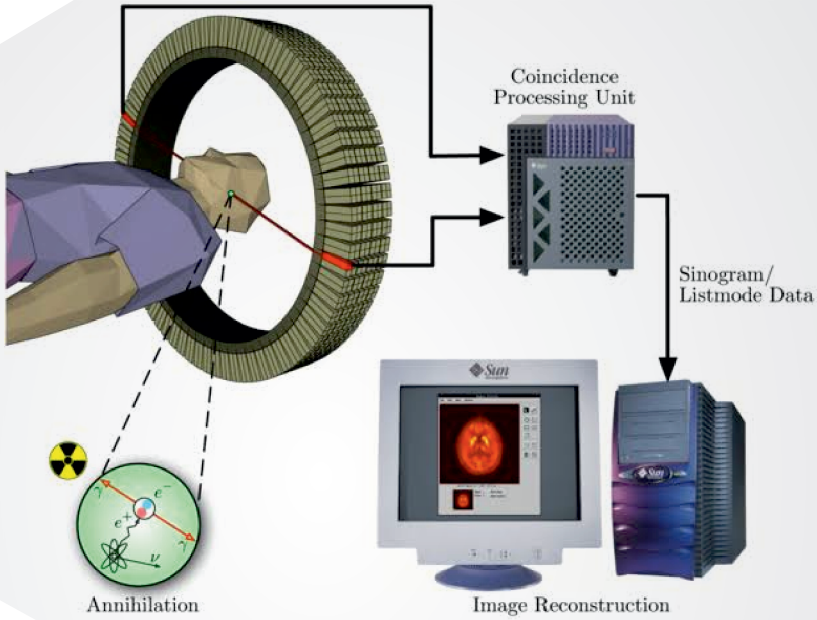

Positron Emission Tomography of brain with [Fluorine-18]-2-Fluoro-Deoxy-Glucose

INDIAN NUCLEAR SOCIETY

INS Newsletter

JAN-FEB-MAR-2023 - VOL 23 ISSUE 1
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TECHNOLOGIES FOR
NEW INDIA@75

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PRESIDENT'S DESK

PROF. B.N. JAGATAP

Dear Fellow Members,

Warm Greetings from the Indian Nuclear Society (INS).

You are aware that the new executive committee (EC) has taken over the functioning of INS from December 10, 2022. The outgoing EC, led by Shri S.K. Mehta, deserves special compliments on its achievements despite the great challenge posed by the Covid-19 pandemic.

We have now reorganized the activities of INS under seven verticals; namely, publication; social media; technical discussions; outreach programs; conferences and workshops; students' forum; and policy and science diplomacy. The programmes organized so far under some of these verticals include, a technical discussion meeting, a joint conference at Aluva, Kerala and a two-day workshop-cum-outreach program at Amravati, Maharashtra.

The technical discussion meeting was held on January 21, 2023 at the AERB auditorium, Mumbai. The discussion was led by Dr. A.K. Nayak, Head, NCPW, DAE, who gave a detailed and inspired presentation on the topic, *'Relevance of Small and Modular Reactors in Indian Energy Scenario: Challenges and Opportunities'*.

The conference at Aluva was organized during February 23-24, 2023 in collaboration with Atomic Energy Retirees' Association Kerala and UC College, Aluva. The theme of the conference was, *Nuclear Energy: Its Generation and Applications,* and it covered topics such as advantages of nuclear power, nuclear fusion and nuclear hydrogen, accelerator technologies, nuclear medicine, nuclear agriculture, rare earths, nuclear waste management, radiological safety and environmental issues.

INS organized a two-day programme at Brijlal Biyani College at Amravati during March 24-25, 2023. The first day of this program consisted of a technical workshop on *'Nuclear Medical Diagnostic Techniques'*. The second day was a public outreach program under the theme, *'Nuclear Science & Technology for Sustainable Development'*.

Our esteemed readers are very well aware of the role of nuclear energy in the sustainable development. The Agenda-2030 of UN lists 17 sustainable development goals (SDGs), which include, (1) No poverty, (2) No hunger, (3) Good health, (4) Quality education, (5) Gender equality, (6) Clean water and sanitation, (7) Renewable energy, (8) Good jobs and economic progress, (9) Innovation and infrastructure, (10) Reduced inequalities, (11) Sustainable cities and communities, (12) Responsible consumption, (13) Climate action,

(14) Life below water, (15) Life above land, (16) Peace and justice, and (17) Partnership for the goals. Achievement of many of these goals require science and technology inputs. It is important to note that the nuclear science and technology cover almost all these science and technology centric SDGs.

Significant discussion exists in the literature on the role of nuclear energy in climate action (Goal 13). In this regard, I would like to draw attention of INS life members to an important article, *'An attainable global vision for conservation and human well-being'*, by H.M. Mallis et al and published in Frontiers in Ecology and the Environment, 16, 563-570 (2018). Some of the data provided in this publication is worth mentioning here, Current world energy mix consists of 76% fossil fuels, 16.2% renewables and 7.8% nuclear. If this energy mix is continued (business as usual), by 2050 CO_2 content of the atmosphere will reach 520 ppm and the rise in temperature will be 3.2°C. This is an unacceptable scenario since as per COP26, the rise in temperature will have to be restricted to 1.5°C by 2050. The above referred paper provides a sustainable pathway for 2050 which involves an energy mix consisting of 54% renewables, 33% nuclear and 13% fossil fuels. This energy mix will limit CO2 content of atmosphere to 442 ppm and temperature rise to 1.6°C. This sustainable scenario underlines the important role of nuclear energy in climate action.

Let us now take into account other SDGs. Goal 2 (No hunger) is related to two aspects, i.e. increase in the food productivity and minimization of the food waste. Importantly both fall in the domain of our nuclear energy program production of high yielding seed varieties by radiation mutation and radiation processing of foods. There are several success stories in these domains in Indian nuclear energy programme.

Readers will immediately recognize the contribution of nuclear medicine in Goal 3 (Good health) and the role of Homi Bhabha National Institute in achievement of Goal 4 (Quality education). Relevance of Indian nuclear energy programme to Goal 6 (Clean water) is very clear considering a large body of work on desalination and water purification technologies. In this context a mention must also be made to the work on isotope hydrology or recharging dry springs in the Himalayan region, and a large number of on-field techniques developed for detection of natural contaminants (fluoride, arsenic, chromium, iron etc.).

Indian nuclear energy programme connects to Goal 9 (Innovation and infrastructure) through the development of the state-of-the-art research infrastructure, i.e., accelerators, synchrotron radiation sources and beamlines, ad various telescopes. The sludge hygienisation technology is a step towards the Goal 11 (Sustainable cities and communities). Indian nuclear energy programme has always cared for the flora and fauna; some of the famed examples are Hornbills of Kaiga, Egyptian vultures of Narora, and spot billed Pelicans of MAPP. These examples connect us to the Goal 14 (Life below water) and Goal 15 (Life above land).

Finally, Goal 17 is related to partnership for the goals; the most important one that we talk here is our partnership in ITER program for limitless green energy beyond 2050.

INS life members will surely appreciate the use of the sustainable development platform to showcase the achievements of the Indian nuclear energy programme. We shall be using it often for our public outreach programmes. We are open to suggestions from our members; please write to me on indiannuclearsociety@gmail.com.

We are also happy to release the first issue of INS News under the newly constituted Editorial Board. We look forward to the active participation of everyone of you in furthering the objectives of our society.

Wishing you every best in your endeavours.

(B.N. Jagatap)

NUCLEAR MEDICINE IMAGING:
Techniques, Radiopharmaceuticals and Radiation Safety

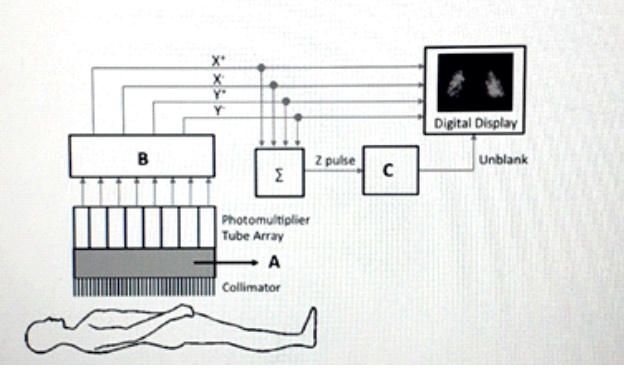
Sushama Awasare, M. K. Ray, Savita Kulkarni, Kamaldeep, M.G.R. Rajan[1]
Radiation Medicine Centre, Bhabha Atomic Research Centre, TMH Annexe, Mumbai 400012
[1]Ex-Radiation Medicine Centre

Medical imaging is the process of visual representation of different tissues and organs of the human body to monitor the normal and abnormal anatomy and physiology of the body, mostly for medical diagnoses. Medical diagnosis is the process of identifying disease from its symptoms, patient's history and clinical workup of the patient. Clinical-workup - the process of obtaining all of the necessary data for diagnosing and treating a patient - will include physical examination, laboratory tests, and may include one or more of the medical imaging techniques available for this purpose. Imaging Techniques, currently available include X-ray, computed tomography (CT), magnetic resonance imaging (MRI), digital mammography, and diagnostic sonography (US) which are in the domain of radiological procedures while single-photon emission computed tomography (SPECT) and positron emission tomography (PET) are termed nuclear medicine (NM) procedures. No one imaging modality can be considered 100% sufficient for diagnosis, and combinations improve probability of correct diagnosis.

NM-imaging has many applications in oncology (cancer/malignancy of different tissues), neurology (brain and nerve disorders), cardiac (heart), congenital heart disease, abdominal illnesses (Gastro-intestinal tract organs), urology (kidney and bladder diseases) skeletal diseases (bone fractures and bone-metastasis), and other medical conditions with patho-physiological aberrations.

Nuclear medicine (NM) is a medical specialty that involves the administration of radioactive isotopes - usually attached to biomolecules/drugs (described later in this article) - for the diagnosis and treatment of various diseases. NM-imaging enables clinicians to identify specific molecular activity and altered physiological functions within tissues and organs of the body, facilitating the early detection of disease and the rapid monitoring of therapeutic responses non-invasively and precisely. Radionuclide imaging is the most important application of radioactivity in NM-imaging. Radionuclide imaging facilities are found in almost every major hospital, performing hundreds and even thousands of imaging procedures per month in larger institutes. NM-imaging, in a sense, is "radiology done inside out" because it records radiation emitting from within the body rather than radiation that is generated by external sources like X-rays. In addition,

nuclear medicine scans differ from radiology, as the emphasis is not on imaging anatomy, but on the function. For such reason, NM is also called a 'physiological imaging modality'.



Schematic diagram of a typical gamma camera.

A. Collimator to collect radiation from the patient to ensure spatial resolution of data collected.

B. Electronics that use the light scintillations from the photomultiplier array, and determines spatial resolution of the distribution of the RPs administered to the patient.

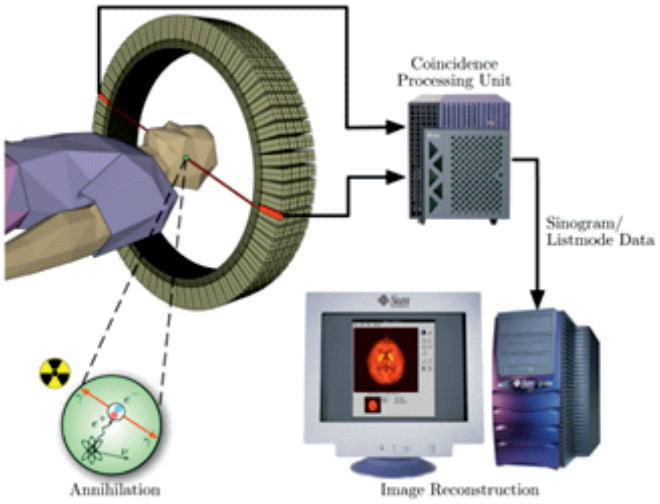
C. Analyser that enables scintillation data to be used to generate 3-D images.

In NM-imaging (also referred to as radionuclide scanning), a radioisotope or radio-pharmaceutical or tracer is introduced into the body, orally or by intravenous injection. The administered tracer enters the circulation and is then taken up by the diseased organ(s), proportional to the extent and intensity of the disease in the organ(s). Its distribution can be determined by recording the radiation it emits, using Gamma Camera or PET-scanner consisting of scintillation detectors. Modern Gamma cameras use thallium activated sodium iodide (NaI(Tl)) crystals, while PET-scanner use BGO and LYSO[1] crystals as the radiation detector. Other components of Gamma camera are collimators, array of photomultiplier tubes and associated electronics. The purpose of the collimator is to define the geometric field of view of the crystal and specifically to define the desired direction of travel of gamma rays allowed to reach the NaI(Tl) scintillator. Photomultiplier tube detects the visible light produced by the scintillator and converts it to a measurable electronic signal. Using images acquired by Gamma camera, it is often possible to recognize the presence, size, and shape of various abnormalities in body organs.

SPECT is a nuclear medical imaging technique which creates a 3D view of radiotracer distribution in the human body using a specialized Gamma camera with two-detector assemblies. To create 3D images, many projection images of the body at different time frames are needed. ^{99m}Tc and ^{131}I are the most commonly used SPECT radio-isotopes.

PET imaging uses a dedicated PET-scanner to generate 3D images of the localization of the radiopharmaceuticals administered to the patient. The difference between SPECT- and PET-imaging is essentially due to the types of tracers used. The tracer used for PET emits particles known as positrons which annihilates with electron and produces two 511 Kev photons which are emitted opposite to each other. These two photons are detected simultaneously by two opposite detectors placed in coincidence. ^{18}F, ^{11}C. ^{13}N. ^{15}O and ^{68}Ga are the radioisotopes which are commonly used for PET imaging.

[1] BGO is Bismuth Germanate scintillation crystal while LYSO is **a Cerium doped Lutetium-Yttrium-based scintillation crystal.** Both offers several benefits compared to many common scintillation materials. LYSO offers high density and short decay time and an exceptional high photon-emission rate, compare to BGO but is more expensive.



Schematic diagram of PET imaging.

The PET gantry composed of a ring of BGO or LYSO crystals that record the coincident radiation from the patient and the data is electronically analysed and converted into 3-D computed tomographic images.

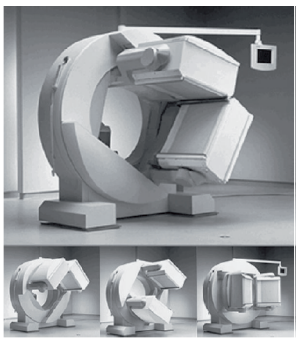
Hybrid Imaging: SPECT/CT and PET/CT

Virtually all modern PET-scanners and an increasing number of SPECT systems are integrated with CT-scanners. These ***hybrid imaging systems*** can acquire PET or SPECT images, along with spatially registered CT images, in quick succession. Both SPECT and PET provide functional information. Although for some radio tracers, the regional anatomy is obvious (e.g., cardiac perfusion studies), there are many cases in which the nuclear medicine study does not provide much in the way of anatomic information. Since clinical decisions may depend not only on increase or decrease in the accumulation of a radiotracer but also on knowing precisely where that signal originated, it has been common practice to complement tomographic nuclear medicine scans with CT or MRI scans The power of hybrid imaging systems, in which a PET or SPECT scanner is integrated with a CT scanner, is that the two scans are acquired in quick succession, and thus the data can be considered to be in fairly good spatial and temporal registration. With good spatial registration, it also becomes possible to consider using the CT scan, which provides a map of tissue attenuation values to compute the corrections for photon attenuation and scatter for the PET and SPECT studies.

Recent advances

PET/MRI has been introduced into clinical practice about a decade ago. A PET/MRI scan is a two-in-one test that combines images from a PET scan and a MRI scan. This new hybrid technology harnesses the strengths of PET and MRI to produce some of the most highly detailed pictures of the organ.

Single Head Gamma Camera



Dual Head Gamma Camera

SPECT Gamma Camera

PET-CT Scanner

PET-MRI Scanner

Radiopharmaceuticals – what are they?

A radiopharmaceutical has two components: a radionuclide (tracer) and a pharmaceutical. The usefulness of a radiopharmaceutical is dictated by the characteristics of these two components. Although the radiopharmaceutical is most used term, others such as tracer, radiotracer, radio-diagnostic agent, etc., are also used.

In nuclear medicine, nearly 95% of the radiopharmaceuticals are used for diagnostic purposes, while those used for therapy constitute 5%. The diagnostic radiopharmaceuticals are further categorised as SPECT radio-pharmaceuticals (labelled with radio-isotopes emitting Gamma rays of suitable energy) or PET radiopharmaceuticals (labelled with radio-isotopes that emit positrons). Positrons collide with electrons and the result is that the positron-electron pair annihilate and convert their mass into two 511 keV gamma rays emitted in opposite directions. Diagnostic radio-pharmaceuticals usually have no or negligible pharmacologic effect, because they are always used in tracer quantities.

What are the ideal characteristics for diagnostic radiopharmaceuticals?

An ideal radiopharmaceutical should have the following characteristics to provide maximum efficacy in the diagnosis of diseases, with minimum dose to patient.

1. The radiopharmaceutical required in any nuclear medicine facility should be readily available, easily formulated and affordable. In addition, it should have a relatively short effective half-life, which should not be longer than the time necessary to complete the study in question.

2. Radionuclides having particulate emission (decaying by alpha or beta particle emission) should not be used as the label in diagnostic radiopharmaceuticals. Radionuclides with gamma ray emission (which decays by electron capture or isomeric transition without any internal conversion) with energy between 30 and 300 keV is preferable.

3. Below 30 keV, γ rays are absorbed by tissue and are not detected by the NaI(Tl) detector. Above 300 keV, effective collimation of γ rays cannot be achieved with commonly available collimators, and image quality is not satisfactory, unless specially designed collimators are used as is used for I-131

4. The radiopharmaceutical should be able to demonstrate larger target-to-nontarget activity ratio.

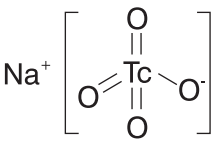
5. Every radiopharmaceutical has a physical half-life (Tp)owing to decay characteristic of the radionuclide. A radiopharmaceutical owing to its biological property will disappear from the human body in exponential manner through urine, faeces or perspiration. This is called biological half-life (Tb). The effective half-life Te is related to Tp and Tb by the equation:

$$\frac{1}{T_e} = \frac{1}{T_e} + \frac{1}{T_e}$$

6. For any diagnostic study, it is desirable that the radiopharmaceutical be localized preferentially in the organ under study since the activity from nontarget areas can obscure the structural details of the picture of the target organ.

SPECT Radiopharmaceuticals – preparation and application

More than 80% of radiopharmaceuticals used in nuclear medicine are ^{99m}Tc-labeled[2] compounds because of its favourable physical and radiation characteristics. The 6-hr physical half-life and very less the little amount of electron emission permit the administration of millicurie amounts of ^{99m}Tc radioactivity without significant radiation dose to the patient. Moreover, the 140-keV photons emitted due to decay of ^{99m}Tc is monochromatic in nature and are readily collimated to give images



Chemical formula of 99m-TcO_4^-

of superior spatial resolution. Furthermore, ^{99m}Tc is readily available in a sterile, pyrogen-free, and carrier-free state from ^{99}Mo–^{99m}Tc generators. The chemical form of ^{99m}Tc available from the moly generator is sodium pertechnetate (^{99m}Tc-$NaTcO_4$). The oxidation state of ^{99m}Tc in pertechnetate ion, $^{99m}TcO_4^-$, is 7+ which is non-reactive in nature. A reducing agent (for example stannous chloride) is used to reduce the ^{99m}Tc to lower oxidation state where complexation with required ligands can be facilitated. Usually cold kits used for making ^{99m}Tc labelled radio-pharmaceuticals houses a suitable reducing agent and a ligand or a pharmaceutical. The pertechnetate eluted from ^{99}Mo–^{99m}Tc generator is conveniently added to the cold kit vial aseptically by means of a syringe.

Radioiodine in the form of ^{131}I- NaI or ^{131}I-MIBG (meta iodo benzyl guanidine) in certain cases is used as a SPECT diagnostic agent. ^{123}I having a half-life of 13.2 hours and photon energy of 153keVis a suitable diagnostic radionuclide and is a better alternative to ^{131}I. It is a cyclotron produced radionuclide and its production is very expensive.

Radionuclides used in NM-imaging by SPECT.

Radioisotope	Decay Mode	Energy emission	Half Life (Hour/Day)
99mTc	Isomeric transition	140 keV	6.03 h
131I	Beta emission	360 keV	8 d
201Tl	Electron capture	68–80 keV × rays	3.05 d
67Ga	Electron capture	93, 185, 300 keV	3.26 d
111In	Electron capture	171, 245 keV	2.8 d
123I	Electron capture	159 keV	13.2 h
133Xe	Beta emission	81 keV	5.25 d

Radioisotopes used in NM-imaging. Of these 99mTc and 131I are the most commonly used. 123I has excellent emission characteristics that makes it suitable for SPECT, but is cyclotron produced and is expensive.

Technetium is a transition metal of silvery grey colour belonging to group VIIB (Mn, Tc, and Re) and has the atomic number 43. No stable isotope of technetium exists in nature. The ground state ^{99}Tc has a half-life of $2.1X10^5$ years. The electronic structure of the neutral technetium atom is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^6\ 5s^1$. Technetium can exist in eight oxidation states, namely, -1 to 7+, which result from the loss of a given number of electrons from the 4d and 5s orbitals or gain of an electron to the 4d orbital.

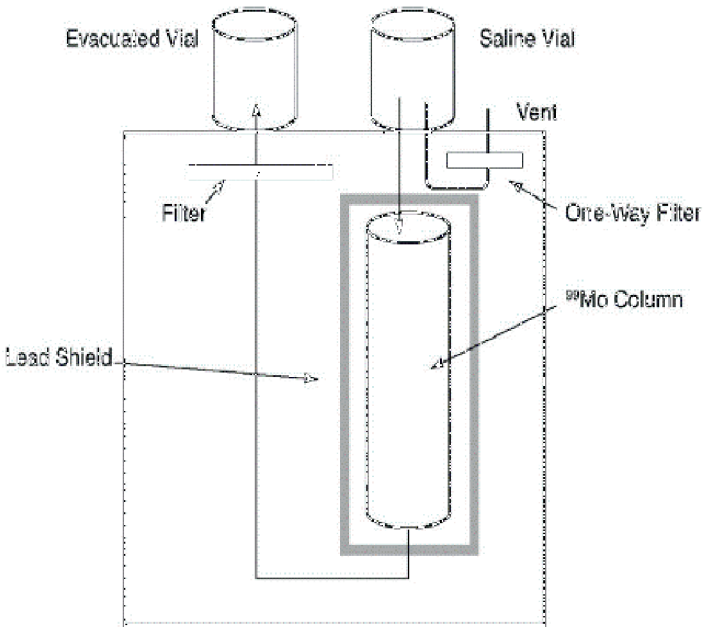
Preparation of ^{99m}Tc-Radiopharmaceuticals

Because of their short half-life, all NM-Radio-pharmaceuticals are prepared in-house in a dedicated hospital radiopharmacy setup. The ^{99}Mo–^{99m}Tc generator is placed in a fume hood where the elution of pertechnetate is done. There are cold kits available for various studies. The manufacturer provides the information about the required amount and volume of radioactive pertechnetate to be injected to the vials. Some preparation requires heating in boiling water bath for 5-10 min. Usually the injections are prepared in a cabinet with class 100 air flow. After the injection is prepared, a small dose is withdrawn and a paper chromatography is performed to ascertain the purity of the radiopharmaceuticals before dispatching to the clinic. All radio-pharmaceutical preparation is accompanied with documentation and proper waste disposal procedure.

Selected Examples of 99mTc-RPs	NM-Imaging
^{99m}Tc-Sodium TcO4-	Thyroid gland and Salivary gland scintigraphy
^{99m}Tc-MDP (methylene diphosphonate)	Skeletal scintigraphy
^{99m}Tc-DTPA (diethylene-triamine penta-acetic acid)	Renal scintigraphy, lung ventilation (aerosol), GFR
^{99m}Tc-HIDA derivatives	Hepatobiliary
^{99m}Tc-MIBI, Tetrafosmin	Myocardiaal perfusion scintigraphy
^{99m}Tc-HMPAO	Cereberal perfusion
^{99m}Tc-sulphur colloid	Liver & spleen scintigraphy
^{99m}Tc-sulphur colloid (0.2 μ filtered)	Lymphoscintigraphy
^{99m}Tc-DMSA (dimercapto succinic acid)	Renal cortical scintigraphy
^{99m}Tc-macroaggregated albumin	Pulmonary perfusion scintigraphy

MAA = methacrylic acid, MDP = methylene diphosphonate, DTPA = diethylene triamine penta-acetic acid, DMSA = di mercapto succinic acid, MAG3 = mercapto acetyl triglycine,

Selected examples of I-131 Rps	NM-Imaging
Na^{131}I	Thyroid gland – hypothyroidism, hypothyroidism, differentiated thyroid cancers, thyroid cancer metastasis (Also used in larger amounts for treating hyperthyroidism and differentiated thyroid cancers)
[^{131}I]-Meta iodo benzyl guanidine (^{131}I-MIBG)	To diagnose neuroendocrine tumours, such as neuroblastomas and pheochromocytomas – often found in children. (Also used in larger amounts for treating these malignancies)
[^{131}I]-labelled monoclonal antibodies	To diagnose a variety of malignancies. Presently, a large number of monoclonal antibodies are available, each of which is specific for a kind of malignancy. These monoclonal antibodies are labelled with ^{131}I and used to look for the presence and spread of these tumours. (Also used in larger amounts for treating for treating these cancers)



Schematic of ^{99}Mo-^{99m}Tc generator and its use in an in-house Radiopharmacy Laboratory

Some of the ^{99m}Tc labelled radiopharmaceuticals and nature of diagnostic studies used for are tabulated above.

PET Radiopharmaceuticals – preparation and application

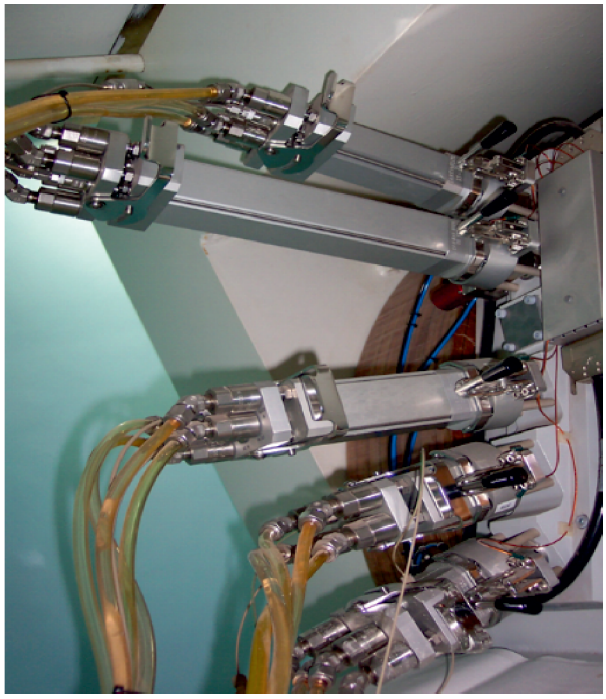
^{99m}Tc- and ^{131}I-Radiopharmaceuticals have contributed enormously to the diagnosis of several human diseases by NM-imaging of the physiological processes involved. However, except for [^{131}I]NaI, all the ^{99m}Tc- and ^{131}I-radiopharmaceuticals used are not true metabolites used in our bodies. True metabolites are made of carbon, hydrogen, oxygen, and nitrogen. The only radioactive isotopes of these are ^{14}C and ^{3}H, which being pure beta emitters are not suited for NM-imaging. However, there are short-lived positron emitting radioisotopes that can be prepared using particle accelerators/ cyclotrons, viz., ^{11}C, ^{13}N, ^{15}O. Since PET-scanners can be used for imaging the presence of these in the body, hence, this encouraged the development of many ^{11}C-labelled molecules but its half-life of 20 minutes was a serious limitation. Radiopharmaceutical chemists have found that ^{18}F, a positron emitter with a half-life of 110 min can be substituted for H in many molecules involved in metabolism and accurately image metabolic processes in diseases. A major breakthrough was in the identification of [^{18}F]-2-fluoro-deoxy glucose, commonly known as ^{18}FDG, which was taken up by cells in the body from the circulation and entered the glycolytic pathway, a metabolic pathway present in all living cells. However, it is not fully metabolized and excreted but is phosphorylated and trapped intracellularly, making it ideal to study the metabolic activity of cells. Since cancer is an abnormally and rapidly growing tissue in the body, it takes up ^{18}FDG more avidly than normal cells and hence, can be imaged.

Summary of radionuclides used in PET NM-imaging.

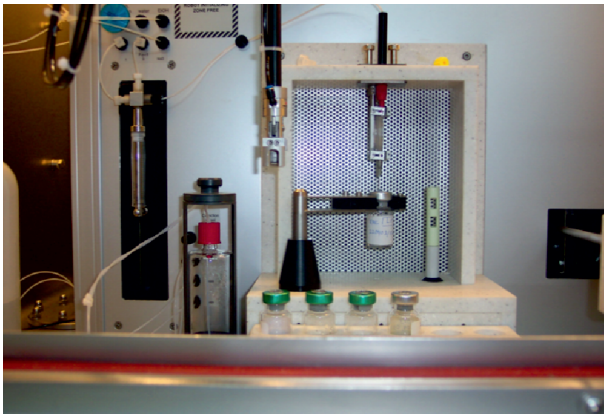
Nuclide	Physical half-life ($T_{1/2}$)	Mode of decay (%)	Photon energy (Kev)	Abundance (%)	Common production method(s)
^{11}C (cyclotron produced)	20.4min	β+ (100)	511	200	$^{14}N(p,)11C$ $^{10}B(d.n)^{11}C$
^{18}F (cyclotron produced)	110min	β+ (97) EC(3)	511	194	$^{18}0(p,n)^{18}F$
^{13}N (cyclotron produced)	10min	β+ (100)	511	200	$^{12}C(d,n)\ ^{13}N$ $^{16}O(p,)^{13}N$ $^{11}C(p,n)\ ^{13}N$
^{15}O (cyclotron produced)	2min	β+ (100)	511	200	$^{14}N(d.n)^{15}O$ $^{15}N(p,n)^{15}O$
^{68}Ga (^{68}Ge-^{68}Ga generator)	68min	β+ (89) EC(11)	511	178	$^{68}Zn(p,n)^{68}Ge$
^{82}Rb (^{82}Sr-^{82}Rb generator)	75s	β+ (95) EC(5)	511 777	190 13.4	$^{98}Mo \rightarrow ^{82}Sr$ (spallation reaction)

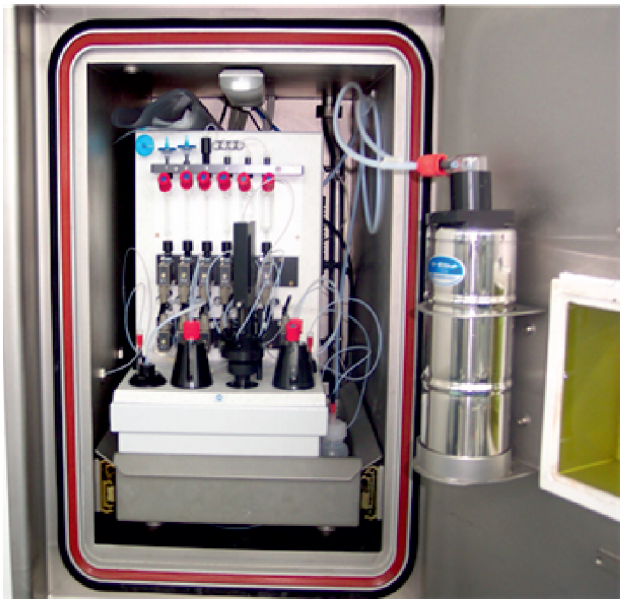
Some promising PET radioisotopes

^{64}Cu	12.7 h	β+ (17.9) β - (39) EC(43.1)	511 578 1345 1666	35.8 39 0.47 43.2	$^{64}Ni(p,n)^{64}Cu$ $^{64}Ni(d,2n)^{64}Cu$ $^{68}Zn(p, n)^{64}Cu$
^{124}I	4.2 d	β + (23) EC(77)	511 603 1691	46 61 10.4	$^{124}Te(p,n)^{124}I$
$^{94}m\,Tc$	52min	β + (70) EC(30)	511 871 1521 1868	140 94 4.5 5.7	$^{94}Mo(p,n)^{94}mTc$
^{44}Sc	3.97 h	β + (94) EC(6)	511	188	$^{44}Ti \rightarrow ^{44}Sc$ $^{44}Ca(d,2n)^{44}mSc,^{44}gSc$ $^{44}Ca(p,n)^{44}mSc,^{44}gSc$



Medical Cyclotron (left) and targets (right) where the PET radioisotopes are produced



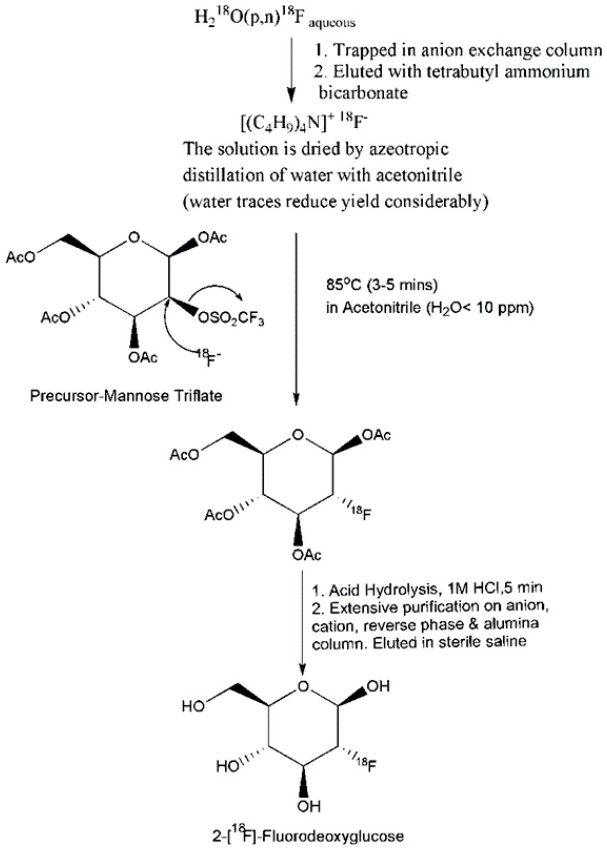


Lead shielded Hot-cells (left) where the PET-radioisotopes produced in the cyclotron are converted to PET-Radiopharmaceuticals. Centre - Automated 18FDG synthesis module housed in hot-cell. Right – Dispensing module housed in a hot-cell to aseptically dispense 18FDG for transport to PET-imaging centres.

Schematic of the production of 18FDG.

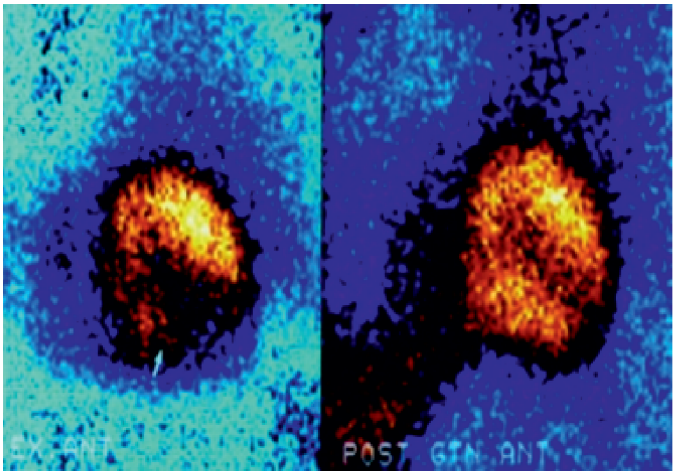
Conversion of the short-lived radioisotope to radiopharmaceutical (RP) suitable for injection into patients involves four major crucial steps:

1. Trapping of the desired isotope for synthesis of RP.
2. Rapid and efficient chemical synthesis of the RP.
3. Post synthesis purification of the RP to ensure radiochemical purity.
4. Final RP product to fulfill stringent QC and pharmacopoeia requirements as it will be injected intravenously into patients.

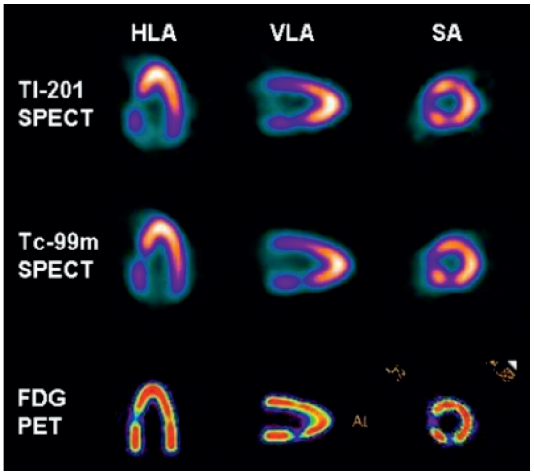


PET-tracers used to study physiological or biochemical pathways:

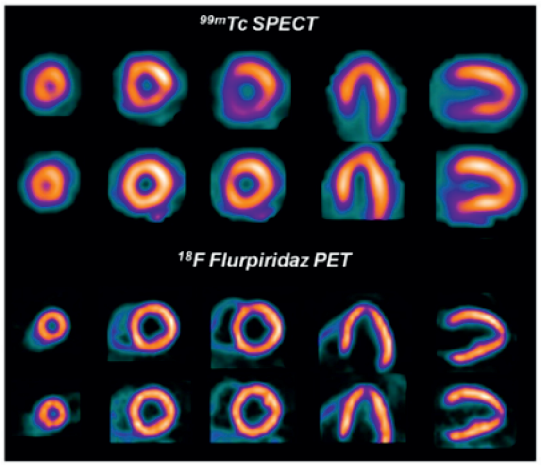
1. ^{18}Fluoro-Deoxy-Glucose:^{18}FDG- a glucose analogue for studying glucose metabolism in tumours/cancers and GLUT-1 receptor expression.
2. ^{18}Fluoro-Ethyl-Tyrosine: ^{18}FET – an amino acid analogue for studying amino acid metabolism in tumours/cancers.
3. ^{18}Fluoro-L-Thymidine: ^{18}FLT – a nucleotide analogue for studying TK1 expression, nucleic acid synthesis and cell proliferation.
4. ^{18}Fluoromisonidazole, hypoxia marker for tumours.
5. ^{18}F-Sodium Fluoride – for skeletal imaging to identify bone-metastasis.
6. ^{18}F-6FDOPA, for brain imaging to identify dementia, Alzheimer's disease, Parkinson's disease and melanomas.
7. ^{18}F-fluoro-octreotide, somatostatin receptor imaging.
8. ^{18}F-choline analogues, prostrate carcinoma.
9. ^{18}F-fluoro-estradiol, estrogen receptors in breast cancer.
10. ^{11}C-Choline for prostate carcinoma.
11. ^{11}C-DOPA for brain imaging to identify dementia, Alzheimer's disease, Parkinson's disease and melanomas.
12. ^{13}N-Ammonia for cardiac imaging.
13. ^{15}O-water – for blood perfusion studies.
14. ^{15}O-labeled CO^2, O^2, and CO have been used to evaluate cerebral blood flow (CBF), the cerebral oxygen extraction fraction (OEF), and the cerebral metabolic rate of oxygen ($CMRO^2$) and cerebral blood volume (CBV), respectively.



A



B



C

An example of how cardiac imaging by NM-techniques has improved with time.

A Planar gamma camera image of myocardium (heart) using ^{201} Tl.

B Centre and Right - comparison of SPECT and PET images of the myocardium (heart muscle) using target specific radiopharmaceuticals and advanced imaging equipment. HLA – horizontal long axis, VLA – vertical long axis and SA -short axis.

C Comparison of ^{99m}Tc-SPECT and ^{18}F-PET images

GMP and Pharmacopeia Quality Assurance in Producing Radiopharmaceuticals for Human Use

Quality assurance (QA) in radiopharmacy covers all steps involved in the production of radiopharmaceutical till its administration into the patient. It ensures that the radiopharmaceutical products are of the quality required for their intended use. Quality assurance therefore incorporates GMP, Quality Control and other factors, including product design, development and active pharmaceutical ingredients (API) used.

Good manufacturing practices (GMP) for radiopharmaceutical products ensures minimizing (and ideally preventing) risks such as cross-contamination, mislabeling, failure, and other potentially-catastrophic problems. In case of radiopharmaceuticals, GMP is also referred to as Good Radiopharmacy practice (GRPP). Since diagnostic radiopharmaceuticals are always produced in small batches and used within a short period, usually within the day, the radiopharmaceuticals are released 'parametrically' meaning that they are released for patients' use after doing routine QC tests except sterility test. This is possible since the SOP used for producing the radio-pharmaceuticals are thoroughly validated. The idea here is that the Small Scale Radio-pharmacies (SSRPs) or Centralized Radio-pharmacies (CPs) which are manufacturing the radio-pharmaceuticals stay committed to the highest possible quality standards by keeping their systems and technologies up-to-date. GRPP includes Good Radiopharmaceutical Practice (GRP) and Good Clinical Practice (GCP).

GMP features five main components called as **"Five P's"** as follows:

1. **Personnel:** As per the GMP guidelines a Small Scale Radiopharmacies (SSRP) as well as Centralized Radiopharmacy (CRP) where radiopharmaceuticals are produced regularly, should have personnel trained in handling radioactivity and also trained for the prescribed job of production, Quality Control (QC) as well as Quality Assurance (QA).
2. **Premises:** Facilities where radio-pharmaceuticals are produced should be located, designed, constructed, adapted, and maintained, in order to suit the operations to be carried out. The laboratories for the handling of radioactive materials should be appropriately designed. Consideration should be given to radiation protection, ALARA (as low as reasonably achievable) compliance, a high level of cleanliness and the appropriate controls to minimize possible microbial contamination.
3. **Processes:** For the manufacturing processes for different radiopharma-ceuticals the SOP should be written, documented, and must be followed strictly.
4. **Procedure:** Processes and procedures go hand in hand. A procedure is a series of guidelines needed to perform a process (with the goal of generating a specific result).
5. **Product:** The raw materials used to produce radiopharmaceuticals should be of highest quality and should be consistent. For final product a quality control featuring regular testing and constant comparisons is imperative and should be with clear specifications at every production phase.

Quality Control:

Important step prior to QC is correct sampling for QC which truly represents the batch. All radiopharmaceuticals should go through a rigorous physicochemical quality control testing like pH, clarity, colour, specific activity, radiochemical purity, radionuclide purity as mentioned in the approved document of the desired product.

All the RPs should go through the Bio-QC testing like BET testing and sterility testing. However, as mentioned earlier, diagnostic 99mTc-, 18F- and 68Ga-radiopharmaceuticals, because of their short half-lives are exempted from the sterility testing prior to release but is done post-facto on a sample and recorded. If sterility fails even once, the entire SOP used for the production of the radiopharmaceuticals has to be re-validated.

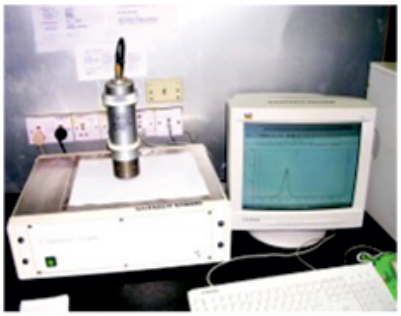
Another important aspect of GMP is validation of manufacturing procedure, calibration or qualification of the equipment used in production, quality control and for monitoring radiation safety. All the equipment should be periodically calibrated. Another requirement of GMP/GRRP is the documentation and record keeping including SOPs for all production.

The production of radiopharmaceuticals comes under the regulatory control of DAE-Radiopharmaceuticals Committee, Drug Controller General of India (DCGI), Atomic Energy Regulatory Board (AERB) for radiation safety, Institutional Ethics Committee for evaluation of new radiopharmaceuticals and the Director General of Civil Aviation (DGCA) where air transportation of radiopharmaceuticals is required considering their short half-life.

QC for ^{18}FDG for parametric Release

1. pH
2. Radiochemical purity by TLC (F-18 content)
3. T ½(for radionuclidic purity)
4. BET Test

TLC test for radiochemical purity



TLC being scanned- single peak shows acceptable purity of [F-18]FDG

Bacterial Endotoxin testing

Radiation Safety in Nuclear Medicine Practice - Philosophy

In nuclear medicine the major emphasis on radiation safety is:

(1) No practice involving radiation exposure shall be adopted unless its introduction produces a net positive benefit to the exposed individual or to the society to offset the radiation detriment it causes.

(2) All the exposures shall be kept as low as reasonably achievable, while taking account of social and economic factors.

(3) Protection of the patient - all preventive measures are taken to avoid unjustified radiation exposure to the patient. The nuclear medicine study performed on the patient should be clinically justified. The amount of radio-pharmaceutical administered to the patient should be optimized. All the necessary measures such as hydration and frequent voiding, diuretics and laxatives should be taken to reduce the radiation dose to the patients.

(4) Protection of the staff, the three cardinal principles i.e. Time, Distance and Shielding (TDS) should be adopted to minimize the external radiation exposure. Radiation Exposure is directly proportional to Time Spent with Radioactive material. The more time spent with radiation more will be the radiation dose. It is therefore important to minimize the time near radioactive sources. Radiation intensity is inversely proportional to the square of the distance.

(5) Protection of the public, in diagnostic nuclear medicine low level of radioactivity is used and these radioisotopes have generally short half-life, hence they pose minimal risk to the general public. Further risk to the family members can be reduced by proper instructions to the patient and relatives after completion of diagnostic studies.

(6) Protection of the environment, all the radioactive waste generated in the diagnostic nuclear medicine department should be disposed of as prescribed by competent authority.

Table: Dose Limits (AERB)

	Whole Body (max)	Whole Body (average)	Lens of Eyes	Skin	Extremity
Adult	30	20 (average over 5 y)	150	500	500
Trainees	6	None	50	150	150
Public	1	1 (average over 5 y)	15	50	50
Comforter	5	None	None	None	None
Visitors	1	None	None	None	None

NOTE: All numerical dose limits have units of mSv in one year except for the limits for comforters and visitors. The limit for these last two groups is per patient diagnostic procedure or treatment.

General References:

1. https://www.iaea.org/resources/hhc/nuclear-medicine/webinars. - Virtual Course in Radiopharmacy. These webinars gives information on laboratory setup, personal protection, QC procedure and documentation.
2. Nuclear Medicine Physics: A Handbook for Teachers and Students – Eds. Bailey DL, Humm JL, Todd-Pokropek A, van Aswegan A – International Atomic Energy Agency, 2014. ISBN 978-92-0-143810-2. https://www.iaea.org/books

NUCLEAR NEWS:
(January – March 2023)

Seaborg joins TerraPraxis coal-to-nuclear initiative

TerraPraxis and Danish floating nuclear power plant developer Seaborg have agreed to assess Seaborg's Compact Molten Salt Reactor (CMSR) as a potential heat source to support the rapid decarbonisation of the global coal fleet. The initiative aims to develop a standardised building system and project delivery model for the fast, low-cost, and repeatable repurposing of 2400 carbon-intensive coal plants with a combined capacity of 2 TWe to run on emission-free heat by 2050.

Energy & Environment - World Nuclear News *(world-nuclear-news.org)*

Nuclear plants vital for Spain, manifesto says

The Spanish Nuclear Society (Sociedad Nuclear Española, SNE) has published a manifesto setting out the strategic importance of the country's nuclear power plants - and warned that there will be no turning back if current closure plans are allowed to go ahead. The manifesto says, "At a critical moment worldwide, in which more and more countries plan to use nuclear energy as a pillar of decarbonisation, energy independence and economic development, it makes no sense for Spain to get rid of this clean and reliable source of energy."

Nuclear Policies - World Nuclear News *(world-nuclear-news.org)*

Bolivia's first radio-pharmaceuticals supplied

President Luis Arce Catacora has delivered the first fluorodeoxyglucose radio-pharmaceuticals produced in Bolivia's new Cyclotron Preclinical Radiopharmacy Complex (CRPC) to patients of the Nuclear Medicine and Radiotherapy Centres of El Alto and Santa Cruz. The cyclotron is intended to provide enough radiopharmaceuticals to allow 5000 patients a year in Bolivia to undergo medical examinations using advanced nuclear medicine products.

New Nuclear - World Nuclear News *(world-nuclear-news.org)*

Polls find strong support for nuclear in UK and Switzerland

A UK poll by international strategy consultancy Stonehaven found a 25% increase in net support for new nuclear power since June 2021, with support growing across every age group, nation and region in the country. Today, net support overall stands at 24% (with 46% agreeing and 22% disagreeing). According to the online survey from 15 to 26 February, 2023 in Switzerland conducted between 15 and 26 February by market research institute DemoSCOPE on behalf of the Swiss Nuclear Forum, 49% of the population is still in favour of the continued use of nuclear energy, while 38% reject it. Similar polls conducted in February and July 2022 found 44% and 52% in favour, respectively.

Nuclear Policies - World Nuclear News *(world-nuclear-news.org)*

Nine Mile Point starts supplying hydrogen

The USA's first-of-its-kind 1 MW demonstration scale, nuclear-powered clean hydrogen production facility has begun operating at Constellation's Nine Mile Point nuclear power plant in Oswego, New York. The company said the new facility will help demonstrate the potential for hydrogen to power a clean economy. The low-temperature electrolysis leverages Nine Mile Point's existing hydrogen

storage system. The plant had previously relied on trucked-in deliveries of hydrogen made from fossil fuels. According to the DOE, about 95% of the hydrogen produced in the USA is currently sourced from fossil fuels.

Corporate - World Nuclear News *(world-nuclear-news.org)*

Welsh university to develop space nuclear propulsion system

Bangor University in Wales will develop a nuclear thermal fuel system to support deep space exploration with funding provided by the UK Space Agency. It is one of eight projects receiving a total of GBP1.6 million (USD1.9 million) in funding through the agency's Enabling Space Exploration fund.

New Nuclear - World Nuclear News *(world-nuclear-news.org)*

South Korea's APR1000 certified for European use by EUR

Korea Hydro & Nuclear Power's (KHNP's) APR1000 reactor design has been formally certified as compliant by the European Utility Requirements (EUR) organisation - a technical advisory group for European utilities on nuclear power plants. The Korean nuclear industry - including KHNP, KEPCO E&C, KEPCO NF, and Doosan Enerbility - officially applied for EUR certification in November 2019. The assessment was launched in February 2021.

Regulation & Safety - World Nuclear News *(world-nuclear-news.org)*

TPU project to use electric discharge to decontaminate concrete

Tomsk Polytechnic University (TPU) and TVEL have launched a project to use electric discharges to speed up the decontamination of radioactive concrete. The aim is to allow decontamination of several square metres per hour. The principle of operation of the installation is based on the destructive effect of pulsed electric discharges with a power of at least 10 KW, which pass through the thickness of the material under a layer of water. The electric discharge method allows to remove layers of concrete from five millimetres, while there are no restrictions on the maximum removal depth.

Waste & Recycling - World Nuclear News *(world-nuclear-news.org)*

New reactor dismantling technique used at Crystal River

Orano Decommissioning Services has implemented an innovative method for dismantling of commercial and research nuclear reactors at the Crystal River unit 3 accelerated decommissioning project in Florida. The patented Optimized Segmentation process aims to reduce the volume of waste for disposal and the amount of segmentation work on the reactor structures. The new process cuts up and removes everything inside the thick-walled, steel alloy reactor vessel (RV) and then precisely repacks the low-level radioactive waste into the RV before cutting the massive component, minus the reactor vessel closure head, and its shielded contents into three large pieces sized for transportation and disposal.

Waste & Recycling - World Nuclear News *(world-nuclear-news.org)*

Canadian university launches subcritical assembly project

Ontario Tech University has begun pre-licensing activities for a new facility to support its undergraduate nuclear engineering programmes and for applied nuclear engineering research. The facility will be unique in Canada. A subcritical assembly - sometimes called a "teaching reactor" - is based on the same nuclear science principles as critical nuclear reactors but

remains in a subcritical state, relying on an external source of neutrons to sustain the nuclear fission chain reaction.

Regulation & Safety - World Nuclear News *(world-nuclear-news.org)*

Poll finds record support for Japanese reactor restarts

For the first time since the March 2011 accident at the Fukushima Daiichi plant, the majority of respondents in an annual survey conducted by the Asahi Shimbun are in favour of Japan's nuclear power reactors being restarted. Rising energy costs following Russia's invasion of Ukraine in 2022 was a factor that influenced their opinion. However, the Asahi Shimbun poll showed that 45% of respondents are in favour of new reactors being built while 46% are opposed.

Nuclear Policies - World Nuclear News *(world-nuclear-news.org)*

Radiation detection drones tested at Belgian site

Test flights of drones fitted with equipment to identify and measure the radiation being emitted from a plume source have been conducted at the Mol site of Belgium's Nuclear Research Centre (SCK-CEN). Further tests flights are planned for later this year to prove a new, precise measurement technique.

Regulation & Safety - World Nuclear News *(world-nuclear-news.org)*

Preparations begin for thorium-HALEU fuel regulatory review

Clean Core Thorium Energy and the Canadian Nuclear Safety Commission (CNSC) have begun the planning phase of a pre-licensing review of Clean Core's ANEEL thorium and high-assay low-enriched uranium (HALEU) fuel, the company has announced. The Chicago-based fuel innovation company is developing ANEEL fuel - the name is taken from Advanced Nuclear Energy for Enriched Life - for use in pressurised heavy water and CANDU reactors. High-burnup irradiation testing and qualification of the fuel is currently under way at the Advanced Test Reactor at the US DOE's Idaho National Laboratory (INL), using test pellets manufactured by the company in partnership with Texas A&M University and INL. The company is also collaborating with US company Centrus as a supplier of HALEU.

Uranium & Fuel - World Nuclear News *(world-nuclear-news.org)*

WANO prepares for growth of new nuclear

World Association of Nuclear Operators (WANO) Chairman Tom Mitchell and new CEO Naoki Chigusa are optimistic about the future of the nuclear energy sector, and are taking steps to ensure the organisation is well placed to offer new players in the industry help and advice. It is now more than three decades since WANO was created with a mission "to maximise the safety and reliability of nuclear power plants worldwide" and Mitchell and Chigusa are determined that it will continue to fulfil that function, with a wave of new entrants to the industry expected in the years ahead.

Perspectives - World Nuclear News *(world-nuclear-news.org)*

Lightbridge fuel offers Pu management option

Simulations have shown that a fuel rod designed by the company significantly outperforms traditional MOX fuel in consuming plutonium, and would be well-suited for consuming excess weapons-grade material.

Uranium & Fuel - World Nuclear News *(world-nuclear-news.org)*

South Korean partnership to develop SMR-powered ships

Nine South Korean organisations have signed MoU to cooperate on the development and

demonstration of ships and offshore systems powered with SMRs. The partners will also develop marine systems and the production of hydrogen using molten salt reactors (MSRs).

New Nuclear - World Nuclear News *(world-nuclear-news.org)*

IEA highlights nuclear's key role in coming years

Renewables together with nuclear power are expected to meet the vast majority of the increase in global electricity demand over the next three years, making significant rises in the power sector's carbon emissions unlikely, according to a new International Energy Agency (IEA) report.

Energy & Environment - World Nuclear News *(world-nuclear-news.org)*

Brazilian parliamentary group to promote new nuclear

Federal Deputy Julio Lopes has launched the Joint Parliamentary Front for Nuclear Technology and Activities, as the industry took a high profile at the Welcome Energia 23 event in Brasilia, including discussions about small modular reactors (SMRs) and a fourth Angra unit.

Nuclear Policies - World Nuclear News *(world-nuclear-news.org)*

Baltic Shipyard signs contract for two more nuclear-powered icebreakers

The agreement signed between the Baltic Shipyard and Atomflot is for two more nuclear-powered icebreakers as part of Russia's Project 22220.

New Nuclear - World Nuclear News *(world-nuclear-news.org)*

Team uses muography to create 3D image of reactor

Researchers at the French Alternative Energies and Atomic Energy Commission (CEA) have used muons - cosmic particles - to remotely and non-invasively create a 3D image of the G2 reactor at Marcoule, France, which is undergoing decommissioning.

Waste & Recycling - World Nuclear News *(world-nuclear-news.org)*

Myanmar signs new nuclear energy agreement with Russia

The Intergovernmental Agreement on cooperation in the use of nuclear energy for peaceful purposes will see the two countries working together on the use of nuclear technology in a number of areas, including training of a workforce for building and running a small modular reactor (SMR).

New Nuclear - World Nuclear News *(world-nuclear-news.org)*

Darlington ready to produce medical radioisotope

Ontario Power Generation's (OPG) nuclear power plant is set to produce molybdenum-99 (Mo-99) after Laurentis Energy Partners and BWXT Medical Ltd completed the installation and initial commissioning of an innovative isotope system.

Regulation & Safety - World Nuclear News *(world-nuclear-news.org)*

Polish universities launching nuclear courses, as PKN Orlen plans 79 SMRs

Six Polish universities, energy firm PKN Orlen and the Ministry of Education have signed a letter of intent for the roll-out of new nuclear energy-related courses to begin in the coming academic year. It comes with Orlen's CEO outlining large-scale plans for adoption of small modular reactors (SMRs).

New Nuclear - World Nuclear News *(world-nuclear-news.org)*

Components ready for fifth Kudankulam unit

Major equipment for India's Kudankulam-5 is complete at the factory of the Russian supplier, Atom-mash. The reactor pressure vessel was assembled in a trial and the pressuriser passed crucial tests.

New Nuclear - World Nuclear News *(world-nuclear-news.org)*

NASA and DARPA target 2027 nuclear rocket engine test in space

The USA's National Aeronautics and Space Administration (NASA) and the Defense Advanced Research Projects Agency (DARPA) are to collaborate on developing and demonstrating a nuclear thermal rocket engine in space by 2027.

Other News - World Nuclear News *(world-nuclear-news.org)*

Construction starts for Russian medical isotopes plant

The aim is to have production lines operating at the plant in Obninsk by 2025, supplying products for the diagnosis and treatment of patients, including a wide range of cancers. Rosatom says it will ensure Russia's sovereignty in the production of radiopharmaceuticals.

New Nuclear - World Nuclear News *(world-nuclear-news.org)*

Robot developed to assist verification of used fuel

A floating autonomous robot could soon play a key role in safeguarding used nuclear fuel around the world. The Robotised Cherenkov Viewing Device (RCVD) has been created through a collaboration between Australian national science agency CSIRO's data and digital specialist arm Data61, Hungarian robotics company Datastart and the International Atomic Energy Agency (IAEA).

Regulation & Safety - World Nuclear News *(world-nuclear-news.org)*

It's time to let the world know we can safely manage nuclear waste

While many agree the benefits of using nuclear energy to fight climate change and build energy security are clear, there is still a major hurdle to overcome before it is widely accepted as a safe and clean part of the energy mix: the perception that the nuclear industry has a waste "problem", writes Laurie Swami, president and CEO of Canada's Nuclear Waste Management Organization.

Perspectives - World Nuclear News *(world-nuclear-news.org)*

Growing number of Canadians favour nuclear expansion, says poll

Support for nuclear power in Canada is growing, with nearly twice as many Canadians now supporting the expansion of nuclear power in the country as opposing it, new data from the non-profit Angus Reid Institute has found.

Energy & Environment - World Nuclear News *(world-nuclear-news.org)*

UK must act on nuclear to meet net-zero aims, review finds

Investment in new nuclear is "a no-regrets option", according to an independent review of the UK government's approach to reaching net-zero greenhouse gas emissions by 2050. Its report makes a number of recommendations for the government to meet its Net Zero Strategy, released in October 2021, in which new nuclear plays a significant part.

Energy & Environment - World Nuclear News *(world-nuclear-news.org)*

Changes to Swedish law proposed to enable nuclear new build

A proposal to amend Sweden's legislation on nuclear power has been presented by Prime Minister Ulf Kristersson and Climate and Environment Minister Romina Pourmokhtari. The

proposed changes would remove the current law limiting the number of reactors in operation to ten, as well as allowing reactors to be built on new plant sites, rather than just existing sites.

Nuclear Policies - World Nuclear News *(world-nuclear-news.org)*

South Korea increases expected contribution of nuclear power

Nuclear energy will account for 34.6% of South Korea's electricity generation by 2036, compared with 27.4% in 2021, according to the latest plan finalised by the country's Ministry of Trade, Industry and Energy.

Nuclear Policies - World Nuclear News *(world-nuclear-news.org)*

Holtec claims SMR-160 can repurpose any coal-fired plant

Holtec International has applied for a patent for multi-stage compressors that would enable any coal-fired plant to be repurposed by replacing its coal-fired boiler with clean steam from the SMR-160.

New Nuclear - World Nuclear News *(world-nuclear-news.org)*

Welsh plan for new nuclear medicine laboratory

The Welsh government is funding a technical feasibility study and outline business plan to secure future supplies of medical isotopes by developing an Advanced Radioisotope Technology for Health Utility Reactor, known as Project ARTHUR.

New Nuclear - World Nuclear News *(world-nuclear-news.org)*

Samsung completes design of CMSR Power Barge

South Korean shipbuilder Samsung Heavy Industries (SHI) has completed the conceptual design for the CMSR Power Barge - a floating nuclear power plant based on compact molten salt reactors - and obtained the basic certification of the design from the American Bureau of Shipping (ABS).

New Nuclear - World Nuclear News *(world-nuclear-news.org)*

IAEA launches research reactor HR modelling tool

A new training tool from the International Atomic Energy Agency (IAEA) provides modelling to develop the skilled workforce needed for new research reactor programmes, from planning to operation. The tool was recently piloted in Senegal, which is planning for a research reactor programme.

New Nuclear - World Nuclear News *(world-nuclear-news.org)*

Compiled by S.K. Malhotra

TWO DAYS SYMPOSIUM ON 'NUCLEAR ENERGY- ITS GENERATION AND APPLICATIONS'

held at Union Christian College, Aluva, Kerala during Feb 23 - 24, 2023

A two-day Symposium, organised by Indian Nuclear Society (INS) jointly with Science Departments of Union Christian College, Aluva, and Atomic Energy Retirees' Association, Kerala (AERAK), provided a forum for scientists and engineers to engage in dialogue and to convey to the new generation of science students on the role of nuclear energy in the transition to clean energy sources and to discuss its potential to contribute to sustainable development and climate change mitigation. The Symposium was intended to address the myths about the use of nuclear energy especially among the younger generation.

The seminar was held on February 23-24, 2023 at MCA Hall in UC College, Aluva. It had financial supports from Nuclear Power Corporation of India (NPCIL), Nuclear Fuel Complex (NFC), Hyderabad, IREL, Aluva and Indian Association for Radiation Protection (IARP) as co-sponsors. The symposium titled: Nuclear Energy - Its Generation and Applications, was attended by students from various universities of Kerala. About 250 students, mainly doing postgraduate studies in chemistry, physics and biological sciences had registered for the event.

The symposium was inaugurated by Vice Chancellor of Cochin University of Science & Technology, Dr K N Madhusoodanan. The inaugural session was presided over by Dr M.I. Punnoose, Principal of UC College and keynote address was delivered by Shri M Venkatachalam, Distinguished Scientist and Executive Director of NPCIL. In his address, Shri Venkatachalam stressed the need for a reliable, low-carbon, and cost-effective sources of power to meet growing global energy demands and reduce greenhouse gas emissions. He said that nuclear energy is considered one of the most efficient and effective ways to produce electricity on a large scale, without the emissions of CO_2 or other harmful pollutants.

The Session-1 of the opening day (23/02/2023) was devoted for Advantages and Challenges in Nuclear Power Generation. In the first talk in this session, Dr Arun Nayak, Head, Nuclear Control & Planning Wing, DAE, focused on possible energy demand of India by 2050 and contributions from renewables and explained the requirements of nuclear power to meet the low carbon energy budget of India. He further explained radiation effects on health of human beings, the biological changes due to radiation, radiation hormesis, ambiguous scientific explanation of linear no threshold (LNT) theory, industrial conspiracy, fabrication of phobia against radiation, and gave some insights and thoughts for future. Dr Martin Mascarenhas, Head, L&PTD, BARC, unfolded the contributions of Beam Technology Development Group of BARC. He stressed the importance of R&D efforts to mature technology demonstration, in two important societal applications, namely, medical isotope separation for production of radioisotopes having important applications in radiopharmaceutical industry and environment friendly waste management solutions based on plasma gasification/ incineration techniques and accelerator-based technologies.

The second session had three talks about topics on Nuclear Fission, Fusion and Hydrogen Generation using nuclear power. The first talk given by Shri Umed Yadav, Additional Chief Engineer, NPCIL was about the understanding fears of radiation from a nuclear energy perspective. He said that the main areas of concern of general public span over Safety, Radiation and Livelihood attributes when it comes to Nuclear Energy. Dr Rhine Kumar, Asst Professor, CUSAT, gave an overview of nuclear fusion reactions and its importance in nuclear power generation. Dr K. Drisya, Asst. Professor, University of Calicut delivered a talk about nucleosynthesis in low-mass stars and briefly discussed attempts to understand galactic chemical evolution through nucleosynthetic models explaining the formation of elements in the universe.

The third session was devoted for radiological safety aspects and environmental issues. First talk was given by Shri S. Bansal, Vice President of Indian Nuclear Society (INS), Mumbai. He shared with audience the basic safety principles followed while harnessing nuclear energy and making use of radiation applications. He told the audience that nuclear power plants are among the safest and most secure facilities in the world. Notwithstanding the few major accidents that have occurred, nuclear power has a safety record that is good compared with those of the viable competing options for producing electricity. The second talk was given by Dr M R Iyer, Former Head, RSSD, BARC. He talked about the development of science in India in early 20th century. He said that thorium reserves in the West Coast of Kerala which provide an eminent position for India to make use of it to harness nuclear power in a big way, was first discovered in as early as 1908 in Travancore. The State followed up with setting up monazite separation plants soon afterwards with international collaborations. Shri G.D. Mittal, Secretary, INS, had a presentation on use of radiation in medicine, agriculture and industry. He said some of the most innovative ways of improving agricultural practices involve using radiation techniques, which can control pests and diseases, increase crop production, protect land and water resources and ensure food safety. He also showcased highlights of the INS activities conducted since its formation.

The first session of second day (24th February) was devoted for nuclear medicine. Dr (Smt.) G.S. Shagos, consultant at Aster Medicity, Kochi gave an introduction on nuclear medicine imaging. She told about the significant progress made by this branch of medicine in the last decade and now a wide variety of radioactive tracers and newer imaging machines are available that help us understand the functioning of organs better, diagnosing neurological conditions like Alzheimer's disease, Parkinsonism, non-invasive imaging of blood flow to heart muscles etc apart from the extensive use of these scans in the management of cancer. In second talk of the session, Dr Vijay Harish Somasundaram, consultant from Rajagiri Hospital, Aluva talked about therapeutic nuclear medicine. The most commonly used radionuclide today for therapy is iodine-131 as sodium iodide solution (131I-NaI), extensively used for the treatment of thyroid related disorders, both malignant and benign. The recent advent of lutetium-177 (177Lu) labelled ligands for targeted treatment of metastatic cancer of prostate and neuroendocrine tumours, has re-established the role of nuclear medicine in precision oncology. Dr Sugilal, Head, FRD, BARC spoke about the Spin-off technologies of Indian Nuclear Power program. He said that management of nuclear waste has led to the development of new

technologies for the safe and effective disposal of radioactive waste. These spin-off technologies demonstrate the versatility and potential of nuclear technology, and highlighted the many ways in which it can be used for the benefit of society. Consistent efforts in R&D have enabled indigenous development of novel processes and technologies in the field of management of radioactive waste and their deployment to realise the waste volume minimization, effective isolation of radionuclide in engineered matrix, minimization of discharges and extracting wealth from waste by separating useful radionuclide from radioactive waste for societal applications. Dr C.V. Midhun, University of Calicut gave a talk on Low Energy nuclear physics. He added that a low-energy particle accelerator based on the Electron Cyclotron Resonance method has been developed at University of Calicut.

The next session focused on nuclear applications in biology and agriculture. In first talk in this session, Dr Susan Eapen, Former Senior Scientist, BARC, told the potential of nuclear energy concealed in the atoms has several applications in agriculture for improvement of food crops and increasing the shelf life of agricultural produce. She further added that nuclear technology can play a crucial role in feeding the world by releasing new climate resilient varieties and in preserving agricultural produce. Dr M Anil Kumar, Head, Botany Department, UC college, Aluva said that mutation breeding is one of the most widely used and successful method of crop improvement. Many varieties of agriculturally important crops have been raised by mutation breeding. Shri Amritesh Srivastava, DGM, NPCIL stressed about nuclear power as an inevitable option. The objective of his presentation was to make general people aware that being a clean, green and safe source, nuclear power can play significant role to achieve carbon neutrality / net zero in the time to come, our efforts should be to establish it as one of the most reliable and clean sources of electricity generation.

The last session was devoted for students' presentations. Seven research students participated and best presentations were given awards. The first prize was bagged for the paper entitled: Study of collective enhancement in nuclear level density by V Parvathi and A K Rhine Kumar. The valedictory and concluding sessions were chaired by Dr. C.M. Sreejith, Controller of Examinations, Mahatma Gandhi University, Kottayam. The certificates of participation were presented to students by the chairperson.

Overall, the symposium provided a platform for an open and informed discussion on nuclear energy, its advantages, and the challenges that must be addressed. We had the opportunity to exchange ideas and share experiences, and we are confident that these discussions will continue to inspire future research. To sum up, it can be said that the two-day symposium was professionally well organised and was a great success. This was indicated from the feedback received from the participants, which was found to be overwhelmingly positive.

By Dr. T.R. Govindankutty & Shri Satyawan Bansal

TWO DAYS INS WORKSHOP-CUM-OUTREACH PROGRAM ON NUCLEAR SCIENCE AND TECHNOLOGY FOR SUSTAINABLE DEVELOPMENT

at Brijlal Biyani Science College, Amravati during March 24-25, 2023

On 24th March a *"Workshop on Nuclear Medical Diagnostics Techniques*" was arranged, with an objective to apprise the audience consisting of Faculty, Research students, Graduate and Post Graduate students the relevance of nuclear medicine imaging in the diagnosis of various human diseases. Around 150 participants attended the workshop.

The program started with inaugural function presided over by the Honourable President Advocate Ashokji Rathi, Brijlal Biyani Shiksha Samiti, Amravati, Chief Guest Dr B. N. Jagatap, President, Indian Nuclear Society, Mumbai, along with experts from DAE, Dr. MGR Rajan, Smt Sushma Awasare, Shri Muktikanta Ray, Dr. Kamaldeep, Dr. Savita Kulkarni. Mr Mohd. Rajik, Education Officer, Municipal Corporation, Amravati, and Dr. Deepak S. Dhote, Principal, Brijlal Biyani Science College Amravati were also present.

The inauguration commenced with the speech by Dr. B.N. Jagatap on *"Nuclear Science and Technology and its necessity for the sustainable development of the Nation".* A brief overview about *"Brijlal Biyani Science College and its Achievements"* was given by Principal Dr D. S. Dhote. Adv. Ashokji Rathi in his brief presidential speech greeted all the participants and wished the program a grand success. The inaugural session ended with 'Vote of Thanks' by Amita Tembhare, Dept of Skill and Vocational Studies.

The first talk of the technical session was delivered by Smt. Sushma Awasare, Scientific Officer, RMC, BARC, Mumbai on *"Nuclear Medicine Imaging Techniques".* She introduced the concept of nuclear medicine (NM) imaging and the techniques used with the specialized NM-equipment like Gamma Camera, single-photon emission computed tomography (SPECT), SPECT combined with Computed Tomography (SPECT-CT), Positron Emission Tomography (PET) and PET-CT. She explained how these physiology-imaging techniques by using specific radioisotopes/ radio-pharmaceuticals and can be used to diagnose a variety of illnesses e.g. strokes, seizures, bone illnesses, and infections by gauging the blood flow and radio distribution within tissues and organs. NM imaging has a well defined and accepted role in oncology, neurology, cardiology, as well as for the diagnosis of skeletal, hepatic, kidney and other diseases by understanding the physiological changes that have taken place.

The second talk was delivered by Shri. Muktikanta Ray, Head, Hospital Radiopharmacy Section, RMC, BARC on *"SPECT radio-pharmaceuticals – preparation and their applications".* He elaborated on the production of radiopharmaceuticals (RPs) for SPECT imaging. These RPs are made using gamma emitting radioisotopes viz., Technetium-99_m, Iodine-131, thallium-201, and indium-111,

xenon-133 etc. He gave examples of the various SPECT-RPs produced and used in patients.

The third talk was by Dr. MGR Rajan, Former Head, RMC, BARC on *"PET radiopharmaceuticals – preparation and their applications".* He discussed the uses of the medical cyclotron for the production of radioisotopes used in PET-imaging. He explained the important role played by PET imaging in cancer diagnosis and management and its role in cardiology and neurology. The most used PET-RPs are Fluorine-18 and Gallium-68, both of which are short-lived and hence, the radiopharmacy involved must be quick so that the ready to use PET-RPs are available in a short time to use in patients.

The fourth talk delivered by Dr. Kamaldeep, Scientific Officer, HPD, BARC on *"Radiation Safety in Nuclear Medicine Practice".* He explained the importance of limiting radiation exposure to staff, students, patient-relatives in a NM-imaging and NM-therapy centre. He explained the regulatory limits of Occupational Dose that one can receive. He also explained the steps taken for protection from radiation in the workplace so that NM-Imaging and NM-therapy can be safe and beneficial to all.

In the last talk of the session, Dr. Savita Kulkarni, Head, Tuberculosis Immunology & Immunoassay Development Section, RMC, BARC, spoke on "*GMP and Pharmacopoeia Quality Assurance in producing Radiopharmaceuticals for Human use".* In this session, Dr. Kulkarni explained the importance of following Good Manufacturing Practice (GMP) in the production of RPs. Following GMP, which includes validated-SOPs, Quality Assurance, Quality Control ensures that the short-shelf-life and small-batch SPECT- and PET-RPs can be produced and used in patients confidently.

All the talks were followed by questions from the audience. The audience's interest was obvious from the level of questions asked by them. The Programme concluded with an overview of the session by Dr MGR Rajan and Dr D.S. Dhote. Online feedback was taken from all the participants. E-Certificates were provided to each participant. Workshop ended with vote of thanks by Dr. Laxmi Sharma, Co-ordinator of Two Days INS Workshop cum Outreach Programme on Nuclear Science and Technology for Sustainable Development.

On 25th March 2023, INS outreach programme on *"Nuclear Energy Sensitization'* was organized at Brijlal Biyani Science College, with an objective to sensitize the general public on the indispensable role of nuclear energy and its technologies in sustainable development of the Nation. Around 200 participants including Faculty, Research students and individuals from social, political, business sectors attended the workshop.

The program started with an inaugural function which was presided over by Honourable President Advocate Ashokji Rathi, Brijlal Biyani Shiksha Samiti, Amravati, and Chief Guest Dr B. N. Jagtap, President, Indian Nuclear Society, Mumbai, and Dr. D. S. Dhote, Principal Brijlal Biyani Science College Amravati convener of the programme. Other speakers from DAE included Dr. Kishore Agarwal, NPCIL, Dr. Sudhanshu Saksena, FTD, BARC, Dr. S Thangavel and Dr. G. Venkateswarulu, NCCCM, Hyderabad, Dr. Mrinal Pai and Dr. Adish Tyagi, Chemistry Group, BARC

First talk was delivered by Dr B.N. Jagatap, President, INS Mumbai, on *"Nuclear energy program in meeting sustainable development".* He explained statistically about the extinction of natural resources and its adverse effect on the environment. He also explained the sustainable

development goals (SDG). He explained the urgency of using Nuclear Science and Technology which covers many of these sustainable development goals.

The second and third talks of the session were by Dr S Thangavel and Dr G Venkateswarulu from NCCCM, Hyderabad. Both of them gave hands-on demonstration and talk on *"Technologies developed at NCCCM for the detection and remediation of contaminants in water".* They explained how Fluoride-Detection Kit is used to detect fluoride contamination in ground water causing dental and skeletal fluorosis. They also demonstrated techniques developed at NCCCM for the detection and remediations of contaminants in water. Various water samples from different regions of Amravati District were tested. They also showed visual detection of available phosphorous in agricultural soil and orthophosphate in water.

The fourth talk was by Dr. Kishor Agrawal on *"Present Nuclear energy scenario in India".* He explained about status of Nuclear Energy Technology in India. Dr. Kishor also elaborated on the Strengths of Nuclear Power and Nuclear Energy. He also explained the Public Perception about Nuclear Science and the reasons behind them. He also showcased the statistics about radiation exposure to Public.

Fifth talk of the day was conducted by Dr. Sudhanshu Saxena on *"Nuclear Energy in Food and Agriculture".* He explained some of the most innovative ways of improving agricultural practices which involve nuclear technology. He elaborated how using isotopes or radiation techniques in agriculture can control pests and diseases, increase crop production, protect land and water resources and ensure food safety. He explained that food-irradiation also quarantines and prevents the spread of insect pests and is used to guarantee the quality of fruits and vegetables enabling export to other countries.

In the fifth Session by Dr Mrinal Pai *"Hydrogen, a clean and renewable fuel".* She explained Hydrogen energy as well as developments in catalyst for DAE and Industrial Applications.

In last talk of the day, Dr Adish Tyagi spoke on *"Careers in DAE".* He explained clearly the excellent Career Opportunities in the DAE, elaborating on the possibilities of Higher Education while in service, a career with opportunities to be of Service of Society and hence, Service to the Nation.

These talks generated a lot of questions from the audience and the Speakers were very happy to clarify their queries and doubts. The Speakers were pleased that the audience had taken so much interest in their talks.

The second day Programme concluded with Speech of Dr. D.S. Dhote, followed by a vote of thanks from the Organizing Committee. Online feedback was also taken from all the participants. Programme ended with the singing of the National Anthem. E- Certificates were provided to all the participants.

By Dr. Laxmi Akhilesh Sharma and
Dipak S. Dhote
Brijlal Biyani Science College, Amravati

ACTIVITIES OF INS

Mysore Branch

To commemorate the completion of 75 years of Independence, Azadi-ka-Amrit-Mahotsav, Bhabha Atomic Research Centre, Mysuru in association with Indian Nuclear Society (Mysore) had organized an Outreach program at campus of Government Junior College, Bilikere on 2nd December 2022. Around 170 students participated in the program. Vice-Principal of the college, Smt. Snehalatha in her welcome speech, highlighted the need of a talk addressing societal issues. Shri A.S. Patil, President, INS (Mysuru) in his introductory speech explained about various activities of Indian Nuclear Society. Dr. A. Anand, Medical Officer, BARC, Mysuru delivered a presentation on "Adolescent Challenges" explaining the importance of the issue in the age of student life. Smt. Saily More, Medical Section, BARC, Mysuru delivered a talk on "Ethics and Behavioral Aspects among Students and the Public Surrounding the School". Presentations were well received by the students and the response from students as well as teachers was good. Awareness booklets in Kannada language about radiation were distributed to students.

INS Mysore branch took part by the way of involving in arranging the display of posters in the 23rd National Symposium on Radiation Physics (NSRP-23) organized by Department of Studies in Physics, University of Mysore & Indian Society for Radiation Physics at Vijnana Bhavan, University of Mysore on 19th -21st January 2023. Radiation awareness posters, mainly applications of radiation in different areas for societal benefits were displayed and explained ornately by nominated Health Physicists to university students, delegates and participants of the symposium. The program was well-received by the student community as well as the scientific fraternity present there.

INS Mysore branch participated in the celebration of "National Science Day" organized at Government Pre-University College, Yelwal, Mysuru on 28th February 2023. Shri A.S. Patil, President, Dr. A. Chandrashekara, Secretary, Shri Malay Ghosh, Treasurer, and Shri Ankush Roy, BARC, Mysuru were present in the program. Shri Patil made the students aware of various programs of Department of Atomic Energy and also highlighted the activities and objectives of Indian Nuclear Society. A scientific talk on "Raman Spectroscopy" was delivered by Dr. A. Chandrashekara. In his talk he explained the students about the significance of celebrating the science day and illustrated the basic concept of Raman Effect and its applications. The program was concluded with prize distribution to winners of various competitions organized by the college. At the end, while expressing about the relevance of science day, students gave their feedback on how they got benefitted by the program. The school authority expressed their sincere gratitude to INS (Mysuru) for being a part of the event and kindling the scientific thinking among students.

Bhabha Atomic Research Centre, Mysuru in association with Indian Nuclear Society (Mysuru) and College of Horticulture, Mysuru organized a technical seminar on "Applications of Atomic Energy in Food and Agriculture" on 8th March

2023 at the campus of College of Horticulture, Mysuru. The seminar was inaugurated by Shri D. Dhavamani, Senior Project Manager, BARC, Mysuru. In his inaugural address Shri. D. Dhavamani explained about the importance of multidimensional issues with regard to the various hitches whenever new useful techniques are being implemented. In his presidential remarks, Shri A.S. Patil, President, INS (Mysuru) had elucidated about activities and objectives of Indian Nuclear Society. Dr. A. Chandrashekara, Secretary, INS (Mysuru) in his introductory remarks spoke about various issues in the fields of agriculture and food where in nuclear isotopes, nuclear radiations and atomic energy could contribute.

Dr. Anand M. Badigannavar, Head, Groundnut Improvement Section, Nuclear Agriculture & Biotechnology Division, BARC, Mumbai delivered a talk on "Applications of Atomic Energy in Food and Agriculture". Shri. Joseph Thomas M, Officer-in-Charge, BARC, Mysuru delivered a talk on "Atoms in the Service of the Nation". Shri. Madhusoodan Ojha, Scientific Officer, BARC, Mysuru delivered a talk on "Energy, Climate Change and Sustainable Development".

The seminar was concluded with a feedback session where both the students as well as the faculty members appreciated the initiative and expressed their gratitude for conducting such an enthralling scientific session.

SOLUTION TO CROSSWORD PUZZLE

(INS Newsletter, Vol. 22 Issue 4, Nov. 2022)

1A	E	E	2T				3M	4A	C	E				5G
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8T	H	E	N	I		9H	E	R	O					U
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15J		16D	O	M	I	A	S	I	A	T				D
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R		L			O		E		P			R		
	26N	U	C	O	N			27A	R	I	H	A	N	T

"Contributed by S. K. Malhotra"

FROM SECRETARY, INS

Dear Members,

The new Executive Committee took over in December 2022 and we have planned the short term and long-term programmes.

1. Technical Programmes:

a. Seminar on "Relevance of Small Modular Reactors (SMR) in Indian Energy Scenario: Challenges & Opportunities" by Dr A.K. Nayak, Head, Nuclear Controls and Planning Wing, DAE was held on 21-01-2023.

b. Two-day Seminar and Outreach Programme was conducted at Union Christian College, Aluva, Cochin, Kerala on February 23-24, 2023. The programme was conducted in association with the Atomic Energy Retirees' Association Kerala (AERAK).

c. Two-day Seminar and Outreach Programme was conducted at Brijlal Biyani College, Amravati on March 23-24, 2023.

d. There are other technical programmes which are being planned and announcement will be made at appropriate time.

2. Branches' Activities:

INS Mysuru Branch conducted various programmes as per the following:

a. Participated by the way of involving in arranging the display of posters in the 23rd National Symposium on Radiation Physics (NSRP-23) organized by Department of Studies in Physics, University of Mysore & Indian Society for Radiation Physics at Vijnana Bhavan, University of Mysore on 19-21 January 2023.

b. Participated in the celebration of "National Science Day" organized at Government Pre-University College, Yelwal, Mysuru on 28-02-2023.

c. Participated in "Applications of Atomic Energy in Food and Agriculture" on 08-03-2023 at the campus of College of Horticulture, Mysuru.

3. Republic Day Celebrations:

INS celebrated the Republic Day, and the National Flag was unfurled by the Chief Guest Shri K Mahapatra, Director, DCS&EM, DAE. The event was attended by most of the EC Members. Shri K Saravana Kumar, Head, ESD-1, DCSEM was the Guest of Honour. Cooperation of Shri Pramod Tanpure of AEJC and his colleagues is highly appreciated.

4. Cleaning Operation of INS Office:

a. The old and unused books and periodicals were disposed of by way of distribution to interested persons and shredding the remaining ones.

b. The storerooms and the steel furniture were repainted.

c. The INS Compound (outside area of INS Office) wascleaned and resurfaced with the support of DCSEM. The INS Executive Committee is grateful to Shri K Mahapatra, Director, DCSEM, Shri K Saravana Kumar, Head ESD-1 and Shri K Basu for their support and help.

5. Digitisation:

a. All the available old issues of INS Newsletters were scanned for posterity.

b. All the Balance Sheets were scanned for the records.

6. INS Constitution Amendments:

a. Through the Special General Body meeting, held on 03-03-2023, certain articles were amended. The full version, along with the revised amendments, is available on INS website.

b. In the same SGBM on 03-03-2023, the membership fees were revised and that would be applicable with effect from 01-04-2023. The revised Membership Application Form, complete with applicable membership fees, is available on INS website.

The INS Office timings are extended and working hours are from 09:30 to 20:00 hours. The members may contact INS Office at the landline numbers – 022-25598327 and 022-25991097.

Yours

GD Mittal

INS EXECUTIVE COMMITTEE

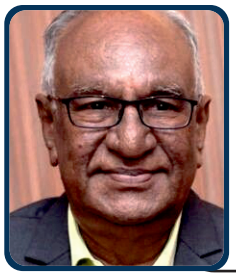
2022-2024

PRESIDENT

Prof. B.N. Jagatap is Formerly Distinguished Scientist & Director Chemistry Group, BARC and Senior Professor, Physics Department, IIT Bombay.

VICE PRESIDENT

Shri Satyawan Bansal is Senior Scientific Officer (SO/H) in Atomic Energy Regulatory Board (AERB), Mumbai.



SECRETARY

Shri G.D. Mittal retired as Scientific Officer from HRD Division, BARC in 2002. He has been actively associated with INS since 1987.

JOINT SECRETARY

Shri Kishor U. Agarwal is currently working as a General Manager in NPCIL.

TREASURER

Shri Om Prakash Rai is working in NPCIL since 1991. He is presently Vice-President of YHAI and Treasurer of BSS (Trust)

JOINT TREASURER

Shri S.B. Dharmadhikari is working in NPCIL as Deputy Chief Engineer in Procurement Directorate.

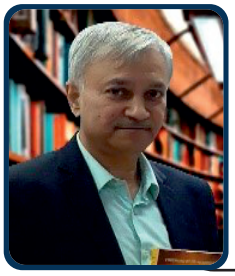
MEMBER

Shri K. T. P. Balakrishnan was with the Reactor Group for major part of his service period, later joined HS&E Group, from where he retired .in 2007. He is presently the vice-President of Atomic Energy Retirees Welfare Association (AERWA).

MEMBER

Dr M.G.R. Rajan retired as Outstanding Scientist and Head, Radiation Medicine Centre, BARC. He was also holding an adjunct position as Deputy Chief Executive, BRIT.

INS EXECUTIVE COMMITTEE
2022-2024



MEMBER

Dr. Suresh Gangotra is Raja Ramanna Fellow with Department of Atomic Energy (DAE).

MEMBER

Shri. V.S.N. Murthy retired as Scientific Officer from Reactor Group, BARC in 2009. He has been actively associated with INS since 2020.

MEMBER

Dr. Mayank Verma is working with the Atomic Energy Regulatory Board, taking care of the reviews related to India's first 700 MWe PHWRs.

MEMBER

Shri Praveen K Rao is working as Scientific Officer with NPCIL in the area of procurement for 700 MWe PHWR Projects.

MEMBER

Dr Nitin More is working with NPCIL, Mumbai. He is Indo-Swiss joint research fellow and actively involved with technical programmes.

MEMBER

Shri Pramoda Kumar Mishra is working as Maintenance Superintentendent at NPCIL, TAPS-3&4.He has experience in commissioning & maintenance of Nuclear Power Plants.

MEMBER

Dr K. Indira Priyadarsini, Formerly Outstanding Scientist and Head, Chemistry Division, BARC. Currently Senior Professor and RRF at UM- DAE CEBS.

HONORARY MEMBER

Shri S. K. Mehta is ex-officio member of the Executive Committee of INS as Formerly President of INS.

PHOTO GALLERY

Discussion Meeting on Small and Modular Reactors (SMR)
held on January 21, 2023 at AERB Auditorium

Dr. A.K. Nayak, Head, NCPW, DAE
delivering talk

A section of the audience

National Symposium on Nuclear Energy: Its Generation and Applications held at
UC College, Aluva, Kerala during February 23-24, 2023

Dignitaries releasing symposium
proceedings

INS Vice President Shri Satyawan Bansal
delivering talk

INS Secretary, Shri G.D. Mittal
delivering talk

Audience at the symposium

PHOTO GALLERY

Workshop on Nuclear Medical Diagnostics Techniques held at
Brijlal Biyani College, Amravati on March 24, 2023

Dr. Dipak Dhote, Principal, Brijlal Biyani College in the inaugural function of the workshop

Audience at the workshop

Speakers of the workshop. First row from left to right: Smt Sushma Awasare, Dr. M.G.R. Rajan, Shri M.K. Ray. Second row from left to right: Dr. Kamaldeep and Dr. Savita Kulkarni

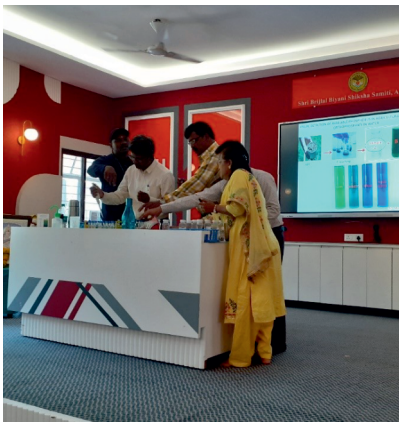
PHOTO GALLERY

INS Outreach programme; Nuclear Science & Technology for Sustainable Development, held at Brijlal Biyani College, Amravati on March 25, 2023

Audience at the outreach programme

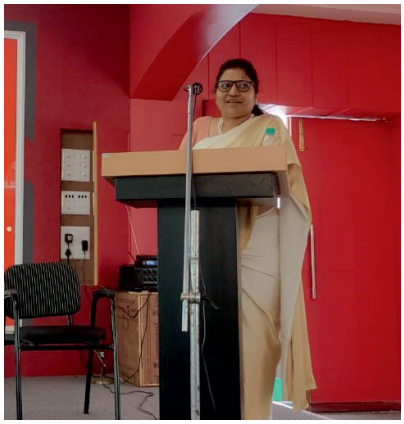
Dr. B.N. Jagatap, INS President addressing the gathering

Shri K.U. Agarwal



Dr. Thangvelu and Dr. Subramanian demonstrating water testing techniques

Dr. Sudhanshu Saxena



Dr. Mrinal Pai

Dr. Adish Tyagi

A student expressing her views

PHOTO GALLERY

INS Mysore Branch Functions

Azadi ka Amrit Mahotsav programme at Government Junior College, Bilikere on December 02, 2022

NSRP-23 during January 19-21, 2023

National Science Day celebration at Government PU College, Yelwal on February 28, 2023

Technical Seminar on Applications of Atomic Energy in Food and Agriculture on March 08, 2023

The views and opinions expressed by the authors may not necessarily be that of INS.
INS Newsletter is published by Satyawan Bansal on behalf of Indian Nuclear Society, Project Square, Anushaktinagar, Mumbai – 400094. E- mail: indiannuclearsociety@gmail.com | Tel: (+91) 022 25598327

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