengaluru, Solapur etc for effective management of the waste.

Large Scale Deployment of Nisargruna Technology to the State of Chhattisgarh

Nisargruna technology was transferred to Chhattisgarh biofuel development authority (CBDA), Government of Chhattisgarh during 2023. During first phase, biogas plants were installed at seven locations from tribal districts of Chhattisgarh. First plant at Janapad Panchyat, Jagdalpur was inaugurated by Shri Bhupendra Baghel, Hon. ex-chief minister on 25th Jan 2023 (Fig. 9). The plant has a capacity of 500 kg cow dung processing per day. The plant has also successfully completed production of 10 KW electricity per day and it is connected to the grid.

Nisargruna for Swachha Bharat Mission

Nisargruna technology has been recommended by Swachha Bharat mission of Government of India for making cities clean. The technology was installed by many municipal authorities throughout the country. Further 2nd phase of Swachha Baharat Mission was launched for rural part of country and Nisargruna technology has been introduced for implementation purpose.

Swachha Bharat Mission, Government of India has made a manual on different technologies suitable for management of waste in cities and mentioned the importance of Nisargruna technology (Fig. 10).

Integration of Nisargruna Technology under Government Schemes

The technology has been supported by Ministry of Development of North Eastern Region (MDoNER) for installation of biogas plants at different locations of the North East Region and implemented successfully. Government of Maharashtra also made this technology mandatory for local bodies to treat the solid waste generated in the state.

GOBAR-Dhan (Galvanizing Organic Bio Agro Resources Dhan) Scheme under the Ministry of Drinking Water & Sanitation, GOI has been conceptualized with an aim to convert waste into bio energy, gas and compost which would not only benefit the people but also maintain cleanliness in the villages. Nisargruna technology has been adopted as a part of this scheme. Many technology holders have registered under

Fig.8: Nisargruna plant installed at Deonar Abattoir, Mumbai.

Fig.9: Nisargruna plant was inaugurated by Chief Minister, Chhattisgarh.

this scheme for setting up the plant at village levels. As a part of this programme, the southern state of Kerala has taken the lead by setting up the country's first bio-gas plant during 2019. The Thuruthi waste treatment plant in Pappinissery Gram Panchayat of Kannur district is treating bio waste collected from public spaces, including community and commercial spaces such as markets. The plant has a capacity of treating 1-ton waste per day. Loni-Pravaranagar Dist Ahilyanagar MS has set up one ton capacity plant under this programme during 2023.

Application of Nisargruna Technology with Reference to Villages.

Nisargruna technology has played significant role in processing biodegradable waste generated at different places including village panchayat. There are many plants constructed in rural area and working satisfactorily for processing waste and making the village clean.

Nisargruna biogas plant has started functioning at Sevalaya campus, Kasuva village, Pakkam PO, near Thiruninravur (TN). The District Rural Development Agency (DRDA) has executed a waste-to-energy plant project at Yercaud near Salem (TN). The plant has a capacity of 02-ton waste processing per day[3].

Pune district of Maharashtra has decided to set up one plant in every tahasil based on Nisargruna technology for treatment of kitchen waste. During first phase 3 plants are ready for commissioning during 2026.

Nisargruna Technology Supported the Gas Supply during LPG Crisis

India's LPG supply is facing serious disruption as tensions in West Asia impact tanker routes through the Strait of Hormuz. With nearly 62 per cent of India's cooking gas imported, the crisis is already hitting restaurants and hotels across major cities. The situation highlights the economic impact on the hospitality sector. Institutions that invested early in waste-to-gas plants saw significant relief from the situation. Nisargruna technology installed at Tata Institute of Social Sciences, Mumbai, BARC, Anushaktinagar, different establishments showed significance of the technology to supply the gas to kitchen.

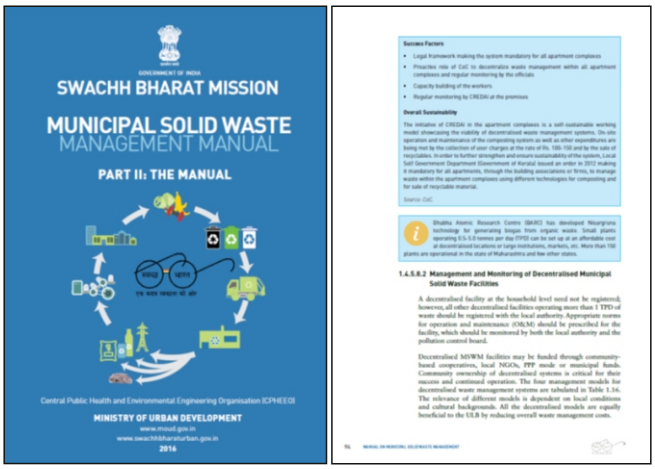

Fig.10: Swachha Bharat Mission Manual highlighted the technology.

Fig.11: Nisargruna plant at Ozar Temple, Dist Pune.

Another success story widely covered by the media during the LPG crisis was the Nisargruna plant at Ozar temple in Pune. The plant has been installed during 2024 and working efficiently with supply of the gas to the canteen (Fig. 11).

Conclusion

BARC's most enduring legacy is the widespread adoption of the Nisargruna biogas technology across India. Hundreds of installed plants are processing thousands of tonnes of organic waste daily, reducing landfill pressure, curbing methane emissions from decomposing waste, and providing clean cooking fuel and organic manure. This represents a significant contribution to India's clean energy and sanitation goals[4,5].

BARC's Nisargruna technology has transformed Indian waste management through several key impacts:

- *Environmental Benefit*: Hundreds of plants process organic waste daily, cutting landfill use and methane emissions.
- *Resource Recovery*: It generates clean cooking fuel and organic manure from "wet waste."
- *Urban Strategy*: The decentralized design helps cities meet Swachh Bharat Mission goals and national waste mandates.
- *Scientific Legacy*: It set a benchmark for biogas efficiency and proved the commercial viability of environmental biotechnology.
- *Economic Blueprint*: Successful commercialization bridged the gap between national labs and industry, maximizing the impact of public research.

Thus, Nisargruna turned a lab innovation into a nationwide standard for sustainable sanitation and clean energy. By successfully shepherding Nisargruna from lab to market, BARC created a blueprint for how other indigenous technologies can be commercialized, thereby amplifying the societal return on investment in public research and strengthening the link between national laboratories and industry.

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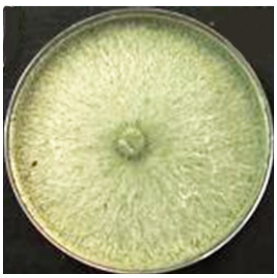
जैव खाद

3

त्वरित वानस्पतिक खाद प्रौद्योगिकी : विकास से परिनियोजन तक

पौलोमी मुखर्जी* और दर्शना सालसकर
नाभिकीय कृषि एवं जैव प्रौद्योगिकी प्रभाग, भाभा परमाणु अनुसंधान केंद्र, ट्रांबे, मुंबई-400085, भारत



ट्राइकोडर्मा कोनिनिओप्सिस वृधि

सारांश

कृषि क्षेत्रों, पवित्र स्थलों में पुष्पांजलि, उद्यानों, बाज़ारों और रसोईघरों वानस्पतिक से उत्पन्न जैव अपघटनीय अपशिष्ट की समस्या का सामना करने के लिए त्वरित खाद प्रौद्योगिकी (आरसीटी) विकसित की गई । आरटीसी में एक एकल सेल्युलोलाइटिक कवक ट्राइकोडर्मा कोनिनिओप्सिस और संबंधित प्रोटोकॉल शामिल हैं। टी.कोनिंनजिओपसिस को उगाना आसान है और इसमें गुणात्मक वृद्धि के लिए न्यूनतम बुनियादी ढांचे की आवश्यकता होती है। आरसीटी को अपनाना आसान है, इसके लिए अपशिष्ट के सुनिश्चित पृथक्करण या मानव शक्ति के विस्तृत प्रशिक्षण की आवश्यकता नहीं है। इसलिए, समाज के सभी वर्गों के अकुशल लोगों को नियोजित किया जा सकता है। यह प्रक्रिया कार्बन पृथक्करण की अग्रगामी है, और प्राप्त खाद जैविक कृषि/खेती के लिए उपयुक्त है। खुले स्थानों में सौंदर्य सुधार, सार्वजनिक स्वास्थ्य एवं स्वच्छता में सुधार, बीमारियों में कमी और पोषक तत्वों का पुनश्चक्रण इस तकनीक के कुछ दूरगामी परिणाम हैं। जबकि कई नगर निगमों द्वारा आवास समितियों से अपशिष्ट उठाव से इंकार किया जा रहा है, आरसीटी जैसी प्रौद्योगिकियां प्रभावी अपशिष्ट प्रबंधन में मददगार हो सकती हैं तथा स्वच्छ भारत मिशन में योगदान कर सकती हैं। विशेष रूप से, आरसीटी को कई कंपनियों को लाइसेंस दिया गया है जिन्होंने इसे देश भर के लोगों के लिए सरलता से सुलभ बनाया है।

Bio Composting

3

Rapid Composting Technology: From Development to Deployment

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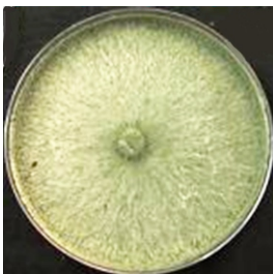

Trichoderma koningiopsis culture

ABSTRACT

Rapid Composting Technology (RCT) was developed to confront the problem of biodegradable waste arising from settings such as agricultural fields, flower offerings at holy places, gardens, markets and kitchens. RCT comprises of a formulation consisting of a single cellulolytic fungus *Trichoderma koningiopsis* and the associated protocols. *T. koningiopsisis* easy to grow and requires minimal infrastructure to multiply. RCT is easy to adopt, does not require strict segregation of waste or elaborate training of manpower. Hence, unskilled people from all sections of the society can be employed. This process leads to carbon sequestration, and the compost obtained is suitable for organic agriculture/farming. Aesthetic reclamation of open spaces, improvement in public health and sanitation, reduction of disease incidence and nutrient recycling are some of the far reaching consequences this technology. With several municipal corporations declining to lift garbage from housing societies, technologies such as RCT can help in effective waste management and contribute to the Swachch Bharat Mission. Notably, RCT has been licensed to several companies who have made it easily accessible to people across the country.

KEYWORDS: *Rapid composting technology, Organic agriculture, Nutrient recycling*

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Introduction

Inordinate urbanization has multiplied the number of authorized and unauthorized garbage dumps strewn across all cities. Their proximity to habitable areas often poses health risks due to toxic leachates and gases. Open burning and self-ignition of garbage in large cities results in the release of thousands of tonnes of deadly fumes with fine particulate matter (Ghosh 2014). On the other hand, at least 50% of garbage generated in India is biodegradable and hence amenable to biological processing (Ghosh 2014). Several technologies such as generation of bio-gas, aerobic and anaerobic composting, vermicomposting, insect-based degradation, are in vogue, each with its share of pros and cons. However, the basic aim of all these technologies is to turn waste into wealth, return it back to the source and derive economically beneficial products. The initiative towards a "Clean India" gave rise to the Swachch Bharat Mission in October 2014. The Swachh Bharat Mission includes a focus on scientific municipal solid waste management, including segregation at source, collection, transportation, processing, and disposal (Wikipedia & https://sbmurban.org/). The effectiveness of any waste-processing technology largely depends on its societal acceptance, environmental compatibility, ease of operation, and economic feasibility. Technologies, that mimic natural biodegradation processes, while being eco-friendly and cost-effective, are more likely to achieve widespread adoption. In this article we describe the development of an aerobic composting technology which uses a single cellulolytic microbe that can be easily multiplied at ambient conditions. This technology provides a scalable solution towards managing biodegradable waste (from kilograms to tonnes) at the source of generation.

Technology development

Aerobic microbial degradation of biodegradable waste, commonly termed composting, not only converts organic waste into nutrient-rich compost but also reduces greenhouse gas emissions compared to anaerobic decomposition.

In natural ecosystems, a diverse group of microorganisms- including bacteria, fungi, and actinomycetes participate in the decomposition process. The addition of lignocellulolytic inoculum at the onset of composting has been shown to enhance the rate of waste degradation significantly (Zhang et al. 2014).It is noteworthy that cellulose, the most abundant natural polymer, is difficult to degrade. Therefore, a fungal strain with high cellulolytic activity, *Trichoderma koningiopsis*, was isolated from the bark of a mango tree as a promising candidate for degrading cellulosic waste (Fig.1). A user-friendly formulation was developed using commonly available sorghum grains as carbohydrate source for mass multiplication of the culture with reasonable shelf life and ease of application (Fig.1).

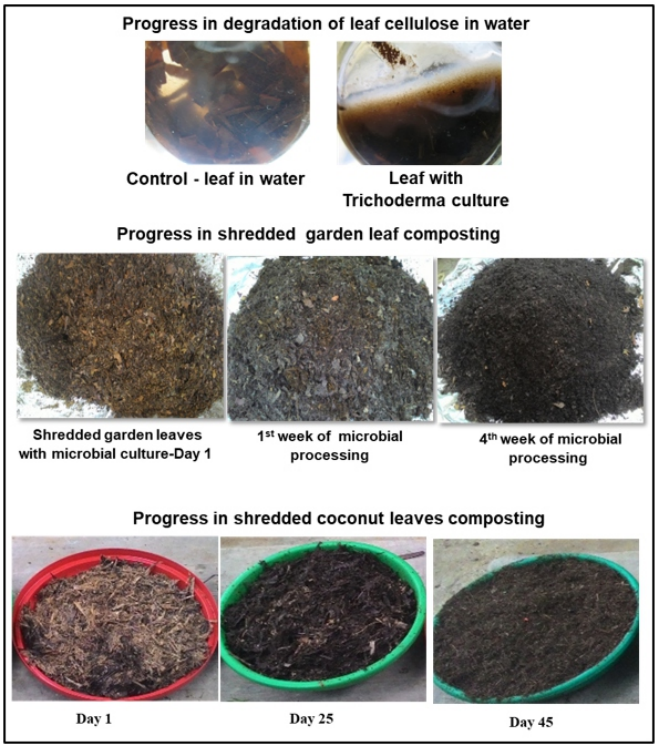

Fig.2a: Different stages of composting process in lab/pilot scale.

Protocol Development for Bio-degradation of Various Biomasses

The protocol for biodegradation was systematically developed through a stepwise scale-up approach, beginning with small-scale laboratory experiments, followed by pilot-scale studies in drums of approximately 100 kg capacity, and finally validated at large-scale (tonnes) under real life conditions of waste generation and processing (Fig.2).

The ideal Carbon/Nitrogen ratio was maintained in the range of 20-40, while moisture content of the feed was maintained within 40-60% (Garg and Tothill 2009)-a critical input. Since waste, such as kitchen waste and dry leaves, inherently vary in their initial moisture and nutrient composition, customized protocols were developed for each category optimizing the dosage of microbial culture and

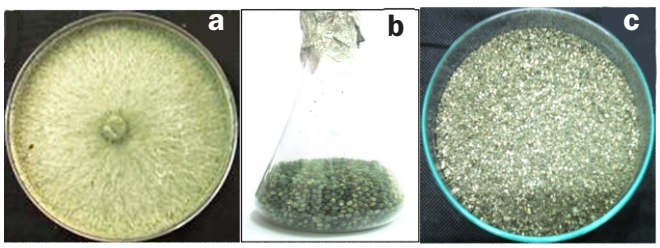

Fig.1: (a) Trichoderma koningiopsis culture, (b) T. koningiopsis growing on sorghum grains (c) T. koningiopsis Formulation for field application.

Fig.2b: Large-scale composting in pits followed by automated sieving.

bulking agents /adsorbents (e.g., coco peat), frequency of upturning (aeration), addition of water (for dry biomass) as required, as well as choice of shredder.

Change in pH, Temperature and Moisture (%) during composting

During the entire period required for composting of kitchen waste, distinct changes in pH, temperature and moisture content, were observed. The pH increased from acidic (~4.3) to alkaline (~8.5) by day 11-13. After Day 13, itstabilized and subsequently declined toward neutral (~7.2–7.8), indicating compost maturation.(Onwosi et al. 2017 and Lin et al. 2018).

Changes in moisture content during composting are dynamic and critical for microbial activity and decomposition efficiency. Moisture content initially ranged between 60-64% and showed a gradual decline with intermittent fluctuations, reaching ~33-35% by day 25.

Changes in temperature during composting, reflects the trend of active thermophilic degradation followed by stabilization during the maturation phase. (Antunes et al. 2016). The rapid increase in temperature from 35°C (ambient) to a peak of 66°C by day 5 confirms intense microbial activity and establishment of thermophilic conditions, essential for accelerated decomposition and effective pathogen reduction. Subsequently, the gradual decline in temperature from day 6 onwards reflects a reduction in readily degradable substrates and a transition towards the stabilization phase.

Strain Improvement through radiation induced mutagenesis

Due issues with lower sporulation rates observed with *T. koningiopsis*, it was desired too improve this aspect by gamma radiation-induced mutagenesis. After exposure to 1.2 kGy dose, one mutant that consistently showed higher and light-independent sporulation was selected. The mutant strain, named as TKDG , will now be included in the modified RCT.

Successful Applications of RCT

In-situ Banana Trash

Bananas are a perennial crop where the pseudo-stem innately collapses after bearing fruits or are felled after harvesting. For every ton of banana fruit harvested, roughly 3 tons of pseudo-stem, 150 kg of rachis, and 480 kg of leaves are produced, along with 100 kg of discarded fruits (Subagyo and Chafidz 2020). Banana by-products such as pseudo-stems and leaves are sometimes returned to the soil to serve as extra nutrients. But, often these discarded into large open-air dumps rendering them unsuitable for chemical and biological breakdown (Torres-León et al. 2018). In a feasibility study at Nandurbar district of Maharashtra, banana pseudo stems and fruit axis were spread along the furrows in the fields parallel to irrigation channels. Controlled dose of RCT formulation (Magic D, product from M/s. Tanay Agronics) was applied through the channels. It was observed that while the outer layers of the pseudo stem dried up the inner layers progressively decomposed in 1.5months and reintegrated into the soil (Fig.3). This saved much of the labour cost involved in gathering, transportation and burning at dumping grounds.

Farm Yard Manure (FYM)

The term “farmyard manure” describes a decomposing mixture of farm animals’ excreta, urine, & leftover debris from roughages or cow feed. A well-decomposed farmyard manure typically includes 0.5% N, 0.2% P_2O_5, and 0.5% K_2O. Common procedures used by farmers to make farmyard manure are flawed with leaching and volatilization causing nutrient loss.

Fig.3: (a) 1st step of manual spraying of culture or sending through drip irrigation, (b) Appearance of the field-furrow after 15 days, (c) after 30 days, (d) final compost after 2 months of application of formulation.

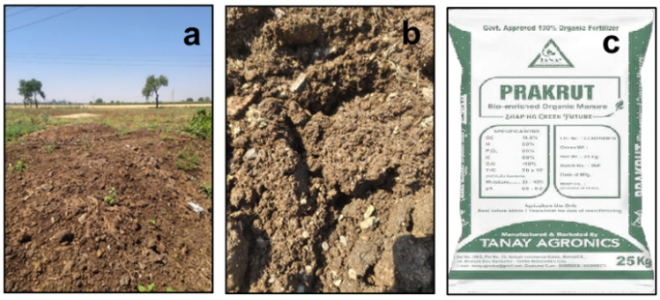

Fig.4: On-field animal dung composting and (a. field and b. close-up view); c. A new product with enhanced Nitrogen content developed by Licensee Tanay Agronics.

Better techniques for FYM preparation that reduce time of decomposition are required. In order to expedite this process, rapid composting formulation was added as 500ml (10^8/ml) per tonne of animal dung. Within 1.5 to 2 months decomposed manure was obtained with: Nitrogen 0.8%, P_2O_5 0.5%, K_2O 0.8% - a considerable improvement over traditional processes which takes about 5 months to mature (Fig.4).

Composting of Kitchen waste

The Homi Bhabha Centre for Science Education adopted RCT in 2018 after the decision of the Brihanmumbai Municipal Corporation to discontinue garbage collection throughout Mumbai. In order to facilitate decentralized waste management, discarded chemical storage drums were repurposed and modified to function as composting units with perforations for adequate aeration. Since implementation, the system has been consistently processing approximately 75 kg of kitchen waste per day, demonstrating operational efficiency and sustainability.

Another notable example is the Kailash Chandra Housing Society located in Mahindra Nagar, Malad. The society generates nearly 250 kg of biodegradable waste daily, all of which is treated on-site using “rapid composting technology” implemented by Chij Agro Industries, a licensee of BARC (Fig.2b). Additionally, around 300 kg of garden waste is processed on-site monthly. The compost produced is utilized within the society's gardens and also serves as a bulking agent for subsequent composting cycles.

Conclusion

This technology is in line with the 12th Sustainable Development Goal of The United Nations, which calls for efficient use of the world’s natural resources, reduced waste generation, and reduced post-harvest losses (World Bank Annual Report). This goal can be achieved by integrating the concept of circular economy (CE) into each stage of a product’s/food/biomass’ life cycle allowing the transformation of waste into valuable products and the concomitant reduction of harmful emissions (Schroeder 2020). Rapid composting technology with many products in the market (Fig.5) is playing its part towards a sustainable future.

Fig.5: A collage of products launched and marketed through online shopping portal.

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अपशिष्ट जल उपचार

4

संधारणीय अपशिष्ट जल उपचार हेतु संकर कणिक अनुक्रमण बैच रिएक्टर (एचजीएसबीआर)

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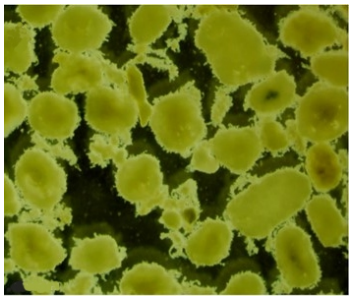

बायोग्रैन्यूल की डिजिटल तस्वीर

सारांश

घरेलू एवं औद्योगिक अपशिष्ट जल से दूषित पदार्थों को प्रभावी ढंग से हटाने के लिए hgSBR एक सघन जैविक उपचार प्रणाली है। यह प्रत्येक बैच के साथ फीड-बैच मोड में प्रचालित की जाती है जिसमें भरण, वातन, नि:सादन एवं क्षय चरण शामिल होते हैं। प्रक्रम स्थिति जैव-मणिका (बायोफिल्म और कणिका) के रूप में अपशिष्ट जल-सूक्ष्मजीव से समुच्चय और कार्यात्मक रोगाणुओं का चयन एवं संवर्धन करती है जो सीओडी, बीओडी, अमोनियम, फॉस्फेट, ठोस और मल कोलीफॉर्म को स्वीकार्य स्तर तक कम कर देते हैं जिससे उपचारित अपशिष्ट जल का सुरक्षित विसर्जन या पुनः उपयोग होता है। कल्पाक्कम टाउनशिप में घरेलू अपशिष्ट जल के उपचार के लिए पूर्ण क्षमता का प्रदर्शन संयंत्र 150 m^3/day और 1500 m^3/day (~ 3200 घर) उपचार क्षमता पर काम कर रहे हैं। इस प्रौद्योगिकी को पूरे भारत में लगभग 28 परियोजनाओं में परिनियोजित किया गया है, जिसमें आवासीय परिसर, विद्यालय, सेना शिविर और प्रयागराज में महाकुंभ 2025 शामिल हैं। प्रगत जैविक उपचार एवं पर्यावरणीय स्थिरता (निम्न भूमि पदचिह्न और लागत) को ध्यान में रखते हुए, देश में अपशिष्ट जल के बुनियादी ढांचे में सुधार के लिए अन्य मुख्य अपशिष्ट जल उपचार प्रौद्योगिकियों की तुलना में जैविक कणों पर आधारित hgSBR लाभकारी हैं।

Wastewater Treatment

4

Hybrid Granular Sequencing Batch Reactor (hgSBR) for Sustainable Wastewater Treatment

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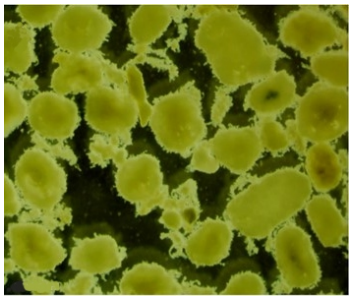

Digital photograph of biogranules

ABSTRACT

The hgSBR is a compact biological treatment system for effectively removing contaminants from domestic and industrial wastewaters. It is operated in fed-batch mode with each batch comprising of fill, aeration, settling and decant phases. The process conditions select and enrich aggregating and functional microbes from wastewater-microbiome in the form of bio-beads (biofilms and granules) which decrease COD, BOD, ammonium, phosphate, solids and faecal coliforms to acceptable levels making safe discharge or reuse of treated wastewater. Full-scale demonstration plants are in operation at 150 m^3/day and 1500 m^3/day (~3200 households) treatment capacities for treating domestic wastewater in Kalpakkam Township. The technology has been deployed in about 28 projects across India including residential complexes, schools, army camps, and Maha Kumbh 2025 at Prayagraj. In view of advanced biological treatment and environmental sustainability (lower land footprint and costs), the biogranules-based hgSBR is advantageous over the other mainline wastewater treatment technologies for improving wastewater infrastructure in the country.

KEYWORDS: *Aerobic granular sludge, Biofilms, Biogranules, Nutrient removal, SBR, Water reuse.*

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Introduction

Effective wastewater treatment is essential to providing sanitation, safeguarding public health, and protecting environment. Activated sludge process (ASP) adopted in 1914 has been the most widely used biological process in wastewater treatment plants (WWTPs) [1]. However, it is no more attractive because of large land footprint, re-circulation flows, inefficient nutrient removal and sludge-bulking challenges. To address these challenges, various biological treatment technologies including moving bed bioreactor (MBBR), membrane bioreactor (MBR), membrane biofilm reactor (MBfR) and sequencing batch reactor (SBR) have been developed. SBR is a fed-batch process offers fine control on treatment and attractive for both centralised and decentralized wastewater treatment.

Microbial communities such as activated sludge flocs, biofilms or biogranules (granular sludge) achieve biological treatment in WWTPs. Formation of biogranules (referred to aerobic granular sludge (AGS), granular activated sludge (GAS) or aerobic granules in literature) was first reported in 1997 for aerobic wastewater treatment [2]. In the last two decades, biogranules have emerged as a favoured option because of robust biodegradation, resilience to toxic pollutants, excellent settling properties and sustainability in terms of lower land footprint and costs. Combination of SBR with biogranules offers compact treatment with advanced biological treatment in WWTPs.

Biogranules Research at BARC

The biogranules represent microbial aggregates comprising of phylogenetically diverse microorganisms self-immobilized in an extracellular polymeric substances (EPS) matrix, distinct from activated sludge flocs. Initial research had focused on cultivation of biogranules under different process conditions, identifying key bioreactor operation conditions and biodegradation of organic and inorganic contaminants of importance to nuclear fuel cycle operations. Formation of biogranules is a developmental process involves induction of bacterial aggregation, formation of tiny aggregates, retention and growth of aggregates into millimetre sized distinct granules. The bioreactor operating conditions such as slow and static feeding, short settling time, aeration rate etc., were found to be critical for cultivation and stability of granules. This research showed that bacteria-laden granules (Fig. 1a and 1b) can be cultivated for biodegradation of several organic compounds including tributyl phosphate, *n*-butanol, dibutyl hydrogen phosphate, nitrilotriacetic acid, 2,4-dinitrotoluene, *p*-nitrophenol, textile dye and acetonitrile [3-7]. Biogranules also removed inorganic pollutants such as ammonium, nitrate, phosphorus, heavy metals and metal oxyanions [9-11]. This work showed that biogranules are suitable for biodegradation or biotransformation of recalcitrant as well as toxic pollutants relevant to industrial processes including nuclear fuel cycle operations.

For larger societal benefit, studies on biogranules-based treatment of domestic wastewater was pursued from 2016 onwards. To address cultivation of biogranules under low-strength domestic wastewater, de novo cultivation of biogranules directly from water or wastewater-borne microbiome with and without carrier material (granular activated carbon) was developed [12-15]. This approach enabled rapid cultivation of biogranules from autochthonous bacteria of sewage and seawater for achieving simultaneous removal of organic carbon, ammonium and phosphate under normal and saline conditions. De novo granulation utilizes the indigenous bacteria that are already thriving in the wastewater or contaminated environment, minimized the time needed for enrichment. Moreover, use of granular activated carbon particles as carrier facilitated enrichment of functional microbes, i.e., ammonium oxidizing bacteria (AOB) and polyphosphate accumulating organisms (PAOs). This is advantageous for establishing partial nitrification-denitrification (PND) and enhanced biological phosphorus removal (EBPR) pathways for removing ammonium and phosphate, respectively. An Indian patent was granted in 2021 for this invention on de novo granulation for bio-beads development and wastewater treatment [16].

Biogranules-based sewage treatment was further evaluated under different conditions including (i) lower temperatures [17], (ii) toxic heavy metals and metal oxyanions, and (iii) antibiotics [18]. These studies suggested resilience and robustness of biogranules to perform biological nutrient removal under varied temperatures (15 to 30°C), in the presence of heavy metals ((Zn(II), Cu(II)), metal oxyanions (chromium, selenite) and antibiotics (oxytetracycline, ciprofloxacin). The data confirmed occurrence of nitrification, denitrification and enhanced bio-P removal pathways in granular bioreactors operated at different temperatures ranging from 15 to 30°C [17] and also in the presence of lower concentrations of toxic emerging contaminants.

hgSBR process development

Initial field-scale tests were carried out in 10 to 100 L

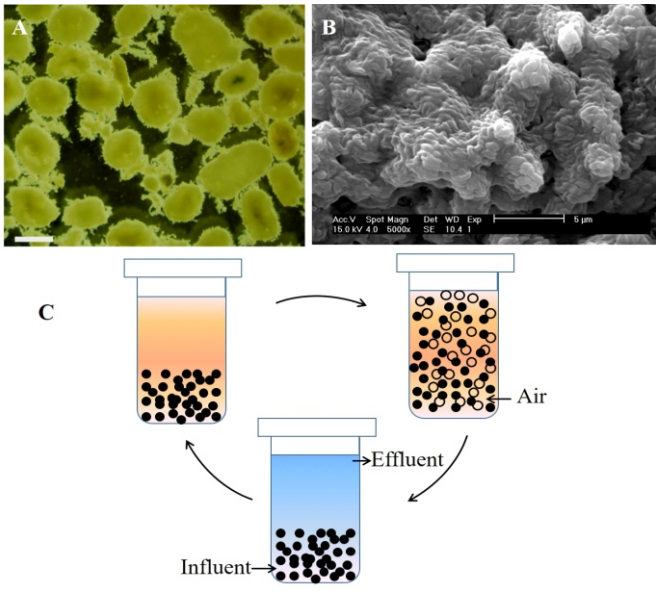

Fig.1: A) Digital photograph of biogranules, scale bar = 1 mm. B) SEM image of a biogranule. C) hgSBR cycle used for cultivating biogranules.

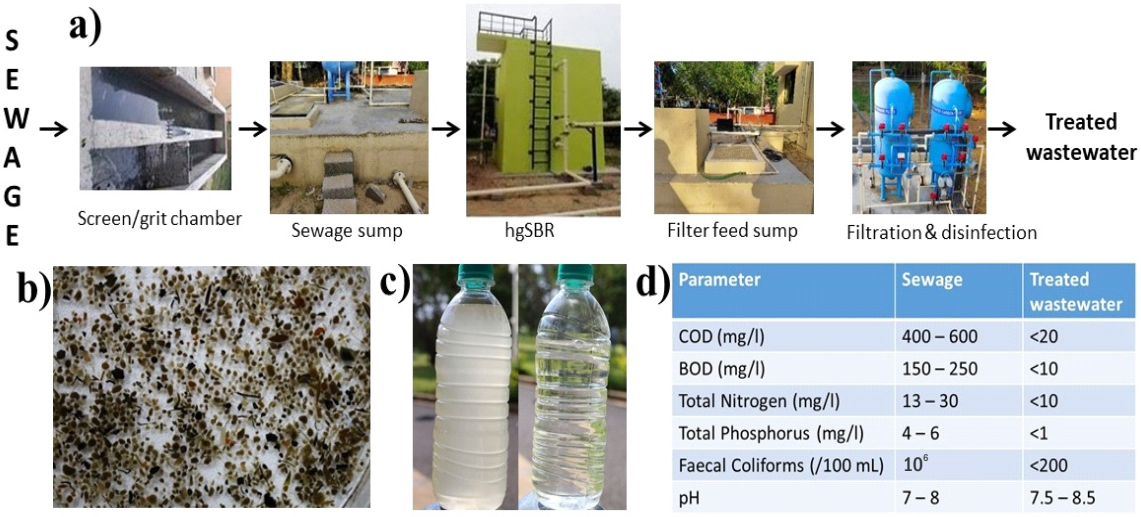

Fig.2: a) Typical process flow of a biogranules-based sewage treatment plant. b) Biogranules (0.2 – 0.5 mm) formed during sewage treatment. c) Sewage before and after treatment using 4 h batch. d) Water quality before and after biological treatment.

volume bioreactors for treating real domestic wastewater. Subsequently, pilot-scale studies were performed in 2 m^3 volume bioreactors with 16.8 m^3/day treatment capacity for evaluating sustained sewage treatment. These studies demonstrated formation of biogranules, enrichment of functional microbes, establishment of nutrient removal pathways and efficient treatment of real domestic wastewater under tropical climate [19,20].

For achieving biological treatment, hgSBR is operated intermittently in fill and draw mode with each batch (cycle) of treatment comprising of filling (static), mixing (aeration), settle and/or decant, and idle phases (Fig.1c). The biological conversions (COD/BOD removal, nitrification, denitrification, phosphate accumulation etc.) are partitioned between the anaerobic and aerobic phases applied during each cycle. The length of cycle and individual phases in each cycle can be adjusted based on influent characteristics and treated effluent quality requirements. Appropriate sizing of tanks and hydraulic flows can be adjusted based on the treatment capacity since hgSBR process is suitable for small, medium and large scale wastewater treatment plants.

Fig.3: Photographs of some hgSBR-STPs. A) 1500 m^3/day plant at Kalpakkam township. B) 500 m^3/day plant used during Maha Kumbh 2025 at Prayagraj. C) 150 m^3/day plant at Surat. D) 400 m^3/day plant at Sangmaner.

hgSBR technology deployment

The knowhow of hgSBR technology was made available to private companies from 2020 onwards [21]. To demonstrate the patented process at reasonable scale and facilitate its commercialisation, two full-scale demonstration plants with treatment capacities of 150 m^3/day and 1500 m^3/day were installed for treating real sewage at Kalpakkam Township. Fig.2 shows typical process flow (Fig. 2a) of hgSBR-STP, morphology of biogranules (Fig. 2b) and sewage treatment performance (Fig. 2c and 2d). In fact, these full scale hgSBR-STPs have contributed to augmenting sewage treatment infrastructure of the township and facilitated technology demonstration to practitioners, and companies involved in developing and providing wastewater treatment infrastructure.

Because of advantages like lesser footprint, reliable and effective treatment, several private companies have entered into technology transfer agreement with BARC for technology commercialization. Presently, it is implemented in over 28 wastewater projects at different places across India majorly for treating domestic wastewater (Fig. 3). Notably, BARC's hgSBR was chosen as the sole technology by Uttar Pradesh (UP) Jal Nigam for providing sanitation during Maha Kumbh 2025 at Prayagraj. As part of this endeavour, 3 numbers of hgSBR-based Sewage Treatment Plants (STPs) each with 500 m^3/day treatment capacity were installed at Sector 10, 13 and 16 in Maha Kumbh Mela area, Prayagraj and used for treating the sewage (black water) collected by the trucks from temporary toilets. The biologically treated wastewater was subjected to ozone treatment and released into a discharge canal. Presently, this technology has been deployed in residential townships, schools, and army camps for providing treating domestic wastewater or mixed wastewater for safe environmental discharge or reuse of treated wastewater in

non-potable applications.

Comparison with other technologies

Side-by-side comparison of biogranules-based process with conventional activated sludge process revealed up to 40–70% reduction in land footprint [22-24]. However, the land footprint reduction in biogranules-based process in comparison to activated sludge-SBR is mainly due to a reduction in the volume of the treatment tank is also significant and up 20 - 30% lower [23]. The land footprint of biogranules-based system is comparable to that of MBR, which is not attractive due to high installation and operational costs because of use of membrane and its biofouling [23,24].

Conclusions

The biogranules research has provided accumulating evidence on reliable formation of biogranules under different process conditions and technological applications for sustainable treatment of domestic and industrial wastewater. The dual combination of bio-beads and SBR operation permits achieving effective biological ammoniacal-nitrogen and phosphate removal essential for avoiding eutrophication in the receiving water bodies. The technology is futuristic for providing new generation wastewater treatment with advantages including lower land footprint, lower energy costs, efficient biological nitrogen and phosphate removals and lesser sludge generation. However, further research addressing granulation mechanisms, identifying key structural biopolymers and optimum aeration rate may help in further improvement. Presently, biogranules-based treatment is largely applied for treating domestic wastewater. Since biogranules exhibit robust metabolism and resilience compared to activated sludge flocs, it is desirable to evaluate biogranules-based system at across different scales for implementing in effluent treatment plants. The fate of emerging pollutants including antibiotics, pharmaceutical compounds, and metal contaminants in biogranules-based systems need to be evaluated in the coming years.

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कृषि अपशिष्ट से संसाधन

5

लाभकारी सूक्ष्मजीवों के लिए इमली के बीज आधारित द्रव्यमान बहुगुणन माध्यम का विकास : कृषि अपशिष्ट से संसाधन

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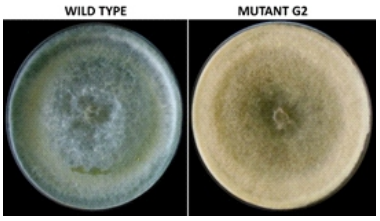

ट्राइकोडर्मा जंगली प्रकार और उत्परिवर्ती नस्ल

सारांश

ट्राइकोडर्मा प्रजाति कई पादप-रोगजनक कवक के विरुद्ध एक जैव कवकनाशक के रूप में कार्य करता है और पौधों में प्रणालीगत प्रतिरोध को प्रेरित करता पाया गया है। ट्राइकोडर्मा प्रजाति के कृषि क्षेत्र में अनुप्रयोगों हेतु द्रव्यमान गुणन की आवश्यकता होती है जिसे ठोस के साथ-साथ तरल अवस्था किण्वन का उपयोग करके प्राप्त किया जा सकता है। इस संबंध में, सस्ते निर्माण के लिए द्रव्यमान गुणन अवस्तर का चयन बहुत महत्वपूर्ण है। इमली के प्रक्रमण से उत्पन्न कृषि अपशिष्ट के प्रभावी उपयोग हेतु इस लाभकारी कवक के विकास के लिए एक आधार सामग्री के रूप में इमली के बीजों का उपयोग किया गया है। उपयोग किए जाने वाला पदार्थ ट्राइकोडर्मा प्रजाति के तेज़ी से विकास के लिए कम लागत वाले द्रव्यमान गुणन माध्यम है। यह पदार्थ ने मौजूदा तरीकों की तुलना में जैव कवकनाशक के बेहतर विकास को समर्थ किया है । इस लेख में प्रौद्योगिकी विकास की सफलता की कहानी को वर्णित किया गया है।

Agro Waste to Resource

5

Development of Tamarind Seed Based Mass Multiplication Medium for Beneficial Microbes: Agro Waste to Resource

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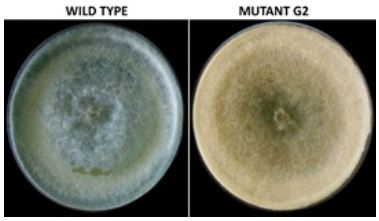

Trichoderma wild type and mutant strain

ABSTRACT

Trichoderma sp. act as a biofungicide against many plant-pathogenic fungi and have been found to induce systemic resistance in plants. The field applications of *Trichoderma* sp. require mass multiplication which can be achieved using solid as well as liquid state fermentation. In this regard, the selection of mass multiplication substrate is very important in order to make cheaper formulation. For effective utilization of agro waste generated from tamarind processing, tamarind seeds have been utilized as a base material for growth of this beneficial fungus. The material used is low-cost mass multiplication medium for faster growth of *Trichoderma* sp. This material supported better growth of biofungicide compared to existing methods. Success story of the technology development has been narrated in the article.

KEYWORDS: *Trichoderma, Agro waste, Fermentation, Tamarind Seeds*

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Introduction

Biological suppression of plant pathogenic fungi has been dominated by use of *Trichoderma* sp. all over the world for last 2-3 decades. *Trichoderma* sp. are free-living fungi that are common in soil and root ecosystems. They are highly interactive in root, soil and foliar environments. They produce or release a variety of compounds that induce localized or systemic resistance responses in plants. *Trichoderma* strains have long been recognized as biological agents, for the control of plant disease and for their ability to increase root growth and development, crop productivity, resistance to abiotic stresses and uptake of nutrients. The field application of *Trichoderma* spp. requires mass multiplication which can be done using solid as well as liquid state fermentation. In the industrialized nations, liquid fermentation is extensively used for multiplication of *Trichoderma* sp. for commercial formulation. However, solid state fermentation is preferred in developing countries like India due to low initial investment as well as availability of cheap labour and space. Presently, solid state fermentation technology uses food grains including sorghum and bajra for commercial mass multiplication of *Trichoderma* sp. at an industrial scale. However, the food grains are comparatively expensive, have short storage life and may not be available freely due to climatic stress. Thus, there is an urgent need to develop a formulation based on easily available material and with lower input cost. The availability of food grain is always demanding and they are costly too. Moreover, these grains are also increasing being used for the production of biofuels, thus adding to its cost. Further, the storage life for these food grains is short and grains are useful for solid state fermentation only. On other hand Tamarind seeds are available as a byproduct and fetches negligible price (Rs 10-15 per kg as compared with Rs 50 -75 per kg of sorghum or bajra grains). They can be procured when available and can be stored for longer time. There is another advantage that it can be useful for both solid as well as liquid formulations depending up on the available facility with the user.

Tamarind Seeds

Tamarind, *Tamarindus indica* L., is a multipurpose tropical fruit tree used primarily for its fruits, which are eaten fresh or processed, used as a seasoning or spice, or the fruits and seeds are processed for non-food uses. The species has a wide geographical distribution in the subtropics and semi-arid tropics and is cultivated in numerous regions. Tamarind has been described as one of the common and most important trees of India. Tamarind trees are grown almost in all parts of the country with states like Karnataka, Orissa, Uttar Pradesh, Madhya Pradesh and Tamil Nadu being the major cultivation centers. India is the world's top producer, exporting several thousands of tonnes of seed, seed powder and fruit pulp each year. Tamarind trees are often grown in gardens and along roadsides and are cultivated commercially in plantations. Usually tamarind fruits are used for edible purposes and seeds are thrown away. These seeds could be used for producing starch which is used for sizing in textile industry and as a general adhesive material (Gaurava et al 2024).

Tamarind seed comprises the seed coat or testa (20-30%) and the kernel or endosperm (70-75%). Tamarind seed is the raw material used in the manufacture of tamarind seed kernel powder (TKP), polysaccharide (jellose), adhesive and tannin. TKP usually contains at least 50-60% of the polysaccharides which is a xyloglucan The unit structure of the tamarind xyloglucan exits as xyloglucan heptasaccharide, octasaccharide and nonasaccharide (Nishinari, et al. 2000). The seeds are also used for other purposes and are presently gaining importance as an alternative source of protein, rich in some essential amino acids. Unlike the pulp the seed is a good source of protein and oil. There has been considerable interest amongst chemists, food technologists and nutritionists in the study of the properties of tamarind seeds due to its quality polyose content which have good gelling behaviour (Marathe et al., 2002).

Development of Technology

Mass multiplication methodology for biopesticide Trichoderma sp has been developed and is available for technology transfer to the industries. All the details of the technology are available on BARC Webpage https://barc.gov.in/technologies/tricho/index.html

The technology was also patented with the Indian Patent File No. 1236/MUM/2012[5].

The technology has been transferred to many industries and products based on the technology are available in the market. Details are given in below.

- Pravara Agrobiotech, Sangamner, Dist. Ahmednagar (MS)
- Ajay Biotech, Pune (MS)
- Agriland biotech, Vadodra (GU)
- Borlong biotechnologies Pvt ltd, Lucknow (UP)
- Ponalab, Bangalore (KA)
- Organica, Govandi, Mumbai
- Panzen Organics Narayangaon, Pune
- Plant Health Solutions, Solapur

Different products based on the technology are available in the market. The products include the following as described in Fig. 1.

Fig.1: Commercial products based on tamarind seed-based formulation of Trichoderma virens, Mass multiplication medium technology has demonstrated the application of low cost material as a growth medium for the agriculturally important microorganism.

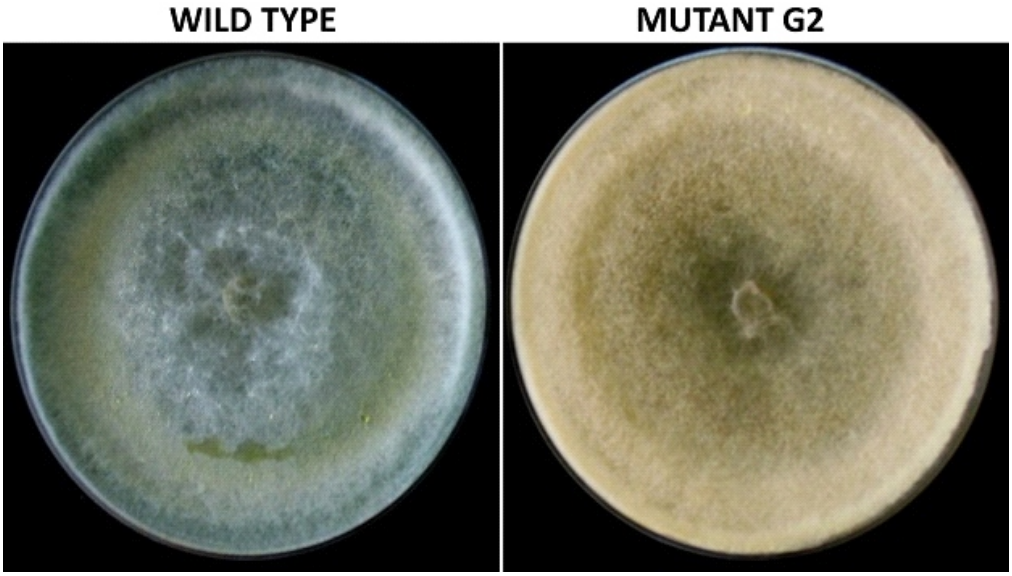

Fig.2: Trichoderma wild type and mutant strain.

Mutagenesis of *Trichoderma Virens*

In order to develop an effective strain for improved disease control under field condition, induced mutagenesis by gamma radiation was practiced at BARC. Sporulated culture (grown in potato dextrose agar slants) of wild type strain of *T. virens* was irradiated with 1250 Gy of gamma-rays (GC5000, BRIT, India). The spores were harvested in sterile distilled water and dilution-plated on PDA amended with rose Bengal (100 mg/L) to restrict colony growth. Morphologically different colonies were transferred to fresh PDA plates. One colony having brown colour conidia and secreting dark pigments in the medium was purified by repeated single-spore isolation and found to be mutant strain (Fig. 2).

The mutant strain was further characterized for the antifungal assay, antibiosis, secondary metabolite production, invitro disease inhibition, *in vivo* inhibition of disease etc. All these studies showed superiority of mutant strain over wild type strain (Mukherjee et al, 2019).

Trichoderma mutant strain showed profuse growth on tamarind seeds (Fig. 3) and was further used for making formulation for field application.

The *Trichoderma virens* mutant strain technology has been combined with mass multiplication medium technology and offered as technology package to industries This technology has transferred to five different companies. Of which, M/s Embio, Mahad has launched a commercial product in the market (Fig. 4).

Further the tamarind seed based medium was also used for BARC-Biostimulant, an actinomycetes strain *Streptomyces rochei* that provide plant growth promotion along with modulation of resistance to damping-off disease.

Thus, the tamarind seeds generated as a low-cost byproduct of tamarind processing has been successfully utilized as a growth medium for mass multiplication of different bio agents.

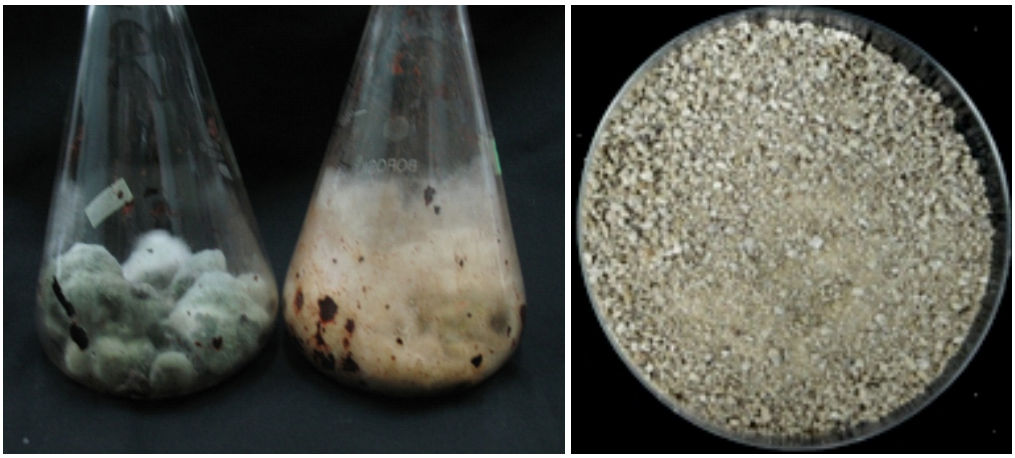

Fig.3: Trichoderma wild type and mutant strain.

Fig.4: Viren: Commercial product of tamarind seed-based formulation of mutant Trichoderma virens.

Conclusion

Mass multiplication of different biocontrol microbes plays significant role in terms stability of the formulation as well its efficacy under field conditions. Trichoderma species has shown promising results when grown on complex substrate rather than simple medium. Tamarind seed-based mass multiplication medium has demonstrated positive results on growth as well as improvement in disease control ability by the microbes.

Thus, tamarind seed-based media enhanced the mass multiplication, gave formulation stability, and improved performance under field conditions of Trichoderma biocontrol agents, demonstrating a sustainable "waste to wealth" technology for farmers.

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कृषि अपशिष्ट

6

संवर्धित मृदा स्वास्थ्य हेतु कृषि-में मूल्यस्थिरीकरण अपशिष्ट का उन्नत फास्फोरस-जिंक उर्वरकों में मूल्यस्थिरीकरण

दर्शना सालसकर[1] एवं सयाजी मेहेत्रे[1,2*]

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गन्ना उद्योग का कीचड़

सारांश

मृदा स्वास्थ्य एवं पोषक तत्व प्रबंधन सतत कृषि के महत्वपूर्ण घटक हैं। मिट्टी एक जीवंत वातावरण है जो फसल उत्पादन की नींव के रूप में कार्य करती है। फसल के लिए पोषक तत्वों की उपलब्धता पोषक तत्वों की उपलब्धता से नियंत्रित होती है। जिंक और फास्फोरस उर्वरक पौधों के स्वास्थ्य में महत्वपूर्ण भूमिका निभाते हैं। इन पोषक तत्वों की उपलब्धता मुख्य रूप से मिट्टी की सूक्ष्मजीव गतिविधि पर निर्भर करती है। इथेनॉल आसवन द्वारा जैव-मिथेनेशन प्रक्रिया में भुक्त धोषण से उत्पादित जैव-आपंक का निपटान उद्योगों के लिए एक बड़ी समस्या है। नए फॉस्फोरस और जिंक उर्वरक निर्माण के उत्पादन के लिए बायोमेथेनेशन के बाद के जैव आपंक के उपयोग के लिए प्रौद्योगिकी विकसित की गई है और फसलों द्वारा अनुप्रयुक्त P के उपयोग में सुधार किया गया है और सफलतापूर्वक व्यावसायीकरण किया गया है। मृदा जैव कार्बन को मृदा स्वास्थ्य का संकेतक तत्व कहा जाता है। जैविक कार्बन की मात्रा और फसल की उपज के बीच सकारात्मक संबंध देखा गया है। किसानों को मिट्टी में कार्बन की मात्रा के बारे में जागरूक करने के लिए क्षेत्र परीक्षण (फील्ड टेस्टिंग) किट विकसित की गई है। यह किट मिट्टी की उर्वरता का तत्काल परिणाम दर्शाता है। इस अध्याय में फॉस्फेट और जस्ता उर्वरक तथा मिट्टी के जैविक कार्बन का पता लगाने वाले उपकरण के महत्व का वर्णन किया गया है।

Agricultural Waste

6

Valorization of Agricultural Waste into Improved Phosphorus-Zinc Fertilizers for Enhanced Soil Health

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Sugarcane industry sludge

ABSTRACT

Soil health and nutrient management are critical components of sustainable agriculture. The soil is a living environment that serves as the foundation for crop production. Availability of the nutrient to the crop is governed by availability of the nutrients. Zinc and Phosphorus fertilizers plays significant role in plant health. Availability of these nutrient is primarily depending on the soil microbial activity.

The disposal of bio-sludge produced in the bio-methanation process of spent wash generated from ethanol distilleries is a big problem for the industries. Technology for utilization of the post-biomethanation biosludge for producing new Phosphorus and zinc fertilizer formulation and improve utilization of the applied P by crops has been developed and successfully commercialized. Soil organic carbon is called as indicator element of soil health. Positive correlation has been observed between amount of organic carbon and crop yield. In order to make farmers aware about the carbon content in the soil, field testing kit has been developed. This kit gives the instant idea of soil fertility. Importance of phosphate and zinc fertilizer and soil organic carbon detection kit has been narrated in this chapter.

KEYWORDS: *Bio-sludge, Soil, Fertilizer*

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Introduction

Phosphorous; being an essential element is indispensable in crop production. Phosphorus deficiency is wide spread many parts of the globe including crop lands of Asia. Costly phosphatic fertilizers like single superphosphate (SSP, 16% P_2O_5), diammonium phosphate (DAP, 46% P_2O_5) and complex fertilizers (NPK containing 32% P_2O_5) need to be used by the farmers. The estimated demand of phosphatic fertilizers in 2022-2023 is 8.3 million MT of SSP, 11.5 million MT of DAP and 10 million MT of complex fertilizers. The benefit of application of phosphatic fertilizers is limited by fixation of added fertilizer P in soils which reduces the utilization of added P by the crops. This leads to lower benefit: cost ratio. Phosphatic fertilizers and soil and crop management strategies ensuring better utilization of P by the crop is a cherished goal to economize cost of crop production and maximize the returns in terms of kg marketable produce per kg of P applied through fertilizer. Earlier scientific investigations have hinted that use of adequate organic manures like farmyard manure etc. may improve the utilization of fertilizer P in agriculture as these manures render soluble organic acids to interfere with chemical transformation of soluble fertilizer P into relatively insoluble P compounds and also compete with P for irreversible ligand exchange sorption in soils[1,2].

Among organic manures, FYM is the most common source however, owing to non-scientific way it is produced in the villages it is not only poor in terms of nutrient content but also the content of water soluble organic matter. Moreover, the availability of adequate organic manures even in the rural belts is becoming problematic due to increasing mechanization in agriculture. The scope of green manuring is limited by farmer's serious concern for the loss of crop season which may generate extra income to the farmer Among other available substitutes of FYM, biosludge produced at post-menthanation step of molasses based distilleries is very rich source of water soluble organic matter and could be used. The molasses based distilleries bear extra cost for its safe disposal. The main objective of this technology was to improve SSP fertilizer product which could result in better use efficiency of applied fertilizer P to the current crop and ensures better utilization of residual fertilizer P to the subsequent crop as well so that the expenditure on P fertilizers can be reduced without sacrificing crop yields and P uptake. The formulation ensures better cost benefit ratio in crop production and also help the distillery to recover a part of the cost incurred in biomethanation step of spent wash generated by the distilleries.

Importance of Zinc

Zinc deficiency in soil is widespread throughout the world, especially in rice croplands of Asia and in soil order of Entisols, Aridisols, Alfisols, Mollisols and Vertisols. A Scrutiny of 1.45 lakh soil samples from different agro-ecological zones comprising different soil types of India in recent years also indicated that 45 per cent mean deficiency of Zn and 49 percent based on compilation of data of 2.52 lakh soil samples from 20 states.

Crops require only a small amount of Zn for their normal growth. A normal crop of rice yielding 7.0 t ha^{-1} removes about 250 g Zn while soil application rates are much higher i.e. 50-60 kg zinc sulfate per hectare as the fertilizer use efficiency of Zn often remain less than 5 per cent owing to large scale fixation of Zn in soils. In Maize-Wheat-Maize cropping sequence, the percent utilization of soil applied Zn had been reported to be 0.22, 0.38 and 0.04 per cent only. Availability of fertilizer Zn to subsequent crops is also poor and keeps on declining with time. In order to economize crop production on sustainable basis, research efforts are warranted to enhance the use efficiency of Zn fertilizer on such soils. The integrated use of organic and inorganic fertilizers has been found promising to maintain higher productivity and to provide maximum stability in terms of crop yield. Bulky organic manure when applied at a rate of 5 to 10 t/ha in rice-wheat cropping system tends to build up the organic matter in wet tropics and could reduce Zn fertilizer dose to about 50 percent. The beneficial effect of organic manures had been attributed to the production of natural complexing agents forming soluble complex with zinc,

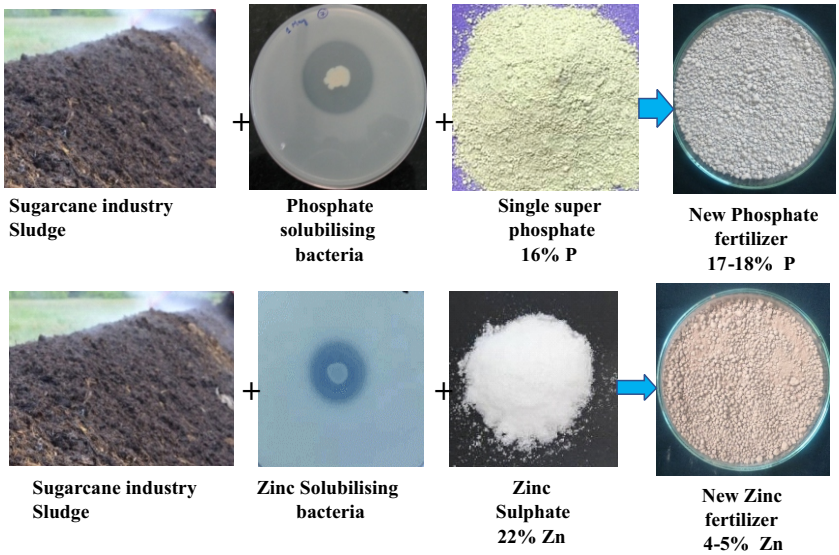

Fig.1,2: Phosphate and Zinc fertilizer formulation developed from biosludge.

which may be efficiently utilized by crops. However, despite the well-known benefits of organic manures, farmers in Asia often do not get adequate supply of FYM to reduce their chemical fertilizer requirement of Zn and other nutrients. In this invention, the process of making Zn formulation based on post-methanation bio-sludge from a molasses based distillery which has higher efficiency than conventional Zn fertilizer ($ZnSO_4.7H_2O$) has been described.

The formulation ensures better cost benefit ratio in crop production and also help the distillery to recover a part of the cost incurred in biomethanation step of 'spentwash' generated by the distilleries.

Technology development and transfer to industries

Sugar industry biosludge was used for the development of the Phosphorus and Zinc enriched fertilizer and tested under field conditions (Fig.1,2). Both the formulations gave excellent performance under field condition for two successive crops.

Both the products are patented and developed as a technology[3,4] has been launched by the companies in the market. Fig.1,2 Phosphate and Zinc fertilizer formulation developed from biosludge[5,6].

Soil organic carbon detection kit

Organic carbon plays significant role in improvement of soil fertility. All the soil fertility parameters like crust formation, drainage, salt accumulation, alkalinity, beneficial microbes, pathogens are linked to organic carbon. If organic carbon is low all these parameters get affected badly. In order to maintain the soil fertility to achieve higher crop yield, improving soil organic carbon is a prerequisite. So periodical monitoring of soil organic carbon is as essential component of soil health management.

Importance of soil organic carbon

Understanding soil Organic Carbon helps farmer in the following ways:

- It increases growth soil microorganisms, which help in effectively maintaining elemental biogeochemical cycles, and makes these nutrients available to the plants in smooth manner.
- It is an excellent soil conditioner and provides a good infrastructure for soil microorganisms.

Fig.3: Different components of soil organic carob detection kit.

- The porosity of soil increases due to addition of organic carbon, thereby increasing aeration and avoiding water stagnation and overall improving soil health.
- Soil organic carbon helps to stabilize soil particles, thus decreasing erosion. It also improves soil structure and workability, enhances aeration and water penetration, increases water-holding capacity and improves nutrients supply for growth of both plants and soil micro-organisms.

Existing methods of soil organic carbon analysis

Presently organic carbon is analysed by using acid titration and CHNS analyser. But there are limitations to analyze organic carbon of soil regularly due to specific reagents, skills and proper setup that are available only at approved laboratories. As these laboratories are in low number and farmers are unable to monitor soil organic carbon on regular basis. Ideally a quick, accurate and field test will be able to guide the farmer for this purpose[7,8,9].

Then how to know the organic carbon content of your soil?

Technology of soil organic carbon detection kit has been developed at BARC for instant analysis of soil organic carbon on the field (Fig.3).

This is very quick and reliable method of organic carbon estimation which helps farmers to decide the doses of fertilizers in proper time and their by helps for improvement of crop yield. Timely application of manures and fertilizers plays key role to increase the crop yield. The technology developed at BARC thus helps to the farmers as well as soil testing laboratories for improvement of soil health.

Fig.4: Different products based on the technology are available in the market.

Fig.5: Technology published as impact story on IAEA Webpage.

Farmers have become more aware about ill effects of chemical day by day and consumers are also demanding organic foods. This kit is an excellent tool to test the organic nature of soil. As this is quick method and all the farmers can perform it on the field, then farmer doesn't have to rely on other agencies for the results. Organic carbon detection kit has become an important tool in organic agriculture which is going to be agriculture of coming years.

Technology dissemination and spread

The technology has been included as a technology package for implementation of AKRUTI programme of DAE. Under this programme use of the technology has been used by farmers on large scale. Farmers are checking their soils regularly and found it very useful. Under this programme this technology has been transferred to about 40 institutes/individuals and they have come up with the products useful for the farmers.

Technology to commercialize the kit has also been transferred to several entrepreneurs and different products are available in the market (Fig.4). This technology has been also included for Start-up programme of Government of India. International Atomic Energy Agency (IAEA) has published the impact story of the technology on the webpage and appreciated the simplicity of the technology effectively solving the problem of the ordinary farmers (Fig.5).

Movement of water conservation and soil improvement in Maharashtra

Panni Foundation (an NGO by Mr Amir Khan) has started an initiative for conservation of water in Maharashtra state for last 4-5 years. Under this programme different villages are taking part for water conservation in the soil by building check dams, terrace and contour bunds, tree plantation etc. It is obvious that in order to conserve water, it is equally important to improve the organic carbon content of soil. So testing soils from entire state has been planned under this activity and thousands of samples are tested every year. Soil carbon improvement has become a movement in entire state and included in all the training programme of this purpose.

Conclusion

Agro waste generated during different processes creates problem either to the environment of other component of ecosystem. But these agro waste if utilized in proper way can be effectively converted to useful fertilizer. Two technologies developed from sugar industry biosludge has shown the way towards sustainable management of waste for production of fertilizer that not only increases the yield but also improves the fertility of soil.

Fertility of the soil was again tested by using soil organic carbon detection kit developed for making farmers aware about the importance.

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Book Review

Interconnectedness OF ALL LIVING THINGS & The Role of Evolution

By Dr. S. Adhikari

What Is Life? by Paul Nurse is a masterful synthesis of biology's foundational ideas, rendered accessible through clear prose, personal narrative, and historical context. Each chapter builds upon the weaving together the cell, gene, evolution, chemistry, and information into a coherent framework for understanding life. Nurse's central thesis is that life is best understood as a dynamic, evolving system-bounded, self-regulating, and information-rich, emerging from the interplay of physical, chemical, and informational processes. This understanding is not merely academic; it is essential for addressing the existential challenges of our time.

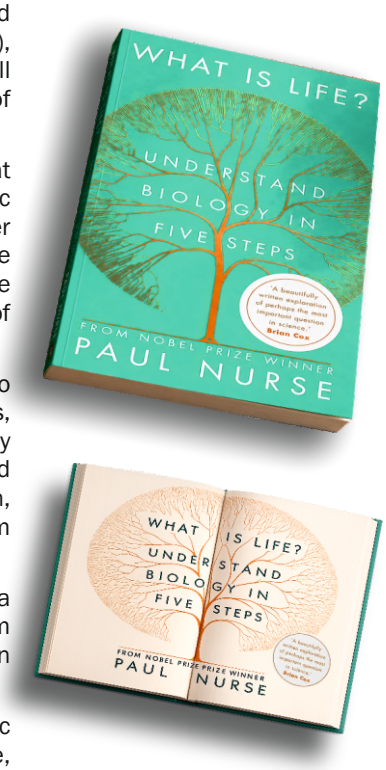
Sir Paul Nurse is one of the most distinguished biologists of his generation, renowned for his pioneering work on the cell cycle. Nurse's Nobel Prize in Physiology or Medicine (2001), shared with Leland Hartwell and Tim Hunt, recognized his discovery of key regulators of the cell cycle work that has had profound implications for cancer research and our understanding of cellular reproduction.

Drawing inspiration from Erwin Schrödinger's classic scientific book, also titled What Is Life? Nurse both pays homage to, and expands upon Schrödinger's focus on genetic inheritance and order in living systems. However, Nurse argues that a complete answer requires a broader perspective, one that synthesizes five foundational ideas in biology: the cell, the gene, evolution by natural selection, life as chemistry, and life as information. These concepts, he proposes, are the "steps" that allow us to climb toward a clearer understanding of life's essence.

Nurse begins his exploration of life with the cell, which he dubs "biology's atom" to emphasize its foundational status. The historical narrative traces the discovery of cells, beginning with Robert Hooke's 1665 observations of cork under a microscope, followed by Anton van Leeuwenhoek's identification of single-celled "animalcules" (bacteria) in pond water and dental plaque. The development of cell theory in the 19th century by Schleiden, Schwann, and Virchow, who famously declared "Omnis cellula e cellula" ("all cells come from cells"), cemented the cell's status as biology's atom.

Nurse also explores the implications of cell division, both in development (from a single fertilized egg to a complex organism) and in disease (such as cancer, which arises from uncontrolled cell division). He highlights the importance of model organisms like yeast in uncovering the mechanisms of cell division, drawing on his own Nobel winning research.

Nurse explains the central dogma of molecular biology: DNA encodes genetic information, which is transcribed into RNA and translated into proteins. The genetic code, composed of triplets of nucleotide bases, specifies the amino acid sequences of proteins. Mutations that introduce variation, is the raw material for evolution. The interconnectedness of all life is illustrated through the metaphor of the "tree of life," with all species tracing back to common ancestors. Nurse elucidates the evolution of biochemical understanding, from early studies of enzymes to modern systems biology, which seeks to map and model the vast networks of interactions within cells.



Dr. Soumyakanti Adhikari joined the Chemistry Division at BARC in 1991 following his graduation from the BARC Training School. He quickly established himself as a specialist in radiation chemistry, focusing his research on free radical chemistry, electron processes in exotic solvents, and the synthesis of nanomaterials for bio-applications. Over a distinguished career spanning several decades, he has received numerous honors, including the IUPAC Young Chemist Prize (2001), the Asia Pacific EPR/ESR Society's Distinguished Service Award (2004), and the DAE-Science & Technology Excellence Award (2008). After serving in leadership roles within BARC's Knowledge Management Group, Dr. Adhikari currently holds the prestigious Homi Sethna Chair Fellowship in the Department of Atomic Energy.

राजभाषा गतिविधियां @भाभा परमाणु अनुसंधान केंद्र

भाभा केंद्र, मुंबई की सामाजिक सरोकार से जुड़ी अर्ध-वार्षिक हिंदी वैज्ञानिक पत्रिका "परमाणु विज्ञान" के प्रथम अंक का लोकार्पण करते हुए श्री विवेक भसीन, निदेशक, भापअकें और अन्य वरिष्ठ अधिकारीगण।

हिंदी माह-2025 में सर्वोत्कृष्ट प्रदर्शन करने वाले प्रतिभागी को "हिंदी सितारा-2025" प्रदान करते हुए भापअ केंद्र के वरिष्ठ अधिकारीगण।

भाभा परमाणु अनुसंधान केंद्र, मुंबई में राजभाषा के प्रचार-प्रसार के अंतर्गत जनवरी - फरवरी, 2026 के दौरान भापअ केंद्र राजभाषा समन्वय समिति एवं हिंदी अनुभाग और वैज्ञानिक सूचना संसाधन प्रभाग (वै.सू.सं.प्र) के संयुक्त तत्वावधान में निम्नवत कार्यक्रमों का आयोजन किया गयाः-

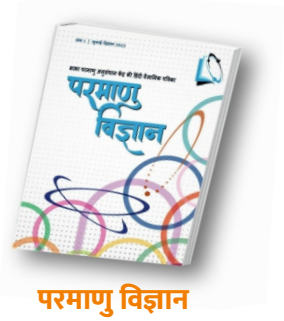
हिंदी पुस्तकों की विशेष प्रदर्शनी - दिनांक 12-30 जनवरी, 2026 तक वै.सू.सं.प्र द्वारा हिंदी पुस्तकों की विशेष प्रदर्शनी आयोजित की गई। श्री विवेक भसीन, निदेशक, भापअ केंद्र द्वारा इस प्रदर्शनी का विधिवत उद्घाटन किया गया। बड़ी संख्या में पाठकों ने इस प्रदर्शनी का लाभ उठाया।

विश्व हिंदी दिवस का आयोजन - श्री विवेक भसीन, निदेशक, भापअ केंद्र की अध्यक्षता में दिनांक 12 जनवरी, 2026 को विश्व हिंदी दिवस समारोह का आयोजन किया गया। इस समारोह के एक भाग के रूप में, नवोदित गायिका कुमारी दृष्टि गुप्ता, अणुशक्तिनगर द्वारा गीतमाला की प्रस्तुति दी गई, जिसे श्रोताओं ने खूब सराहा।

पत्रिकाओं का लोकार्पण - 12 जनवरी, 2026 को आयोजित विश्व हिंदी दिवस के कार्यक्रम के अवसर पर केंद्र के निदेशक श्री विवेक भसीन के कर-कमलों से निम्नवत पत्रिकाओं का लोकार्पण किया गयाः-

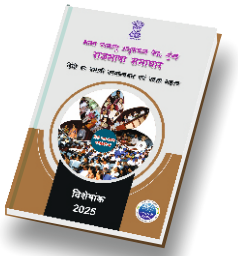
- परमाणु विज्ञान - भापअकें, मुंबई की सामाजिक सरोकार से जुडी अर्ध वार्षिक हिंदी वैज्ञानिक पत्रिका।
- राजभाषा समाचार विशेषांक - हिंदी माह, 2025 की विभिन्न गतिविधियों पर आधारित संकलन।

हिंदी माह, 2025 के पुरस्कारों का वितरण - 12 जनवरी, 2026 को हिंदी माह, 2025 के दौरान आयोजित विभिन्न प्रतियोगिताओं के 115 विजेता प्रतिभागियों को पुरस्कृत किया गया। इसके अतिरिक्त, 01 सर्वोत्कृष्ट प्रदर्शन करने वाले प्रतिभागी को "हिंदी सितारा" से सम्मानित किए गए जबकि दो (02) अन्य प्रतिभागियों को "हिंदी विशिष्ट प्रतिभागिता" पुरस्कार प्रदान किए गए।



परमाणु विज्ञान

सामाजिक सरोकार से जुडी अर्ध वार्षिक हिंदी वैज्ञानिक पत्रिका।



राजभाषा समाचार

हिंदी माह, 2025 की विभिन्न गतिविधियों पर आधारित संकलन।

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