INDIAN NUCLEAR SOCIETY

INS News Letter

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From Editor's Desk

At the outset I would like to thank the honourable members for extremely encouraging response to the maiden issue of INS e NL published on Technology day. I sincerely hope that they will continue to guide us with their critical and constructive feed backs.

In an attempt to turn challenge of COVID 19 into an opportunity, GOI has announced multiple steps to usher in its policy of Atmanirbhar Bharat. One of these steps relate to a paradigm shift in its policy to i) establish research reactor in PPP mode for the production of medical isotopes to promote welfare of humanity through affordable treatment of cancer and other diseases; ii) establish facilities in PPP mode to use irradiation technology for the food preservation to complement agricultural reforms (whereby farmers need not go through APMC markets and can sell their produce on e trading platforms nationwide) and assist farmers and iii) to link India's robust start up ecosystem to nuclear sector. Technology Development and Incubation Centres will be set up for fostering synergy between research facilities and tech entrepreneurs . These new initiatives are aimed at strengthening "Make in India" policy and gradual reduction of import of medical isotopes and promotion of export of irradiated food items. Govt announcement to support MSMEs financially may also witness new candidates evincing interest on these avenues.

INS decided to approach some competent Nuclear Scientists who had made a mark during their active service and are still active as consultants (post retirement) in private enterprises in the areas of focus under new policy. It is heartening that all of them responded promptly suggesting the road map which each of them perceive to ensure the success of the new initiative. Perspective of pvt. entrepreneurs has been articulated by Chief Editor, NuFFooDS Spectrum and Biospectrum Asia, a leading monthly which focuses on the topics in the fields of pharma and agriculture . PET Imaging is perhaps one of the most dependable modern diagnostic nuclear techniques for malignant tumours. Dr M.G.R.Rajan has been kind to share his perspective on the "Status of PET Imaging in India". Our last NL was released on Technology Day (11th May), celebrated since 1998 to applaud the team of "SHAKTI" which made every Indian proud. In this issue we bring to you a glimpse of "Buddha Smiled" as perceived by Dr Anill Kakodkar, one of the leading architects of our multidimensional Nuclear Programme.

COVID 19 has changed the lives of people across the globe. It does not appear that we will be able to return to normal (pre COVID19) days any time soon. We have to learn to live with prescribed SOPs. After waiting for almost 4 months, steps have been initiated to take over charge from old EC. INS activities in the COVID regime have to be tuned to the ground realities. Organisation of Webinars on the contemporary topics and of interest to members has to start early. I also feel that to spread the message of nuclear science and technology far and wide, we need to plan outreach programs for all sections of society. We need to identify members who can help INS in preparing quality education material in the form of short films, stories and poems (in all national languages) which can be comprehended by house wives as well as school going children. I would urge members to share their thoughts on the future activities of society on **insvkmeditor@gmail.com.** Your feed back will guide us in our endeavours to meet your aspirations and to make INS a vibrant professional body we all are proud of.

Vijay Manchanda

DAE NEWS

Unit-3 (700 Mwe) of Kakrapar Atomic Power Project achieves First Criticality

The Unit-3 of Kakrapar Atomic Power Project achieved its first criticality on July 22, 2020 at 09:36 hours. This achievement has been lauded by the Honourable Prime Minister of India, who has called it a shining example of Make in India and a trailblazer for many such future achievements. This is a historic development, as KAPP-3 is a first of a kind, indigenous 700 MWe Pressurised Heavy Water Reactor (PHWR). It is indigenously designed by Indian scientists and engineers. The components & equipment for the reactor have been manufactured by Indian industries and the construction and erection was undertaken by various Indian contractors.

The reactors are designed and constructed to the highest safety and quality standards comparable to the best in the world. The indigenous 700 MWe PHWRs have advanced safety features like steel lined inner containment, Passive Decay Heat Removal system, Containment Spray system, Hydrogen Management systems etc. The fuel loading of the reactor core was completed by mid-March 2020. Thereafter, many tests and procedures were carried out during the lockdown period following all COVID 19 guidelines.

KAPP-3 is the front runner in a series of sixteen indigenous 700 MWe PHWRs which have been accorded administrative approval and financial sanction by the Government and are at various stages of implementation.

R&D Activities by DAE w.r.t. COVID-19 pandemic

TIFR develops country's first low-cost mask testing equipment

A team of scientists led by Professors Arnab Bhattacharya and Shankar Ghosh of TIFR, along with Ronak Sutaria of air quality research group Respirer Living Sciences (RLS), built a prototype - mask integrity test resource (MITR) that measures fine particle (0.3µm) filtration through N95 masks. This was built during the lockdown using items such as a vacuum cleaner, boxes, bottles, and a plastic ball (used as a mannequin). For the project, different types of N95 and surgical masks being used by Tata Memorial Hospital in Mumbai were tested at TIFR. A major contributing factor that enhances filtration efficiency was a layer of electrically charged fibres that trap particles in N95 masks. The charge diminishes significantly when cleansed using alcohol based solutions. Researchers also developed a procedure to recharge these N95 masks. The equipment costs between Rs. 30,000-50,000, ranging from the most basic one to a slightly advanced unit while imported machines cost about Rs 10 lakh.

BARC develops Sodium Hypochlorite Electrolyser Plant (SHEP)

SHEP is able to produce onsite Sodium Hypochlorite of 0.1-1% concentration as recommended by WHO/ICMR and CDC, USA as one way to disinfect areas contaminated with novel corona virus . The Mixed Metal Oxide (MMO) coating on the anode of the Ti based electrodes is the heart of SHEP which controls the selectivity of the desired electrochemical reaction. Onsite Electrolysis Process offers many advantages such as reduced operational costs, desired concentration and volume of the product and can be conveniently deployed at hospitals and other commercial premises.

Editor

> **"Science knows no country, because knowledge belongs to humanity, and is the torch which illuminates the world."**
>
> **– Louis Pasteur**

The Making of a Nuclear Weapons State : Dr Anil Kakodkar reminisces an historic event, " Buddha Smiled"

Some times in 1972, Mr. Meckoni, our Group Director, asked me to meet BARC Director Dr Raja Ramanna. He did not say anything specific but conveyed that it was an urgent matter and asked me to meet him at the earliest. Dr Ramanna asked me to meet Dr Chidambaram, who was working in the Physics Group under Dr Iyengar. Dr Ramanna then asked me something strange. He enquired whether I had the habit of talking in my sleep. I replied that I could not possibly know that myself. He enquired whether my wife had noticed anything. I said that while she had not mentioned anything of the kind thus far, that did not mean I did not talk in my sleep , and I would ask her. …..

Dr Chidambaram briefed me about the assignment. It was the work related to nuclear device for the PNE to be carried out at Pokhran. They were looking for a mechanical engineer for the design and fabrication of the device. He provided a lot of relevant information. After meeting him, I went to meet Soni in his workshop. They had been trying various methods but not making headway. Mr. P. R. Dastidar, who was working on control systems, had suggested that I should be inducted in the work. Mr. Soni was doing his best but things had reached a stage where a Mechanical Engineer was needed. …….

I began work on the design of the device and in time, things came under control. Soon the preparation activities expanded. The Terminal Ballistic Research Laboratory (TBRL) at Chandigarh was actively involved in them from the Defence Research Development Organisation's (DRDO) side. We had to visit TBRL frequently for long durations to coordinate interfaces between the work of the two institutions. This was both at the design level as well as at the logistics level, including the planning and coordination of work at the Pokhran site. Our help was needed at many places. A lot of gadgets had to be fabricated. Team spirit was so high that individual, group or organizational boundaries and identities had all melted away. Every necessary task was performed without quibbles, whose job it was. The team had to be necessarily small given the sensitivity of the project, comprising a few highly dependable and competent personnel. That means each one of us became a one man battalion. Everything had to be done under suitable cover to maintain secrecy. For me, this was a big challenge, being accountable to multiple programs, and not letting anyone getting wind of what I was doing secretly. This was indeed a great learning experience for me……

My work required me to travel without leaving a trail. All relevant information was restricted and even Mr. Meckoni, to whom I was supposed to be reporting, did not know about my whereabouts. To his credit, he himself told me that I should not tell him anything. But others in my division at Trombay were not as charitable and were resentful. I never told anyone what I was working on to begin with and now, I would disappear for days or weeks without telling anybody. I would never travel directly to any destination. It will always be a circuitous route to avoid leaving clues or being tracked. I would usually travel under different aliases. Once, I was travelling as Prof. Rao. A DRDO Engineer was slated to meet me. As I was waiting for him, the fact that I was supposed to be Prof Rao left my mind. Someone approached me and asked, "Are you Prof. Rao? I said, no outright. Fortunately, he had probably seen me earlier and recognized me. In a hushed tone he said, 'Dr Kakodkar, I was supposed to meet you as Prof. Rao'. I remembered my alias, and we moved on.

Finally, the time came to prepare the test at site. A lot of work was required. It was not possible to fabricate everything at the workshop in Trombay and then transport all of it to the site. Some items were fabricated elsewhere, including at Jodhpur, which is the largest city close to Pokhran. We reached the site weeks in advance. The amenities were scarce. logistics was difficult. ……

One day while travelling from the base camp at Pokhran to the site, which was a long distance away, our jeep broke down. On examining the engine, we found that the fan belt was torn and needed to be replaced. Getting a new fan belt or arranging alternate transport would easily have taken three to four hours. I decided to make a rope out of the shrubs growing around us and fashioned it into a belt. That allowed us to cover the remaining distance, saving the precious day. Such were the circumstances under which the work had to be carried out – very challenging yet very enjoyable. …….

Our main job at the site was integration. A shed next to the pit was erected for this purpose. We used to work in this shed as well as in the pit making several trips up and down was a regular feature. ….

We had our share of difficulties while assembling the device. Some of the people working with us began panicking and started reciting religious hymns. We had to tell them to maintain composure and focus on their work, so that others were not distracted by their panic. One day we were late in completing the day's work and returned to the base around 11:30 P.M. Meanwhile, some one has reported to Dr Ramanna that we were delayed because we were having difficulties. We found him anxiously pacing up and down. When he saw us, he asked what has happened. I replied there had been some assembly difficulties, but everything had been solved successfully. He asked me what the difficulties were, and I replied that he would not understand. I reassured him with a colloquial phrase "Ho Jayega", meaning it will be done. I used that phrase a number of times in the conversation that day. This led to Dr. Ramanna dubbing me, 'the "Ho Jayega" man'. If Kakodkar said, "Ho Jayega", that means that it would be done. In many such moments of crisis, I have seen some people panic while others who stay calm and composed rise to the occasion. That day, I realized the importance of being trained as a hardcore engineer. After our job was done we moved to the control room which was located several kilometres away. Mr. Seshadari was carrying out the control related activities His job involved specially developed instrumentation and the laying of cables, which were running all over the place. He had also worked on the trigger. …..

And then, the countdown began. The button was pressed. The mound rose right in front of our eyes and went down. People started jumping with excitement. Everyone wanted to rush to the crater. Dr. Ramanna tried to restrain them himself by telling them that it was not scientific to do so and would destroy the evidence. Moreover, the personnel could place themselves in danger, as the ground had fractured and could cave in, leading to the entrapment. No body was listening, and finally, Dr. Ramanna had to shout to stop them from moving. One must always proceed scientifically.

The experience of Pokhran in 1974 was a great learning, generally, in terms of new program domain but particularly in terms of human dynamics that I witnessed before, during and after the tests. Working in a team, in extreme weather at the site and back in the less harsh environs of RED in BARC, the interpersonal relations that I experienced were eye openers. And, on a greater level, India grew in stature globally and the world realized that the country could not be ignored.

(Excerpts with the permission of authors from the book "FIRE and FURY: Transforming India's Strategic Identity" by Anil Kakodkar and Suresh Gangotra published by Rupa Publications India Pvt Ltd 2019 - Editor).

INS invited some well known experts with vast experience in nuclear industry to solicit their response to the recent policy announcement of GOI to open / enlarge some areas related to societal benefits of radioisotopes and irradiation in PPP mode. The responses are presented here.

Setting up of a Nuclear Reactor for Production of Medical Isotopes and Irradiation facilities for Food Preservation in PPP mode

The honourable Finance Minister, in her speech, indicated a big boost to the Atomic Energy Programme and proposed i) to establish a research reactor in PPP mode for producing isotopes for medical use, ii) to establish facilities in PPP mode to use irradiation technology and iii) to set up technology development cum incubation centres.

These reforms will certainly play a big role in enhancing the activities in a synergistic manner. Let us briefly recapitulate what has been done in this direction by the DAE (Department of Atomic Energy) till date and how the private sector has participated. Application of radiations for societal benefits, in particular for health sector started way back in 1952 when the Cancer Research Institute (CRI) was established in the Tata Memorial Hospital (which had been founded in 1941 by Sir Dorabji Tata Trust). In 1957, the Ministry of Health took over the Tata Memorial Hospital. The transfer of the administrative control of the Tata Memorial Centre (Tata Memorial Hospital & Cancer Research Institute) to the Department of Atomic Energy in 1962 was the next major milestone. The Tata Memorial Hospital and Cancer Research Institute merged as the two arms of the Tata Memorial Centre (TMC) in 1966 as a classic example of private philanthropy augmented by

Government support with a mandate for Service, Education & Research in cancer. The Advanced Centre for Treatment, Research, and Education in Cancer (ACTREC) at Kharghar in Navi Mumbai is a new R&D satellite of the Tata Memorial Centre (TMC). It has the mandate to function as a national centre for treatment, education, and research in cancer. In the past 5 decades, a number of private hospitals have added Radiotherapy and Chemotherapy treatment for cancer patients.

Same is the case for the nuclear medicine. Radiation Medicine Centre (RMC) was founded as a division of Bhabha Atomic Research Centre in 1963, next to TMC, by Dr. Bhabha, with the mandate of providing diagnostic and therapeutic services. A one year post-graduate Diploma in Radiation Medicine (DRM) in collaboration with the Science and Medical faculties of Delhi University was started in 1962; RMC was permitted to run 1year DRM affiliated with Bombay University in 1973. Since 2000, DRM course tenure has been increased to 2 years and is now affiliated to the Homi Bhabha National Institute (HBNI), Mumbai. Jaslok Hospital, in 1973, was the first private hospital in this country to start a full-fledged, well equipped Nuclear Medicine & RIA Department and also the first hospital in the country to utilize the “radio-isotopic cow” for Tc-99m developed by the BARC. In September 2002, 16 MeV medical cyclotron facility and PET scanner was commissioned at RMC to produce isotopes having short half life for medical applications. As of now, there are about 20 medical cyclotrons in the private sector meeting the demand for isotopes of short half life. India's largest, 30 MeV medical cyclotron is now operational at the Variable Energy Cyclotron Centre (DAE) in Kolkata. It has the potential to meet the entire country's needs as well as the export of Germanium-68 and Palladium-103. Germanium-68 is the 'parent' isotope for Gallium-68 generators, used in the diagnosis of breast cancer. Palladium-103 is used to treat prostate cancer.

Eighty per cent of all diagnostic medical scans, worldwide, rely on the availability of the radioisotope Molybdenum-99 and its daughter product, Technetium-99m (^{99m}Tc), produced in the research reactors. There is a shortage of reactor produced isotopes for medical use and thus it is a welcome step to establish a research reactor in PPP mode exclusively for isotope production. The design and the overall economics need to be worked; the power of the reactor will not be high but the flux needs to be high thus requiring enriched Uranium/Plutonium as fuel. There are a number of similar reactors in developed countries and some are in the universities /polytechnics.

The production of radioisotopes involves several interrelated activities, including the fabrication of targets; their irradiation; transportation of the irradiated targets to processing facilities; radiochemical processing (or encapsulation in sealed sources); quality control; and transportation to end users. In 1989, Board of Radiation and Isotope Technology (BRIT) was set up as an interface between the isotope producer (BARC) and the users in the industry and the hospitals. BRIT has a number of facilities and laboratories to convert the radiochemicals received from BARC, to the radiopharmaceuticals and other compounds required by the users. BRIT finds it difficult to keep pace with the market requirements as the isotope production is primarily based on the availability of the multipurpose reactor Dhruva, which caters to other requirements as well. The medical cyclotrons in the public / private sector are likely to play a complementary role in producing isotopes for medical applications. Last year another reactor Apsara 2, has been commissioned in BARC which has enhanced the isotope production but still cannot meet the total requirement and thus the need for import. A dedicated reactor for isotope production in the PPP mode will certainly help to reduce/eliminate the import.

After a number of applications in industry, environment, health and agriculture sectors were discovered by the scientists, a need was felt for a forum/interface for interaction among the industrial users of Radioisotopes and Radiation Technologists; thus the National Association for Applications of Radioisotopes and Radiation in Industry (NAARRI) was founded in 1976. In the last international conference held in Mumbai by NAARRI in 2018, it was reported that spices and herbs are the most common irradiated food products in the world; use of irradiation as a quarantine measure is the most remarkable development; there is enough evidence that consumers buy irradiated food; about 30,000 tons of guavas, mangoes, sweet potatoes, papayas, dragon fruits, longans, lychees and cherries are exported from Mexico, Hawaii, Vietnam and Australia.

After the design and successful operation of the Spice Irradiator in BRIT, the technology for setting up the gamma radiation processing plants was transferred, by the DAE, to the private sector in 2001. The design of this Spice Irradiator was based on the experience of ISOMED plant which was set up in 1974 for sterilisation of disposable medical products and devices, as a grant from the IAEA. Although, before the spice irradiator, a potato onion irradiator (POTON), designed for low dose and large throughput, was set up at Lasalgaon, it did not turn out to be a commercially viable proposition; now it is being used mainly to irradiate spices and also mangos for export to the US. In the past 20 years, only about 20 plants have been commissioned in the private sector, the first was in 2005; most of these plants are multipurpose and are built with the subsidy provided by the Ministry of Food Processing Industry (MOFPI). The first 3 plants were also supported by the Technology Development Board of the Department of Science and Technology (DST) with some soft loan. There are only 2 fabricators, both small scale industries; the volume of business is too small to attract bigger players; only last year Walchandnagar has shown interest and has signed a technology transfer agreement with DAE. The food items being irradiated at present are 1) food additives like honey extract, walnut shell granules, etc. 2) health food like coffee extract, green tea etc. 3) spices, herbs, dry fruits, mangoes and pet food. The radio isotope used in the radiation processing facilities is Cobalt 60 which is produced in the power reactors. Nuclear Power Corporation Ltd (NPCIL) is enhancing the production by making provisions in the new 700 MWe reactors being built; at present about 3 MCi is being produced which not only meets the local demand but some of it is also exported. After commissioning of the first 2 units of 700 MWe reactors the production is likely to be doubled. BRIT receives Cobalt 60 from NPCIL and after fabricating the pencils/sealed sources, supplies to radiation processing plants as well as hospitals for cancer treatment. There is an in built subsidy by the DAE as the price charged is almost 30% of the international price.

Introducing radiation processing plants in PPP mode for food grains and other agro produce will go hand in hand with the reforms which have been announced. The Union Cabinet cleared ordinances aimed at lifting restrictions on key commodities such as cereals, pulses, onion, potato and giving farmers the freedom to sell their produce directly or through e-trading platforms to entities of their choice, instead of being confined to state 'mandis'. This will enable the farmers to enter into an agreement with private sector players. These reforms will largely free the sector from a system of inspectors and permits. These ordinances are aimed at providing barrier free interstate and intra-state trade in agriculture produce and eliminating intermediaries. Wheat, Rice, Sooji, Rawa Atta and Maida are approved for Radiation Preservation by The Indian Ministry of Health and Family Welfare; but irradiation has not caught up on a large scale due to logistics and the cost involved. For low value products & requiring low dose, through put has to be very high and the plant design has to be different from the design of the multipurpose plants now available in the market. These plants can be designed and integrated with the food parks or with the storage facilities which can now be in the PPP mode, the nodal Ministry being the Atomic Energy or the Ministry of Food Processing.

For the new entrepreneurs wishing to establish radiation processing plant, at present, the capital cost for a multipurpose plant designed for the Cobalt 60 loading of 1 MCi, could cost about Rs 10 crore, excluding the cost of land and Cobalt ; civil works and the machinery would cost about Rs 425 lakh each and the auxiliary equipment about Rs 50 lakh. This proportion and the total cost will vary marginally if designed for different Cobalt loading. Before designing the plant, one should have an idea of the annual throughput of different products and the packaging of the product. 1 MCi loading of Cobalt on an average can process 8000 to 10000 tons of different products with different dose requirements in a year. Overall Cobalt utilisation efficiency is different for different designs and also varies with density of the product. Cobalt cost as of now is about Rs 100/Ci and is supplied and loaded by BRIT. The plants are designed and operated following the AERB guidelines. To start with an MOU is signed with BRIT for establishing the facility; BRIT assures some initial technical help and confirms the supply of Cobalt. As I have indicated above, MOFPI has been giving some grant/subsidy after evaluating the project and the products planned to be irradiated. This is based on some percentage of the cost of plant and machinery and the technical civil works. May be with the announcement of liberal loans for MSME sector, the interest on the capital would come down to make it an attractive proposition. The total time required from ground breaking to commissioning could be about 18 months. At the time of commissioning, 10% of the designed capacity of Cobalt is permitted to be loaded by AERB. Subsequently, as the business picks up, one increases the source strength or vice versa. The largest component of the operating expense is the decay of Cobalt 60 with half life of 5 years. After about 30 to 40% of the designed capacity of Cobalt 60 is loaded with matching business growth, one can start recovering the capital expense; this may take 3 to 4 years. The life of the plant is assumed as 40 years. The IAEA publishes the directory of radiation processing facilities operating in all the member states.

A lot of R&D has been done in the past three decades on the application of Electron Beam Technology as well. In many respects, Electron Beam Irradiation is better than Cobalt-60. Raja Ramanna Centre for Advanced Technology (RRCAT) has developed a demonstration radiation processing facility, based on Electron Accelerator, in the Fruit and Vegetable Mandi Complex, Indore. The demonstration facility is based on the indigenously developed 10 MeV, 5 kW electron linear accelerators (linacs). For commercial viability the power of these machines need to be at least 20 kW which will be the next logical step. Worldwide, there are over 1,400 high-current industrial electron beam accelerators in commercial use; this number is much more than the commercial gamma irradiators. Another variant can be a 'Mobile Irradiator' The irradiator can be installed on a 40 ft. trailer bed and can be moved to different places as and when required. These irradiators can be designed to use either Cobalt-60 or Cs-137. The infrastructure, in particular the roads, would need improvement.

The third focus is on the Technology Development cum Incubation Centres. About 20 years back, a new division named Technology Transfer and Collaboration Division (TTCD) was established in BARC. Over the years, a number of spin off technologies have been transferred to the industry. The web site is updated with the list of technologies available for transfer in different areas like agriculture & biosciences, radiation technologies, medical equipment, instrumentation and many others. This activity is further strengthened by including technologies developed by other units of DAE and is renamed as 'Entrepreneur's Corner, Technology Transfer, Consultancy and Scientific Services'. Technologies available for incubation are also added. Under DAE-Societal Initiative, 'AKRUTI' (Advance Knowledge and Rural Technology Implementation) programme, the technology deployment exclusively in rural sector is offered in the form of technology package called Akruti Tech Pack consisting of 15 technologies and 3 technical consultancy services at an affordable price. These will be implemented through technically oriented NGOs working in that village and will become the incubation centres for future entrepreneurs.

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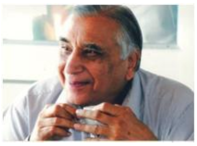

Director Technical, Microtrol Sterilisation Services Pvt. Ltd. and President NAARRI, Former Director, Reactor Projects Group &Technical Coordination and International Relations Group, BARC and Former Scientific Consultant, Academy Industry Interaction in the office of the Principal Scientific Advisor to the Govt.

Low Energy Electron Irradiation and Mobile Irradiation facilities

Post harvest loss is a major economic factor in agriculture and affects all crops to some extent. Irradiation by either Gamma Rays produced by Cobalt 60 or by Electron Beams produced by electron accelerators is now accepted worldwide as a method to reduce post harvest losses in agricultural crops and is used commercially in many countries.

Potato is one of the major crops of India. Most of the potatoes grown in India are harvested from January to March just prior to the hot summer months necessitating their storage at a temperature of about 10^0 C in cold storages. India has a large network of cold storages but still about 30% of the potatoes produced do not have access to a cold storage. Another problem of storing potatoes in cold storages is that they develop sugars which make them sweet in taste. Such potatoes are not used for making for example, potato chips because the chips turn brown and are not accepted by customers.

To permit farmers to store potatoes at room temperature in their farms it was proposed to irradiate potatoes with low energy electron beam so that only the skin (where the cells responsible for sprouting are present) is irradiated leaving the bulk unirradiated. In use, the skin of potatoes is removed thus removing the irradiated part, leaving the useable part of the potato unirradiated.

Consumers who are hesitant to consume irradiated food will have no hesitation using potatoes irradiated with low energy electron beam. Further the useable part of the potato will not accumulate sugar and hence can be used by potato chip manufacturers.

Raja Ramanna Center for Advanced Technology had developed electron accelerator which could accelerate electrons to energies up to 750 KeV. Experiments to irradiate potatoes were carried out using this accelerator with electron beams of 400 KeV and 500 KeV energy. The potatoes have to be rotated to get uniform irradiation. In the absence of a suitable arrangement for rotating potatoes, these were partially irradiated and then rotated by hand and irradiated again. This was repeated several times to get uniform irradiation. These experiments confirmed that irradiated potatoes do not sprout even when stored at about 25 Degrees for several months [1]. Bhabha Atomic Research Center carried out experiments to measure sugar content of irradiated potatoes and these confirm that potatoes irradiated with such low energy electron beams do not develop sugar even after storage. They also tested the quality of chips made from these potatoes and found them to be very acceptable [2].

A major advantage of electron accelerators of such low energy and power is that they can be designed for mounting on a truck making them mobile, going from one village to another, irradiating potatoes and other crops wherever possible. Thus the farmer will have access to a frontline technology at his doorsteps. The truck will house the accelerator, potato handling system as well as shielding. The potato handling system will not only transport the potatoes to the electron beam but will also rotate them while they are being irradiated so that the potatoes are irradiated uniformly.

Cost of manufacturing such an accelerator along with potato handling system, shielding, etc is expected to be about Rupees 1 Cr. Assuming irradiation of 7 tonnes of potatoes per hour and ten hours of operation per day the return will be about Rs. 20 Lakhs per month if the farmer is charged Rs. 1.00 per kg for irradiation. When potato harvest season is over, the electron accelerator can be used either for irradiating other crops or for industrial applications. Even four months of operation per year of the accelerator for irradiation of potatoes can easily recover the cost of accelerator and its operation within a few years.

The advantages to the farmer are many. The cost of keeping one kg of potatoes in cold storage for 8 months is about Rs. 2.00. Now the farmer can get the potatoes irradiated at his door step and he can store the potatoes in house, all at a cost much less than cost of keeping them in cold storage. The farmer can sell potatoes when the price is right. Further he will have a new market, namely chip manufacturers.

Developed countries are using electron accelerators extensively for several applications. Low energy electron accelerators are used for curing of polymers, cross linking of polymers, grafting of polymers etc. Application areas are production of cross liked cables which have superior heat and chemical resistance, production of heat shrinkable plastic, production of adhesive coated paper and plastics etc. **This is great opportunity for high tech industries in India to get into a frontline technology which has immense potential for applications in agricultural as well as in industrial sector. Further this technology will help the farmers directly and will reduce post harvest losses of agricultural produce. Government of India has given emphasis to technologies which will reduce post harvest losses and has created a Ministry of Food Processing Industries for this purpose. Finally most of the technologies involved have been developed at Raja Ramanna Center for Advanced Technology, Indore as well as at Bhabha Atomic Research Center, Mumbai.**

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Former Director, Raja Ramanna Center for Advanced Technology, Dr. Bhawalkar has received many awards in his career, the important ones being Padma Shri conferred by President of India in 2000, S.S.Bhatnagar Award for Engineering Sciences in 1984, Firodia Award for excellence in Science and Technology in 2000 and Homi Bhabha Award of Indian Nuclear Society for lifetime achievement in 2010.

Irradiation facilities for Food Preservation in PPP mode : View of NuFFooDS Spectrum

One of the major problems of India's agriculture and food sector is the huge amount of food wastage. By conservative estimate Rs 45,000 crore worth of food is wasted in India each year. But there is an important difference between food wastage in other countries and in India. In several other countries wastage is on the plates while in India it is more at harvest and transportation level due to lack of adequate facilities for proper storage, transportation and processing facilities.

Wastage of food affects the country in many ways. Firstly, it is a major loss for farmers who have to just throw it without earning any money. Secondly, it is a social issue as so much food is wasted when the country has a large number of undernourished population. Lastly, it causes environmental degradation. The process of wastage itself affects the environment and all the natural resources like land and water used for growing the food also impact environment without any positive outcome when the food grown by using these resources goes waste.

Although Ministry of Food Processing Industries (MoFPI) has initiated several steps to boost the food processing industry , much more needs to be done on storage and logistics facilities . One more solution to the problem, as the readers of this newsletter are very well aware, is food irradiation. It has a dual benefit as it decreases food losses by increasing the shelf life of food products and also reduces risk of food borne diseases. One more advantage is that as the shelf life is increased and the food becomes more safe due to irradiation, its export prospects also grow.

With better export prospects, the production can also grow. Currently various new hybrid /mutant varieties of crops (including food grains having much more yield prospects than the existing ones) are not being introduced as the problem could be of storage of so much of extra production. But growing exports will solve that problem.

It is a very significant and important step by the government to use the public-private partnership (PPP) model for creating more food irradiation facilities. Although the announcement is made, the details of the scheme are yet to be announced. Currently there are about twenty irradiation facilities in the country in private sector for multiple products. However, the facilities at two centres , Agriculture Produces Market Committee (APMC), Turbhe in Navi Mumbai and at Lasalgaon in Maharashtra are exclusively used for food products. These are being operated by a wing of Department of Atomic Energy (DAE) called Board of Radiation and Isotope Technology (BRIT).

The industry feels that the cost benefit ratio will be crucial in expanding the irradiation market in India. The irradiation process cost will have to be loaded on the final food product. If initial investment is high, as some feel, it will increase the processing cost and reflect in the final price. In such a situation the low-end products with high cost of irradiation added to them will not be accepted by the consumers. For high end products like meat, spices, fish whose prices are already high, adding additional burden of irradiation processing cost will not make much difference for the consumers and those products are likely to be accepted by them.

However, there is another view that irradiation is actually more useful for low end products like onion, potato, carrot as it stops sprouting. While loading the fixed cost if it is properly divided over a longer period and over larger throughputs, it will not affect the price of even low-end products much. Currently, from low end product onion to high end products spices, mangoes and lychees are irradiated.

But beyond the price, the issue of acceptability is more important. We already have an experience of genetically modified or GM crops. We have not been able to move an inch forward on GM crops front beyond cotton. Irradiation is even a step ahead in 'danger' than GM in people's mind as they have fixed notions of radiation. In a common man's sub-conscious mind there is a close link between radiation and cancer. Most of the people will get confused between irradiated and radioactive foods as they may not be able to know the difference between the two.

Thus, the government, through its regulator like Food Safety and Standards Authority of India (FSSAI) and organisations like Bhabha Atomic Research Centre (BARC), will have to launch a massive campaign for large scale acceptance of irradiated food products.

Only when people will understand the proper meaning of the process of irradiation then only its acceptability will grow. That will lead to expansion of irradiated food market, justifying and proper utilisation of more irradiation facilities. Unfortunately, in such matters the common man finds that sometimes the scientists themselves are divided in two groups with one group raising warning signals and confusing common people.

In this context it is important to know that FSSAI has a rule making it mandatory to mention on the package label if the food is irradiated. Due to this the fish exported to US is sent via Vietnam where there is no such rule and hence the product enters the US market and accepted.

One can understand how the Indian consumers will respond after seeing the label mentioning irradiated food. This does not mean that the rule should be withdrawn. But only way is to increase acceptability of the irradiated product so that the label will not prevent the people from buying those foods. This can happen only through a sustained campaign and still it may take a long time for acceptability.

For instance, microwave oven is a common gadget in middle class households. There is no fear in the people's mind of electromagnetic radiation contaminating the food inside. That level of comfort will have to be brought in case of irradiated foods. This is necessary because the financial issues like investment depend upon that.

But if the acceptability is not seen, the private players will not come forward for setting up plants. But unless the plants are set up and irradiated food products are floated in the market the acceptability will not even begin. So, what is first is an important issue and hence the government's role will be crucial as it will have to give several concessions for initial partners in PPP to bring the products into the market and make people taste them and accept them. Only then the private players will come forward.

The industry is also little wary about the regular supply of radioactive material to be used for irradiation process as it is going to be supplied by only one agency, BARC. When the number of irradiation facilities will grow due to PPP model, will the supply remain uninterrupted is a question the industry has. Safe handling of radio active material and disposing off the waste and its monitoring is also a crucial issue. Although SOPs will be framed, how it will be monitored when being handled by private companies to ensure safety is also an issue to be considered. Strict implementation of rules will be needed for that.

These two issues have been underlined in a research paper in Foods 'Potential Use of Gamma-Irradiated Ethnic Ready-to-Eat Foods to Improve the Nutritional Status of Landslide Victims', in 2016. It said, the irradiated ethnic ready-to-eat foods were generally well accepted by the respondents (in Java), though the cost-benefit of mass production was still of great concern.

Despite all this, the PPP model needs to be tried by taking precautions on these points in the initial period. The step is important for the farmers to raise their income and for the country to reduce food wastage and improve food safety.

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> **"Science and everyday life cannot and should not be separated."**
>
> **– Rosalind Franklin**

Radiation Processing of Foods in India

Government recently announced to establish facilities in PPP mode to use irradiation technology for food preservation. This shift from giving subsidy to establish a facility in PPP is a major reform that may boost the technology in a big way. In fact, facilities built with subsidies failed to nurture/promote the technology. Many promoters were interested in the subsidy rather than nurturing the technology. Radiation processing of foods is a highly regulated, multidisciplinary and multifaceted technology. Thus a facility to be established in a PPP mode is promising. The marketing reform whereby farmers need not go through APMC will also enhance the technology demand. The commercial viability of any technology depends upon its need, efficacy, benefit over the other existing technology, its cost and ease of application.

Radiation processing of spices, pet foods and mangoes is currently being carried out for exports. It is necessitated as importing countries demand spices hygienised by gamma irradiation. Similarly pet foods need to be irradiated for exports. Mango irradiation in India is the outcome of quarantine needs of its exports to USA. Though irradiation of mangoes as a quarantine measure for export to USA is approved, it has a long way to go to attain its full potential. Demand from USA seems to be huge and competition tough with other countries. **Some of the reason for low volumes of exports at present are transportation and operation cost. High transportation cost by air is a big hurdle and reason for low volumes. To reduce transportation cost, export by sea rout is needed. Recently, this has become feasible by employing combination treatment to extend shelf life to 45 days. USDA has approved it. Operational cost shall also come down due to large volumes arriving at the facility. Similarly, Australian and New Zealand markets are to be explored for exports of fresh fruits and vegetables.**

Huge potential exists for exporting marine products treated with gamma to make it free of pathogens like Salmonella and Listeria, to name a few. However, facilities need to be equipped to carry out the treatment at low temperatures. Another export potential that has been ignored is dried products of animal and marine origin. Radiation processed Intermediate Moisture Foods (IMF) have huge demand in South Korea, South Africa and Argentina markets. The new markets need to be explored. **One of the ways to enhance commercial viability is to locate radiation processing facility in food parks. These food parks will have pack house, primary, secondary processing as well as post treatment storage facilities and transport like container loading services for exports.** Onions and garlic are other commodities to be explored for exports devitalized by gamma radiation. China for example exports its irradiated garlic.

Currently, radiation processing of foods is not being practiced for domestic markets. There are many reasons. The technology to establish itself in the domestic market has to be better than conventional methods to allow switch over. It should be need based, cost effective, and be compatible with current practice of trade. Right now it seems to be at disadvantage as compared to the existing processes of food preservation. Let us evaluate needs and requirements of the technology for domestic markets. Foods have been grouped into several classes based on the purpose and dose of irradiation.

Class 1 includes bulbs, stems, roots, tubers and rhizomes. The purpose of irradiation is inhibition of sprouts / devitalization. Limitations are that it can only mitigate losses due to sprouting (3-5%) and not losses due to dehydration and microbes that are major in these (>20%). In fact, irradiation may enhance losses due to extra handling as currently radiation processing are stand alone service facilities. It adds to the cost of transportation to the facility. Further commodities being seasonal and to be treated within short span of dormancy period adds another dimension. Thus the treatment to be effective has to be combined with cold storages to prevent microbial and dehydration losses. Cold storage induces losses due to sprouting during retailing. Therefore, combination treatment becomes a necessity. Thus the technology to be viable for these commodities should include proper design, with sorting, grading, pellet irradiation. The facility should have backward integration with farmers for sufficient supply of the produce. It should include huge pre- and post-irradiation storage for forward integration.

There is also potential of marketing irradiated products listed in Class 3 like cereals pulses and their milled products. Again, it will require to be complemented with proper packaging and post treatment storage. Irradiation plant located in a food park with primary and secondary processing shall be advantageous. Huge scope for class 4 &5 for chilled fish, aquaculture, meat, meat products exists. But the facilities to carry out gamma irradiation at low temperature do not exist at present. Right now, marine products for distant markets have to be transported in frozen condition. Freezing affects quality and cannot kill pathogens if present. Irradiated chilled fish and marine products not only shall extend shelf-life but also eliminate pathogens like Salmonella.

Good potential also exists for improving quality and trade of dried foods of animal and fish origin (class 7). Irradiated Intermediate moisture Foods (IMF) will be much better in quality and safety than the dried foods that are being marketed now. The through put of radiation processing plants for foods is very high (e.g. onions 6-10 tons/hr). Thus radiation processing plant has to cater to wide variety of products that have varied requirements with regard to dose and handling. So it should be designed for multiple produce in sufficient quantities to run three shifts a day and for 300 hundred days of the year. Only then the facility shall be commercially viable. The higher returns may come when the facility is a partner in procurement, processing and storage to share profits. A facility located in a food park will generate better returns.

To summarize spices, pet foods, herbal products and mangoes are known to give good returns. However, cereals, pulses and their milled products, dried products of marine and animal origin seems to also have a huge potential that may give even better returns. The volumes of these commodities are very high and dose of gamma radiation treatment required are low.

The radiation processing plant will require about 2 acres of land. Building and technical civil works shall cost between 5 to 6 crores INR. In addition plant and machinery, laboratory, dosimetry equipments and auxillary machinery may cost another 10-11 crores INR. Source (Co 60) will cost additional 1crore onwards. Also one has to consider the running expenses of radiation processing plant which range between 60 to 80 lakhs per annum. The cost of the radiation processing facility, however will vary with design capacity and the type of machinery. The technology require huge investments and is highly regulated, with fairly long gestation period of four to five years and is in a nascent stage for domestic markets. Therefore, needs hand holding by the government. Thus the government announcement in establishing these facilities in a PPP to prevent huge post harvest losses is a welcome step. However, modalities are to be worked out between the government and the private entrepreneurs. Radiation processing is environment friendly green technology and is very safe. The facilities have been in operation since last fifty years in India with no mishap / accident.

Govt. reforms in establishing radiation processing facilities in PPP mode and allowing farmers to trade their produce without APMC is a landmark decision. There is a golden opportunity to now establish a radiation processing food park with backward and forward integration. The backward linkage will assure supply of foods in sufficient quantities for processing. Forward linkages will make the facility commercially viable for both domestic and export markets.

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> ***One, remember to look up at the stars and not down at your feet. Two, never give up work. Work gives you meaning and purpose and life is empty without it. Three, if you are lucky enough to find love, remember it is there and don't throw it away.***
>
> ***— Stephen Hawking***

Setting up a Nuclear Research Reactor for Production of Medical Radioisotopes in Public Private Partnership

Introduction

The recent announcement of the Government of India to set up a nuclear research reactor for radioisotope production under public private partnership (PPP) model is a welcome step. It might look a bit strange to leave an important activity of the Department of Atomic Energy to private sector, however such an out of the box thinking in this key area is highly essential to sustain the production of radioisotopes for peaceful applications, more specifically for the management of cancer. Such models are already tested and running very effectively in some countries.

Examples of similar facilities

The Missouri University Research Reactor (MURR) is one of the important research reactors engaged in the production of radioisotopes and is owned and operated by a University, the University of Missouri-Columbia (UMC). MURR, operational since 1966, is a 10 MW pool type research reactor having a neutron flux of $6x10^{14}$ $n.cm^{-2}.s^{-1}$. Perkin Elmer, a private radiopharmaceuticals company has recently set up a radioisotope laboratory complying with good manufacturing practices (GMP) to process isotopes and prepare radiopharmaceuticals. There are other examples where the research reactor provides irradiation services to private radiopharmaceutical manufacturers who transport the irradiated targets to their dedicated facilities for processing and preparation of radiopharmaceuticals. Lutetium-177 is produced in Israel by using a reactor in the EU region, processing done in Israel and radioisotope supplied worldwide. The fission moly (molybdenum-99) used for the manufacture of technetium-99m generator is produced using a consortium of research reactors. The irradiated LEU targets are shipped to different facilities for processing. Purified ^{99}Mo is then sold to radiopharmaceutical manufacturers for the preparation of the generators.

Is there an opportunity to set up a commercial research reactor?

The major reactors engaged in radioisotope production are listed in Table 1. There are several striking features to be noticed about these reactors. The first one, all listed reactors except OPAL, Australia are very old and towards the end of their life time. These reactors continue to be operated mainly because of their indispensability in the production of radioisotopes. The second important aspect is that once set up a research reactor can be used for several decades. Thus, though the initial cost of building the reactor is high, it can be recovered by effectively utilizing the reactor during its long life time. The third feature is that irrespective of the location, the radioisotopes prepared in these reactors are used globally.

Though the number of reactors in the World is declining, the demand for radioisotopes is increasing very rapidly. This is mainly because of the new developments in molecular nuclear medicine using therapeutic radioisotopes for the treatment of different types of cancers. A reactor focusing on the production of molybdenum-99, iodine-131 and lutetium-177 will be a success if the project is catered for global supply. Hence, the DAE's thinking on the setting up of a research reactor and isotope production facility in PPP model is well thought out and will be a boost for the availability of radioisotopes globally. DAE's capability for building the reactor coupled with the private company's ability to do competitive commercial operation targeting global demand could turn out to be a profitable venture.

TABLE 1: MAJOR NUCLEAR RESEARCH REACTORS USED FOR RADIOISOTOPE PRODUCTION

Reactor	Country	Year of Comm.	Power, MW	Neutron Flux (th)
BR-2	Belgium	1961	100	$11x\ 10^{15}$
HFR, Petten	Netherlands	1961	45	$2x10^{14}$
LVR-15	Czech Republic	1957	10	$1x10^{14}$
Maria	Poland	1974	30	$4x10^{14}$
OPAL	Australia	2006	20	$1.4x10^{14}$
SAFARI -1	South Africa	1965	20	$2.8x10^{14}$
MURR	USA	1966	10	$6x10^{14}$

The type of reactor facility needed

While designing a research reactor for radioisotope production, two aspects which are crucial to be considered are the neutron flux and the irradiation volume. A high-power research reactor doesn't necessarily mean a high flux reactor and the vice versa. In order to do an effective radioisotope production a flux $>5x10^{14}$ $n.cm^2.sec$ is essential and a compromise on this will reduce the utility of the reactor. The neutron flux is critical as the yield of production is directly proportional to it. The specific activity (activity/weight) of the radioisotope produced is also directly related to the neutron flux. The specific activity of the radioisotope formed is very critical for most applications. For example, cobalt-60 used in teletherapy can be prepared only in high flux research reactors whereas low specific activity cobalt-60 prepared in low flux reactors can be used for industrial irradiators.

While designing a new nuclear research reactor for production of radioisotopes, the irradiation volume should be maximized so that the growing demand of radioisotopes for the next fifty years can be taken care of. It is also possible to develop some flux trap positions where the highest flux is available. Such positions can be used for the preparation of lutetium-177, an isotope which is having very high demand for targeted therapy of cancer. It will be advantageous to design the reactor such that the unloading of the target can be done while the reactor is in operation.

Radioisotopes having major market share

There are over 100 radioisotopes that have some application and can be prepared in a nuclear reactor. However, the commercial market is limited to less than a dozen radioisotopes. Table 2 lists the most important radioisotopes that have the largest market share. A research reactor/radioisotope production facility for the production of these radioisotopes will be able to sustain on a profitable basis.

TABLE 2: IMPORTANT REACTOR PRODUCED RADIOISOTOPES AND THEIR APPLICATIONS

	Radioisotope	Half life	Application
1.	Molybdenum-99	66 hours	Parent radioisotope for ^{99m}Tc used for SPECT imaging
2.	Iodine-131	8.01 days	Radionuclide therapy of cancer
3.	Lutetium-177	6.73 days	Radionuclide therapy of cancer
4.	Samarium-153	46.3 hours	Radionuclide therapy of cancer
5.	Cobalt-60	5.27 years	Source for Industrial Irradiators
6.	Iridium-192	74 days	Brachytherapy of cancer

Planning the facility

The setting up of a research reactor takes considerable time and hence the facility must be planned in two stages. The first stage will be the setting up of the research reactor. Approximately about 2-3 years prior to the anticipated commissioning of the reactor the isotope and radiopharmaceutical manufacturing facilities can be set up, preferably in the same campus and adjacent to the reactor.

The isotope production facility should have hot cells and shielded boxes for handling the large quantum of radioactivity produced. This can be sub categorized into i) Hot cells for processing radioisotopes such as iodine-131, lutetium-177 and samarium-153; ii) Hot cells for processing of fission moly; iii) Hot cells for handling of cobalt-60 and iridium-192 and manufacture of sources. The radioisotopes can be either sold as such or as finished products. Hot cells for processing irradiated U-235 targets for the preparation of fission molybdenum-99 and iodine-131 can also be set up at the same site. The reactor and isotope facility should also be planned such that commercial irradiation of targets can be undertaken for global isotope producers which will also be a good source for revenue.

Along with the production facility, a waste disposal facility also needs to be made as the disposal of the used sources is the responsibility of the supplier. The disposal cost of ^{68}Ge sources used in PET-CT quality control is about 3-4 lakhs even when the activity to be disposed is a few hundred microcuries. There are over 300 PET-CT machines operating in India and the cost incurred for re-export of spent source of germanium-68 or sodium-22 is ~ Rs. 10 Crores. Similar requirement for disposing spent ^{68}Ge/^{68}Ga generator will also be arising. Such support will help the nuclear medicine departments in cost reduction and will be an income generating activity.

Investments and returns

It is difficult at this preliminary stage to guess the exact investment needed for setting up the reactor, radioisotope production and radiopharmaceuticals laboratory. Identification of the activities planned and the scope of the facility are to be well defined to arrive at the estimated cost of the facility. Assuming that hot cells and production plants will have to be sourced from abroad, a financial outlay of about Rs. 250-300 Crores for building, infrastructure and equipment can be estimated for the isotope processing laboratory alone. The construction of the laboratory can be finished in about 3 years and a return on investment is possible from the very first year of operation provided the reactor is functional and licensed to full capacity operation. The facility will have a life time of at least forty years.

One of the major worries for the investors will be the return on investment and this can be assessed only if the operation is defined. There is a good market for radioisotopes and radiopharmaceuticals in India as there is a large import component as of now. Once the products are made locally the Indian market will increase substantially. The major revenue earning radioisotopes will continue to be molybdnum-99, iodine-131 and lutetium-177. The market will expand provided the products are readily available on demand. For example, the annual sale of 20000 doses of high specific activity lutetium-177 alone can bring revenue of 200 crores, on a very conservative basis.

There is a huge international market for radioisotopes which can be captured by a competitive private company but difficult to access by a government entity. This is to be seen in the light of the fact that most of the reactors in the World are old and will be decommissioned soon. The earlier practice of setting up the reactors and subsidizing the cost of production by the Government is slowly getting phased out and the users have to pay the market price for radioisotopes. All the above are possible if the operation is done by a private company in a competitive manner and without the administrative obstacles faced by a Government department for procurement of raw materials and sale of finished products.

Who shall be the private partner?

Finding the appropriate private partner for a research reactor project is an important task. Most of the private companies are likely to shy away from such a project where the incubation time is large, the potential revenue is uncertain and the industry is tightly controlled by a nuclear regulatory body. Any private investor will like to put their money in tested fields where the return of investment is assured and the controls are minimal. However, some of the major Indian pharma companies such as Biocon, Dr. Reddy's Laboratories, Dabur, Zandu etc. could be tapped to form a consortium to invest in a nationally important project. Another potential investor could be Reliance who successfully developed the Jio model, where no return of the investment was sought for a few years till the market was sensitized and developed. TATA group might be another willing partner who might be interested to work with the Department of Atomic Energy for an important cause, cancer care. After all the department of Atomic Energy's origin has a lot to do with the vision of the great J.R.D. Tata who funded the setting up of an institute for fundamental research, the TIFR. Another more relevant example is the Tata Memorial Hospital, which was initially commissioned by the Sir Dorabji Tata Trust in 1941 as a centre of excellence for cancer care and was taken over by the Ministry of Health in 1957.

Conclusion

The setting up of a research reactor in public private partnership model is the need of the hour to sustain the availability of radioisotopes for cancer care. The research reactor to be set up should have a neutron flux >5x10^{14} n.cm^{-2}.s^{-1} for it to work as an effective facility with high output of quality products. The project can be in two phases with the radioisotope production facility installation starting 2-3 years prior to the commissioning of the reactor. The commercial viability of the project is assured as the radioisotopes are globally produced in reactors which are towards the end of their useful life and hence a new entrant will be able to get adequate market share. The 'private' partner in the PPP model should have the willingness to invest in a business having a long incubation time but targeted to cancer care.

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"If you want to have good ideas, you must have many ideas."
– Linus Pauling

Status of PET Imaging in India

Positron emission tomography (PET) imaging, a revolutionary nuclear medicine diagnostic procedure, became available in India for the first time in October 2002, with the commissioning of the Medical Cyclotron Facility (MCF) and PET scanner at RMC, BARC, by the Prime Minister of India. The PETtrace Medical Cyclotron capable of 16.5 MeV proton beam or 8 MeV deuteron beam at the MCF can produce short lived positron emitters viz., fluorine-18 (T1/2=110 min), oxygen 15(T1/2=2 min) , nitrogen-13(T1/2=10 min) and carbon-11(T1/2=20 min). Of these, fluorine-18, is the work-horse of PET-imaging, and is converted to [F-18]-2-fluoro-deoxyglucose ([F-18]FDG) and administered to patients for PET scans.

[F-18]FDG is most used PET-radiopharmaceutical by oncologists, cardiologists and neurologists for the diagnosis and staging of cancer, neurological diseases and heart diseases respectively. After administering the [F-18]FDG intravenously and allowing the patient to rest for a while, till the radiopharmaceutical equilibrates in the body, the patient is scanned, usually from head to toes in a PET scanner. The scanner detects the two 511 KeV γ-rays at 180° emitted following positron-electron annihilation, when the positron emitter in the PET-radiopharmaceutical decays. To increase the scanning speed, the PET scanner is designed with 360° ring of fast detectors with low dead-time and after enormous computation, generate a 3-D digital image that represents the distribution of the radiopharmaceutical in the body.

Figure 1. The Triad that has made Molecular Imaging using PET a reality in Nuclear Medicine.
(Left) GE-PETtrace Medical Cyclotron installed at RMC – used for making short-lived PET radioisotopes- ^{18}F, ^{11}C, ^{13}N and ^{15}O. (Right) Synthesis Module for making F-18 labeled PET-Radiopharmaceuticals – importantly [^{18}F]FDG. (Below) A PET scanner with a CT scanner in tandem so that a fusion image of PET and CT can be created to improve clinical diagnosis.

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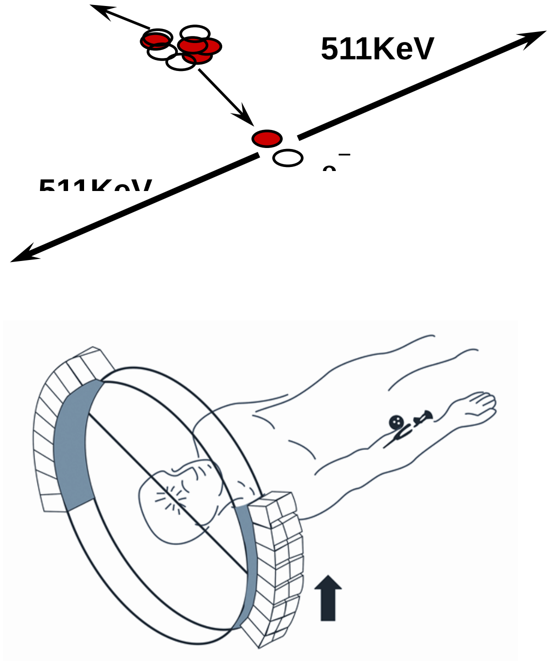

Steps in PET imaging

- Production of Positron Emitting radioisotopes (Cyclotron)
- Positron Emitting Radioisotopes are converted to PET-radiopharmaceuticals (PET-RPs)
- PET-RPs are administered into patients and allowed to equilibrate through blood circulation.
- Positron produced by radioactive decay travels 1-3 mm (depending on decay-energy before electron-positron annihilation.
- Coincident Detection – Simultaneous detection of two 511KeV photons produced by annihilation by electronic collimation within 10 -12 nanoseconds.
- Find line of response (LOR).
- Minimum distance and angle of LOR from centre
- Event registration as distance r and angle q
- Data stored as sinogram (Raw Data)
- Accidental, Scatter and Attenuation Correction
- Image Reconstruction using appropriate reconstruction method

Figure 2. Steps in PET imaging. PET imaging is capable of providing images of better contrast and resolution than are obtained with scintillation cameras.

Presently, there are 24 medical cyclotrons installed in the country that are being used for producing positron emitting radioisotopes used for PET-radiopharmaceuticals. The medical cyclotrons are from several manufacturers and produce a proton beam with energies ranging from 11 MeV to 19 MeV. Medical cyclotrons installed in India are from General Electric, USA; Ion Beam Applications, Belgium; Siemens, USA; Sumitomo, Japan; Advanced Cyclotron Systems Inc., Canada. There is one 30 MeV IBA machine installed at VECC, DAE, Kolkata, which is designed for producing both PET-radioisotopes as well as SPECT radioisotopes. Since medical cyclotrons are installed and operated in the public domain, the AERB has stringent controls on licensing the operation of these machines and related equipment used to convert the cyclotron-produced radioisotopes to radiopharmaceuticals.

History of PET-imaging

The development of PET followed the recognition of the following requirements: 1. True molecular imaging required that the radio-tracers used are made of elements like carbon, nitrogen, oxygen andhydrogen. 2. That radioactive isotopes of C, N and O were available only as short-lived, positron-emitting radionuclides viz., carbon-11, nitrogen-13, and oxygen-15 [1]. The positron annihilation radiation emitted had physical properties that were well-suited for tomographic reconstruction through coincident detection with electronic collimation. However, it took several decades for the science behind PET to evolve with contributions from multi-disciplinary efforts involving Physics, Chemistry, Biological Sciences, Computer Science and Imaging Technology.

The earliest positron scanner using two opposed NaI(Tl) detectors for imaging of patients with suspected brain tumors was assembled by William Sweet, then the Chief of the Neurosurgical Service at the Massachusetts General Hospital in 1953 [2]. The PET-scanner as we know it today was the brainchild of the American scientist Michel Ter-Pogossian and his team at Washington University in the 1970s. Ter-Pogossian was inspired by the number-crunching power of CT scanners, and developed the first computerized PET scanner in 1975 using a hexagonal array of 24 NaI (Tl) detectors connected to coincidence circuits to achieve the "electronic" collimation of annihilation photons [3]. The radiations detected by the detectors at 180° within a short specified time frame of nanoseconds are used for the quantitative reconstruction of an image by a computer-applied algorithm. The constructed image is thus a quantitative distribution of radioactivity in the patient.

Since its discovery in 1937, fluorine-18 has become the workhorse in PET-imaging due to its favorable physical and nuclear characteristics. The only other positron emitting radio-halogens are bromine-76 (half-life: 16.1 hours) or iodine-124 (half-life: 4.18 days) but their long half-lives, much lower theoretical maximum specific activity, higher positron energy, atomic size and last, but not the least, difficulty of production makes fluorine-18 ideal as a positron emitting label. Further, fluorine-18 displays simpler decay and emission properties and a high positron abundance (97%) [4]. As a result of its shorter half-life (110 minutes) and its lower positron energy (maximum 635 keV), administration of fluorine-18-labeled radiopharmaceuticals gives a lower radiation dose to patients than other radio-halogens.

Fluorine-18 can be produced in both nuclear reactors and proton/deuteron accelerators [5-7]. In the reactor, the nuclear reaction $^{16}O(t,n)^{18}F$ involving fast neutron bombardment of a lithium carbonate target, sufficiently enriched in lithium-6, to produce energetic tritons, necessary for the nuclear reaction that produces fluorine-18. The inherent contamination with radioactive tritium, the lower yield, and the time consuming inconvenience of handling targets in a reactor, makes the accelerator route very convenient and the reactor method is now history. The method of choice is to use a compact 'medical cyclotron' that can produce a proton beam (typically with a kinetic energy of about 9 - 20MeV) and use the nuclear reactions $^{18}O(p,n)^{18}F$ or $^{20}Ne(d,\alpha)^{18}F$ reactions, though the former is the preferred of the two methods, as it produces significantly higher yields and specific radio-activities than the latter.

Once the PET-radioisotope is produced, its conversion to the desired radiopharmaceutical (RP) suitable for injection into patients involves four major crucial steps:

- Trapping of the desired isotope for synthesis of RP.
- Rapid and efficient chemical synthesis of the RP.
- Post synthesis purification of the RP to ensure radiochemical purity.

- Final RP product to fulfill stringent QC and pharmacopoeia requirements as it will be injected intravenously into patients.

This process is carried out using radiochemical synthesis in a well-shielded hot-cell housing a computer-controlled synthesis module.

PET-isotopes and PET-RPs

PET-imaging, unlike computed tomography (CT) or magnetic resonance imaging (MRI), does not image anatomy (physical structures inside the body). Instead, PET scans with [F-18]FDG produce images of physiological functions in the body. These include blood flow, cell/tissue physiology (cellular metabolism and growth). In the brain, parts of the brain responsible for specific mental processes can be imaged. Patients swallow or are injected with safe quantities of radiopharmaceuticals called ‘tracers’, and are then scanned using a PET-scanner consisting of 360 degree rings of detectors that scan and track the tracers around the body. Computers process this information into images showing body function.

However, PET is not used in medicine as often as other scanning techniques. PET techniques are often considered complex and expensive, though the information from a PET-scan is more specific and often decisive in diagnosing and staging cancer as compared to CT and MRI. Further, PET can help to decide on the treatment strategy . However, to produce and use [F-18]FDG, in a PET-machine, hospitals need need to invest about Rs.30 – 40 crores for a medical cyclotron, radiopharmacy equipment, civil, electrical, HVAC work etc. Trained manpower and recurring costs are also there. Average break-even period for a well-designed facility is five years.

Fusion Imaging: PET and Computed Tomography (PET-CT) and PET and Magnetic Resonance Imaging (PET-MRI)

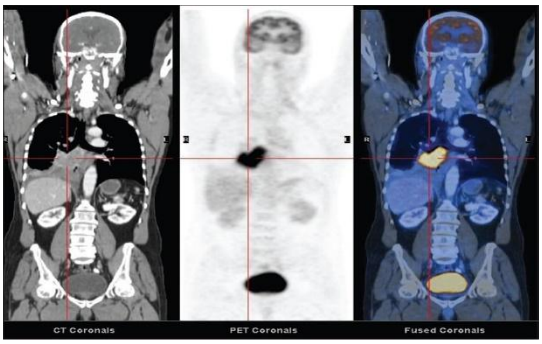

Figure 3: Whole body PET-CT coronal images show abnormal local FDG uptake in right lung.

Presently, there are 222 PET-CT and 3 PET-MRI scanners in the country. These use the PET-radiopharmaceuticals available from the 24 medical cyclotrons in the country. Yet, this is not adequate for the size of our population. Though PET has long been a primary modality in detecting many cancers, it also has the downside of radiation exposure for patients. More recently, newer PET imaging techniques, such as time-of-flight imaging, have lessened the need to increase the tracer dose to improve image quality. In addition, the advent of silicon photomultipliers (SiPMs) on PET scanners has improved sensitivity. The introduction of fusion imaging, where the patient is imaged by CT followed immediately by PET, both built into one scanner, giving a fused PET/CT image and similarly, PET/MRI image has greatly improved diagnosis and staging of cancers. This is because the CT and MRI gives the exact anatomical location of PET-RP uptake, enabling the nuclear medicine physician to make an unequivocal diagnosis. Fusion images can also aid in dose reduction with obtaining quality images with lesser administration of the PET-RP.

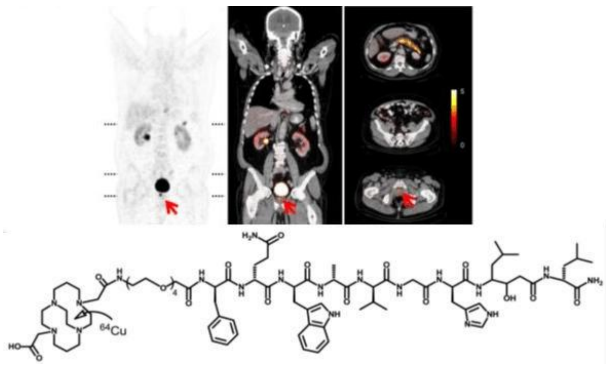

Fig. 4. Comparison of PET and PET/CT images of a patient with prostate cancer (above) using a Cu-64 GRPR-targeting peptide [8].

The information that [F-18]FDG provides regarding the metabolism of cancers has opened a large area of applications for other [F-18]-RPs. They include [F-18]NaF for metastatic bone imaging, [F-18]nucleotides for imaging cell proliferation, [F-18]-labelled amino-acids for brain tumours, other [F-18]-tracers for Alzheimer’s disease, breast cancer, prostate tumours etc, etc.

The great success of PET-imaging has prompted the search for other suitable PET radionuclides for linical imaging. Of these, gallium-68 (T1/2=68 min) , and copper-64 (T1/2=12h) have proven to be useful. Being metallic radionuclides, they can be complexed to a large variety of molecules. Shown in Fig 2 is the use of [Cu-64]-GRPR-targeting peptide for imaging prostate cancer. The sensitivity of this tracer for malignant prostate tumours and their metastases is unique. Copper-64 production requires medium energy protons (10 – 12 MeV) bombarding nickel-64 solid target. The 30 MeV IBA-cyclotron recently commissioned at VECC, Kolkata has the potential to produce the much in demand Gallium-68 by natGa(p,xn) (represented by ^{69}Ga(p,2n) + ^{71}Ga(p,4n) reactions

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Synopsis of the Book: "The Saga of Atomic Energy in India – Why Nuclear Power is still sub critical? by Dr Mahadeva R. Iyer , published by AUTHORS PRESS, New Delhi

The book traces the history of evolution of the Atomic Energy program in India from its very inception under the pioneering leadership of Dr Homi Bhabha as seen by one who was involved with the program as a "bystander" away from the policy making circles. It traces the phenomenal foresight of Dr Bhabha in making the country the 5th in the world to start nuclear operations in India. The author reminiscences the exciting moments in the march of a country that just came out of the shackles of a century of foreign domination. The book analyses the remarkable achievements of the Atomic Energy Program in the face of stifling international control regimes, discusses the reason why it remains still sub critical in Nuclear Power, gives a realistic prediction of nuclear power growth in the next 2 to 3 decades and goes on to suggest possible steps to make it relevant to the national context "sooner than later". It also contains reprints of 65 or so articles written on the topic by the author in the last 15 years.

The Foreword for the book is by Dr Srikumar Banerjee, Former Chairman, Atomic Energy Commission. He considers it ***"an authentic description of the evolution of the Atomic Energy Program in India as captured by the author that has perhaps never been done before".*** Book is available on Amazon.in.

News Snippets

75th Anniversary of the Trinity Nuclear Tests, 16 July 2020 - Nuclear Testing's Discriminatory Legacy Must Never be Forgotten: UN expert

"The hazards of nuclear testing continue to affect the lives of many innocent victims and governments worldwide should redouble efforts for global nuclear disarmament" – From the statement issued by Baskut Tuncak, the UN Special Rapporteur on toxics on the 75th anniversary of the Trinity tests. https://www.ohchr.org/EN/NewsEvents/Pages/DisplayNews.aspx?NewsID=26103&LangID=E

Pro-nuclear Energy Protesters rally against Greenpeace in Paris

A group of pro-nuclear protesters demonstrated against the closure of a major reactor in France on Monday - taking their rally to the Paris headquarters of Greenpeace. The protest comes as state-controlled utility EDF plans to shut down the second and last ageing nuclear reactor of its Fessenheim plant near the German border overnight. The French government is working to reduce the share of atomic power in its electricity mix to 50% by 2035 from the more than 71% currently, as well as to promote more renewable energy, sparking an intense debate. Advocates of nuclear power say it is essential to providing sufficient quantities of carbon-free energy to balance intermittent renewable sources, such as wind and solar.

https://www.reuters.com/article/us-france-nuclear-protest/pro-nuclear-energy-protesters-rally-against-greenpeace-in-paris-idUSKBN2402QN

UAE Completes Construction of Barakah 2

The Emirates Nuclear Energy Corporation (ENEC) has completed the construction of unit 2 of the Barakah nuclear power plant. The unit, which is in the Al Dhafra region of Abu Dhabi, has been officially handed over to ENEC subsidiary Nawah Energy Company.

Nuclear News (New Nuclear), July 15, 2020

Low Dose Lung Radiotherapy – an Alternative Route to Treat Pneumonia linked to COVID-19

Low dose lung radiotherapy (LDRT) can effectively remove the inflammation of the lungs and therefore can be effective in saving the lives of critically ill patients with respiratory failures caused by various pathogenic organisms including COVID-19. As of today, dozens of hospitals across the USA and Germany are using LDRT to treat and save the lives of seriously ill COVID-19 patients. India with its highly capable scientific staff in nuclear sciences and outstanding medical experts in viral diseases and their treatment would be able to contain COVID-19 which is rapidly becoming pan-endemic.

Current Science Vol. 118 N0. 12, June 25, 2020 (Editorial)

Indian Firm Completes ITER Cryostat Manufacture

Indian company Larsen & Toubro (L&T) Heavy Engineering Ltd has completed the final segment of the ITER cryostat, bringing to an end an eight-year work programme. Work on the cryostat will now continue at the ITER site in southern France where the sections will be assembled, sited and welded over the next four years. The first completed section - the cryostat base - was installed in ITER's Tokamak pit in May.

https://world-nuclear-news.org/Articles/India-completes-ITER-cryostat-manufacture

CANDU unit sets North American Operating Record

On 10 July 2020**,** Darlington unit 1 set a new Canadian and North American nuclear record with 895 consecutive days of unbroken operation. Ontario Power Generation's (OPG) Candu **reactor has now been online since 26 January 2018.** The previous record of 894 days was held by unit 7 at OPG's Pickering plant.

https://world-nuclear-news.org/Articles/Candu-unit-sets-North-American-operating-record

New Material Finally Makes it into the Almighty Nuclear Code

Scientists working at Idaho National Laboratory (INL) have announced the approval of a new high-temperature metal after 12 years and a $15 million Department of Energy investment. Alloy 617, a “combination of nickel, chromium, cobalt and molybdenum,” is tolerant and strong at temperatures of more than 1,700 degrees Fahrenheit. It could be used in existing high temperature nuclear facilities as well as cutting-edge applications like molten salt reactors.

https://www.popularmechanics.com/science/a30260390/new-material-high-temperature-nuclear-code/

Report on Safety Lessons Learned from Nuclear Power Plant Operating Experiences Worldwide (2015-2017)

The seventh edition of the IAEA/NEA Nuclear Power Plant Operation Experience has been published, providing an overview of lessons learned by operators during the 2015-2017 period.

https://www.iaea.org/newscenter/news/now-available-report-on-safety-lessons-learned-from-nuclear-power-plant-operating-experiences-worldwide-2015-2017

Nuclear Technology Helps to Develop Heat-Tolerant Tomato Varieties in Mauritius

The IAEA, in partnership with the FAO, assisted the National Food and Agricultural Research and Extension Institute (FAREI), Mauritius to develop new tomato varieties named Summer King, Summer Star and Rising Star using radiation.

https://www.iaea.org/newscenter/news/nuclear-technology-helps-to-develop-heat-tolerant-tomato-varieties-in-mauritius

COVID-19 and Low Carbon Electricity: Lessons for the Future
The COVID-19 pandemic has transformed the operation of power systems across the globe and offered a glimpse of a future electricity mix dominated by low carbon sources. The performance of nuclear power, in particular, demonstrates how it can support the transition to a resilient, clean energy system well beyond the COVID-19 recovery phase.
https://www.iaea.org/newscenter/news/covid-19-and-low-carbon-electricity-lessons-for-the-future

Baobab Trees can Predict Climate Change
Baobab trees can live longer than 2,500 years. This video shows how scientists in South Africa use nuclear technology to analyse wood extracts of Baobab tree and help forecast future climate change.
https://www.iaea.org/newscenter/multimedia/videos/baobab-trees-can-help-predict-climate-change

Farming on Poor Soil with Little Rainfall in Kenya's Drought-prone Areas: Isotopes Used to Develop New Strategies.
Despite poor soil fertility and water scarcity, thousands of farmers in Kenya have increased their crop yields by 17-20% and saved 20% of their fertilizer costs thanks to climate-smart agricultural techniques, introduced with the support of the IAEA, in partnership with FAO.
https://www.iaea.org/newscenter/news/farming-on-poor-soil-with-little-rainfall-in-kenyas-drought-prone-areas-isotopes-used-to-develop-new-strategies

Fire at Uranium Enrichment Facility of Iran
The IAEA has been informed by Iran about a fire in a building at the site of the Natanz uranium enrichment facility early on July 2, 2020. Iran said the cause was not yet known, adding there were no injuries or radioactive contamination.
https://www.iaea.org/newscenter/pressreleases/iaea-informed-about-natanz-incident-safeguards-activities-to-continue

Low Levels of Radioisotopes Detected in Europe Likely Linked to a Nuclear Reactor The recent detection of slightly elevated levels of radioisotopes in northern Europe is likely related to a nuclear reactor that is either operating or undergoing maintenance. The IAEA reiterated that the observed air concentrations of the particles were very low and posed no risk to human health and the environment.
https://www.iaea.org/newscenter/pressreleases/low-levels-of-radioisotopes-detected-in-europe-likely-linked-to-a-nuclear-reactor-iaea

Started with IAEA Support, China's Electron Beam Industry Opens World's largest Wastewater treatment facility
The world's largest wastewater treatment facility using electron beam technology was inaugurated in China this month. Built on technology transferred by the IAEA, the treatment process will save 4.5 billion litres of fresh water annually.
https://www.iaea.org/newscenter/news/started-with-iaea-support-chinas-electron-beam-industry-opens-worlds-largest-wastewater-treatment-facility

IAEA Releases 2019 Data on Nuclear Power Plants Operating Experience
The IAEA released its annual nuclear power status data for 2019 collected by the Power Reactor Information System (PRIS). At the end of December 2019, the global operating nuclear power capacity was 392.1 GW(e), comprising 443 operational nuclear power reactors in 30 countries. Throughout 2019, nuclear power supplied 2586.2 TWh of emission-free, low-carbon baseload electricity. At the end of 2019, over 57.4 GW(e) of capacity (54 reactors) was under construction in 19 countries, including four that are building their first nuclear reactor.
https://www.iaea.org/newscenter/news/iaea-releases-2019-data-on-nuclear-power-plants-operating-experience

Towards Improved Cancer Treatment: IAEA and Okayama University to Cooperate in Boron Neutron Capture Therapy R&D
Boron Neutron Capture Therapy (BNCT) is a non-invasive therapeutic technique for treating invasive malignant tumours. IAEA and Japan's Okayama University have signed an agreement that provides a three-year framework for enhanced cooperation in this area.
https://www.iaea.org/newscenter/news/towards-improved-cancer-treatment-iaea-and-okayama-university-to-cooperate-in-boron-neutron-capture-therapy-r-and-d

Drone Test Yields Breakthrough for Use of Nuclear Technique to Fight Mosquitoes - IAEA Study

The use of drones can significantly increase effectiveness and reduce costs in the application of Sterile Insect Technique (SIT) to suppress disease-carrying mosquitoes, according to an International Atomic Energy Agency (IAEA) study. The finding marks an important step forward towards the large-scale deployment of this method to control the vectors of dengue, yellow fever and Zika.
https://www.iaea.org/newscenter/pressreleases/drone-test-yields-breakthrough-for-use-of-nuclear-technique-to-fight-mosquitoes-iaea-study

IAEA Launches Initiative to Help Prevent Future Pandemics

The International Atomic Energy Agency has launched the Zoonotic Disease Integrated Action project, or ZODIAC. The ZODIAC project will establish a global network to help national laboratories in monitoring, surveillance, early detection and control of animal and zoonotic diseases such as COVID-19, Ebola, avian influenza and Zika.
https://www.iaea.org/newscenter/pressreleases/iaea-launches-initiative-to-help-prevent-future-pandemics

IAEA Opens New Laboratory to Help Countries Tackle Health, Food and Climate Change Challenges

IAEA has opened a state of the art laboratory named after Yukiya Amano, the former Director General, IAEA. The new facility will increase the IAEA's capacity to assist countries to fight and prevent trans boundary animal and zoonotic diseases like COVID-19 and to tackle challenges related to climate change and food safety.
https://www.iaea.org/newscenter/pressreleases/iaea-opens-new-laboratory-facility-to-help-countries-tackle-health-food-and-climate-change-challenges

Dozens of Countries Receive COVID-19 Testing Equipment from the IAEA

IAEA has so far delivered more than 250 consignments to 80 countries with supplies to help fight against the COVID-19 pandemic, with many more to be shipped in the coming weeks.
https://www.iaea.org/newscenter/pressreleases/dozens-of-countries-receive-covid-19-testing-equipment-from-the-iaea

Drought Tolerant Crops: IAEA and FAO Help Zambia Improve Production and Farmers' Income

Two new varieties of cowpea, a major source of protein in Zambia, developed using nuclear technologies are being released to offer significantly improved yields and quality to farmers and the community at large. Seeds of these varieties will be available to farmers of Zambia later this year.
https://www.iaea.org/newscenter/news/drought-tolerant-crops-iaea-and-fao-help-zambia-improve-production-and-farmers-income

Malian Farmers Adapt to Climate Change, Improve Water Use, Crop Yield and Livelihood Using Nuclear Techniques

Since 2014, the IAEA, in partnership with FAO, has provided expert advice, laboratory and field equipment and consumables on the use of nuclear and isotopic techniques to track fertilizer and water use efficiency in the semi-arid Sahel region of Segou in central Mali . Participating farmers have reported a 37% increase in crop yield and a 43% reduction in water use for irrigation.
https://www.iaea.org/newscenter/news/malian-farmers-adapt-to-climate-change-improve-water-use-crop-yield-and-livelihood-using-nuclear-techniques

Argentina's Newly Recognized Fruit Fly Free Areas Expedite Fresh Fruit Exports to China

Argentina's areas growing cherries and other stone and pome fruits have been recognized as fruit fly free by China, enabling exports to the world's largest fresh food market. This was achieved with the help of nuclear techniques through the support of the IAEA in partnership with FAO.
https://www.iaea.org/newscenter/news/argentinas-newly-recognized-fruit-fly-free-areas-expedite-fresh-fruit-exports-to-china

Radiation Technologies Give Panamanian Experts a Glimpse below the Surface of the Panama Canal's Waters

With IAEA support, experts in Panama have learned how to leverage radiation technologies to model the movement of sediments in the Panama Canal as well as in nearby lakes. On the basis of these models, they are planning to develop new dredging practices to ensure the continued flow of people and products through this world-famous maritime route.

https://www.iaea.org/newscenter/news/radiation-technologies-give-panamanian-experts-a-glimpse-below-the-surface-of-the-panama-canals-waters

Nuclear Techniques Support Crop Production on Salt-affected Soils in Middle East

Through its technical cooperation programme, and in partnership with the FAO, the IAEA trained and worked with 60 scientists from Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, the United Arab Emirates and Yemen, who are now using nuclear and isotopic techniques to improve crop yields on salt-affected soils.
https://www.iaea.org/newscenter/news/nuclear-techniques-support-crop-production-on-salt-affected-soils-in-middle-east

Benin Enhances Production and Export of Soybean Using Bio-fertilizers and Isotopic Technology

With support from the IAEA and the FAO, researchers at the University of Abomey-Calavi in Benin, the National Agricultural Research Institute of Benin (INRAB) and several local and international NGOs have helped local farmers to increase the yields of soybean through use of inoculum, a biofertilizer. Isotopic techniques were used to establish this efficacy and the ability of the plants to uptake the biofertilizer and fix nitrogen from the air.
https://www.iaea.org/newscenter/news/benin-enhances-production-and-export-of-soybean-using-bio-fertilizers-and-isotopic-technology

Nuclear Technique Opens New Markets for Ecuador's Fruits

Ecuador, one of the largest producers of tropical fruit in the Western Hemisphere, is adding non-traditional fruits to its export portfolio as a result of successfully fighting off the Mediterranean fruit fly with the help of Sterile Insect Technique (SIT). The farmers are now shipping golden berries, dragon fruit and tree tomatoes to markets in the United States, Latin America and the European Union.
https://www.iaea.org/newscenter/news/nuclear-technique-opens-new-markets-for-ecuadors-fruits

Turning 60 and Far from Retirement: Happy Birthday, Global Network of Isotopes in Precipitation!

Initiated in 1960 by the IAEA in cooperation with the World Meteorological Organization (WMO), the Global Network of Isotopes in Precipitation (GNIP) has become the world's largest and most comprehensive collection of isotope data in atmospheric waters, helping scientists worldwide to study the global water cycle and the origin, movement and history of water. In the last 60 years, the GNIP has collected more than 130,000 monthly isotope records in collaboration with many contributors from around the world.
https://www.iaea.org/newscenter/news/turning-60-and-far-from-retirement-happy-birthday-global-network-of-isotopes-in-precipitation

World's Only floating nuclear power plant goes fully operational in Russia

A one-of-a-kind floating nuclear power plant - Akademik Lomonosov designed and built by Russia, has become the most northerly nuclear facility in the world, as it begins commercial operations in a small town called Pevek in the far eastern region of Chukotka. It is equipped with two KLT-40S icebreaker nuclear reactors, generating up to 70 megawatts of electricity and 50 gigacalories an hour of heat energy. The unique characteristic of this plant is its ability to provide heat, electric energy, and drinking water to the region.
https://www.rt.com/business/489551-russia-floating-nuclear-plant

Researchers Make Nuclear Fusion Safer and More Stable in Groundbreaking Discovery

A new study by researchers from Princeton University has claimed that they have found new methods for making nuclear fusion safer and, therefore, possible. It is a system where the plasma could be molded in such a way that it reacts as the team desires it to. In addition, the system also handles Magnetic Islands, bubble-like structures that are capable of releasing a high amount of energy at any time, making fusion reactions extremely dangerous. The researchers claim, sending radio waves through a fusion reaction can thwart these Magnet Islands from building up by hindering the flow of plasma and keeping the temperature under check. This process makes fusion reaction safer and more stable.
https://interestingengineering.com/researchers-make-nuclear-fusion-safer-and-more-stable-in-groundbreaking-discovery

> "We cannot solve problems with the same thinking we use to create them."
>
> – Albert Einstein

Conferences/Competitions

Call for Papers: International Conference on Applications of Radiation Science and Technology

Interested contributors have until 31 July 2020 to submit abstracts for the Second International Conference on Applications of Radiation Science and Technology (ICARST-2021), to be held at IAEA headquarters in Vienna, Austria, from 19 to 23 April 2021.
https://www.iaea.org/newscenter/news/call-for-papers-international-conference-on-applications-of-radiation-science-and-technology

Crowdsourcing Competition: Call for Innovative Solutions Deployed at Nuclear Power Plants

IAEA has announced a crowdsourcing competition on innovations that nuclear power plants can use to boost their competitiveness. The innovations should be based on practices already in place at power plants. Selected participants will be invited to present their work at the annual Nuclear Operators' Forum, planned to be held on the sidelines of the 64th IAEA General Conference, in September 2020. Last date of submission is 15 August 2020.
https://www.iaea.org/newscenter/news/crowdsourcing-competition-call-for-innovative-solutions-deployed-at-nuclear-power-plants

Join us on August 26, 2020 for the Next GEN IV Webinar: Molten Salt Reactor Safety Evaluation – A US Perspective

Reactor safety evaluation historically focused on maintaining adequate containment of radionuclides during the maximum credible accident. However, as progressively larger light water-cooled reactors (LWRs) were developed in the 1960s, the increased potential for catastrophic accidents necessitated expanding the safety adequacy from the containment of radionuclides under all conditions to the prevention of accidents and the mitigation of their consequences.

MSR designs as envisioned have a readily apparent high degree of passive safety. Their combination of low pressure, low stored energy within containment, negative reactivity feedback, and effective passive decay heat removal substantially reduces the potential for cascading and escalating events. This MSR resiliency opens an alternative demonstration pathway that refocuses safety adequacy on containment of credible accidents, precluding the need for complete probability information.

August 26, 2020 at 8:30 am (EDT) (UTC -4)

For more information, please contact: Patricia Paviet at Patricia.Paviet@pnnl.gov or visit the GEN IV International Forum website at www.gen-4.org

Compiled by S. K. Malhotra

The views and opinions expressed by the authors may not necessarily be that of INS

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