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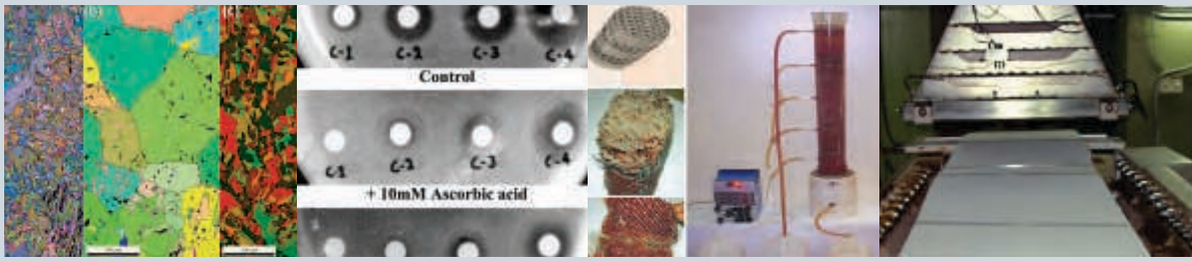
BARC NEWSLETTER



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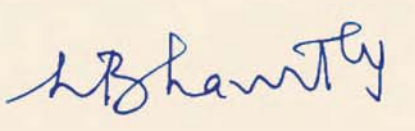
From the Editor's Desk

On behalf of the Editorial Committee, let me take this opportunity to wish you and your families a very happy and prosperous 2012.

BARC Newsletter has been exciting Scientists/Engineers for more than three decades now and has successfully completed two years of publishing in its new format. We are getting several positive feed-backs both from the scientific community in BARC, DAE and also from various Institutes in India and abroad. We are constantly endeavoring to improve the quality of the BARC Newsletter.

Starting from this year, we have introduced a new feature in our Newsletter. We will be publishing short articles, involving new R&D work or technological innovation or development carried out by our Scientists and Engineers under the heading "Brief Communication". We shall appreciate receiving contributions from you in your field of work. This communication will provide the right platform for publishing your work quickly and also help other researchers at BARC to know about your work. The proforma for submitting this Brief Communication can be found at the SIRD Divisional Website, under the hyperlink "Request Forms".

Once again wishing you all a very happy and productive new year!



Dr. K. Bhanumurthy
On behalf of the Editorial Committee

भारत का तिरसठवां गणतंत्र दिवस 26 जनवरी (गुरुवार), 2012

संबोधन
डॉ. रतन कुमार सिन्हा
निदेशक, भापअ केंद्र

भारत के तिरसठवें गणतंत्र दिवस के अवसर पर
डॉ. रत-ा ु मार सि-हा, ि-देशज, भापअ ेंद्र
ज1 संबोध-ा

"अपने देश के तिरसठवे गणतंत्र दिवस के अवसर पर मैं आप सभी को हार्दिक बधाई देता हूँ। प्रति वर्ष इस समारोह में हम अपने राष्ट्रध्वज को सलामी देते हैं। हम अभिनंदन करते हैं सुरक्षा बल के उन सभी सदस्यों का जो हमारे देश की रक्षा कर रहे हैं।

यह समारोह हमें अपनी हाल की गतिविधियों और पिछले वर्ष की महत्वपूर्ण उपलब्धियों की समीक्षा करने का अवसर प्रदान करती है। हमारे 15000 से अधिक साथियों वाले विशाल संस्थान के कार्यक्रमों का अवलोकन एक बड़ा काम है। अत: इस अवसर पर, हाल की उपलब्धियों की एक झलक दिखाने के लिए मैं कुछ मुख्य गतिविधियों और उनके परिणामों पर प्रकाश डालना चाहता हूँ।

अनुसंधान रिएक्टर

अनुसंधान रिएक्टर ध्रुवा का उपयोग आइसोटोपों के उत्पादन, अनुसंधान, पदार्थों का परीक्षण मानव संसाधन विकास में निरंतर किया जा रहा है। इसके प्रयोक्ताओं में विभिन्न शैक्षणिक संस्थानों के अनुसंधान छात्र भी शामिल थे। वर्ष 2011 के दौरान लगभग 1000 रेडियोआइसोटोप नमूने, चिकित्सा एवं अन्य प्रयोगों के लिए सुपुर्द किए गए। न्यूमेटिक कैरियर सुविधा में विभिन्न अनुसंधान प्रयोजनों के लिए एक सौ सड़सठ नमूने किरणित किए गए। रेडियोआइसोटोपों की बढ़ती हुई मांग को पूरा करने के लिए एक अतिरिक्त ट्रे रॉड को ईंधन की स्थिति में संस्थापित किया गया। हल्का पानी रिएक्टरों के लिए शट ऑफ सामग्री के विकास हेतु विशेष बोरॉन मिश्रधातु नमूनों और रक्त किरणकों के लिए कोबाल्ट स्लग्स को भी किरणित किया जा रहा है। थोरियम आधारित मिक्सड ऑक्साइड ईंधनों के किरणन व्यवहार का अध्ययन करने के लिए एएचडब्ल्यूआर ईंधन पिनों से युक्त एक प्रोटोटाइप फ्यूएल एसेंबली को जून, 2011 से रिएक्टर में किरणित किया जा रहा है।

25 वर्ष पुराने ध्रुवा रिएक्टर की लगातार उपलब्धता और सुरक्षित पचालन को सुनिश्चित करने के लिए विभिन्न उपकरणों और घटकों की पुर्नसज्जा/प्रतिस्थापन के लिए कदम उठाए गए हैं। सुरक्षा उन्नयन की दृष्ट से थे ट्रॉली माउंटेड डीजल इंजन चालित पंप सेट कमीशन किए गए ताकि यदि अधिक समय के लिए विद्युत आपूर्ति बाधित हो जाए तो भी निरंतर कोर कूलिंग की जा सके।

वर्ष के थैरान सायरस रिएक्टर से ईंधन निकालने तथा कोर अनलोडिंग का काम पूरा कर लिया गया। अप्सरा रिएक्टर को 2 मेगावाट रिएक्टर में अपग्रेड करने का काम प्रगति पर है।

प्रगत भारी पानी रिएक्टर (AHWR) हेतु क्रांतिक सुविधा का प्रचालन, विभिन्न प्रयोगों के लिए आवश्यकतानुसार कई बार किया गया। उदाहरण के लिए अभिक्रियता के विमंदक ताप गुणांक के मापन के लिए और संसूचकों के परीक्षण के लिए इसका प्रचालन किया गया।

30 मेगावाट हाई फ्लक्स अनुसंधान रिएक्टर (HHFR) के अभिकल्पन के अतिरिक्त, अधिक मात्रा में किरणन और आइसोटोप के उत्पादन हेतु 125 मेगाावाट अनुसंधान रिएक्टर के अभिकल्पन का कार्य आरंभ हुआ। इन दोनों परियोजनाओं को XIIवीं योजना के दौरान आरंभ करने का प्रस्ताव है।

नाभिकीय विद्युत रिएक्टरों के लिए अनुसंधान एवं विकास और जीवन प्रबंधन सहायता

नाभिकीय विद्युत संयंत्रों के प्रचालन में सहायता

भापअ केंद्र ने 540 मेगावाट दाबित भारी पानी रिएक्टरों की प्रचालनरत स्थिति में शीतलक चैनलों के निरीक्षण हेतु बार्सिस (BARCIS) का विकास करके एनपीसीआईएल को इसकी आपूर्ति की है। इस प्रणाली का प्रयोग करते हुए टैप्स-4 के 16 शीतलक चैनलों का निरीक्षण हाल ही में किया गया है।

540 मेगावाट के दाबित भारी पानी रिएक्टरों की दाब नलिकाओं के रोल्ड ज्वाइंट रीजन से चाँदी के नमूने लेने के लिए एक सर्कम्फरेंसियल स्क्रैपिंग टूल का विकास किया गया है जिससे नमूनों में हाइड्रोजन की मात्रा का मूल्यांकन किया जाएगा ।

टैप्स-1 एवं 2 के कोर श्राउड के वेल्ड रीजन से नमूने निकालने के लिए अभिकल्पित बोट सैंपलिंग प्रणाली का फुल स्केल मॉक अप ट्रायल सफलतापूर्वक किया गया।

टैप्स-1 एवं 2 के लिए बोरोन कार्बाइड युक्त नियंत्रण छड़ों का निर्माण किया गया।

प्रगत भारी पानी रिएक्टर (AHWR) इंजीनियरी विकास

AHWR के लिए तारापुर में एक फुल-हाइट प्रयोगात्मक लूप वाली ताप-द्रवीय परीक्षण सुविधा बनाई जा रही है ताकि AHWR के समाकालित ताप-द्रवीय आचरण का अनुकरण किया जा सके। अनुकारी AHWR सुविधा के जिस मुख्य सुविधा भवन में विभिन्न प्रणालियां लगाई जाएंगी और जिस संलग्न भवन में विद्युत एवं नियंत्रण उपकरण लगाए जाएंगे उनका निर्माण कार्य पूरा कर लिया गया है।

AHWR अभिकल्पन अलग अलग तरह के ईंधन के प्रयोग में उत्तम लचीलापन प्रथन करता है। इस क्षमता का प्रदर्शन करने के लिए यह दिखाया गया कि 3.6% समृद्ध यूरेनियम ईंधन लगभग 60,000 MWd/Te का डिस्चार्ज बर्नअप देता है।

कंप्यूटर कोडों का विकास

एक तापीय द्रव चालित प्रणाली कोड को स्वदेश में विकसित ३डी स्पेस काइनेटिक कोड के साथ जोड़ा गया और विभिन्न रिएक्टर क्षणिकाओं का अनुकरण करने के लिए इस युग्मित कोड का प्रयोग किया गया।

द्रव फिल्म विश्लेषण के आधार पर AHWR बंडल में अभिकल्प सीमा के पूर्वानुमान के लिए एक क्रियाविधिक उपकरण का विकास किया गया तथा क्वथन जल रिएक्टर स्थितियों के अधीन डाटा के साथ कोड का मान्यकरण किया गया। परिणाम से यह संकेत मिलता है कि प्रायोगिक मान्यकरण के पश्चात AHWR से ऊर्जा में वृद्धि संभव है।

नैनो-द्रवों पर प्रायोगिक कार्यक्रम

कुंड क्वदान स्थितियों के अधीन ऊष्मा अंतरण व्यवहार के लिए विभिन्न नैनोद्रवों पर किए गए अनेक प्रयोगों से यह देखा गया कि जल में परिक्षेपित नैनों कणों की अति अल्प सांद्रता के साथ भी क्रांतिक ऊष्मा अभिवाह (CHF) में महत्वपूर्ण बढ़ोत्तरी होती है।

ईंधन विकास एवं आपूर्ति

ध्रुवा रिएक्टर तथा FBTR के लिए भी ईंधन समुच्चायों का उत्पादन जारी है। पीएफबीआर के प्रथम क्रोड हेतु मॉक्स ईंधनों का संविरचन जारी रहा और कलपाक्कम में समुच्चायन का कार्य प्रारंभ करने के लिए ईंधन पिनें तैयार हैं ।

द्रुत प्रजनक रिएक्टर के लिए प्रगत ईंधन हेतु निर्माण प्रौद्योगिकियों के विकास का कार्यक्रम काफी आगे बढ़ चुका है। FBTR में परीक्षण किरणन के लिए आईजीकार को यूरेनियम युक्त धात्विक ईंधन की कुछ पिनों की आपूर्ति की गई। यूरेनियम धातु चूर्ण में परिक्षेपित 15 एवं 30 wt% UO_2 वाले सर्मेट ईंधन का अभिलक्षणन माइक्रो संरचना के रूप में किया गया। उच्च संचालन ईंधनों के विकास के एक भाग के रूप में 5% BeO युक्त UO_2 बनाया गया तथा इसका अभिलक्षणन माइक्रो संरचना एवं विस्तार गुणांक के रूप में किया गया। उच्च संचालन ईंधनों के विकास के एक भाग के रूप में 5% BeO युक्त v बनाया गया था इसका अभिलक्षणन माइक्रो संरचना एवं एक विस्तार गुणांक के रूप में किया गया। परिच्छादी पदार्थ के रूप में प्रयोग किए जाने के लिए प्रस्तावित U-Zr मिश्रधातुओं का ताप-भौतिकीय गुणधर्म मूल्यांकन, माइक्रो संरचनात्मक अध्ययन एवं ईंधन परिच्चाद संगतता परीक्षण किए गए।

AHWR क्रांतिक सुविधा में प्रयोगों के लिए $(Th\text{-}U^{235})O_2$ ईंधन पिन क्लस्टर तथा P_u की परिवर्ती मात्रा के साथ AHWR प्रकार को $(ThO_2{}^{233}UO_2\text{-}P_4)O_2$ ईंधन पिनों का निर्माण किया गया और उसके बाद ध्रुवा रिएक्टर में उनका किरणन किया गया। AHWR के लिए ईंधन निर्माण में लगे कार्मिकों को मिलने वाले विकिरण की मात्रा को कम करने के उद्देश्य से, $ThO_2\text{-}^{233}UO_2$ के निर्माण हेतु एक संविरचन प्रक्रम चित्र विकसित किया गया। संहत उच्च ताप रिएक्टर (CHTR) के हिस्से पुर्जों तथा ईंधन निर्माण के लिए सरोगेट पदार्थों का प्रयोग करके संविरचन परीक्षण किए गए।

अप्सरा रिएक्टर के नए क्रोड हेतु संविरचन प्रौद्योगिकी का पूर्ण विकास करने के लिए पचालों की स्थापना हेतु उच्च यूरेनियम भरण (अर्थात् 4.4 ग्राम/सीसी) सहित प्राकृतिक यूरेनियम सिलिसाइड वाले थे मॉडल ईंधन असेंबलियों का संविरचन किया गया। मुझे यह घोषणा करते हुए खुशी हो रही है कि नए अप्सरा के लिए स्वदेशी समृद्ध यूरेनियम का उपयोग करके वास्तविक ईंधन के संविरचन का काम ट्रांबे में पिछले सप्ताह शुरू किया गया।

पुनर्संसाधन एवं अपशिष्ट प्रबंधन

ट्रांबे स्थित प्लूटोनियम संयंत्र का सुरक्षित प्रचालन जारी रहा एवं किरणित अनुसंधान रिएक्टर ईंधन बंडलों को पुनर्संसाधित किया गया।

कलपाक्कम पुनर्संसाधन संयंत्र (KARP) ने वर्ष 2011 में एक वर्ष में सबसे अधिक बैचों को संसाधित करके एक नए मील के पत्थर को पार कर लिया।

देश में पहली बार, भुक्तशेष ईंधन के पुनर्संसाधन में एक वैकल्पिक विलायक के रूप में हाइड्रॉक्सिल अमाइन नाइट्रेट (HAN) के संश्लेषण के लिए एक प्रक्रम का विकास किया गया।

ट्रांबे और कलपाक्कम स्थित अपशिष्ट प्रबंधन सुविधाएं सुरक्षित रूप से प्रचालनरत रहीं तथा परमाणु ऊर्जा विभाग के इन केंद्रों के संयंत्रों एवं सुविधाओं को द्रव एवं ठोस अपशिष्टों के प्रबंधन संबंधी सेवाएं पदान की गईं तथा पर्यावरणीय निस्सरणों को विधिवत निर्धारित सीमाओं के अंदर रखा गया।

देश भर में उपयोग के बाद प्राप्त भुक्तशेष विकिरण स्रोतों का सुरक्षित रूप से निपटान किया गया।

ट्रांबे की नवनिर्मित विद्युत रिएक्टर थोरिया पुनर्संसाधन सुविधा (PTRTF) तथा अतिरिक्त अपशिष्ट टैंक फार्म (AWTF) की बहुत सी संस्थापित प्रणालियों का शीत कमीशनन किया गया। कोल्ड क्रुसिबल इन्डक्शन मेल्टर का प्रयोग करने वाली काचन प्रौद्योगिकी ने अनुकारित अपशिष्ट भरण प्रयोगों को सफलतापूर्वक पूरा करके एक अन्य मील का पत्थर पार किया। कलपाक्कम स्थित तीव्र रिएक्टर ईंधन चक्र सुविधा (FRFCF) के अपशिष्ट प्रबंधन संयंत्रों के लिए संपूर्ण अभिकल्प एवं इंजीनियरी इनपुट प्रदान किए गए।

नाभिकीय पुनर्चक्रण बोर्ड-प्रचालन और परियोजनाएं

तारापुर स्थित विद्युत रिएक्टर ईंधन पुनर्संसाधन संयंत्र (PREFRE-II) का उद्घाटन जनवरी 2011 में हुआ था और जून, 2011 में तप्त कमीशनन किया गया था। इसने जुलाई 2011 से उत्पादन शुरू कर दिया है। इस संयंत्र ने संरक्षा, संवेश प्रवाह एवं उत्पाद गुणवत्ता की दृष्टि से प्रचालन निष्पादन में उत्कृष्टता प्राप्त कर ली। कलपाक्कम के परियोजना विद्युत रिएक्टर ईंधन पुनर्संसाधन संयंत्र (P-3A) में उपकरण का निर्माण कार्य संतोषजनक रूप में प्रगति पर है।

रेडियोआइसोटोप एवं विकिरण प्रौद्योगिकी

रिफाइनरियों में शेल-ट्यूब प्रकार के उच्च थब वाले ताप विनिमयकों में रिसाव का पता लगाने के लिए डाईब्रोमोबाईफिनायल के रूप में ^{82}Br का प्रयोग करते हुए रेडियोट्रेसर परीक्षण किए गए।

^{131}I का उत्पादन एवं आपूर्ति बढ़ाने के लिए एक शुष्क आसवन प्रक्रम का विकास करके उसका क्रियान्वयन किया गया।

भापअ केंद्र ने विकिरण संसाधन अनुप्रयोगों जैसे रबर कंपोजिटों, केबल रोधक, नैनो-कंपोजिटों, रेलवे लाइनरों आदि के विकास एवं परिनियोजन के लिए उद्योग को अंतरापृष्ठ प्रथन करना जारी रखा।

स्वास्थ्य, संरक्षा एवं पर्यावरण

विकिरण संसूचन

अत्याधुनिक बृहतक्षेत्र महीन प्लास्टिक प्रस्फुरण संसूचकों का प्रयोग करते हुए बीटा गामा हैंड एंड फुट मॉनीटर का विकास पूरा करके प्रणाली को लागू किया जा चुका है ।

मात्रामिति

कार्मिकों के डोज को मॉनीटर करने एवं गुणवत्ता आश्वासन में प्रयोग करने के लिए स्वचालित सूक्ष्म संसाधित्र आधारित अंशांकन प्रणालियों का अभिकल्पन एवं संविरचन किया गया।

नैथनिक एक्सरे रेडियोग्राफी जाच के लिए मरीज को दि जाने वाली मात्रा का आकलन डोजिमेट्रिक मात्रा का प्रयोग करके किया जाता है जिसे प्रवेश सतह मात्रा (ESD) कहा जाता है। भापअ केंद्र अस्पताल में जनवरी 2011 से विभिन्न एक्स-रे जांच के दौरान ताप-संदीप्त मात्रामिति का प्रयोग करके ESD मापन किए गए तथा 800 मरीजों के आंकड़े प्राप्त किए गए।

विकिरण कर्मियों एवं पर्यावरण का मॉनीटरन

अग्रांत नाभिकीय ईंधन चक्र में पर्यावरण संरक्षा निगरानी विकिरण से बचाव एवं औद्योगिक स्वास्थ्य सेवाएं, यूरेनियम कारपोरेशन ऑफ इंडिया लिमिटेड, इंडियन रेअर अदर्स लिमिटेड एवं नाभिकीय ईंधन सम्मिश्र की सभी पचालनरत इकाइयों को प्रथन की गईं। व्यावसायिक कर्मियों में विकिरण की मात्रा एईआरबी द्वारा निर्धारित सीमाओं के अंदर पाई गई।

कर्नाटक में गोगी स्थित यूरेनियम खनन परियोजना एवं उड़ीसा में छत्रपुर स्थित मोनाज़ाइट संसाधन संयंत्र के लिए पर्यावरणीय प्रभाव मूल्यांकन किया गया। भापअ केंद्र, वैज़ाग एवं तुम्मलापल्ली स्थित यूरेनियम खनन परियोजना के लिए बेसलाइन पर्यावरणीय सर्वेक्षण किए गए।

आपातकालीन तैयारी एवं अनुक्रिया

दो नए आपातकालीन अनुक्रिया केंद्रों (ERCs) की स्थापना प्लाज्मा अनुसंधान संस्थान गांधीनगर एवं आरएमपी मैसूर में की गई। दो सौ साठ सुरक्षा कर्मियों को विकिरण आपातकालीन अनुक्रिया हेतु प्रशिक्षित किया गया।

भौतिक विज्ञान एवं अनुप्रयोग

भौतिकी

माउंट आबू में लगे TACTIC टेलिस्कोप का बेहतर फोकल प्लेन ऑप्टिक्स तथा इलेक्ट्रॉनिक्स द्वारा उन्नयन किया गया है जिससे संसचन संवेदनशीलता में लगभग २ के गुणक से सुधार हुआ है।

भारी पानी संयंत्र, मणुगुरू के लिए बोरॉन आइसोटोप अनुपात विश्लेषण हेतु एक तापीय आयनीकरण द्रव्यमान स्पेक्ट्रममापी (TIMS) का विकास किया गया है।

त्वरक चालित प्रणालियों (ADS) का U-233 प्रजनकों के रूप में अध्ययन करने से पता चला कि प्रभावी न्यूट्रॉन गुणन कारक (Ke_{ff}) के उपयुक्त चयन द्वारा U-233 उत्पादन दर में बिना किसी खास नुकसान के, त्वरक के लिए आवश्यकता से अधिक ऊर्जा का उत्पादन करना संभव है।

एक इलेक्ट्रॉन त्वरक आधारित उप-क्रांतिक न्यूट्रॉन गुणन प्रणाली के रिएक्टर भौतिकी अभिकल्प अध्ययन किए गए।

पिछले वर्ष के दौरान लघु अभिवाह संपीडन जनरेटरों पर कई प्रयोग किए गए जिसमें 40 और उससे अधिक की प्रभावशाली धारा सतत प्राप्त हुई। 10^9 न्यूट्रॉन प्रति स्पंद से अधिक के उत्पादन के लिए एक प्लाज्मा फोकस आधारित संलयन युक्ति का विकास किया गया।

तीव्र रिएक्टरों की नाभिकीय संरक्षा में ऊर्जा निस्सरण का आकलन महत्वपूर्ण है। स्पंदित तीव्र रिएक्टरों के गतिक अनुकरण के लिए 1-D एवं 2-D युग्मित न्यूट्रॉनिक हाइड्रोडायनामिक कोड विकसित किए गए।

सोल-जेल मार्ग द्वारा नैनो आकार के फेज टाइटेनियम ऑक्साइड अर्धचालक उत्प्रेरक तैयार करने की प्रक्रिया का विकास किया गया।

रसायनिकी एवं विकिरण रसायन

रिसॉर्सिनॉल-फार्मल्डिहाइड (RF) बीड्स के आकार एवं आकृति के नियंत्रित संश्लेषण हेतु एक नई विधि का विकास कर लिया गया है और क्षारीय अपशिष्ट से सीजियम के निष्कर्षण हेतु इसका संतोषजनक परीक्षण किया गया है।

तारापुर की कैटेलिटिक हाइड्रोजन पुनर्योजन परीक्षण सुविधा की आवश्यकताओं की पूर्ति के लिए बड़ी मात्रा में सहायक उत्प्रेरक के हाइड्रोजन अल्पीकरण एवं उत्पादन हेतु स्टेनलेस स्टील वायर गॉज समर्थित Pt-Pd उत्प्रेरकों के संविरचन के लिए एक इलेक्ट्रोड रहित सह-निक्षेपण तकनीक का विकास किया गया।

दाब एवं ताप की मृदु स्थितियों में 15 चक्रों तक लगभग 3.5 wt.% हाइड्रोजन का उत्क्रमणीय रूप से भंडारण कर सकने वाले Mg-Pd कंपोजिट चूर्ण का विकास किया गया है।

वस्त्रों में जीवाणुरोधी गुणों के विकास के लिए, सिल्वर नैनोकणों के साथ इसकी क्रियात्मकता का आसान मार्ग स्थापित किया गया है। सामाजिक, नैथनिक एवं उच्च महत्व के क्षेत्रों जैसे रक्षा एवं अंतरिक्ष में ऐसे वस्त्रों के प्रयोग की प्रबल संभावना है।

पॉजिट्रॉन लाइफटाइम, विलोपन इलेक्ट्रॉन संवेग, काल एवं संवेग सहसंबंध के सहसंबंधी मापन की सुविधा स्थापित की गई।

बैच विलायक निष्कर्षण एवं सहायक द्रव झिल्ली (SLM) अध्ययन द्वारा एक अभिनव त्रिपथकार डाई-ग्लाइकोलामाइड

का मूल्यांकन एक्टिनाइडों के लिए एक निष्कर्षक के रूप में किया गया।

पथर्थ एवं धातुकी

एक क्लोराइड भरण के रैफिनेट फेज में एक प्रमुख घटक इट्रियम के पृथक्करण के लिए प्रायोगिक स्थितियों का इष्टतमीकरण किया गया।

उच्च ताप रिएक्टरों के लिए ईंधन के उत्पाथ्न हेतु हमारे कार्य के एक भाग के रूप में, यूरेनियम ऑक्साइड ईंधन कर्नेल्स के हस्तन के लिए TRISO कोटिंग इकाई का कमीशनन किया गया। TRISO कणों पर कार्बन की ओवरकोटिंग के लिए एक अपकेंद्री ग्रैन्युलेटर कोटिंग सुविधा का भी कमीशनन किया गया।

PFBR रिएक्टर चलाने के लिए एन्टिमनी-बेरिलियम न्यूट्रॉन स्रोत की आवश्यकता होती है। तुर्भे की बेरिलियम संबंधी सुविधाओं में, अपेक्षित विशिष्टताओं वाले कुछ हॉट प्रेस्ड बेरिलियम ब्लॉकों का संविरचन हाल ही में किया गया है। पहले स्टैक की डिलीवरी मार्च २०१२ के अंत तक एवं शेष की डिलीवरी वर्ष के अंत तक होने की उम्मीद है।

एल्युमिनियम धातु फोम के निर्माण हेतु एक चूर्ण धातुकी आधारित प्रक्रिया का विकास किया गया है। उत्कृष्ट ऊर्जा अवशोषण अभिलक्षणों वाला यह पथर्थ परिवहन पैकेज कंटेनरों में प्रयोग के लिए सर्वथा उपयुक्त है।

जीवन विज्ञान

बलगतिकी और गतिकी के ऐसे प्रोटियोमिक परिवर्तनों पर प्रकाश डाला गया जिनके कारण परम विकिरण रोधी रोगाणु *डीनोकोकस रेडियोड्यूरंस*, किरणन के बाद भी पुन:प्राप्त हो जाते हैं।

यूरेनियम जैव-पुनर्प्राप्ति-बायोरेमेडिएशन अध्ययन करके समुद्री फिलामेंटस नाइट्रोजन-फिक्सिंग साइनोबैक्टीरियम *एनाबीना टोरुलोसा* एवं आनुवांशिक रूप से संयोजित *डीनोकोकस* विकृति की प्रभावी उपयोगिता का पता लगाया गया।

प्रगत प्रौद्योगिकियां एवं अनुप्रयोग

इलेक्ट्रॉन त्वरक एवं उच्च शक्ति इलेक्ट्रानिकी

खारघर के इलेक्ट्रॉन किरणपुंज केंद्र में 10MeV, 10kW RF लाइनेक का 3 kW किरणपुंज शक्ति पर नियमित प्रचालन किया गया एवं प्रायोगिक अध्ययनों के लिए इसका उपयोग किया गया।

एक्स-रे कार्गो स्कैनिंग अनुप्रयोगों के लिए एक 3/6 MeV द्वैत ऊर्जा संहत रैखिक त्वरक का अभिकल्पन किया गया है। प्रोटोटाइप प्रणाली के घटकों को नियमित उत्पादन के लिए पुन: अभियंत्रित किया गया है।

सुदूरीकरण एवं रोबोटिकी

भापअ केंद्र ने डिजिटल रेडियोथेरेपी सिम्युलेटर की प्रौद्योगिकी उद्योग को हस्तांतरित कर दी है। यह सिम्युलेटर कैंसर के प्रभावी उपचार हेतु विकिरण किरणपुंज के आकार एवं अभिविन्यास के उचित चयन के लिए उपयोगी है।

भापअ केंद्र ने एक बल परावर्ती टेली-रोबोट विकसित किया है जो दूर-प्रचालन प्रौद्योगिकी के एक नए उत्पादन को निरूपित करता है और अनेक प्रगत लक्षणों से युक्त है।

एक मोबाइल रोबोट एजेंट का विकास जोखिम भरे क्षेत्रों में दूर से कार्य करने के लिए किया गया है जिसका पे लोड 3 कि.ग्रा. तक है और इसके गोलीय कार्यक्षेत्र की त्रिज्या 1100 मि.मी. है।

सेल आर्म के सर्वो-नियंत्रित स्वचालित ट्रैकिंग सुविधायुक्त एक परिशुद्ध पर्यवेक्षण शीर्ष (हेड) का विकास किया गया है जो कक्ष प्रचालनों में पूर्वानुमानी अवलोकन, घ्लुक अहेड ऑफ हैंडङ प्रणाली पर कार्य कर सकता है।

रसायन इंजीनियरी एवं प्रौद्योगिकी

सल्फर हेक्सा-फ्लोराइड गैस के उत्पादन के लिए एक प्रौद्योगिकी निदर्शन संयंत्र का कमीशनन किया गया। हीलियम रेफ्रिजरेशन संयंत्र के लिए ढके हुए टरबाइन एवं ब्रेक व्हील इम्पेलर को विकसित किया गया है। एक प्रोटाटाइप संहत इलेक्ट्रोलाइजर संयंत्र का सफलतपूर्वक संस्थापन तथा कमीशनन किया गया। लीथियम धातु संयंत्र का कमीशनन एवं प्रचालन किया गया।

कंप्यूटर सेवाएं

47 टेराफ्लॉप के सतत निष्पादन के साथ भापअ केंद्र अनुपम-अध्य समांतर प्रक्रमण सुपरकंप्यूटर की भंडारण क्षमता बढ़ाकर 512 टेराबाइट करने के लिए हाल ही में उसका उन्नयन किया गया।

साइबर सुरक्षा के क्षेत्र में भापअ केंद्र ने एक अद्वितीय सुरक्षित नेटवर्क एक्सेस प्रणाली (SNAS) का विकास एवं नियोजन किया है जो फायरवॉल, अंतर्वेधन (इंट्रूजन) संसूचन प्रणाली, नेटवर्क मॉनीटरन एवं क्लायंट पीसी सुरक्षा के कार्यों को एकीकृत करता है।

प्रगत यंत्रीकरण

ध्रुवा की नियंत्रण एवं यंत्रीकरण प्रणालियों के उन्नयन के लिए, रिएक्टर ट्रिप लॉजिक प्रणाली, आपातकालीन क्रोड शीतलन प्रणाली, स्टार्ट-अप लॉजिक प्रणाली एवं अलार्म आख्यापित्र (एनन्शिएशन) प्रणाली का विकास, स्वगृहे विकसित क्रमादेशनीय तर्क नियंत्रक TPLC-32 के आधार पर किया गया है। नाभिकीय रिएक्टर अनुप्रयोगों के लिए अनेक उच्च प्रयोक्ता अनुकूल

संवेदकों का विकास किया गया है। इनमें मल्टीप्वाइंट पराश्रव्य स्तर संवेदक, LOCA अर्हताप्राप्त परम दाब संवेदक आदि शामिल हैं।

इलेक्ट्रॉनिकी

एक डिजिटल स्व-उत्तेजित लूप (SEL) आधारित आरएफ नियंत्रण प्रणाली का अभिकल्पन किया गया तथा भापअ केंद्र-टीआईएफआर लाइनेक के १५० मेगा हर्ट्ज अतिचालक रेज़ोनेटरों के साथ इसका सफलतापूर्वक परीक्षण किया गया।

पतली फिल्म निक्षेपण प्रयोजन हेतु एक 150 W, 13.56 MHz ठोस अवस्था RF विद्युत प्रवर्धक का अभिकल्पन, परीक्षण

एवं संस्थापन किया गया।

400 keV RF गुहिका के लिए एक RF नियंत्रण प्रणाली का अभिकल्पन एवं परीक्षण किया गया।

भूकंप विज्ञान

भापअ केंद्र भूकंपमितीय डाटा केंद्र में अनेक नई तकनीकों और मॉडलों को क्रियान्वित किया गया ताकि भूकंपी घटनाओं के स्थलों की उतनी सही जानकारी प्राप्त की जा सके जो अंतर्राष्ट्रीय भूकंपमितीय एजेंसियों की रिपोर्ट से मेल खाती हो। देश में अथवा देश के निकट पड़ोस में आए अधिकतर भूकंपी स्थलों का स्थान-निर्धारण किया गया। इसमें 5% से भी कम चूक हुई।

सुरक्षित पेयजल के लिए प्रौद्योगिकियां

भापअ केंद्र सुरक्षित पेय जल अनुप्रयोग के लिए व्यवसायिक आकार की स्वदेशी झिल्लियों तथा झिल्ली अवयवों का विकास करता रहा है। नाभिकीय निर्लवणीकरण निदर्शन परियोजना (एनडीडीपी) में आयातित तत्वों के बदले स्वदेश में विकसित पतली परत वाली संयुक्त प्रतिलोम परासरण झिल्लियों के प्रथम बैच को लोड किया गया। यह संयंत्र रात-दिन प्रचालररत रहा है।

सौर-ऊर्जा चालित जल शुद्धिकरण प्रणालियों के विकास के एक भाग के रूप में, ट्रांबे में एक सौर प्रकाश वोल्टीय (PV) ऊर्जा चालित जल शुद्धिकरण निदर्शन इकाई का अभिकल्पन, संस्थापन एवं कमीशनन किया गया। यह ब्रेकिश जल निर्लवणीकरण के लिए स्वदेशी झिल्ली का प्रयोग करता है और इसकी क्षमता 10 लीटर प्रति घंटा है। यह सुवाह्य, बैटरी रहित एवं स्टैंडअलोन प्रकार का है।

नाभिकीय कृषि

नई दिल्ली के राष्ट्रीय पादप अनुवांशिक संसाधन ब्यूरो (NBPGR) की पादप जननद्रव्य पंजीयन समिति ने ब्रुचिड रोधी ट्रांबे वाइल्ड यूरिड जननद्रव्य एवं ट्रांबे मूंगफली म्यूटेंट, TGM 112 के पंजीयन को अनुमोदित किया है।

पिछले वर्ष पच्चीस निसर्गऋण संयंत्र कार्यरत हो गए हैं।

प्रौद्योगिकी हस्तांतरण

भापअ केंद्र ने गोवा राज्य में विज्ञान एवं प्रौद्योगिकी पर आधारित विकास में तरक्की पर सहयोग हेतु गोवा सरकार के साथ एक समझौता ज्ञापन पर हस्ताक्षर किया।

मानव संसाधन विकास

"पाठशाला" नामक एक ई-लर्निंग प्लैटफार्म शुरू किया गया है जिसमें बड़ी संख्या में वीडियो पाठ्यक्रमों, नाभिकीय ऊर्जा संयंत्र (NPP) सिम्युलेटरों एवं ई-व्याख्यान नोटों को शामिल करके इसे प्रशिक्षार्थियों एवं भापअ केंद्र प्रशिक्षण विद्यालय के प्राध्यापकों के लाभ हेतु सर्वर पर डाला गया।

दो वर्ष पूर्व शुरू हुए QUEST सतत शिक्षण कार्यक्रम के अंतर्गत वैद्युत विज्ञान वर्ग के अधीन पाठ्यक्रमों के चार सेट मुंबई की पऊवि इकाइयों के कर्मचारियों को दिए गए और बहुत से लोग इन पाठ्यक्रमों का लाभ उठा रहे हैं। मैं आग्रह करता हूँ कि अधिक से अधिक कर्मचारी अपनी कुशलता में संवर्धन करने हेतु इस अवसर का लाभ उठाएँ।

होमी भाभा राष्ट्रीय संस्थान (HBNI) की प्रगति जारी रही तथा अनेक प्रमुख संस्थानों के साथ इसने अपने संबंध मजबूत करना जारी रखा। अब तक विभिन्न शैक्षिक कार्यक्रमों के अंतर्गत 261 डिग्री और डिप्लोमा की उपाधियां दी जा चुकी हैं। विभिन्न कार्यक्रमों के अंतर्गत नामांकन करानेवालों की संख्या में लगातार वृद्धि जारी है और यह संख्या 3000 पार कर चुकी है। इसमें से केवल पीएच.डी. के लिए ही 1300 से अधिक नामांकन हुए हैं।

वैज्ञानिक सूचना संसाधन प्रसारण

ग्यारहवीं योजना अवधि के दौरान भापअ केंद्र ने पऊवि संस्थानों की वैज्ञानिक उत्पादकता एवं इनपुटों का विश्लेषण करने के लिए नोडल एजेंसी के रूप में, पऊवि प्रकाशनों एवं उनके साइटेशन पर एक विस्तृत रिपोर्ट प्रस्तुत की जो विभिन्न इकाइयों से प्राप्त इनपुटों पर आधारित थी। भापअ केंद्र एक वर्ष में लगभग 1100 पब्लिकेशनों का प्रकाशन करता है।

ट फ्यूजन इंजीनियरिंग ट पर एक प्रदर्शनी आयोजित की गई। वैज्ञानिक स्टाफ को अंतर्राष्ट्रीय जर्नलों में अधिक से अधिक लेख प्रकाशन करवाने के लिए प्रेरित करने हेतु एक ऑथर्स "वर्कशॉप" संचालित किया गया जिसमें लगभग 800 वैज्ञानिक स्टाफ शामिल हुए।

जन जागरूकता कार्यक्रम तथा विद्यार्थियों का दौरा

वर्ष के दौरान 14 संस्थानों के लगभग 2000 विद्यार्थियों ने भापअ केंद्र का दौरा किया। सात संस्थानों में संगोष्ठियां तथा अन्य संबंधित आयोजन किए गए जिनमें लगभग 2500 विद्यार्थियों तथा शिक्षकों ने भाग लिया। इस कार्यक्रम को मजबूती प्रदान करने के लिए, भापअ केंद्र मीडिया समिति के लिए लगभग 100 वैज्ञानिकों तथा इंजीनियरों की सूची बनाई गई है। इस दल ने भापअ केंद्र के कार्यक्रमों तथा गतिविधियों एवं नाभिकीय ऊर्जा के तदयों का प्रसार करने के लिए हाल के आयोजनों में भाग लिया। हाल ही में भापअ केंद्र ने कोल्हापुर स्थित डी.वाई. पाटील विश्वविद्यालय एवं जयपुर में राष्ट्रीय बाल विज्ञान कांग्रेस में पदर्शनी लगाई जिसमें कई हजार विद्यार्थियों ने भाग लिया।

योजनागत परियोजनाएं

हम शीघ्र ही ग्यारहवीं योजना अवधि की समाप्ति पर पहुँच रहे हैं। बारहवीं योजनाबद्ध परियोजनाओं के लिए प्रस्तावों को योजना आयोग के समक्ष प्रस्तुत किया गया है। हमें चालू योजनाबद्ध परियोजनाओं के अंतर्गत मांगे गए सभी संसाधनों का उपयोग करने एवं परियोजना रिपोर्टों में दिए गए आउटपुटों की डिलीवरी के लिए तैयार रहना होगा। मैं आप सभी से अपील करता हूँ कि योजनाबद्ध परियोजनाओं के क्रियान्वयन के लिए सभी पहलुओं पर समयबद्ध कारवाई करना जारी रखें।

सुरक्षा एवं भौतिक संरक्षण

हमारे केंद्र का भौतिक संरक्षण सर्वाधिक महत्वपूर्ण है। सुरक्षा के उच्च स्तर के प्रभावी क्रियान्वयन में सहयोग देने के लिए मैं, अपने केंद्र के सभी सुरक्षा कार्मिकों का अभिनंदन करना चाहता हूँ तथा सभी अधिकारियों एवं स्टाफ को धन्यवाद देना चाहता हूँ।

मैं अग्निशमन कार्मिकों की उत्कृष्ट सेवाओं के प्रति भी आभार प्रकट करता हूँ जिन्होंने हमारे केंद्र की विभिन्न स्थापनाओं पर कड़ी निगरानी रखी है।

इस स्थल के सुंदर परिवेश को देखकर हमारे पुष्प-कृषि एवं भू-दृश्य अनुभाग के कार्मिकों के योगदान की मैं सराहना करता हूँ। उन्होंने इस वर्ष मानसून के दौरान वनक्षेत्र में लगाए जाने वाले पेड़ों की विभिन्न प्रजातियों के 25000 पौधों को नर्सरी में तैयार किया है।

चिकित्सा सेवाएं

हमारे कर्मचारियों एवं उनके परिवार वालों को अंशदायी स्वास्थ्य सेवा योजना के अंतर्गत चिकित्सा सेवाओं के द्वारा अति प्रभावपूर्ण रूप से उत्तम स्वास्थ्य देखरेख सेवा प्रदान की जाती रही है।

प्रशासनिक वर्ग

प्रशासन, स्थापना के साथ-साथ मानवशक्ति योजना, कार्मिक आंकड़ा प्रबंधन, वित्त एवं लेखा और सुरक्षा जैसे क्षेत्रों में

प्रशासनिक वर्ग अपना महत्वपूर्ण योगदान करता रहा है।

मैंने आजके अपने भाषण में कुछ महत्वपूर्ण बिंदुओं को छोड़कर उन सब उपलब्धियों को शामिल नहीं किया जिनका उल्लेख संस्थापक दिवस तथा स्वाधीनता दिवस के भाषण में किया गया था।

निष्कर्ष

मेरे प्रिय साथियों, वैसे तो हम अपने लक्षित कार्यक्रमों में अपना सर्वोत्कृष्ट योगदान देते आए हैं फिर भी यह आवश्यक है कि हम अपने केंद्र के लक्ष्यों और देश की निरंतर बढ़ती अपेक्षाओं को पूरा करने के लिए अपने केंद्र के उत्पादनों को परिष्कृत करें और बढ़ाएं ताकि राष्ट्रीय विकास और आर्थिक प्रगति के साथ कदम से कदम मिला कर चल सकें । हमारे समाज के कुछ तबकों में कुछ निराधार भय व्याप्त हो जाने के कारण नकारात्मक सोच पैदा हो गई है जिसे दूर करने के लिए हमें कई मोर्चों पर लगातार काम करना होगा। इसके लिए आवश्यक है कि हम जो भी काम करके दें या उत्पाद बनाएं वह उत्कृष्ट हों और अत्यंत प्रासंगिक हो।

मुझे पूरा विश्वास है कि आप सभी अपना सर्वोत्कृष्ट योगदान प्रदान करते रहेंगे ताकि आने वाले वर्षों में हम अपनी उच्च प्रासंगिकता और मूल्यों की श्रेष्ठता की परम्परा को कायम रख सकें।

इसलिए मित्रों, आइए इस सुअवसर पर, दृढ़ संकल्प होकर स्वयं को राष्ट्र के प्रति पुन:समर्पित करें और प्रण करें कि अपने देश की अपार जनसंख्या के जीवन स्तर को बेहतर बनाने के लिए भारतीय नाभिकीय कार्यक्रमों के सभी पहलुओं के प्रति लगातार अपना योगदान करेंगे और नाभिकीय विज्ञान और प्रौद्योगिकी के अग्रणी क्षेत्रों की अद्यतन जानकारी के साथ देश की सेवा करते रहेंगे।

आप सभी को धन्यवाद। जयहिन्द।"

63rd Republic Day of India
26th January (Thursday), 2012

Address by
Dr. Ratan Kumar Sinha
Director, BARC

" Dear Colleagues,

I convey my hearty greetings to all of you on the occasion of the 63rd Republic Day of our country. Every year, as a part of this celebration, we salute our national flag. We remember with reverence the members of our armed forces, who provide security to our country.

The function provides us an opportunity to review the highlights of our recent activities and some major achievements during the past year. Taking stock of the programmes of our vast organisation of over 15000 colleagues is a voluminous exercise. Therefore, on this occasion today, I intend to touch upon several representative activities and resultant outputs, just to provide glimpses of our achievements during the recent past. A larger version will be placed on our web-site and also printed in BARC Newsletter.

Research Reactors

Research reactor Dhruva continued to be well utilised for isotope production, research, material testing and human resource development. The users included research scholars from various academic institutions. During the year 2011, nearly 1000 radio-isotope samples were delivered for medical and other uses. One hundred and sixty-seven samples were irradiated in pneumatic carrier facility for various research purposes. An additional tray rod was installed in one of the fuel positions to meet the increased demand of radio-isotopes. Special boron alloy samples for the development of shut off rod materials for light water reactors and cobalt slugs for Blood Irradiators are also being irradiated in the tray rod. A prototype fuel assembly consisting of AHWR fuel pins is being irradiated in reactor, since June 2011, to study the irradiation behavior of thorium-based mixed-oxide fuels.

Steps have been initiated to refurbish/replace various equipment and components of the 25 year old Dhruva Reactor to ensure its continued availability and safe operation. As a part of safety upgrade, two trolley mounted diesel engine driven pump sets were commissioned to provide uninterrupted core cooling during extended power outage condition. Defueling and core unloading of Cirus reactor were completed during the year. Work on the upgrade of Apsara reactor to a 2 MW reactor is in progress. Operation of the Critical Facility for Advanced Heavy Water Reactor (AHWR) was done on need-based manner several times, for various experiments; for example, for the measurement of moderator temperature coefficient of reactivity and for testing of detectors.

In addition to the design of a 30 MW High Flux Research Reactor (HFRR) design of a 125 MW research reactor for bulk irradiations and isotope production has commenced. Both these projects are proposed to be initiated during the XII Plan.

R & D and Life-Management Support for Nuclear Power Reactor

Support for Operation of Nuclear Power Plants

BARC has developed and supplied BARCIS (BARC Channel Inspection System) to NPCIL for in-service

inspection of coolant channels of 540 MWe PHWRs. Using this system, inspection of 16 coolant channels of TAPS-4 were recently carried out.

A Circumferential Scraping Tool for pressure tubes of 540 MWe PHWRs has also been developed to obtain sliver samples from rolled joint region of pressure tubes for the evaluation of hydrogen content in the samples.

A full scale mock-up trial of boat sampling system designed for removal of samples from the weld regions of core shroud of TAPS-1 & 2 was successfully conducted.

Control elements containing boron carbide were manufactured for TAPS-1&2.

Advanced Heavy Water Reactor (AHWR) Engineering Development

The AHWR Thermal Hydraulic Test Facility (ATTF) is a full-height experimental loop for AHWR, being built at Tarapur to simulate the integrated thermal-hydraulic behaviour of AHWR. The construction of the main facility building housing various systems of the facility simulating AHWR as well as the annexe building housing the electrical and control equipment has been completed.

AHWR design provides excellent flexibility in using different types of fuel. To demonstrate this capability, it was shown that 3.6% enriched uranium fuel can provide a discharge burn-up of nearly 60,000 MWd/Te.

Development of Computer Codes

A thermal hydraulic system code has been coupled with an indigenously developed 3-D space kinetic code and the coupled code used to simulate various reactor transients.

Based on the liquid film analysis, a mechanistic tool has been developed for the prediction of the design margin in the AHWR bundle and the code validated with data under Boiling Water Reactor conditions. The results indicate a possibility of enhancement of the power from AHWR after experimental validation.

Experimental Programme on Nano-fluids

Several experiments performed with different nanofluids for heat transfer behaviour under pool boiling conditions showed that the Critical Heat Flux (CHF) increases significantly even with a small concentration of nanoparticles dispersed in water.

Fuel Development and Supply

Production of fuel assemblies for Dhruva reactor as well as for FBTR is being continued. Fabrication of MOX fuels for the first core of PFBR was continued and fuel pins are ready for initiating the assembly work at Kalpakkam.

The programme for the development of manufacturing technologies for advanced fuels for FBRs has progressed substantially. A few pins of metallic fuel containing U have been supplied to IGCAR for test irradiation in FBTR. Cermet fuels comprising 15 and 30 wt% UO_2 dispersed in U metal powder were characterised in terms of microstructure. As a part of the development of high conducting fuels, UO_2 containing 5% BeO was made and characterised in terms of microstructure and coefficient of expansion. Thermo-physical property evaluation, micro-structural studies and fuel-clad compatibility tests of U-Zr alloys, proposed to be used as blanket material, have been carried out.

(Th-U^{235})O_2 fuel pin cluster and AHWR type (Th-Pu)O_2 fuel pins with varying Pu content were manufactured for experiments in AHWR Critical Facility, followed by irradiation in Dhruva reactor. A fabrication flow sheet for the manufacture of ThO_2- $^{233}UO_2$ has been developed with the objective of reducing the personnel radiation dose involved in the manufacture of fuel for AHWR. Fabrication trials have been carried out for the manufacture of fuel and components for Compact High Temperature

Reactor (CHTR) using surrogate materials.

Two model fuel assemblies containing natural uranium silicide with high uranium loading (i.e. 4.4 gm/cc) were fabricated for the new core of Apsara reactor to establish the parameters to fully develop the fabrication technology. I am glad to announce that the fabrication of actual fuel for the new Apsara, using indigenous enriched uranium has started last week in Trombay.

Reprocessing and Waste Management

The Plutonium Plant at Trombay continued to operate safely and irradiated research reactor fuel bundles were reprocessed.

The Kalpakkam Reprocessing Plant (KARP) crossed a new milestone in 2011 by processing the highest number of batches in one year.

For the first time in the country, a process has been developed for the synthesis of Hydroxyl Amine Nitrate (HAN) as an alternate solvent in spent fuel reprocessing.

Waste Management Facilities at Trombay and Kalpakkam operated safely and provided services with regard to the management of liquid and solid wastes to all the plants and facilities at these DAE Centres, duly maintaining environmental discharges well below the authorised limits.

Spent radiation sources received from all over the country, after their utilisation, were safely disposed. Many of the installed systems of the newly built Power Reactor Thoria Reprocessing Facility (PTRTF) and Additional Waste Tank Farm (AWTF) at Trombay were cold commissioned. Vitrification technology employing Cold Crucible Induction Melter crossed another milestone by successful completion of simulated waste feed experiments. Complete design and engineering inputs were provided in respect of waste management plants of Fast Reactor Fuel Cycle Facility (FRFCF) at Kalpakkam.

Nuclear Recycle Board - Operations and Projects

The Power Reactor Fuel Reprocessing Plant (PREFRE – II) at Tarapur, which was inaugurated in January 2011 and hot commissioned by June 2011, started production since July 2011. Excellent operating performance in terms of safety, throughput and product quality has been achieved by this plant. Erection of equipment in the Project Power Reactor Fuel Reprocessing Plant at Kalpakkam (P-3A) is progressing well.

Radioisotopes and Radiation Technology

Radiotracer investigations using ^{82}Br as dibromobiphenyl were carried out for the detection of leaks in a shell-tube type high-pressure heat exchanger system in refineries.

A dry distillation process to enhance production and supply of ^{131}I was developed and implemented.

BARC continued to provide an interface to industry for developing and deploying radiation processing applications such as rubber composites, cable insulation, nano composites, railway liners etc.

Health, Safety and Environment

Radiation Detection

Development of beta gamma hand and foot monitor using state-of-the-art large area thin plastic scintillation detectors has been completed and the system has been deployed.

Dosimetry

Automated microprocessor based calibration systems have been designed and fabricated for use in personnel dose monitoring and quality assurance. The patient dose in diagnostic X-ray radiography examinations is estimated using the dosimetric quantity called Entrance Surface Dose (ESD). ESD measurements were carried out using

thermoluminescent dosimeter during different X-ray examinations at BARC Hospital since January 2011 and the data for 800 patients was acquired.

Monitoring of Radiation Workers and Environment

Environmental safety surveillance, radiation protection and industrial hygiene services in the front-end nuclear fuel cycle were provided to all operating units of Uranium Corporation of India Ltd., Indian Rare Earths Ltd. and Nuclear Fuel Complex. Radiation dose to occupational workers was found to be well within the limits prescribed by AERB.

Environmental Impact Assessment was carried out for the uranium mining projects at Gogi, Karnataka and Monazite Processing Plant at Chatrapur, Odisha. Baseline environmental survey was carried out for BARC, Vizag and Uranium mining project at Tummallapalle.

Emergency Preparedness and Response

Two new Emergency Response Centres (ERCs) have been established at Institute for Plasma Research, Gandhinagar and RMP, Mysore. Two hundred sixty security personnel were trained on Radiation Emergency Response.

Physical Sciences and Applications

Physics

The TACTIC telescope at Mt.Abu has been upgraded with improved focal plane optics and electronics, resulting in improved detection sensitivity, by a factor of about 2.

Thermal Ionisation Mass Spectrometer (TIMS) for Boron Isotope Ratio analysis has been developed for Heavy Water Plant at Manuguru.

A study on the use of Accelerator Driven Systems (ADS) as U-233 breeders showed that by a suitable choice of the effective neutron multiplication factor K_{eff}, it is possible to produce power in excess of the requirement for the accelerator, without significant loss in the U-233 production rate.

Reactor physics design studies of an electron accelerator based sub-critical neutron multiplying system were carried out.

A number of experiments on Small Flux Compression Generators were carried out during the last year with an impressive current gain of 40 and more achieved consistently. A plasma focus based fusion device was developed to generate more than 10^9 neutrons per pulse.

Estimation of energy release is important in nuclear safety of fast reactors. 1-D and 2-D coupled neutronic-hydrodynamic codes have been developed for dynamic simulation of pulsed fast reactors.

A process for preparation of nano-sized phase titanium oxide semiconductor catalyst by sol-gel route has been developed.

Chemistry and Radiochemistry

A new method for size and shape controlled synthesis of Resorcinol-Formaldehyde (RF) beads has been developed and tested satisfactorily for the extraction of Cs from alkaline waste.

An electrodeless co-deposition technique for the fabrication of Stainless Steel wire gauge supported Pt-Pd catalysts for hydrogen mitigation and production of the supported catalyst in large quantities has been developed, meeting the requirement of the Catalytic Hydrogen Recombiner Test Facility at Tarapur.

Mg-Pd composite powders, that reversibly store about 3.5 wt.% hydrogen upto15 cycles under mild conditions of pressure and temperature, have been developed.

For developing bacteria resistance in fabrics, a simple

route of its functionalisation with silver nanoparticles is established. Such fabrics have potential for application in societal, clinical and high-end areas like defence and space.

The facility for correlated measurement of positron lifetime, annihilating electron momentum, age and momentum correlation has been set up.

A novel tripodal diglycolamide was evaluated as an extractant for actinides by batch solvent extraction and Supported Liquid Membrane (SLM) studies.

Materials and Metallurgy

Experimental conditions were optimised for the separation of yttrium, which forms a major constituent, in the raffinate phase from a chloride feed.

As a part of our work for the production of fuel for High Temperature Reactors, TRISO coating unit was commissioned for handling uranium oxide fuel kernels. A centrifugal granulator coating facility to produce the carbon overcoat on TRISO particles was also commissioned.

PFBR requires antimony – beryllium neutron source for start up of the reactor. A couple of hot pressed beryllium blocks with requisite specifications have been recently fabricated in the beryllium related facilities at Turbhe. The first stack is expected to be delivered by March end 2012 and balance by the end of the year.

A powder metallurgy based process for the manufacture of aluminum metal foam has been developed. With superior energy absorbing characteristics, this material is well-suited for use in transport package containers.

Life Sciences

The kinetics and dynamics of proteomic changes leading to the post-irradiation recovery of the extremely radioresistant microbe *Deinococcus radiodurans* were elucidated.

Uranium biorecovery - bioremediation studies revealed the potential utility of the marine filamentous nitrogen-fixing cyanobacterium *Anabaena torulosa* and of the genetically engineered *Deinococcus* strain.

Advanced Technologies and Applications

Electron Accelerators and High Power Electronics

The 10 MeV, 10 kW RF Linac at Electron Beam Centre, Kharghar, has been operated regularly at 3 kW beam power and utilised for experimental studies.

A 3/6 MeV dual energy compact linear accelerator for X-ray cargo scanning applications has been designed. The components of the prototype system have been re-engineered for regular production.

Remotisation & Robotics

BARC has transferred the technology of Digital Radiotherapy Simulator to industry. This simulator is useful for proper selection of size and orientation of the radiation beam for efficacious treatment of cancers.

BARC has developed a force reflecting tele-robot, which represents a new generation of remote handling technology with several advanced features. A Mobile Robot agent has been developed for remote working in hazardous areas with a pay-load up to 3 kg and spherical workspace of 1100 mm radius.

A precision viewing head with servo-controlled autonomous tracking of cell arm has been developed that offers predictive viewing, 'look ahead of hand' mode of functioning, in cell operations.

Chemical Engineering and Technology

A Technology Demonstration Plant for the production of Sulphur Hexa-fluoride gas has been commissioned. Shrouded turbine and brake wheel impeller for helium refrigeration plant has been developed. A prototype compact electrolyser plant was successfully installed and commissioned. Lithium Metal Plant was commissioned and operated .

Computer Services

The BARC Anupam-Adhya parallel processing supercomputer with sustained performance of 47 Teraflops has recently been upgraded to achieve 512 Terabytes of storage capacity.

In the area of cyber security, BARC has developed and deployed a unique Secure Network Access System (SNAS) that integrates functionality of Firewall, Intrusion Detection System, Network Monitoring and client PC security.

Advanced Instrumentation

For upgrade of control and instrumentation systems of Dhruva, reactor trip logic system, emergency core cooling system, startup logic system and alarm annunciation system have been developed, based on in-house developed programmable logic controller TPLC-32. Several highly customised sensors for nuclear reactor applications have been developed. These include Multipoint Ultrasonic Level Sensor, LOCA qualified Absolute Pressure Sensor, etc.

Electronics

A digital Self Excited Loop (SEL) based RF control system has been designed and successfully tested with the 150 MHz super-conducting resonators of BARC-TIFR LINAC.

A 150 W, 13.56 MHz solid state RF power amplifier has been designed, tested and installed for thin film deposition purpose.

An RF control system for 400 keV RF cavity has been designed and tested.

Seismology

With the objective of locating seismic events as accurately as reported by international seismological agencies, several new techniques and models have been implemented at BARC Seismic Data Centre. The location of most events occurring in and within the immediate vicinity of the country was determined with $< 5\%$ error.

Technologies for Safe Drinking Water

BARC has been carrying out the development of commercial size indigenous membranes and membrane-elements for safe drinking water application. The first batch of indigenously developed thin film composite reverse osmosis membranes has been loaded in the Nuclear Desalination Demonstration Project (NDDP), replacing the imported elements. The plant is operating round the clock.

As a part of the development of solar energy driven water purification systems, a solar photovoltaic (PV) energy driven water purification demonstration unit was designed, installed and commissioned at Trombay. It uses indigenous membrane for brackish water desalination and has capacity of 10 liters/h. It is portable, battery-less and stand-alone type.

Nuclear Agriculture

Plant Germplasm Registration Committee of National Bureau of Plant Genetic Resources (NBPGR), New Delhi has approved the registration of Bruchid resistant Trombay wild urid germplasm and Trombay groundnut mutant, TGM 112.

Twenty Five Nisargruna plants have become functional during the previous year.

Technology Transfer

BARC has signed an MoU with the Government of Goa on Collaboration for Promotion of Science and Technology Based Development in the State of Goa.

Human Resources Development

An e-learning platform named as "Pathsala" containing a large number of video courses, nuclear power plant (NPP) simulators and e-lecture notes, has been launched and hosted on server for the benefit of trainees and faculty members of the BARC Training School.

Under the QUEST Continuing Education Programme started about two years ago, four sets of courses under the Electrical Sciences Group have been offered to employees of DAE units in Mumbai and many are taking advantage of these courses. I urge more employees to avail this opportunity to upgrade their skills.

The Homi Bhabha National Institute (HBNI) continues to grow and strengthen its linkages with several premier institutes. To date, 261 degrees and diplomas have been awarded under the various academic programmes. The number of enrolments under the different programmes continues to swell having crossed the 3000 mark, with the Ph.D. cases alone being above 1300.

Scientific Information Resources Dissemination

BARC, as the nodal agency for analysing the scientific productivity and inputs of DAE institutions, during XI Plan period, submitted a detailed report on DAE publications and their citation, based on inputs received from various units. BARC publishes close to 1100 publications in a year.

An exhibition on "Fusion Engineering" was organised. An "Author's Workshop" conducted to motivate scientific staff to publish more in the International Journals was attended by about 800 scientific staff.

Public Awareness Programmes and Student Visits
Approximately 2000 students from fourteen institutions visited BARC during the year. Seminars and related events were conducted in seven educational institutions. These were attended by nearly 2500 students and teachers. To further strengthen this programme, nearly 100 scientists and engineers have been enlisted to form the BARC Media Committee. This team has participated in the recent events to spread the message of the programmes and activities of BARC and facts on Nuclear Energy. Very recently, BARC conducted exhibitions in DY Patil University, Kolhapur and at National Children's Science Congress, Jaipur where several thousand students participated.

Plan Projects

We will be soon approaching the end of the XI Plan period. The proposals for the XII Plan Projects are submitted to the Planning Commission. We must gear ourselves to utilise all the resources sought under current plan projects and deliver the outputs envisaged in the project reports. I earnestly appeal to all of you to continue to take timely actions in all aspects of the implementation of Plan projects.
Security and Physical Protection

The physical protection of our Centre is of paramount importance. I wish to compliment all the security personnel and thank all officers and staff of our Centre for their cooperation in effective implementation of high level of security.

I also acknowledge the excellent services of the Fire Service personnel who continue to maintain a strict vigil on the various establishments of our Centre.
The contributions of the personnel of our Floriculture and Landscaping Section, as evident by the beautiful ambience at this venue, are much appreciated. They have raised in the nursery 25000 saplings of different species of forest trees to be planted during monsoon this year.

Medical Services

Medical Services under the Contributory Health Services Scheme continued to provide excellent health-care services for the employees and their families very effectively.

Administrative Group

Administrative Group continued to provide its vital supporting function in the field of administration, establishment, including manpower planning, personnel data management, finance and accounts and security.

In my speech today, barring a few major highlights, I have not touched upon all the salient achievements earlier reported on the Founder's Day and Independence Day.

Conclusion

My dear colleagues, while we have been doing our best in the pursuit of our programmes, there is a need for further refining and enhancing the outputs from our Centre to meet the targets and enhanced expectations from the nation consistent with national development and economic growth. The negative perceptions in some sections of the society due to unfounded fears need to be addressed in multiple ways that include our demonstrating continued excellence and high relevance in all our deliveries.

I am sure, all of you will continue to put in your best efforts, so as to sustain our tradition of excellence with high relevance and value in the years to come.

Friends, therefore, on this very special day, let us all firmly resolve and rededicate ourselves to continue contributing to all facets of the Indian nuclear programmes and remain abreast with the frontier areas of nuclear science and technology to serve our nation for the betterment of the quality of life of the vast population of our country.

Thank you all. Jai Hind."

Heating Tumors to Death using Functionalized Fe_3O_4 Magnetic Nanoparticles

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Abstract

Application of Magnetic Nanoparticles (MN) has emerged as a potential mode of hyperthermia, a modality for cancer therapy, in which temperature of a tumor is increased beyond physiological temperature up to 40-43 °C. We have prepared Fe_3O_4 magnetic nanoparticles (Fe_3O_4-MN), which were surface-functionalized with polyethylene glycol (Fe_3O_4-PEG-MN) and oleic acid (Fe_3O_4-OA-MN) to make them water and lipid soluble, respectively; as well as to control their size. The particle sizes for Fe_3O_4-MN, Fe_3O_4-OA-MN and Fe_3O_4-PEG-MN were found to be 12, 6 and 8 nm, respectively. Under induction heating conditions, these MN preparations could achieve hyperthermic temperature. Interestingly, Fe_3O_4-OA-MN showed higher cytotoxicity in human breast cancer cells as compared to Fe_3O_4-MN and Fe_3O_4-PEG-MN, which was further enhanced when MN treated cells were subjected to induction heating.

Introduction

Fe_3O_4 based Magnetic Nanoparticles (MN) have gained increasing attention in the recent past as prospective candidates for diagnosis and targeted therapy of cancer [1,2] due to their biocompatibility and chemical stability under physiological conditions. These MNs provide dual benefits (i) diagnosis of cancer sites due to their potential as contrasting agent using magnetic resonance imaging, and (ii) therapeutic applications because of their heating ability (40-43 °C; hyperthermia) by induction heating for killing the cancer cells. Hence, the MNs could prove as unique weapons to trace out hidden cancer cells in patients, and once the target is located, kill them effectively (Fig. 1). Moreover, MN-based heating systems could also be employed for controlled release of drug from caged drug delivery systems, designed to release their content at defined temperatures, which could be further exploited to combine advantages of nanoparticles based drug delivery and hyperthermia modality of cancer therapy.

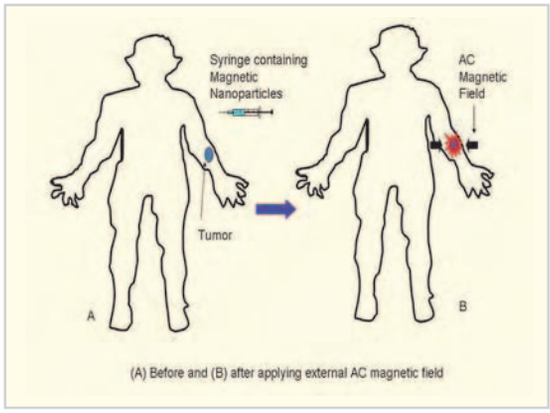

Fig. 1: Schematic outline of application of Magnetic Nanoparticles in Cancer Therapy

Application of hyperthermia to tumor tissue is done in two ways: (i) applying external source of heat (e.g. water bath, microwave, ultrasound, infrared sauna) which is also called 'external or extracellular hyperthermia' and (ii) delivering MN inside the cancer cells followed by application of alternating current (AC) field, which would increase the temperature of tumor mass. The latter approach is known as 'intracellular hyperthermia' (Fig. 2). Cell

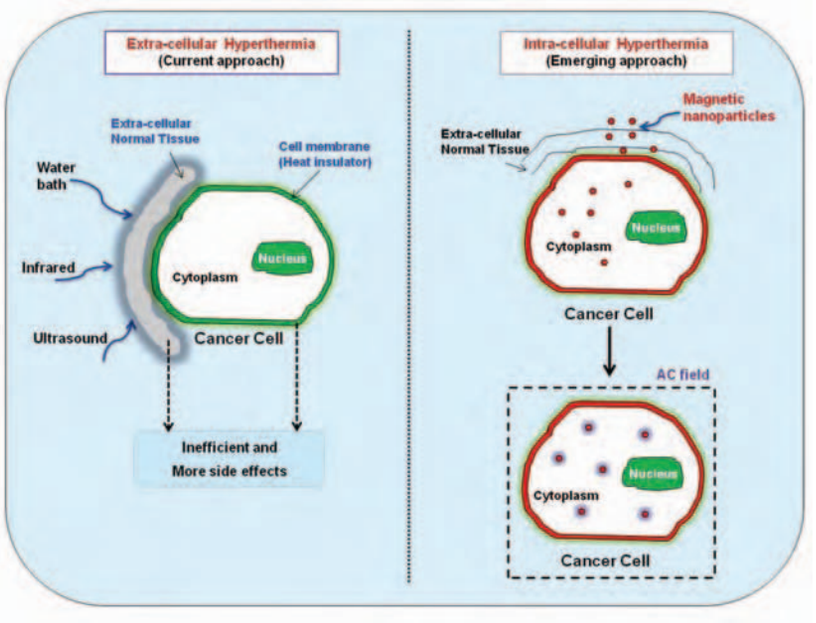

Fig. 2: Extracellular *vs* intracellular hyperthermia

membranes, with lipid as one of the major constituents, thermally insulate the tumor cells heated from external sources. Consequently, extra heat from external source has to be provided to achieve the therapeutic temperature, which may cause blisters, burns, swelling, blood clots, bleeding under clinical conditions. Therefore, application of hyperthermia using extracellular approach has faced practical problems. On the other hand, intracellular heating using internalized MN at the tumor site provides an efficient approach for hyperthermia application (Fig. 2).

In the present study, we have used Fe_3O_4 based MN, which have Fe^{2+} and Fe^{3+} ions (written as $Fe^{II}O$, $Fe_2^{III}O_3$) and are generally called magnetite. Fe_3O_4 has Curie temperature (T_c) of 585 °C, saturation magnetization (M_s) of 92 emu/g at room temperature and coercivity (H_c) of 323 Oe [1,2]. When size of Fe_3O_4 bulk material is decreased (in the range of nanometers), its intrinsic magnetic property changes. Below a certain dimension, each particle behaves as a magnetic single-domain. Its magnetic anisotropy energy is proportional to the particle volume (KV, K anisotropic constant and V particle volume). For small particles, the surrounding thermal energy (kT) is sufficient to overcome magnetic anisotropy energy (KV) resulting in spontaneous reversion of magnetization of a particle from one easy direction to other. MN with particle size (~5 nm) can have large magnetic moment (5×10^3 μ_{BM}) and thus 'super' is prefixed to paramagnetic term because overall system shows the paramagnetic nature (i.e. net magnetization ~ 0 emu/g, coercivity ~ 0 Oe) in absence of magnetic field [1-3]. This behavior is called superparamagnetic. Such superparamagnetic particles can be used in diagnosis and targeted therapy of cancer [4,5]. Magnetic nanoparticles suspended in liquid medium, called ferro-fluids, when placed under external AC magnetic field, try to orient the magnetic moment of nanoparticles towards the direction of magnetic field and would result in heat generation involving mechanism(s) like (i) Neel's relaxation; (ii) Brownian rotational loss (iii) hysteresis loss and (iv) eddy current [6].

The major advantages with application of MN smaller than 50 nm are (a) their high effective surface area for easy attachment of ligands, (b) better tissue diffusion and (c) reduced magnetic dipole-dipole interaction. As a result, no magnetization is retained in these particles after removal of magnetic field i.e. their superparamagnetic nature [6]. In-vivo administration of MN requires their controlled size and reduced

agglomeration for targeted delivery to the diseased site. However, MN prepared by chemical route usually agglomerate and are larger in size posing serious practical limitations. Capping the surface of nanoparticles would change their intrinsic physico-chemical properties like surface functionality, charge, reactivity and dimension making them more stable and suitable for *in-vivo* applications. Surfactants like oleic acid (OA) would result in oil dispencible nanoparticles, whereas hydrophilic MN could be prepared by capping agent like polyethylene glycol (PEG). The variation in lipophilicity would affect the cellular interaction of MN, their cellular uptake and hence, the net outcome of their therapeutic efficacy.

Fig. 3: Induction heating system

In the present work, we employed Fe_3O_4 nanoparticles (Fe_3O_4-MN) capped either with water soluble PEG (Fe_3O_4-PEG-MN) or oil soluble OA (Fe_3O_4-OA-MN). The heating behavior of MN under AC induction and their efficacy to kill human breast cancer cells was investigated.

Experimental Section

Fe_3O_4 MN were prepared by co-precipitation method from Fe^{2+} and Fe^{3+} ions in NH_4OH solution. $FeSO_4.7H_2O$ and $FeCl_3.6H_2O$ precursors were used for Fe^{2+} and Fe^{3+} ions, respectively. The surface of particles was functionalized with polyethylene glycol (PEG-6000) and oleic acid (OA). These MN were characterized using X-ray diffraction, FT-IR, VSM and Mössbauer techniques [7].

Heating of MN was performed in plastic micro-centrifuge tube (1.5 ml) using induction heater (Easy Heat 8310, Ambrell, UK ,frequency 265 kHz) with 6 cm diameter (4 turns) coil as shown in Fig. 3. MN suspended in 1 ml of distilled water were placed at the centre of coil and samples were heated for 10 min at a current of 100-600 A. Magnetic field generated at the centre of the coil was calculated from the relationship: $H = 1.257ni/L$ (in Oe) where, n, i and L denote the number of turns, applied current and the diameter of the turn in centimeters, respectively. The magnetic field could be varied from ~ 80 to 500 Oe by changing the current from 100 to 600 A.

Human breast cancer cell line (MCF7) was obtained from National Centre for Cell Sciences, Pune, India. Cells were cultured in Dulbecco's Modified Eagle Medium (DMEM) supplemented with 10 % fetal calf serum (FCS) and antibiotics in humidified atmosphere of 5% CO_2 at 37 °C. The desired number of cells was seeded in complete medium for overnight followed by treatments with different types of MN for morphological studies using confocal microscopy.

Results and Discussion

XRD patterns of Fe_3O_4-MN, Fe_3O_4-OA-MN and Fe_3O_4-PEG-MN showed that these MN were crystalline in cubic structure with lattice parameter a = 8.39(1) Å [7]. Increased broadening of diffraction peaks was observed after capping with OA or PEG due to reduction of particle size. Average crystallite sizes of Fe_3O_4-MN, Fe_3O_4-OA-MN and Fe_3O_4-PEG-MN were found to be 12, 6 and 8 nm, respectively. Chemical bonding between surfaces of particles with capping agent is supported by FT-IR study [7].

Microstructures of these particles were studied by Transmission Electron Microscopy. Fe_3O_4-MN shows agglomerated particles with individual size of 20 nm (Fig. 4a). The selected area electron diffraction (SAED) of Fe_3O_4-MN shows the rings, which correspond to the fcc structure (Fig. 4b).

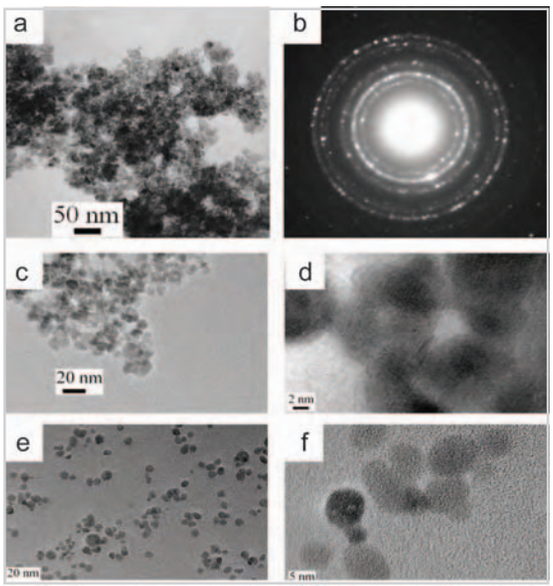

Fig. 4: (a) TEM and (b)SAED images of Fe_3O_4-MN. (c) TEM and (d) HRTEM images of Fe_3O_4-PEG-MN. (e) TEM and (f) HRTEM images of Fe_3O_4-OA-MN.

Agglomeration of particles was reduced after capping with PEG (Fig. 4c, d) and OA (Fig. 4e, f). In order to understand magnetic behavior of these particles, magnetization was recorded up to $\pm 1.0 \times 10^4$ Oe (Fig. 5). Unsaturated magnetization is found for all these samples with very small coercivity (~ 3 Oe) indicating superaparamagnetic nature of these particles. Magnetization values at 1.0×10^4 Oe were found to be 59.7, 34.39 and 37.37 emu/g for Fe_3O_4-MN, Fe_3O_4-OA-MN and Fe_3O_4-PEG-MN, respectively. Reduction in magnetization after coating with PEG or OA is related to reduced agglomeration of particles. With reduction of particle size and agglomeration, spin relaxation of domain increases and consequently, magnetization decreases. Mössbauer study supports the increase of superparamagnetic fraction with capping of PEG or OA [7].

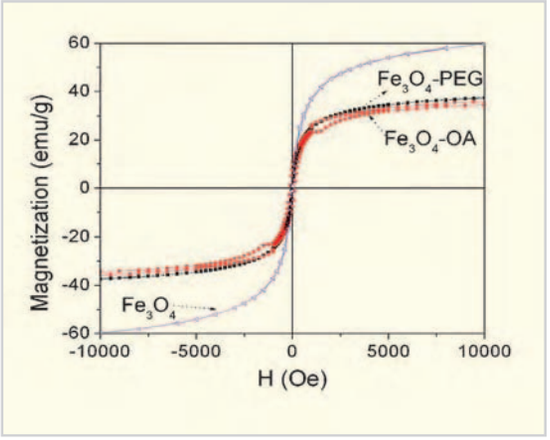

Fig. 5: M vs. H curves for Fe_3O_4-MN, Fe_3O_4-OA-MN and Fe_3O_4-PEG-MN. Here, M is expressed in term of emu per g of Fe_3O_4 content using VSM measurement.

Further, we have studied the heating ability of these MN under AC magnetic field. The MN suspended in distilled water were placed in induction heating coil (see Fig. 3). Fig. 6 shows the rise in temperature with increasing current (100-600 A) applied for 10 min to 10 mg of each sample. To achieve hyperthermic temperature, the required current is 250 A for Fe_3O_4-MN and 550 A for Fe_3O_4-OA-MN and Fe_3O_4-PEG-MN. Also, the results show that the hyperthermia temperature (42 °C) could be obtained using 2 mg for Fe_3O_4-MN and 5 mg for

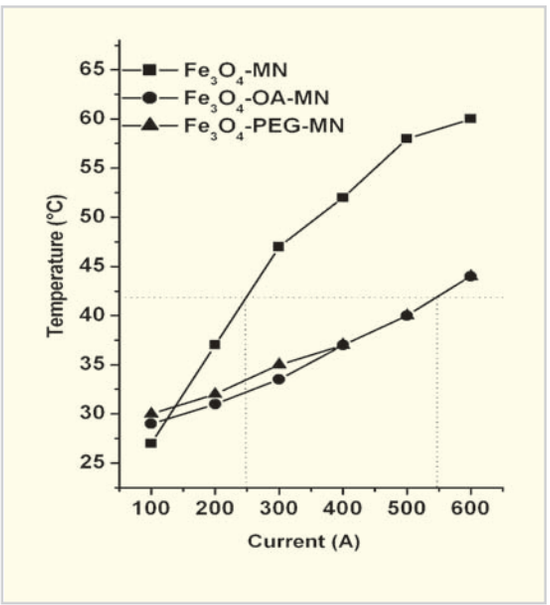

Fig. 6: Heating abilities at increasing current for different MN samples at a particular concentration (10 mg)

Fe_3O_4-OA-MN or Fe_3O_4-PEG-MN at 500-600 A. The specific absorption rate (SAR) of these samples were calculated at 400 A (335.2 Oe or 26.6 kA/m). The SAR values for Fe_3O_4-MN, Fe_3O_4-PEG-MN and Fe_3O_4-OA-MN were 38.4, 28.3 and 33.5 W/g, respectively [7].

Morphological alteration was evaluated in MCF7 cells treated with different types of MN with or without induction heating (Fig. 7a-h) to further evaluate their efficacy. Compared to control cells (Fig. 7a,b) and cells treated with Fe_3O_4-MN and Fe_3O_4-PEG-MN (Fig. 7c,e), rounded off and less clustered cells were observed in Fe_3O_4-OA-MN treated cells (Fig. 7e). Cells treated with Fe_3O_4-MN under induction heating did not show significant effect on morphology (Fig. 7d), however, effect was more pronounced in Fe_3O_4-PEG-MN treated cells under same condition (Fig. 7f). It was interesting to observe that the cells showed more rounding off and cell density was remarkably reduced when treated with Fe_3O_4-OA-MN followed by induction heating (Fig. 7h) suggesting better efficacy of Fe_3O_4-OA-MN to induce toxicity in cancer cells under induction heating conditions.

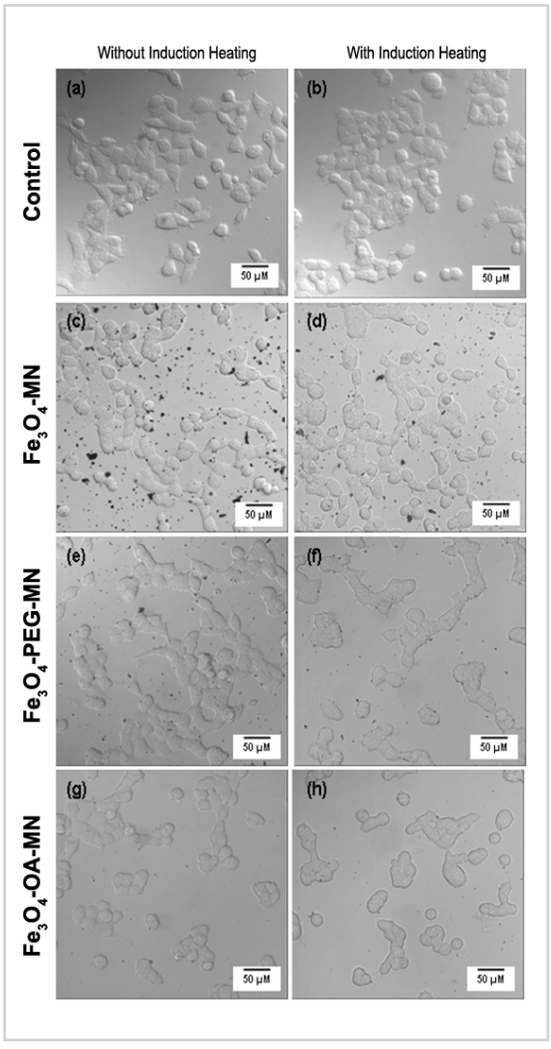

Fig. 7: Effect of different MN treatment on morphological alterations in MCF7 cells with or without induction heating. Untreated control (a-b) and cells treated with Fe_3O_4-MN (c-d) Fe_3O_4-PEG-MN (e-f) and Fe_3O_4-OA-MN (g-h) were observed under bright field mode of confocal microscope.

Conclusions

Reduced agglomeration of Fe_3O_4 magnetic nanoparticles (MN) was found when capped with PEG or OA which results in an increase of the ratio of superparamagnetic to ferromagnetic fraction. Hyperthermic temperature can be achieved at reasonably low concentration (2-5 mg) of MN suggesting their suitability for hyperthermia applications. The alteration in morphology of human breast cancer cells was more effective when MN were capped with OA followed by induction heating. Further experiments are underway to validate these results under *in vivo* animal experiment models.

Acknowledgement

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Quantification of Fluoride from Radioactive Liquid Wastes by Pyrohydrolysis Separation and Ion Chromatography

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Abstract

It is demonstrated, that the fluoride can be separated from LIQUID WASTES using pyrohydrolysis method. The routine method for separation of halides from ceramic samples was modified for radioactive liquid wastes. Subsequently, after separation by pyrohydrolysis, fluoride was determined from the pyrohydrolysis distillates by ion chromatography. Total time taken to determine fluoride is about 45 min including 30 min for the pyrohydrolysis and 15 min for ion chromatography. The results of recovery tests ranged 98% or above. The limit of detection for fluoride is 0.5 mgkg^{-1}.

Keywords: Determination of Fluoride, Pyrohydrolysis separation, Radioactive wastes

Introduction

India has vast potential of nuclear power due to abundance of thorium. It is used in the form of ThO_2 as a fertile material for production of ^{233}U which acts as a nuclear fuel. Selective separation of ^{233}U from unreacted Thorium is carried out by dissolving the irradiated ThO_2 in concentrated HNO_3 solution in presence of fluoride as a catalyst. Aluminium is also added during dissolution to reduce the corrosion potential of fluoride towards the reaction vessel. ^{137}Cs and ^{90}Sr are major fission products present in the acidic waste generated after separation of U and Th. Aluminium and fluoride are the principal inactive constituents of this waste. Large quantities of radioactive wastes are generated during reprocessing. High level liquid waste (HLLW) is vitrified before disposal by geological deposition. Vitrification is a high temperature process during which there is a possibility of the component aluminum vaporizing as fluoride resulting in the formation of corrosive off-gas constituents containing fluorine. Added to this, presence of fluorine limits the solubility of thorium and aluminum in borosilicate glass leading to phase separation. This in turn affects the chemical durability and increases the corrosion of borosilicate glass. Therefore, estimation of fluoride is essential for development of any suitable process and also most important from the point of controlling the corrosion of process containers and environmental pollution due to radioactivity leakage after geological deposition.

Pyrohydrolysis technique has been routinely used in the nuclear industry for the separation of fluoride & chloride from solid ceramic nuclear fuels and reactor materials[1]. The method consists essentially of passing a current of steam over the pulverized sample at high temperature, followed by condensation of hydrofluoric and hydrochloric acids thus produced. For liquid samples, Ion selective electrode (ISE) is used for the direct measurement of fluoride. Two important factors that affect the results of ISE are the proper sample matrix matched calibration of ISE and the proper selection of buffer required for decomplexing fluoride and also to provide constant ionic strength background for measurement. This is possible if the knowledge of sample background is available. Many times background of sample is unknown which makes the selection of buffer and

preparation of calibration curve very difficult resulting in erroneous values. Pyrohydrolysis separation gives a very clean separation without any process contamination. Therefore, a procedure was developed in this laboratory for separation of fluoride from LIQUID SAMPLES using pyrohydrolysis technique.

The pyrohydrolysis separation method employed for CQC of nuclear fuel materials was adopted with some modifications for separation of fluoride from radioactive liquid wastes. Fluorides of elements in higher oxidation states (δ/+3) are rapidly and virtually quantitatively decomposed during pyrohydrolysis, while those of alkali and alkaline earth metals react slowly and require addition of accelerators. In the current procedure we report U_3O_8 as an accelerator to assist the technique for the separation of fluoride from radioactive liquid wastes.

Experimental

Instrumentation: For pyrohydrolysis, an all quartz pyrohydrolysis set up consisting of two concentric tubes was used[2]. The outer tube has an inlet and serves as preheater for O_2+H_2O gas used for pyrohydrolysis. The inner tube houses the sample boat and is attached to gas outlet. The gas outlet tube is cooled by a condenser. Condensate is collected in a polypropylene bottle containing dilute NaOH. A schematic diagram and a photograph of the pyrohydrolysis set-up are presented in Fig.1.

A Dionex DX-500 ion chromatography system consisting of an IP-20 isocratic pump, a self regenerator suppressor in external recycle mode and an ED-40 conductivity detector with a conductivity cell and DS3 stabilizer has been used for obtaining all the chromatograms. Sample was introduced through a 100 μL loop fitted with a Rheodyne injector. Separation of anions was achieved with an analytical column (Dionex, Ion Pac,AS 18, 250x4mm) coupled with a guard column (AG18, 50x4mm). The Peaknet chromatography workstation was used for instrument control, data collection and data processing. A schematic diagram with a photograph of Dionex Ion Chromatography system is shown in Fig. 2. The system is made in two parts to handle the samples distillates taken out from radioactive glove box. The column & guard column are installed in fume hood and electronic instrumentation is kept out side of the fume hood for easy maintenance (See fig 2).

Reagents: All the reagents were of analytical grade and all solutions were prepared using high purity deionised water of resistivity 18.2MΩ.cm. All solutions were filtered through a 0.45 μm membrane filter and degassed before use. A mobile phase of 15 mM NaOH at a flow rate of 1ml/min was used. Standard solution of F^- was prepared by appropriate dilution of stock solutions of 1mg/L concentration of NaF.

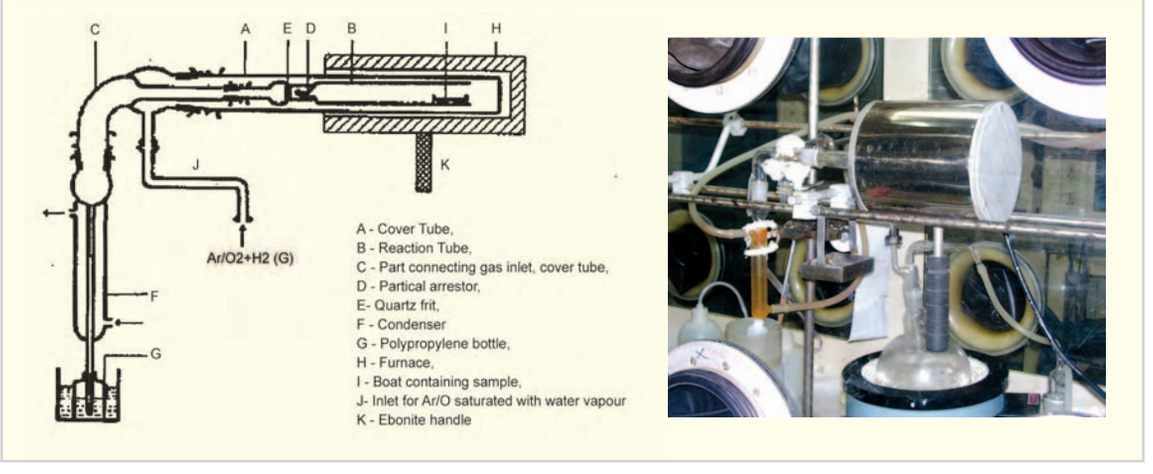

Fig. 1: A schematic diagram and a photograph of the pyrohydrolysis set-up in the glove box.

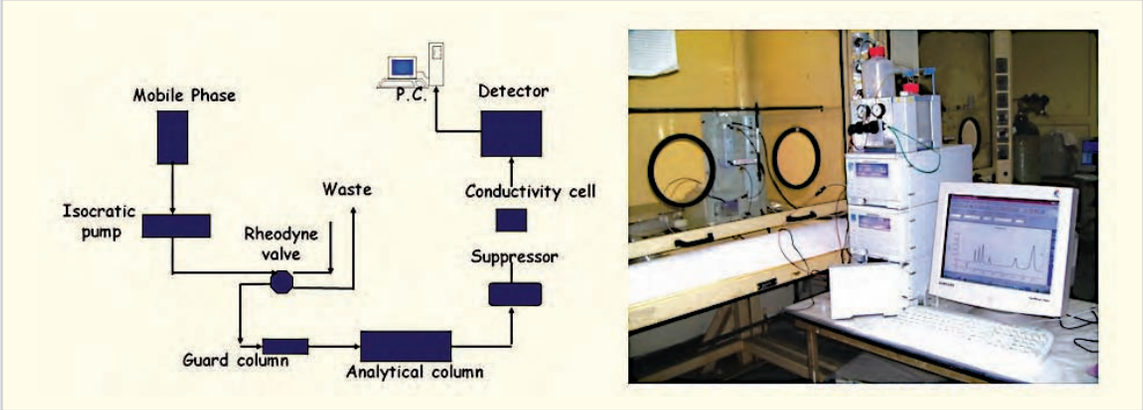

Fig. 2: A schematic Diagram with a photograph of Dionex DX-500 Ion Chromatography system.

Procedure: For the pyrohydrolysis separation, about a gm of pre-pyrohydrolyzed U_3O_8 was taken in a quartz boat and weighed of amount liquid sample was added so as to make a paste. In case of acidic wastes, calculated amount of sodium hydroxide was added in the boat to neutralize the waste. Then the quartz boat was introduced in the reaction tube of pyrohydrolysis setup which is specially designed for this purpose. The steam was passed for ten minutes with controlled heating by positioning the furnace to allow the sample to dry. Finally distillation was carried out at 950^{0}C and distillate was collected in a PVC bottle containing 5 mL of dilute NaOH solution.

Results & Discussion

Pyrohydrolysis: This technique was first introduced by Warf et al[3] in 1950 and the term pyrohydrolysis was assigned to describe the method. The method is based on the following thermodynamic principle of the general equilibrium reaction

$$MF_{2n} + nH_2O \rightarrow MO_2 + 2nHF\,,$$

which depends on temperature as the standard entropy of two moles of hydrogen fluoride is about twice that of one mole of water. The reaction should accelerate with the increase in temperature and addition of some flux. Several authors have used this technique to determine the fluoride content of various inorganic materials, but only the reaction conditions used, seem to be different[4-12]. Various materials have been used for designing pyrohydrolysis setups and diverse designs have also been fabricated for fast and quantitative recovery.

The various parameters, such as size of a sample, amount of U_3O_8, heating rate of steam generator, time and rate of distillate collection, were studied for the liquid waste samples and were optimized (Table 1). The use of U_3O_8, an oxygen rich compound, not only served as a base material to the liquid matrix but also acted as an accelerator for the dissolution of halides in steam.

Though, the fluoride ion selective electrode for fluoride has been widely employed in the past, ion-

Table 1: The optimized parameters for pyrohydrolytic separation of F from radioactive liquid wastes

Pyrohydrolysis process initial temperature (°C)	Pyrohydrolysis process final temperature (°C)	Oxygen Flow rate (cc/min)	Time of distillation (hr)	Sample size (g)
100-200 (First 10 minutes) heating by positioning the furnace	925-950 (Last 20 minutes) heating by sliding over the furnace	150-175	0.5	0.1-0.2 + (1g. U_3O_8)

Table 2: The results of F recovery from spiked waste samples

Spiked sample	F- added (μg)	F- found (μg)	% Recovery
1	48	47	98
2	48	49	102
3	53	53	100
4	63	64	102

chromatography was adopted for determination of fluoride due to its sensitivity. Total time taken to determine fluoride was about 45 min including 30 min for the pyrohydrolysis and 15 min for ion chromatography. The results of recovery tests were within 10%. The limits of detection for F are 0.5 mgkg^{-1}.

As the certified reference standards were not available, accuracy of the method was checked by spiking the standard solution of fluoride in radioactive liquid waste samples. Table 2 shows that recovery of spiked F samples at three different concentration levels following present method. The percent recovery was in range from 98 % to 102 %. The method was further authenticated by comparing the results of F obtained by IC with fluoride ion selective electrode method. The results agreed with in ± 10 % (Table 3). The method was successfully applied to the determination of F in radioactive liquid wastes.

Table 3: The results F using fluoride ion selective electrode and ion chromatography from various radioactive liquid wastes.

Sample	F- Direct by ISE (ppm)	F-PH / IC (ppm)
Slag Dissolver Solution	225	239
Pu-oxalate supernatant	18.2	21.1
Low Level Liquid waste	15.6	15.3
Analytical Waste	36.4	37.1
Reactor pool water	0.5	0.5

Conclusion

The routine pyrohydrolysis method used for solid ceramic samples can be used for separation of fluoride from LIQUID WASTES. This separation by pyrohydrolysis is clean without contamination and the pyrohydrolysis distillates can be determined fluoride contents by ion chromatography. The sample can be analyzed for fluoride within 45 min with recovery 98% or above and detection limit 0.5 mgkg^{-1}.

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Microstructural and Microtextural Studies in Zr Based Alloys

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Abstract

An overview of microstructural and textural changes taking place during the processing of the Zirconium alloys and their role in the hydriding behavior is presented. The linkage between the microstructural evolution and textural development is demonstrated in case of Zircaloy-4 clad tube fabrication. An algorithm is presented for the reconstruction of the high temperature phase microstructure, using which the significant variant selection taking place during the transformation of β-Zr into α–Zr is demonstrated. The role of microstructure on the hydride formation is discussed in terms of effect of grain/phase boundaries.

Introduction

Some of the most functionally critical in-reactor components like pressure tube and clad tubes are made up of Zr based alloys. The service performance of the components made by these alloys largely depends on their as-fabricated microstructure and texture. Hydride formation, irradiation creep and growth are some of the important life limiting phenomena which are directly influenced by the component's microstructural and textural conditions. Hence it is important to understand (a) the evolution of the microstructure and texture during the fabrication (b) the role of the microstructure on the phenomena like hydride formation etc [1]. Such understanding helps in tailoring the microstructures for mitigating the ill effects of the hydride formation. Understanding of the microstructural evolution as a function of process parameters also helps in optimizing the fabrication flow sheet to obtain the desired microstructures that enhance component performance.

The present paper presents an overview of microstructural and textural evolution studies in various Zr based alloys and the microtextural aspects of hydride formation in them. Along with the conventional characterization tools of transmission electron micrscopy (TEM), and X-Ray Diffractometry (XRD), scanning electron microscopy (SEM) based electron back scatter diffraction (EBSD) has also been extensively used. EBSD has the advantage of offering images with reasonably higher spatial resolution combined with the local orientation information. Thus, it combines the imaging capabilities of SEM with the textural capabilities of XRD [2] and opens up some interesting possibilities which are demonstrated in this article.

Evolution of Texture and Microtexture during Zircaloy-4 clad fabrication:

Thermo-mechanical processing (TMP) steps used for the fabrication of Zr components are aimed at obtaining required dimensional tolerances and optimized microstructure. The final microstructure, and associated properties, is often a cumulative outcome of series of changes occurring at each stage of processing. Hence, a systematic characterization of the microstructural and textural evolution in each of the stages of the PHWR clad fabrication was carried out and presented in Fig.1. The fundamental mechanisms responsible for observed changes were investigated and the important observations emerging out of this study could be summarized as below

- β quenching produced a nearly randomized texture and relatively large Widmanstatten grains of a phase (Fig 1b)
- Hot extrusion (HE) had resulted in the formation of the bi-modal grain size distribution and the development of a strong crystallographic texture (see Fig 1b). The HE texture was essentially made up of two fibers viz, ND||(0001) and ND||$(10\bar{1}0)$ which are characteristic fibers expected of recrystallization and deformation respectively.
- Subsequent cold deformation steps have resulted in strengthening of the $(10\bar{1}0)$ fiber while the annealing steps made the (0001) fiber stronger (see the orientation distribution function (ODF) maps in the Fig 1c). Microtexture analysis had revealed that the observed textural changes were essentially from grains of larger size.
- TEM investigations have revealed the signatures of the dynamic recrystallization (formation of high angle grain boundaries, and equi-axed grains with relatively low dislocation density in conjunction with elongated grains) during the HE. Pilgered structures on the other hand exhibited heterogeneous microstructures with heavy dislocation networks (Fig.1d). TEM of "Final annealed" sample indicated that the sample had undergone partial recovery.

Reconstruction of high temperature β phase:

As shown in the previous section one of the important steps of the component fabrication is the β-quenching step which results in texture randomization. However, the degree of texture

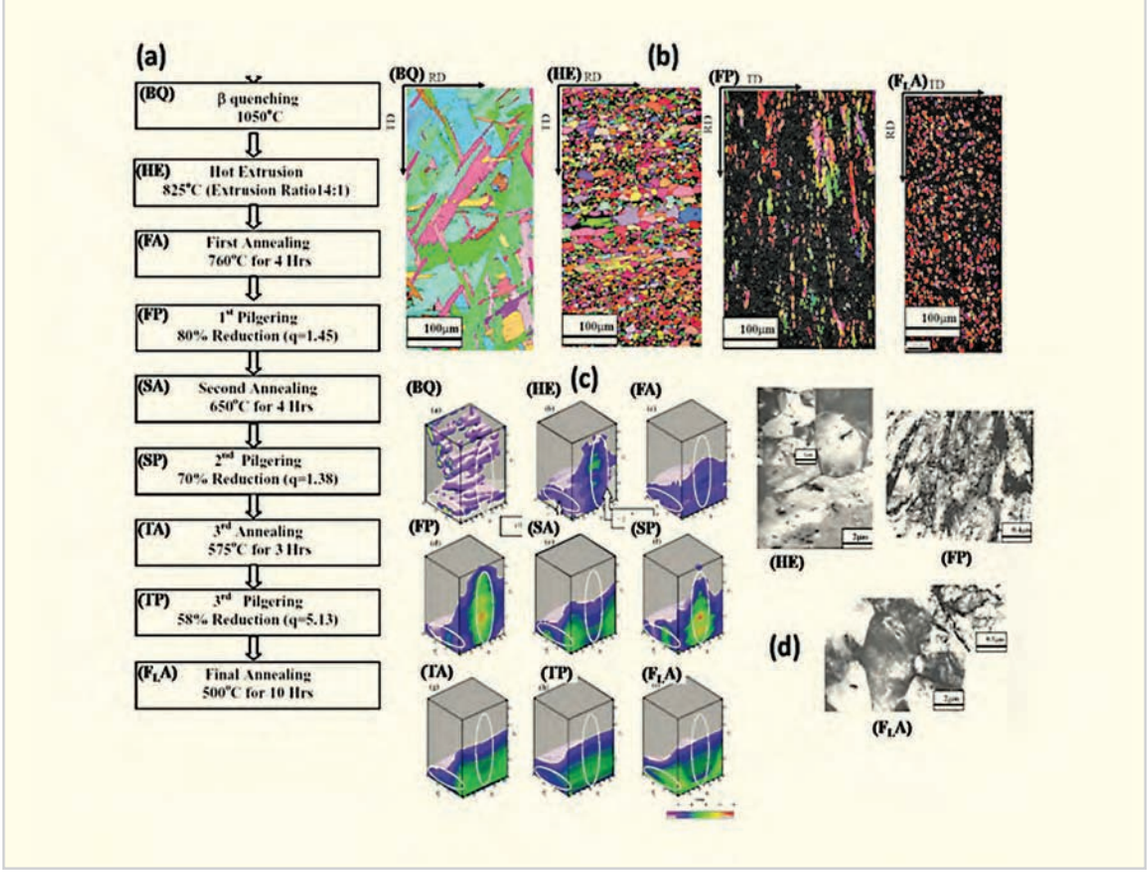

Fig. 1: (a)TMP processing steps and the conditions involved in the fabrication of the Zircaloy-4 clad tubes for the PHWR reactor. (b) Microstructural evolution as characterized by EBSD during some of the selected TMP stages (c) Textural evolution in terms of 3-D ODF maps. (d) TEM micrographs of the samples from specific stages of the TMPs.

randomization and the resulting microstructure subsequent to quenching are functions of the nature of the phase transformation that occur during quenching and the prior high temperature microstructure. Hence, knowledge of microstructure in the high temperature phase regime and nature of transformation in terms of variant selection can be helpful in optimizing the quenching parameters. In this context, we had developed an algorithm to reconstruct the microstructure of the high temperature phase using the micro-texture data (EBSD data) of the room temperature phase [3].

The principle of reconstruction is based on the fact that in case of Burger's orientation relationship (OR)[2], each a grain (product) can have 6 possible β (parent) variants. Hence by considering at least three a grains which have formed form same parent β grain it is possible to deduce the orientation of the parent grain and thus reconstruct the parent microstructure. The actual algorithm is explained below.

1. Consider a product grain G_i (where i = 1,2,3…) has G_{i+1},G_{i+2},- - -G_{i+N} as its neighbors – see Fig. 2a. Fig. 2b shows possible triplets containing G_i and its neighbors with the condition that each grain of the triplet is neighbor to other two.
2. For grains in a given triplet find all possible parent orientations

$$B_{li}^{\beta} = T_l^{\alpha\to\beta} G_i^{\alpha} \quad B_{li}^{\beta} = T_l^{\alpha\to\beta} G_i^{\alpha} \qquad (1)$$

Based on the above algorithm, we reconstructed various transformed microstructures in case of Zircaloy-4 samples which have undergone a wide range of transformations ranging from diffusional to martensitic. An example of such reconstructed microstructure is presented in the Fig 3, which also shows the identification of the product variants based on the just mentioned algorithm. It is clear that there is considerable degree of variant selection (see Fig. 3d).

Where, $T_{l=1..6}^{\alpha\to\beta} = D^{-1} S_{l=1..6}^{\alpha}$ and $S_{l=1.6}^{\alpha} = (E_{\alpha}, C_{6z+}, C_{3z+}, C_{21+}, C_{22+}, C_{23+})$ are the hexagonal symmetry operators D is the matrix representing Burgers OR for $\beta \to \alpha$ and i=1..3 are the grain IDs in the selected triplet, B_{li}^{β} is the parent orientation for the product orientation of G_i^{α}. Of these parent solutions, common solution to all the three grains of the triplet is selected as a '*potential solution'.*

3. These steps are repeated for all triplets of G_i– yielding, say *n*, *potential solutions* for G_i. In order to assign an 'optimum' solution to G_i, we find the mean solution ($S^m_{k,l}$) and mis-orientation($\Delta S_{k,l}$) between each pair of the potential solutions: S_k and S_l where *k* and *l* run

$$S^m_{k,l} = mean(S_k, S_l) k \neq l \qquad (2)$$

$$\Delta S_{kl} = Cos^{-1}\left(\frac{(Trace(S_k \cdot S_l^{-1}) - 1)}{2}\right) k \neq l \qquad (3)$$

Reject any $S^m_{k,l}$ for which $\Delta S_{k,l}$ is more than user specified maximum misorientation tolerance (δ_{max}). Final solution (S_{final}) for G_i is the mean of all $S^m_{k,l}$ weighted by $W_{k,l}$ (weightage factor for $S^m_{k,l}$).

$$W_{k,l} = \frac{(\delta_{max} - \Delta S_{k,l})}{\sum_{k=1}^{n-1}\sum_{l=k+1}^{n}(\delta_{max} - \Delta S_{k,l})}$$

$$S_{final} = \sum_{k=1}^{n-1}\sum_{l=k+1}^{n}(W_{k,l} S^m_{k,l}) \qquad (4)$$

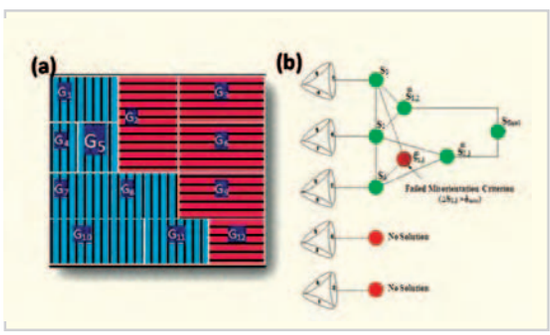

Fig. 2: Schematic showing the product a grains. Grains belonging to common parent b are marked with the same color/shade. Subscripts (G_i) indicate the product grain IDs. (b) Adopted algorithm. Let G_i = 5. Neighbors of G_5 are G_1, G_2, G_4, G_7 and G_8. The triplets formed by G_5 are [5,1,2], [5,2,8], [5,8,7], [5,7,4] and [5,4,1]. Note that all the three grains of these triplets are neighbors to each other. Triplets either have a common parent variant, i.e. a "potential" solution for the parent b, or "no solution". The next step is to link the "potential" solutions through a generalized misorientation criterion.

Based on the above algorithm, we reconstructed various transformed microstructures in case of Zircaloy-4 samples which have undergone a wide range of transformations ranging from diffusional to martensitic. An example of such reconstructed microstructure is presented in the Fig 3, which also shows the identification of the product variants based on the just mentioned algorithm. It is clear that there is considerable degree of variant selection (see Fig. 3d).

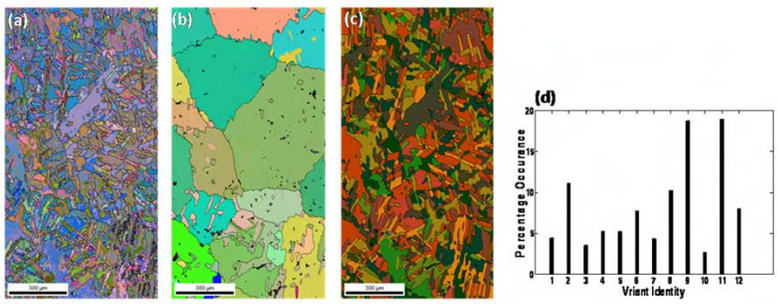

Fig. 3: (a) EBSD microstructure of b quenched microstructure of Zircaloy-4 (b) The reconstructed map of parent phase (b) (c) Microstructure of product phase with each product grain colored according to its variant identity (d) Frequency distribution of product variants.

Some of the important advantages of this algorithm in comparison to other existing ones are its (a) less sensitivity to measurement errors in orientation measurement (b) practical elimination of spurious unification of the grains belonging to different parent grains (c) independence of calculated solution from user defined angular tolerance (δ_{max}).

Thus, we are able to reconstruct the high temperature microstructure, and correlate the observed textural developments by identifying the variant selection taking place during the phase transformation using the just mentioned algorithm. This capability is expected to be of immense help in optimizing the β quenching process and gaining further insight into the mechanism of β to α phase transformation.

Role of grain/phase boundaries in hydride formation:

Hydride formation is known to be one of the life limiting factors in case of Zr based structural components used in thermal nuclear reactors. Understanding the mechanism of hydride formation can help tailor suitable microstructures for better hydride mitigation in these alloy components. Previous works, which are largely based on TEM and optical investigations, have indicated that the hydrides preferentially form along the grain boundaries of the matrix phase. However, very little information was available on the role of nature of the grain boundaries and interfaces in controlling the hydride formation, as these techniques inherently lack local orientation information and suffer from poor statistics [4,5]. In the present article we report, substantial improvement in understanding of the role of grain/phase boundaries with explicit use of local orientation measurements through EBSD technique.

Fig. 4 depicts the hydride microstructures in case of single phase (Zircaloy-2) and two phase (Zr-2.5Nb) Zr alloys. It is quite evident that majority of hydrides were along α/α boundaries in case of Zircaloy-2 and α/β interfaces in case of Zr-2.5Nb alloy. A detailed analysis of the microtexture data on these hydride samples revealed following important facts on the preference of hydrides for particular interfaces.

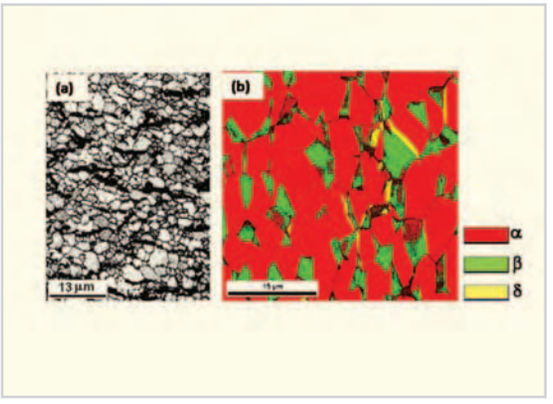

Fig. 4: Hydride distribution in Zirconium based alloys (a) Zircaloy-2 (b) Zr-2.5%Nb alloy. It is clear that in both the cases the hydride phase is along the interfaces of the grains only.

- In case of single phase alloy, (Zircaloy-2), formation of hydrides was preferred on certain grain boundaries. Those boundaries which are characterized by low coincident site lattice (CSL) values, in general, were resistant to hydride formation. This could be attributed to relatively higher atomic order among such boundaries which lowers their energy and thus decreases their potency for heterogeneous nucleation of secondary phases.

- Higher resistance to hydride formation was also observed in boundaries surrounded by elastically harder grains. This observation was rationalized by the expected higher stresses generated during the hydride formation (due to inherent volumetric expansion involved in hydride formation) along boundaries formed elastically hard grains.

- Hydrides in the two phase Zr-2.5%Nb alloy in a completely recrystallized condition have formed primarily along α/β interfaces, with only a minor fraction of hydrides being along a/a grain boundaries.

- Majority of the hydrides were along those α/β interfaces which had a misorientation corresponding to burger's OR. However, not all the α/β interface which are related by the burger's OR are having the hydrides along them. Selection α/β interfaces as the favorable nucleation sites by the hydrides was attributed to high hydrogen partitioning between the α and β phases on account of the large differences in solid solubilities of hydrogen in α and β phases. This makes α/β interface the nearest available heterogeneous nucleation site for most the precipitation of hydride.

Acknowledgements

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Biological Process for Denitrification of High Sodium Nitrate Bearing Waste Effluents of Reprocessing Origin

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Abstract

A process for treatment of high sodium nitrate loaded reprocessing waste has been developed and demonstrated in a flow through bioreactor. Denitrification of as high as 28000 mg/L of NO_3 (~ 0.45 M $NaNO_3$) bearing waste to below 20 mg/L was accomplished at a residence time of 50 hours by passing the waste solution spiked with methanol (a carbon source) and traces of micronutrients. The process was successfully tested for treatment of actual intermediate level waste solution of reprocessing origin. Traces of radionuclides did not have any deleterious effect on denitrification performance of the biomass. Steady performance on continuous operation of the column over six months has assured the viability of the process for practical applications.

Keywords: Biodenitrification, Pseudomonas, radioactive effluent, sodium nitrate, bioreactor

Introduction

Growing use of nitrate bearing products in our daily life (fertilizers, food preservatives, pectin, etc.) coupled with the increasing discharge of nitrate bearing waste from various domestic and industrial sources have led to radical changes in nitrate and nitrite proportions in the environment leading to ecological imbalance. Increasing levels of nitrate in ground water as well as in surface water are also of concern as it finally enters the human body through drinking water and can cause serious health hazards. Stringent norms for nitrate discharge and limits are in force everywhere and WHO and EEC has set 50 mg/L NO_3^- (11.1 mg/l NO_3-N) as the limit in groundwater, while regulatory standards in India specify that concentration of nitrates in treated effluents should be below 45 mg/L NO_3^-, before such effluents can be discharged to the environment.

Internationally, various methods including chemical, ion exchange, reverse osmosis, thermal degradation, biological denitrification, etc., are being considered as feasible options, yet it is accepted that all processes, except biodenitrification, partition the waste effluent into two streams viz., a small volume fraction containing the entire nitrate and a nitrate lean large volume fraction suitable for direct discharge. In contrast, biodenitrification fulfills the ultimate objective of converting nitrate to nitrogen gas. However, industrial scale application of the process has so far been limited for purification of drinking water, and to some extent for treatment of low nitrate bearing waste-water from fertilizer industry, nuclear industry, etc. [1-2]. A biodenitrification plant is functional in WMD, BARC for treatment of up to 2000 mg/L nitrates in low level waste [3]. For treatment of high nitrate bearing effluents, Francis and Mankin accomplished denitrification of about 20,000 mg/L of NO_3^- wastes using a column packed with fine particles of anthracite coal in suspension [4], Glass and Silverstein achieved success in denitrification of 36,000 mg/L of NO_3^- as $Ca(NO_3)_2$ in a tank as well as in pond bioreactors [5] and Dhamole et. al. from BARC, India successfully denitrified a 40,000 mg/L of NO_3^- as $NaNO_3$ using a stirred tank reactor [6].

Investigations carried out in our laboratory over the last several years have helped to develop a flow through bioreactor capable of denitrification of higher $NaNO_3$ bearing effluent. An overview of the process development work is presented here.

Origin and characteristics of waste effluents generated in nuclear industry

Processing of uranium from barren liquor at the front end and reprocessing of spent fuel at the back end of nuclear fuel cycle results in various types of nitrate bearing waste effluent. Nitrate in the form of ammonium nitrate and magnesium nitrate are generated at the front end, while three types of waste including $NaNO_3$ loaded declad waste, neutralized evaporator condensate and acidic (HNO_3) HLW are generated from reprocessing operations. From radioactivity point of view, these $NaNO_3$ bearing effluents, as intermediate level waste, are stored in underground carbon steel tanks. The $NaNO_3$ concentration in such waste varies from 50,000 -150,000 mg/L. As the process of nitrate removal is applicable after decontamination of waste, a dilution of about 2-5 times is expected during treatment as well as transfer of the waste.

Biodenitrification process

Bio-denitrification is a natural phenomenon accomplished by the microorganisms as a part of their respiratory process where nitrate serves as an electron acceptor and the carbon source as an electron donor. A large number of micro organisms are known to be capable of denitrification where the nitrate is reduced to nitrogen gas through a sequence of enzymatic reactions, viz.,

$$NO_3^- \longrightarrow NO_2^- \longrightarrow NO\uparrow \longrightarrow N_2O\uparrow \longrightarrow N_2\uparrow$$

The overall reaction can be represented as follows:

$$NO_3^- + \text{carbon source} \rightarrow N_2 + CO_2 + H_2O + OH^-$$

Biotechnology makes use of these microorganisms by providing suitable conditions, essentially an external carbon source and micronutrients for microbial respiration and growth leading to denitrification. In general, the rate of denitrification by microorganisms is quite slow by its very nature and high nitrate environments are usually toxic to most microbes. Identification of a suitable microbial strain or consortia of organisms, which can grow in high nitrate concentrations and with minimal growth requirements, is the most important step for a practically viable process.

Biomass and bioreactor of present study

Biomass from an industrial fertilizer unit for treatment of nitrate at low concentrations (~2000 mg/L) was used as inoculum and adapted during batch studies to a 'minimal medium' containing methanol as carbon source. The inoculated biomass was then allowed to grow in stainless steel wire gauge modules (Fig.1) stacked in a glass column. These sturdy modules although new for this application, were selected with the expectation that its high internal surface area would be colonized by bacterial growth which would remain attached to it and that the release of gases like CO_2 and N_2 would have no effect on functioning of the column during prolonged use. To initiate

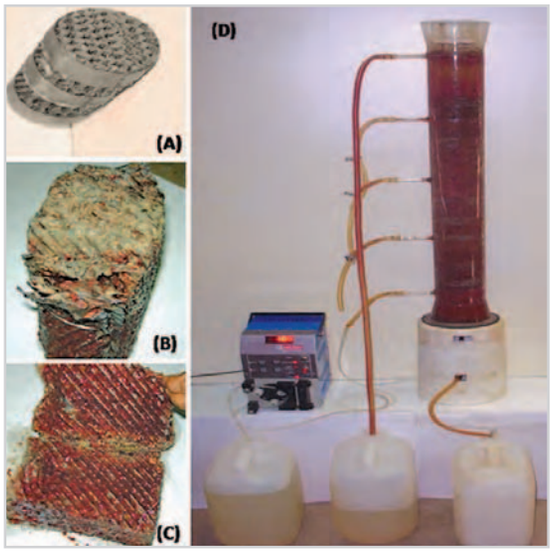

Fig.1: Actual photograph of the (A) module before loading on column, (B) module loaded with biomass, (C) cross sectional view of the biomass loaded module and (D) bioreactor (4.8L) setup

biomass growth, a nitrate bearing feed containing 730 mg/L NO_3^- as $NaNO_3$, minimal growth medium including methanol as carbon source and traces of micronutrients was fed through the column in the up flow mode using a peristaltic pump. Denitrification performance was monitored by analyzing effluent samples for NO_3^- and NO_2^-. After achieving complete denitrification and stable column performance over a period of two months, conditions were optimized wherein a C/N ratio of 0.94 and the minimal micronutrient composition required in feed was determined [7]. Using these optimized feed conditions the column was then run with gradual increase of nitrate concentration. This approach was adopted to gradually select acclimatized biomass for denitrification of high nitrate bearing effluent.

Identification of the biomass

After about 2 years of operation of the column, biomass sample from column was sent for identification at the Institute of Microbial Technology, Chandigarh, India. The biomass was identified as aerobic bacilli bearing Gram negative, short, motile rods which were oxidase positive, indicating *Pseudomonas aeruginosa*. The features showing short motile rods, with length ranging from 1.5-3.0 ìm, are seen in SEM micrographs (Fig.2). The selective growth of *Pseudomonas* species are expected, as these are known to be ubiquitous organisms with the ability to colonize diverse niches due to its range of metabolic capabilities and ability to overcome environmental challenges.

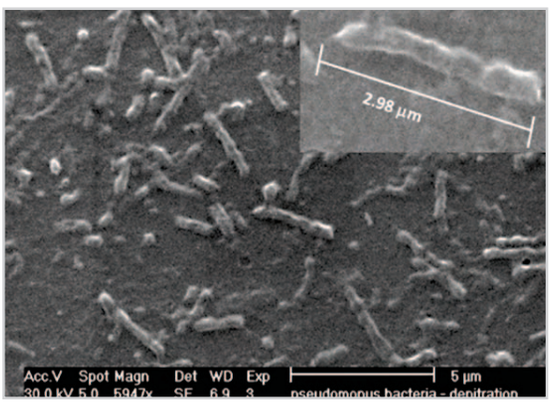

Fig.2: SEM micrograph of biomass (*Pseudomonas aeruginosa)*

Treatment of actual effluent

The actual ILW received after necessary pretreatment for removal of ^{137}Cs, ^{90}Sr, ^{99}Tc and ^{106}Ru was found to contain 17,500 mg/L nitrate and $1x10^{-3}$ mCi/L of gross β activity. For denitrification, the column was acclimatized by passing a $NaNO_3$ solution of similar concentration level followed by actual feeding of radioactive waste. The typical profile of column acclimatization followed by treatment of actual waste is shown in Fig.3 [8]. Exposure of the biomass to high nitrate conditions leads to an increase in effluent nitrate concentration initially which then decreases over a period of time. This shows that acclimatization of the biomass is a gradual process. Interestingly, once the biomass acclimatization phase is through, steady operation is obtained over an extended period of time. Though only about 50 L of the waste (20 column volumes) was treated due to limited waste availability, the run was continued with the same denitrification performance for six months with simulated waste. The criteria used for selection of modules as support for biomass growth were vindicated as can be seen from the file photograph of the internal part of the modules (Fig 1). Under stable operating conditions, about 50% of module volume was found to be occupied by the biomass (wet weight of the module

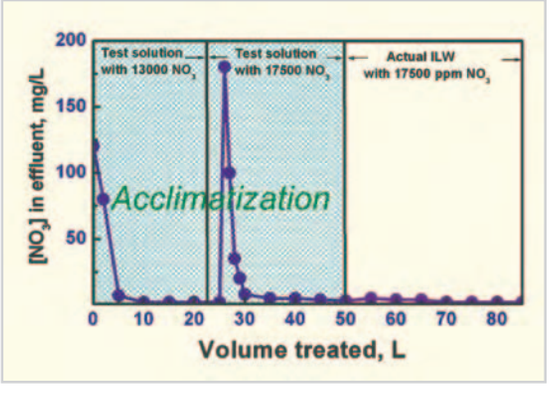

Fig.3: Biodenitrification of actual ILW containing 17500 mg/L of NO_3^- as $NaNO_3$ at the residence time of 50 hours after suitably acclimatization of biomass under similar conditions

increased from 400 g to about to about 1500 g due to biomass growth). Results of the study suggest that the bioreactor is effective for treatment of $NaNO_3$ bearing reprocessing waste.

Effect of gamma radiation

Because of the low volumes of actual waste used in treatment, the effect of gamma radiation on denitrification performance of the column could not be ascertained in the earlier study. However, exposure of the biomass to radiation environment from the low level streams over a prolonged time period during actual operation is inevitable. To study the effect of such radiation, ^{137}Cs radiotracer was added into feed solution (activity level: 0.05 mCi/L) and passed through the bioreactor (2.5 L) already stabilized with 20,000 mg/L of NO_3^-, at the flow rate of 50 mL/h (residence time: 50 h) over a period of one month. Based on the analysis of ^{137}Cs, NO_3^- and NO_2^- activity, it was found that the waste was completely denitrified throughout the course of the study and almost no activity was absorbed by the biomass. Biomass had therefore received a constant radiation dose similar to exposure to a column filled with 0.05 mCi/L of ^{137}Cs solution for a period of one month. This corresponds to exposure of the biomass in column to low level waste having $1x10^{-3}$ mCi/L ^{137}Cs activity for a period of 50 months. It can therefore be concluded that the biomass used in present study is suitable for treatment of low level effluent.

Effect of flow rate and process performance under optimized conditions

Studies on flow rate variation are integral to establishing optimum conditions for good plant through put. It was practically observed that as in case of change of nitrate concentration in feed, flow rate variations also required time for biomass acclimatization. For example, a flow rate variation study from 50 to 70 mL/h, after ensuring stable denitrification performance of a column at 17,500 mg/L of NO_3^- with a residence time of 50 hours (flow rate: 50 mL/h, column volume 2.5 L), was found to show satisfactory results. However further increase in flow rate to 80 mL/h led to a sharp rise in effluent nitrate level. It can therefore be stated that denitrification of 17,500 mg/L NO_3^- can be carried out at an average residence time of 35 hours. This was confirmed at several concentrations during the process of gradual adaptation of biomass in another (4.8 L) column. The performance of the column under optimized conditions was monitored over several months and the results are shown in Fig.4. Complete denitrification of 4400 mg/L nitrate required only 2 hours while it takes about 50 hours for denitrification of 28,000 mg/L NO_3^- bearing effluent. Results of this study are useful in scale up of the process to meet desired plant throughput.

Conclusions

Operations of the column under minimal growth conditions and gradual acclimatization of the

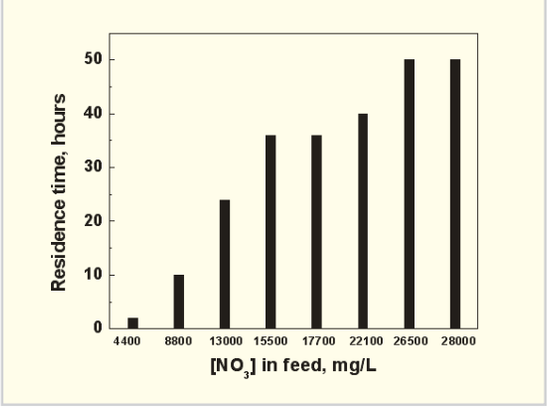

Fig.4: Denitrification performance under optimized conditions during gradual acclimatization of biomass (4.8 L Bioreactor)

biomass to higher nitrate bearing environment by the *Pseudomonas sp* has been established. The growth of biomass on the interstices of the metal sheets of wire gauge packing modules was found to be conducive to building the flow through bioreactor. The biomass has demonstrated capability for denitrification of as high as 28,000 mg/L of nitrate bearing solution with only methanol as carbon source (C/N ratio of 0.94) and traces of

micronutrients. It is established that denitrification performance of the biomass will not be affected even in presence of traces of ^{137}Cs activity, and hence the process is promising for treatment of high nitrate bearing low level nuclear effluents generated from back end of nuclear fuel cycle. Efforts are being made to demonstrate the process on a larger scale.

Acknowledgement

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Developments in Electron Beam Processing Technology

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Abstract

An industrial pulse type 2 MeV electron beam accelerator is situated at BARC-BRIT Complex, Vashi, Navi Mumbai to develop and demonstrate applications useful for Indian industry. Studies have been carried out on industrial applications viz. polymer modifications, crystalline alterations, biological changes, environmental protection etc. Significant expertise is gained in applied radiation chemistry/physics, processing aspects, accelerator technology, beam diagnostics, dosimetry, operation and maintenance. A number of industrial materials have been irradiated on large scale using the accelerator. The facility has become an important demonstration-cum-semi commercial service unit meeting the needs of various R&D activities and the industry. This article gives an account of the successful industrial applications developed at the facility.

Introduction

High energy Electron Beam (EB) radiation induces cross-linking, chain scission and grafting reactions in polymer materials through free radical mechanism which produce one or more polymer-blend based products having special properties e.g. high temperature stability, heat-shrinkability (memory effect), solvent resistance, controlled melt flow, degradation to low molecular weight products, surface modification etc. Main application areas in this category are thin film curing used as thermo-shrinkable products, cross-linked wire and cable insulations, heat shrinkable terminal joints and end caps, micro-fine PTFE powder etc. The advantages of EB processing are well understood viz. a) desired chemical changes are induced at room temperature, b) processed material remains pure as no additional chemical catalysts, initiators etc, are required - hence environment friendly, c) ability to process large throughputs with high dose, d) suitability to hook up to the industry's existing on-line process, e) energy efficient, f) incorporates a switch ON and OFF type radiation equipment (EB accelerator) - hence more safe. To facilitate studies in material processing, an industrial-friendly 2MeV/20kW EB accelerator was installed at BARC-BRIT complex, Vashi, Navi Mumbai[1]. It started operation since 2001 (Fig1). The accelerator is housed in a shielded cell (concrete wall thickness of 1.3m) having a multi-bend labyrinth with separate entry and exit ports where power roller conveyor system has been installed for the material transport in and out of the irradiation zone during commercial scale operations. The accelerator is a single cavity RF pulse type with electron beam extracted in air through a thin titanium foil. The beam is made to scan over an area of 100cm x 10cm which constitutes the irradiation zone. The accelerator comprises of main systems like high voltage pulse power, RF power source, beam scanning, high vacuum and process controls. Our main objectives have been to identify the commercially viable applications suitable for Indian industry, to understand the applied radiation chemistry aspects involved in the process and to collaborate with the related industry to optimize and standardize beam and process parameters. While some of the developed technologies have been demonstrated on industrial

Fig.1: A view of the irradiation cell (top: RF Cavity; bottom: irradiation area with conveyor)

scale for the industry to adapt the technology, the facility is also rendering commercial services on batch scale to the industry.

Features of the EB accelerator

Pulse Electron Beam Energy : 2 MeV; *Current* : 10mA; *Pulse width* :~ 500µS; *Pulse Repetition Frequency* : 50 Hz; *RF frequency*: 120MHz; *Irradiation area*: 100cm x 10cm in air; *Dose at centre:* ~33kGy/s; *Irradiation gadgets*: SS mesh conveyor, power roller system, wire and cable handling, Sheet handling, product trays, waste water treatment system, water-cooled target

Development of Industrial Applications[2-4]

A number of applications have been developed using the accelerator of which some are mentioned below.

1. EB cross-linking of polyethylene 'O' rings: Process optimization studies have been carried out for EB induced cross-linking of polyethylene 'O' rings to impart high temperature (200^{0}C) dimensional stability. The physicochemical characteristics of the finished product have been studied using techniques like DSC, sol-gel, melt-flow index and thermo-mechanical analysis. In order to uniformly cross-link these 'O' rings (2 mm wall thickness, 50mm and 15 mm inner dia.) on a commercial scale, a special conveyor system has been designed which can meet the desired dose uniformity and throughput. Initially a multi-spindle under beam geometry was designed and used to irradiate around 100,000 rings per day on a commercial scale at the accelerator facility. Currently the rings are being irradiated in flat bed geometry (as shown in fig2.).

Fig.2: PE O rings being irradiated

Fig. 3: Viscose pulp sheets under the beam

These O-rings are used as high temperature gaskets in drum closures. Similarly, automobile bushes made up of HDPE (used in silencer vents) are also cross-linked partially on the threaded portion, to withstand the temperature up to 200^{0}C.

2. De*gradation of Polytetraflouroethylene (PTFE):* EB irradiation technique has been used to reduce the molecular weight of PTFE (teflon) scrap under

room temperature without adding any chemical additives. Process parameters have been optimized to ensure uniform reduction in the molecular weight of the product on a pilot-plant scale. Microfine powder $<10\mu m$ has been obtained from the electron beam irradiated scrap using normal conventional grinding technique to use as industrial lubricants and coatings. The product has been tested by the user industries and meets their requirements.

3. Special grade paper pulp for viscose rayon industry: EB treatment has been utilized to bring down the degree of polymerization (DP) of paper pulp (fig.3). The treated pulp is used during the viscose-rayon process and studied for the reduction in the requirement of reagents such as NaOH and CS_2 in comparison with unirradiated paper pulp. It has been observed that up to 40% reduction in the quantity of CS_2, NaOH/H_2SO_4 can be achieved by using the irradiated pulp instead of conventionally aged pulp. The feasibility of using EB process on a pilot-plant scale has been demonstrated in collaboration with Indian rayon industry. Reduction of the CS_2 concentration leads to much less pollution of atmosphere as the emission levels of H_2S are significantly reduced.

4. *Development of EB cross-linkable formulations for wire and cables:* Work has been carried out in cross-linking the cable insulations using electron beam processing. The process resulted in a product that offers many advantages over chemically cross-linked cables *viz.* increased operating temperature of 120°C, less loading of chemical additives, much lesser insulation thickness, high throughput and energy savings (as cross-linking is done at room temperature). In collaboration with Indian industry EPR/EPDM based formulations that can be cross-linked using EB radiation have been developed to meet the specifications as demanded by Indian Railways for wire insulation and sheathing materials to be used in high power diesel locomotives. An 'eight type' irradiation gadget (fig.4) has been designed to impart uniform dose through out the radial portion of the cable insulation. About 1000m cables were irradiated at the facility for M/s. NICCO cables Kolkatta. The irradiated cables met all the requirements of the Indian Railways. Subsequently, Indian cable industry adapted EB technology and five accelerators have been set up exclusively for this purpose by different cable manufacturers. Thus cross-linking of wire and cables by electron beam accelerators has become the most important commercial application in India during the last six years. Further, in collaboration with the polymer R&D institutions, special polymer blends based on EPDM, NBR, HNBR, PE, PP, Nylon have been developed targeting quality industrial products such as O-rings, automobile parts, wire and cable insulations etc. which have high temperature stability, improved aging characteristics, solvent resistance etc.

Fig. 4: Irradiation set up used for cable treatment

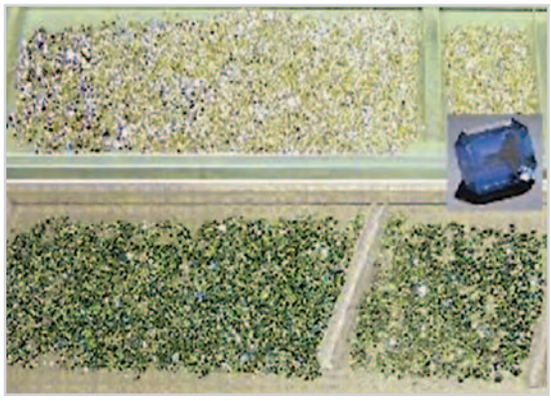

Fig.5: Unirradiated diamonds(Top); Colored Diamonds (Bottom) by EB irradiation

5. *EB processing of Automobile tyre components:* 2 MeV electron beam has been utilized to increase the green strength of various rubber components

(pre-curing using EB at room temperature) used in making automobile tyre. The required mechanism, optimization of process in terms of exposure parameters have been evaluated in collaboration with Indian Rubber Manufacturer's Association (IRMRA) and an Indian tyre industry. The final results encouraged us to manufacture an end-product viz. automobile tyre, using EB processed rubber components. The properties were evaluated directly on the end product. It was observed that pre-curing of tyre components such as chords, inner liner is definitely advantageous in improving overall green strength, temperature stability, aging properties, abrasion resistance and in reducing curing time (about 17%). With the encouraging results obtained, several tyres were made using EB processed rubber components as part of demonstration technology to the Indian rubber industry. The demonstration was very fruitful as one tyre industry has set up the accelerator in India recently.

6. *Colour enhancement of precious stones*: Western part of India is an important hub for trade in cut and polished diamonds. EB irradiation of diamonds leads to specific colour centres there by changing/ enhancing the colouration. Spectroscopic and EB irradiation studies were carried to enhance the colour of low valued cut and polished diamonds in order to bring value addition (fig.5). For precious stones like diamonds and topaz, the accelerator process parameters such as the beam energy, current, exposure time, dose, irradiation conditions have been standardized. The diamond irradiation services have been successfully extended on commercial basis for several years using 2 MeV accelerator. Other accelerator facilities set up by the Indian private industry also are rendering these services on commercial basis.

Microbiology and EB Dosimetry

Studies are underway for EB hygienization of sewage waste water to evaluate its reusability for agriculture purpose. A semi-pilot scale plant has been designed, fabricated and used for the purpose of treating waste water at a throughput of 250L/hr. EB dosimetry and calibration of thin radiachromic/ CTA films using graphite calorimetry and current density measurements are standardised as part of developing reliable dose and dose assurance programme.

Conclusions

BARC introduced EB processing technology to the Indian industry and helping them to adapt and realize its potential benefits. It is estimated that the technology has so far contributed more than Rs800crores worth products in India in the last five years.

Acknowledgements

Our sincere gratitudes to all RTDD colleagues and collaborators for their useful contributions.

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Antibiotics and Antioxidants: Friends or Foes During Therapy?

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Abstract

Different types of biochemical and physiological factors (including commonly used cellular and dietary antioxidants) affect the activity of therapeutic antibiotics. The findings from our lab have shown that the presence of glutathione, N-acetylcysteine or ascorbic acid in the growth medium decreases the bacterial susceptibility towards fluoroquinolone and aminoglycoside antibiotics. However the mechanism behind the antioxidant mediated protection against these two groups of antibiotics could be different. In addition, presence of glutathione increased antibacterial activity of β-lactam antibiotics showing that glutathione could act as a differential antibiotic susceptibility modulator for bacteria. Our data therefore demonstrate that therapeutic effectiveness of antibiotic treatment could be modulated by the dietary intake and cellular level of these antioxidants.

Introduction

Antibiotics are natural or synthetic compounds with selective bactericidal or bacteriostatic effects that eliminate pathogens or slow their growth such that host defense mechanisms can clear the infection. The mechanisms of antibiotics actions are well studied, particularly in relation to their targets interactions. Majority of the commonly used antibiotics fall into following groups: DNA damage-causing agents, inhibitors of protein synthesis, inhibitors of cell wall biosynthesis and metabolic inhibitors. Antibiotics are weapons of choice in fight against infectious bacterial diseases, however, their overuse and misuse has contributed significantly to the growing problem of antibiotic resistance and emergence of superbugs such as Methicillin Resistant *Staphylococcus aureus* (MRSA) and New Delhi Metallo-beta-lactamase-1 (NDM-1) isolates. Therefore knowledge about molecular mechanism of antibiotic action, related bacterial response and factors modulating antibiotic activity could be of used for development of improved antibacterial substances and therapeutic regimen, which could help us in keeping pace with remarkable adaptability of bacteria.

In our lab, we are studying the effect of dietary and cellular antioxidants on antibacterial effect of commonly used antibiotics. Dietary supplements such as vitamin C (Ascorbic acid) and E (α-tocopherol), having antioxidant properties, are prescribed many a times by the physicians along with antibiotics during the course of treatment of an infection. Besides antioxidants such as N-acetylcysteine (NAC) are used as auxiliary medication in certain pathological conditions along with the antibiotic therapy (NAC is used as a mucolytic agent in combination with clinically relevant antibiotics for treatment of lower respiratory tract infection). Therefore it is important to understand the effects of antioxidants on the antibacterial action of commonly used antibiotics. We are actively working to understand how different antioxidants affect the action of diverse antibiotics under *in-vitro* and *in-vivo* conditions and what are the mechanisms operating behind the observed effect. The overall aim of our studies was to understand the effect of commonly used antioxidants on antibacterial efficacy of therapeutically relevant antibiotics. It was followed up by understanding the role of reactive oxygen species (ROS) in the antibacterial action of antibiotics which displayed

reduced effectivenessin presence of the antioxidants.

We have used wild type *E. coli* K-12 strain MG1655 as the model test organisms for our study. During the course of our studies we have examined the effect of a number of antioxidants *viz.* glutathione, ascorbic acid, histidine, mannitol, sodium pyruvate and α-ketoglutarate on susceptibility of MG1655 against antibiotics such as streptomycin, chloramphenicol, tetracycline, ampicillin, penicillin and ciprofloxacin *etc.* After initial rounds of standardization 10 mM of antioxidant concentration was chosen for further studies (depending on their maximum achievable intra-cellular concentration and toxic side effects). The major findings of our studies are abridged under following sub-headings:

Glutathione and Ascorbic Acid Antagonize ROS Mediated Anti-bacterial Action of Ciprofloxacin

The effects of antioxidants on the antibiotic susceptibility of MG1655 were first analyzed by the antibiotic disk diffusion method, in which zone of inhibition around the antibiotic disk placed on the bacterial cell lawn reveals antibiotic susceptibility of the bacteria under study. Reduction in the zone of inhibition around the ciprofloxacin disks indicated that the presence of 10 mM glutathione (GSH) or ascorbic acid (ASC) in the growth medium leads to reduced ciprofloxacin susceptibility of MG1655 cells (Fig. 1). The action of antibiotics such as chloramphenicol and tetracycline was not visibly affected due to presence of these antioxidants. Other antioxidants, such as histidine, mannitol (scavengers specific for singlet oxygen and hydroxyl radicals respectively), sodium pyruvate and α-ketoglutarate did not alter MG1655 susceptibility towards any of the antibiotics (data not shown) suggesting that only nonspecific antioxidants (capable of neutralizing different types of ROS) having low redox potential could provide protection against ciprofloxacin.

Quantitative estimates of the protection offered by GSH and ASC were made by measuring minimum inhibitory concentration (MIC) of ciprofloxacin for

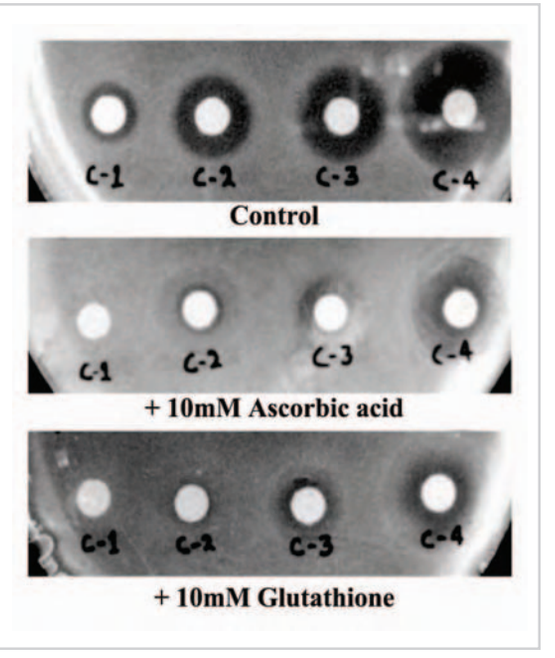

Fig. 1: Decreased susceptibility of MG1655 towards ciprofloxacin in the presence of 10 mM glutathione (GSH) or Ascorbic acid (ASC). C-1, C-2, C-3 and C-4 correspond to 40, 200, 400 and 2000 ng of ciprofloxacin spotted on the Whatman disk.

MG1655 in LB-agar in presence and absence of either antioxidant as per the clinical laborarory standard institute (CLSI) guidelines and our results showed that the protective effect against ciprofloxacin is more pronounced with GSH than for ASC. The MIC of ciprofloxacin increased 3 fold in the presence of ASC and >10 fold in the presence of GSH as compared to the control (Table 1). Ciprofloxacin is a representative member of fluoroquinolone group of antibiotics, which act by inhibiting DNA topoisomerase II and DNA topoisomerase IV activities. It was further found that GSH gives protection against other fluoroquinolones as well such as ofloxacin, norfloxacin and gatifloxacin (please see table 1 and reference 3 for details).

Antioxidant mediated protection against ciprofloxacin could be through scavenging of ROS generated in the presence of antibiotic. Consequently effect of mutations in oxidative stress defense genes *viz.* superoxide dismutases (*sodA, sodB* & *sodC*), catalases (*katE* & *katG*) and alkyl hydro peroxide reductase (*ahpCF*) on ciprofloxacin

Table 1: Susceptibility of MG1655 towards different antibiotics in the presence and absence of 10 mM GSH or ASC.

Antibiotic	MIC in μg/ml		
	Control	+ GSH	ASC
Ciprofloxacin	0.03	> 0.3	0.09
Ofloxacin	0.05	> 1.0	N.D.
Streptomycin	8	> 250	20
Kanamycin	6	> 250	> 10
Gentamycin	2	> 200	N.D.
Spectinomycin	20	> 300	N.D.
Tetracycline	4	4	4
Chloramphenicol	8	4	8
Ampicillin	8	4	8
Penicillin	64	48	64

susceptibility of MG1655 was studied. These genes encode enzymatic defense system against ROS, regulating their intracellular steady-state level. Besides effect of multi-copy *sod* genes on ciprofloxacin susceptibility of MG1655 was also examined. Among different single and multiple mutants of *katE, katG* & *ahpCF* studied, *katG ahpCF* double mutant (JI374) and the *katE katG ahpCF* triple mutant (JI377) strains having severely compromised H_2O_2 scavenging functions (7) exhibited significantly increased ciprofloxacin susceptibility in comparison to MG1655 (Fig. 2). Similarly *E. coli* cells carrying *sodC* mutation also

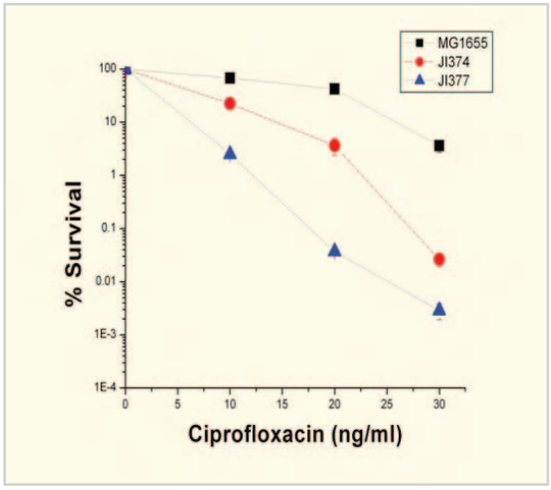

Fig. 2: Graph showing increased ciprofloxacin susceptibility in *katG ahpCF* double mutant (JI374) and the *katE katG ahpCF* triple mutant (JI377) strains in comparison to the wild type parent strain MG1655.

exhibited slightly increased ciprofloxacin susceptibility (3). Furthermore *E. coli* cells having any of the multi-copy *sod* genes showed better survival in comparison to wild type parent strain at low ciprofloxacin concentration (3). Our genetic data therefore suggested that the antibacterial action of ciprofloxacin involves ROS, such as superoxide anions and hydrogen peroxide and antioxidant mediated protection against ciprofloxacin could be due to scavenging of ROS.

No Role of ROS Scavenging in Antioxidant Mediated Reduced Bacterial Streptomycin Susceptibility

Like in case of ciprofloxacin, GSH and ASC were found to protect *E. coli* cells against streptomycin as well. Streptomycin belongs to aminoglycoside group of antibiotics, which act by interfering with bacterial protein synthesis machinery. GSH was found more effective as compared to ASC, since MIC of streptomycin increased by 2.5 fold in the presence of ASC and more than 30 fold in presence of GSH as compared to the control (Table 1). Both GSH and ASC were found to inhibit the antibacterial action of other aminoglycosides (such as kanamycin, gentamycin and spectinomycin, please see table #1 for details). During the course of our studies we also investigated whether this antioxidant-mediated protection against streptomycin is specific to MG1655 or it can be seen across diverse *E. coli* strains such as W3110, Xl-1 blue and DH5á. Our results showed that GSH and ASC were effective against streptomycin in the above mentioned strains as well. It implies that, irrespective of the genetic background, GSH and ASC interfere with a step that is crucial for antibacterial action of streptomycin in *E. coli*.

Our genetic data suggested that unlike ciprofloxacin, mitigated streptomycin susceptibility of *E. coli* cells is not due to antioxidant mediated scavenging of ROS. None of the single and multiple mutants of *katE, katG* and *ahpCF* exhibited increased streptomycin susceptibility. Similarly mutated or multi-copy *sod* genes also failed to alter the bacterial

streptomycin susceptibility levels. Our genetic data was further corroborated by the NBT reduction values which demonstrated that streptomycin treatment does not lead to induction of oxidative stress in *E. coli*, whereas ciprofloxacin indeed increases the ROS levels in bacterial cells (4). It implies that the mechanism by which antioxidant mediated protection is brought about against these two classes of antibiotics is not same. Our data therefore also emphasized that other than ROS scavenging process, additional and alternate mechanisms operate behind antioxidant-mediated protection against various antibiotics.

Glutathione can act as bacterial antibiotic susceptibility modulator

An important observation made during the course of our study was that GSH not only reduces the antibacterial action of above mentioned antibiotics but it also augments the efficacy of β-lactams such as penicillin and ampicillin (1, 5), since *E. coli* cells were found to be more susceptible towards them in presence of GSH (Table 1). However, we found that this effect was specific to GSH, as the presence of ASC did not make any difference to the antibiotic susceptibility of MG1655. Therefore our studies demonstrate that GSH can act as an important modulator of antibiotic susceptibility for bacteria (Fig. 3).

Effect of Glutathione Precursors on Bacterial Antibiotic Susceptibility

GSH is a naturally occurring tri-peptide (glutamic acid-cysteine-glycine) and its biosynthesis is limited by the amino acid l-cysteine. N-acetylcysteine (NAC) is acetylated derivative of the amino acid cysteine. It is used as an important antioxidant and precursor of GSH in higher organisms. Since we have demonstrated that GSH is an important antibiotic susceptibility modulator, therefore it is of interest to study the effect of GSH precursors on antibiotic susceptibility of bacteria. Consequently the effect of cysteine and NAC supplementation on bacterial antibiotic susceptibility was determined. Like GSH, both cysteine and NAC exhibited protection against antibacterial action of fluoroquinolones and aminoglycosides (please see reference 2 for details). The extent of protection was found to be higher with NAC in comparison to cysteine. Apart from *E. coli*, NAC had profound effect on other bacteria such as *Klebsiella aerogens, Klebsiella pneumoniae,* and *Pseudomonas aeruginosa* in terms of their survival and antibiotic susceptibility modulation. Besides, NAC also augmented the action of β-lactam antibiotics. Our studies therefore suggest that administration of aerosolized NAC as a mucolytic agent during the course of antibiotic therapy for respiratory tract infection could modulate the outcome of therapeutic process depending on the target bacterial pathogen and antibiotic being used for the therapy. Taken together our data further indicates that GSH and its precursors in general act as crucial determinant of antibiotic activity against bacterial species.

Concluding Remarks

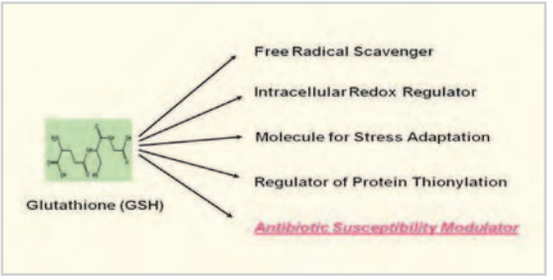

Fig. 3: Biochemical functions associated with glutathione inside bacterial cells (according to Masip *et al.*, 2006). The function indicated in red color is assigned by us on the basis of results from our lab (1,5).

On the basis of our studies it can be concluded that antibacterial action of therapeutically relevant antibiotics could be either diminished or augmented by the presence of antioxidants like GSH, NAC and ASC. Our study adds to the knowledge that apart from existence of other antibiotic activity modulation factors, dietary and cellular antioxidants also play a critical role in determination of bacterial antibiotic susceptibility. Although detailed mechanism(s) of antioxidant mediated modulation of antibiotic activity are yet to be fully understood, these findings

are of immense value. Dietary supplements such as vitamin C (ASC), cystiene rich foodstuffs and auxiliary medication like NAC, which have antioxidant properties, are prescribed sometimes along with antibiotics during the course of treatment of an infection. The therapeutic effectiveness of antibiotic mediated treatment under such conditions might be altered due to increased dietary intake and cellular levels of these antioxidants. Hence, further investigations surrounding the intake of antioxidants on antibacterial effect of different antibiotics for treatment of various infections are warranted in future. Currently, we are working in this direction to understand the real time effects of antioxidant supplementation on antibiotic mediated clearance of bacterial infection in an animal model of study.

Acknowledgements

We are grateful to different people in scientific community who have provided strains and plasmids related to this study. We also thank Dr S. K. Apte, Associate Director (B), BMG and Head MBD for his constant encouragement and support during the course of this work.

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Planning Your Investments: report of a seminar

The Women's Cell BARC organized a half-day seminar on the topic "Planning Your Investments" on September 15, 2011 at the Central Complex Auditorium, BARC in co-ordination with HDFC Bank Ltd., Chembur Branch. The aim was to bring in awareness, especially among the female employees, on the importance of financial planning and the options available to them. The inaugural session began with a welcome address by Dr. Sunita Singh, Convenor, Women's Cell where she highlighted the relevance of the topic and introduced the two speakers Ms. Shyamali Basu and Shri C. Kshemender. Shri N.D. Sharma, Controller, BARC presided over this session.

The first invited speaker was Ms. Shyamali Basu the Vice-President and Business Head (Mumbai Retail) at the HDFC Asset Management Company. Her talk on "Need for investment and asset allocation- View on the current market scenario" dealt with investing in equities. She demonstrated the power of equities by citing real-life examples. Explaining the basic tenets of equity investment, she pointed out that in the long run, equities generate better returns as compared to other asset classes. She concluded her talk with the advice that diversification across stocks, sectors, markets, asset classes, time periods and index levels was the best way to play safe when investing in equities.

The second speaker for the seminar was Shri C. Kschemender, the Zonal Head – Mumbai, HDFC Life with about 12 years of experience in the banking and insurance industry. The road map of his talk included the need for financial planning, and the impacting factors, with special focus on insurance as a key tool in financial planning. He explained that the two grossly classified tools in the financial planning are the Debt market and the Equity market. The former is considered as a considerably safe investment with medium volatility and moderate liquidity. On the other hand, the equity market is considered as a high liquidity, risky investment tool as the returns are highly dependent on the profit-making capabilities of the company. He too stressed on the need for diversification across both Debt and Equity. He too stressed the need for diversification across both Debt and Equity. He explained the power of Insurance, citing the various options available such as Children's Plan, Pension Plan and Savings Plan, in safeguarding the future. He also highlighted the various aspects of the Unit linked plans which have the advantage of both insurance and investments.

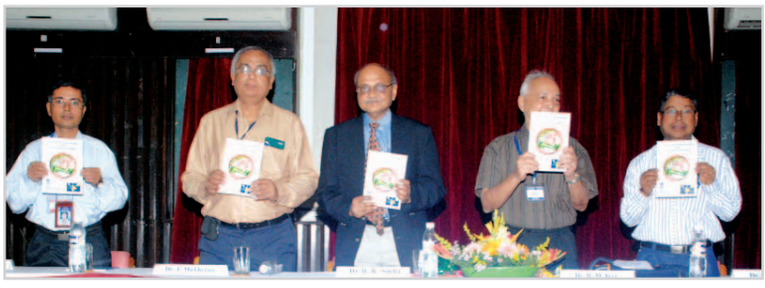
Both the talks were well-received by the audience as was evident from the questions and discussions that followed. The programme concluded with a formal Vote of Thanks by Dr. B.K. Sapra, Member, Women's Cell, BARC.

The guests with the members of Women's Cell, BARC.

DAE-BRNS Theme Meeting on Emerging Trends in Application of Lasers and Accelerators in Nanomaterials (ETALAN-2011): a report

In the International Year of Chemistry, the Radiation & Photochemistry Division, BARC in collaboration with the Indian Society for Radiation & Photochemical Sciences (ISRAPS) organized a DAE-BRNS theme meeting on Emerging Trends in Application of Lasers and Accelerators in Nanomaterials (ETALAN-2011) at Training School Hostel, BARC during October 20-21, 2011. The purpose of this meet was to identify challenges and opportunities in cross-cutting areas of nanoscience and nanotechnology with the growing role of lasers and accelerators.

The meeting was inaugurated by Dr. R. K. Sinha, Director, BARC. He spoke about the role of nanoscience in various areas of nuclear energy programme and released a book of abstracts. Dr. T. Mukherjee, Director, Chemistry Group and Chairman ETALAN welcomed the delegates. Dr. S. K. Sarkar, Head, Radiation & Photochemistry Division and Convener ETALAN spoke about the genesis and objective of the meet. Dr. R. M. Iyer, Former Director, Chemistry & Isotope Group released a commemorative publication volume during 25 years of operation of the LINAC-based Pulse Radiolysis Facility at RPCD and of the various stages of evolution of this facility. Dr. M. C. Rath, Secretary, ETALAN proposed the vote of thanks.



Releasing of the bound volume commemorating the Silver Jubilee of 7MeV electron LINAC-based pulse radiolysis facility. From left to right: Dr. M. C. Rath, Dr. T. Mukherjee, Director, Chemistry Group, Dr. R. K. Sinha, Director, BARC, Dr. R. M. Iyer, Former Director, C&I Group, Dr. S. K. Sarkar, Head, RPCD

About 150 scientists participated from universities and national laboratories around the country. In this meeting current status and new opportunities were discussed with sixteen invited talks in seven sessions a poster session for contributed papers presented young researchers in the following areas:

- Synthesis & characteriztion of nanomaterials using lasers and accelerators
- Modification of properties of nanomaterials using lasers and accelerators
- Fast & ultrafast spectroscopy on and with nanomaterials using lasers and accelerators
- Use of nanomaterials in lasers and accelerator devices.

Nanoscale synthesis and characterization methods were presented to understand and design materials and interfaces with properties like radiation, temperature, and corrosion resistance. The dual advances of temporal and spatial resolution promised by fourth-generation light sources based on lasers and accelerators provided femtosecond as well as nanometer scale understanding of various physical and chemical phenomena. Discussion on specific applications, especially in the nuclear energy programme, was carried out in the round up session.

A special session was conducted with talks by Dr. T. Mukherjee and Dr. S. K. Sarkar to celebrate the Silver Jubilee of the 7 MeV electron LINAC based Pulse Radiolysis Facility. This is one of the oldest accelerator based facility in BARC and the main work-horse for Radiation Chemistry Research in the centre and also a large in number of institutions / universities in the country.

Vigilance Awareness Week at BARC

As per the Directives of the Central Vigilance Commission, Vigilance Awareness Week was observed in BARC from 31st October to 4th November 2011. In addition to taking of the Vigilance Pledge, the following programmes were also organized as a part of observance of Vigilance Awareness Week:

1. Poster competition on 31st October, 2011
2. Debate on "Role of citizens in controlling corruption" held on 1st Nov. 2011
3. One Act Play on vigilance staged on 2nd Nov. 2011
4) Quiz competition conducted on 3rd Nov. 2011.

On the concluding day, on 4th November 2011, a panel discussion on the topic entitled "Ethics in Scientific/Research institutions" was organized at the Central Complex Auditorium, BARC, Trombay, during which the following Dignitaries were invited:

a) Shri K.B. Sainis, Director, BMG
b) Shri N.D. Sharma, Controller, BARC.
c) Dr. B.N. Jagatap, Head, AMPD
d) Shri A. Ramaiah, IFA, BARC
e) Dr.K.R.S. Chandrakumar, SO/E, TCS
f) Shri A. Shreedharan, Secretary, AEW&SU

Proceedings of the Panel Discussion was conducted by Shri Goverdhan Rao, HPD, BARC.

A week long Vigilance Awareness week was thus concluded with a special address to the gathering by Director, BARC, followed by distribution of prizes to the winners of the above contest.

The Vigilance Awareness Week programme was well received by the employees and participants and generated deep interest amongst all strata of employees, aimed at inculcating probity and transparency in public life.

14th ISMAS Symposium-Cum-Workshop on Mass Spectrometry (14th ISMAS-WS 2011) : Highlights

The Indian Society for Mass Spectrometry (ISMAS) with its headquarters at the Fuel Chemistry Division, BARC organized the 14th ISMAS Symposium-cum-Workshop on Mass Spectrometry (14th ISMAS-WS 2011) at Munnar during November 7-11, 2011. This event was also a part of the celebration of 2011 as the International Year of Chemistry, as declared by IUPAC.

Prof. S.K. Aggarwal, President ISMAS and Chairman, Organizing Committee of 14th ISMAS-WS 2011, inaugurated the Symposium-cum-Workshop and also gave the welcome address. Shri P.G. Jaison, Treasurer, ISMAS and Convener, Organizing Committee, highlighted the scope of 14th ISMAS-WS 2011. Dr. Arnab Sarkar, Secretary, Organizing Committee, proposed a vote of thanks. A bound volume of the 14th ISMAS-WS 2011 and a special ISMAS Souvenir- cum-Bulletin were on the occasion and were distributed to all the delegates.

There were about 110 delegates including 13 overseas speakers who participated in the 14th ISMAS-WS 2011. The event provided a forum for researchers to share their rich experience in the field of mass spectrometry with other practitioners. The scientific programme was covered in 13 technical sessions spread over 5 days. There were 25 Invited Talks by distinguished mass spectroscopists from within the country and from overseas. Invited Talks covered various applications of Mass Spectrometry for Biomedical Sciences, Hydrology, Environmental Science, Geological Science etc. There were 38 Contributed Papers presented as posters in the two Poster Sessions on November 8, 2011 and November 10, 2011. There were two Tutorial Lectures on Secondary Ion Mass Spectrometry (SIMS) by Prof. David McPhail, Imperial College, UK and by Dr. Philip Sailot, Cameca, France, covering the basic principles, advances in instrumentation and typical applications of the technique. There were 8 oral presentations made by the instrument manufacturers to update the participants on the latest developments in Mass Spectrometry Instrumentation.

Prof. S.K. Aggarwal, President, ISMAS and Chairman of the Organizing Committee, delivering the welcom e address during the Opening Ceremony of 14th ISMAS-WS 2011.
On the dais from left to right: Dr. Arnab Sarkar, Secretary, Organizing Committee and Shri P.G. Jaison, Treasurer, ISMAS and Convener, Organizing Committee.

Speakers from overseas included Prof. Stephen Blanksby (Australia), Dr. R. Javahery (Canada), Dr. Philip Saliot (France), Prof. R. Hergenroder & Dr. Andreas Hilkert (Germany), Dr. David Alonso (Spain), Prof. Jentaie Shiea (Taiwan), Prof. D.E. Sykes, Prof. David McPhail, Dr. John Cantle, Dr. Kevin Boyce, Dr. Nick Roberts and Dr. Zenon Palacz (UK).

Speakers from India included Dr. M.V. Jagannadham (CCMB, Hyderabad), Dr. M. Kameswara Rao (DRDE, Gwalior), Dr. S. Sengupta (IGIB, Delhi), Dr. A.S. Sarpal (IOCL, Faridabad), Dr. Dipankar Ghosh (JNU, Delhi), Prof. D. Schwudke (NCBS, Bengaluru), Dr. V. Balaram (NGRI, Hyderabad), Prof. A.K. Chakarborti (NIPER, Mohali), Dr. R.D. Deshpande, Prof. R. Ramesh & Dr. Sunil K. Singh (PRL, Ahmedabad), Prof. A. Chakrabarti (SINP, Kolkata) and Dr. T. Prashanth (SJRI, Bengaluru).

One of the important aspects of 14th ISMAS-WS 2011 was the oral presentations made by Research Scholars pursuing their Ph.Ds. at different Institutes in the country. In addition, there was a special session on Industrial Applications of Mass Spectrometry highlighting the key role played by mass spectrometry in various projects going on at Heavy Water Board (HWB), India.

14th ISMAS-WS 2011 concluded with a Valedictory Function on November 11, 2011. Awards were distributed to the winners of the best Research Scholar Presentation and the Contributed Paper Presentations.

Fourth Supervisory Training Programme on Spent Fuel Reprocessing : a report

The supervisory training programme on "Spent Fuel Reprocessing" was conducted at BARC, Trombay during March 21st, 2011 to April 1st, 2011 on various subjects related to nuclear fuel, spent nuclear fuel and its reprocessing. The supervisory training programme on "Spent Fuel Reprocessing" was designed and formulated mainly for the supervisors who are working in reprocessing plants and either have not received any formal training or had received training about 10-12 years ago. In addition, this programme was also designed for those supervisors who are associated or are working in fuel fabrication, reactor operation, and waste management plants etc.

During the inaugural programme, on 21st March 2011, Shri P. N. Patil welcomed the gathering. Shri R.G. Yeotikar, Officer-in-Charge, Training and organizer of this programme, introduced the syllabus of the programme and explained the importance of the selected subjects. Shri P.M. Gandhi, Chief Superintendent, RF, PP; Shri P. Janardan, Head, Fuel Reprocessing Division; Shri K. N. S. Nair, Head, Technology Development Division; Shri Kanwar Raj, Head, Waste Management Division and Shri S. D. Misra, Director, Nuclear Recycle Group addressed the trainees and emphasized importance of training and its usefulness in updating knowledge in various aspects of spent fuel reprocessing. They have also emphasized the importance of spent fuel reprocessing and concept of closed nuclear fuel cycle in the development of sustained power supply to the country's economy. Shri Kanwar Raj indicated that, we should take all the steps in all walks of life for reduction of generation of radioactive waste in all the plants of Nuclear Fuel Cycle, laboratories, etc. Vote of thanks was given by Shri Prahlad Patange.

Shri R.G. Yeotikar, Officer-in-Charge, Training, Nuclear Recycle Group, briefing about the course and the subjects of the Fourth Supervisory Training Programme on Spent Fuel Reprocessing, during inauguration on 21st March 2011. Others on the dais (from left to right) are Shri K.N. S. Nair, Head, TDD; Shri S. D. Misra, Director, NRG; Shri P. Janardan, Head, FRD and Shri Kanwar Raj, Head, WMD. The training programme was conducted during 21st March 2011 to 1st April 2011.

After inauguration, Shri P. Janardan, Head, Fuel Reprocessing Division, presented an invited talk on the subject "Basic philosophy for spent fuel reprocessing and future perspective".

The training programme was designed and organized by Shri R. G. Yeotikar, Officer-in-Charge, Training, NRG and conducted and coordinated by Shri P. N. Patil, Shri Ved Ram Shakya and Shri P. Patange. Total 50 participants attended this supervisory training programme.

Eighth Supervisory Training Programme on Radioactive Waste Management : a report

The supervisory training programme on Radioactive Waste Management is designed and formulated for the supervisors who are associated in waste generation in various plants/facilities/research labs and engaged in waste management and either have not received any informal training or have received training about 10-12 years ago. In the past, four numbers of these training programmes were conducted at BARC, Tarapur. The fifth Supervisory Training Programmes was conducted at Centralized Waste Management Facility (CWMF), Kalpakkam in 2007 and sixth & seventh at BARC, Trombay, in 2008 and 2009 respectively. In continuation to this series "Eighth Supervisory Training Programme on Radioactive Waste Management" was conducted at BARC, Trombay during 28th Feb. to 11th March, 2011. This training programme covered various aspects of Radioactive Waste Management, radiation protection and industrial & fire safety.

Total 58 participants attended this supervisory training programme. Majority of them were belonging to waste management plants/facilities/ projects from Trombay, Tarapur and Kalpakkam. Few supervisors from reprocessing plants such as PP Trombay, KARP Kalpakkam and PREFRE Tarapur and from reprocessing projects also attended the course. Apart from these, the supervisors from other Divisions of BARC, Trombay, who are radioactive waste generators such as ROD, RCD, AFD, RMD,FCD, UED, etc also attended this course. As per request, few participants from AERB and Indian Navy also attended this training program.

During the inaugural programme, on 28th February 2011, Shri P. N. Patil welcomed the gathering. Shri R.G. Yeotikar, Officer-in-Charge, Training and organizer of this programme, introduced the syllabus of the programme and explained the importance of the selected subjects. Shri D.S. Rana, Head, ED&CD, Shri P. Janardan, Head, FRD, Shri K.N.S. Nair, Head, TDD and Shri Kanwar Raj, Head, Waste Management Division, addressed the trainees and emphasized importance of training and its usefulness in updating knowledge in various aspects of radioactive waste management. Shri Kanwar Raj indicated that we should consider waste as source of wealth since many useful isotopes are present in it and make all efforts to minimize the volume of waste. Vote of thanks was given by Shri P. N. Patil.

Shri Kanwar Raj, in his invited talk, presented the philosophy of radioactive waste management. He explained the waste management practices followed in India with emphasis on safety and reduction of the impact on environment and on the future generation.

The training programme was carried out by way of classroom lectures, demonstrations and visits to various plant / facilities at Trombay such as Plutonium Plant, Waste Immobilization Plant, RSMS, ETP and Dhruva reactor. The training programme was designed, organized and conducted by Shri R. G. Yeotikar, Officer in Charge, Training, NRG and coordinated by Shri P. N. Patil.

The Valedictory Function of this training programme was held on 11th March 2011 and was presided over by Shri Surender Kumar, Head, TSS, WMD. The other guests of honour were Shri P. Janardan, Head, FRD; Shri P. M. Gandhi, CS, RF, PP and Dr. V. Arumugam, Head, RPS, TDD.

Promotion of Science and Technology by BARC: an MOU with the Government of Goa

BARC has entered into collaboration with the State of Goa, for contributing to the overall development of the State specifically based on promotion of science and technology. State of Goa is the first in the country to have entered into Memorandum of Understanding (MoU) with BARC.

Dr R K Sinha, Director, Bhabha Atomic Research Centre (BARC) and Shri Sanjay Srivastava, Chief Secretary, Government of Goa (GoG) signed a MoU for collaboration towards promotion of science and technology based development in Goa on 29th December 2011, at Porvorim, Goa.

BARC has developed expert knowledge base in various scientific fields and also has experience in translating this knowledge base for societal benefit. Programs like BARC Centre for Incubation of Technologies (BARCIT) and Advanced Knowledge for Rural Technology Implementation (AKRUTI) for large scale deployment of spin off technologies have been successfully implemented by BARC scientists and engineers. Some of the technology areas identified for collaboration with the GoG, among others, are as follows-

(i) Networking between Research Centres / Universities / Government Agencies to form Technology Synergiser
(ii) Advanced interactive classrooms for science colleges, engineering colleges and schools
(iii) National Knowledge Network (NKN) connected advanced state-of-the art R&D facilities for sharing
(iv) Processing and preservation of marine and agro products
(v) Management of bio-degradable waste and production and use of energy as well as manure; and
(vi) Clean and safe drinking water technologies.

This collaboration is expected to not only help tackle basic problems like waste management/clean drinking water in the urban living but also help spread scientific awareness amongst the students and society at large.

Dr R K Sinha, Director, BARC (second from left) and Shri Sanjay Srivastava, Chief Secretary, GoG (fourth from left) exchanged documents after signing MoU on 'Collaboration for Promotion of Science and Technology in Goa' at Porvorim, Goa on 29th Dec. 2011. Also seen are Dr Anil Kakodkar, Former Chairman, AEC and Homi Bhabha Chair Professor (third from left), Shri T. M. Balakrishna, Secretary to Chief Minister, GoG (fifth from left) and Shri .V P. Rao, Education Secretary, GoG (first from left).

National Conference on Machine Vision & Image Processing NCMVIP2011: a report

A National Conference on Machine Vision (MV) and Image Processing (IP) was held at the College of Engineering Pune (COEP), Pune from 7-9 Dec. 2011. It was jointly organized by the Electronics & Instrumentation Services Division, BARC and COEP. It was sponsored by BRNS, IEEE Pune Section and IET Mumbai network.

During the inaugural function, Dr. A. D. Sahasrabudhe, Director, COEP gave a welcome speech. Dr. S. Kar EISD, BARC, Co-convener of the conference gave a brief overview of the conference. Mr. R. K. Patil, Associate Director (C), E&IG, BARC, delivered the inaugural address, explaining the impact of the latest developments in the field of MV & IP on industry and the research efforts in BARC in this area. In his talk, Mr. Patil mentioned about the in-house developments in BARC on Vision for robot guided operations, Graphics and Visualization, Tele-robotics : obstacle detection and ranging, Biometrics, Dosimetry, Automated inspection and Radiographic & tomographic imaging techniques. He observed that applications built employing MV & IP tools have huge potential for use in DAE programme as well as in industry. Mr. V. M. Joshi, Head, EISD, BARC, presented the theme of the conference. The key note speaker was Dr. Sankar Pal, Former Director, ISI, Kolkata. Dr. Mrs. M. A. Joshi, Dean R&D, COEP and Convener of the conference proposed the vote of thanks.

Every session was initiated with an invited speech by an expert in the field, followed by a set of contributory papers. In all 42 papers contributed by different researchers were presented in these sessions. One important issue raised during the conference was an open discussion on "How to Apply for Various Grants" for research activities. The significant role played by BRNS in providing funding for research activities at academic institutes was brought out and consequently several fruitful collaborative projects are expected to take shape in the near future. Exhibition of products in machine vision field put up by a number of industrial organizations, was arranged in along with the event.

(From left to right) Dr. S. Kar, Mr. V.M.Joshi, Dr. Sankar Pal, Mr. R. K. Patil, Dr. A.D.Sahasrabudhe and Dr. M.A. Joshi during the inaugural session of the conference

BARC Scientists Honoured

Honour for BARC

BARC received the unique honour of being the highest contribution of journal articles published by Springer & was the winner of Springer's Maximum Article Contribution Award in 2010.

Name of the Scientist	:	**Dr. R.B. Grover** **Director, Homi Bhabha National Institute (HBNI) and Principal Adviser, Department of Atomic Energy (DAE)**
Award	:	Distinguished Alumnus Award of the Indian Institute of Science (IISc.) for the year 2011.
Award Citation	:	"During a career spanning four decades, Dr. Grover has distinguished himself as an academic, research and development engineer and a science administrator. His knowledge of nuclear engineering and nuclear law has earned him the title. "Nuclear Diplomat."In presenting this award to him, the Alumni Association feels greatly honoured that one of its members has risen to the level of such distinction and achievement".

Name of the Scientists	:	**Sanjeev Sharma, Vikrant Agashe and P.K. Pal** **Division of Remote Handling and Robotics, DM&AG, BARC**
Title of the Paper	:	Use of Mobile Robots for Mapping Radiation Field around Particle Accelerators
Award	:	Best Presentation Award
Presented at	:	Safety (CARS-2011) held at BARC, Mumbai, India, during November 16-18, 2011.

Name of the Scientist	:	**Gokhale Onkar S.** **Reactor Safety Division**
Title of Poster	:	Study of Induction Heating of Fuel Bundle Simulator using COMSOL Multiphysics
Award	:	Best Poster Award - Popular Choice
Awarded at	:	2nd National COMSOL Conference 2010, 29-30 October, 2010, Bangalore.

Krishna Vad

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