IWSA NEWSLETTER

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Rainbow- 2016

BRANCHES

ROORKIE 1979 ▪ HYDERABAD 1979 ▪ PUNE 1980 ▪ NAGPUR 1982 ▪ KOLHAPUR 1982
DELHI 1987 ▪ KALPAKKAM 1987 ▪ BARODA 1988 ▪ LUCKNOW 1997 ▪ AMRAVATI 2010

Activities involving adults, senior school children and Teacher trainees at Rainbow-2016

Sports day activities for children from Nursery and Day Care

Pyjama party in Day Care

Hostel Day - 2016

From the Editor's Desk

Dear IWSA Members,

I hope you enjoyed reading the December 2015 issue with articles on International Year of Light, the Nobel Prizes for the year 2015, about the successful IWSA fund raising drive and many other interesting information about the IWSA activities.

We are here again with the first issue of 2016. This year marks the 75^{th} anniversary of discovery of the important element plutonium, which has made a great impact on mankind, in more ways than one. Dr.Vasudeva Rao, former Director of Indira Gandhi Centre for Atomic Research and currently Raja Ramanna Fellow with DAE has written an article on Plutonium – a unique element. Dr. Rao is a specialist in the chemistry of nuclear fuel cycle and actinide elements and thus the most appropriate scientist to share his knowledge on this subject. We are also presenting you another article on plutonium by two young women scientists from BARC. Thus you can enjoy reading about plutonium from the perspective of a very experienced scientist of DAE and also about the dreams regarding the future role of plutonium in our country's energy scenario from the young researchers.

In this Newsletter, we are presenting to you detailed reports on the various activities of IWSA. Science Academies sponsored Lecture Workshop on "Bioinformatics" was jointly organized by IWSA and Karmaveer Bhaurao College, Vashi, on 6^{th} and 7^{th} Feb. 2016. Several popular science lectures were held in various colleges of Mumbai and Navi Mumbai. A teaching aids exhibition - Rainbow 2016 was held on 3rd and 4th March 2016 on the theme of Science, Maths and Nature.

Indian Women Scientists' Association (Baroda Branch) has conducted training workshops and seminars during last year. Recently the branch has conducted two talks on "Conscious Living: A Need for Students" & Literary Touch (Poetry) in Science for Positive Pathway" and also a National Workshop on "Hyperspectral Remote Sensing of Natural Resources". A detailed report on these events has been included in this Newsletter. I hope that this will inspire other IWSA branches to conduct similar events and send us reports to be included in future issues of the Newsletter.

With Best Wishes,

Dr. Shyamala Bharadwaj
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Contents

President's Message

Dear IWSA Members,

Since the dawn of New Year 2016, IWSA HQ at Vashi has been bubbling with various activities for the last four months. I have great pleasure to present before you the same in detail.

The first activity was a skill development workshop "Udaan" for Balwadi teachers which was held at IWSA's ICICI Multipurpose Hall from 14^{th} to 16^{th} January, 2016. The objective of Udaan was to develop aptitude, skills and enhance knowledge when dealing with children. Udaan was followed by an annual cancer detection camp in memory of Late Dr. Jayashree Nadkarni funded by her family, where 83 participants were screened. A two-day lecture workshop on Bioinformatics, sponsored by the three National Science Academies in collaboration with KBP College, Vashi held on 6^{th} and 7^{th} February was attended and well appreciated by 53 college students from Mumbai and Navi Mumbai.

Five BRNS sponsored IWSA popular science lectures – one each in SIES College, Sion, VES College, Chembur and Padmashree Dr. D. Y. Patil College, Navi Mumbai and two at IWSA Complex were held which were attended by a large number of students. The valedictory programme of IWSA's Science Nurture program was held on 26^{th} February at IWSA Complex. Teaching Aids Exhibition "RAINBOW" was held on 3^{rd} and 4^{th} March, 2016 at IWSA Complex and was visited by about 2000 children and 1500 teachers and general public.

Executive and sub-committee members and Mr. Amit Modi of Techshiksha visited Anisha Global School at Hingewadi, Pune and interacted with teachers and students. On sports day which was held on 6^{th} February, 2016, children of Nursery and Day Care Centre participated with profound enthusiasm.

Besides these, day-to-day management of existing projects and a plethora of planning for future programmes like setting up of the virtual lab – collecting information on logistics, exploring different avenues for funding, prioritization of project stages, making modules for the experiments etc. were undertaken.

The triennial conference on 'Sustainability' has also been initiated with Dr. Surekha Zingde as Convener. All members are requested to mark the dates "December 2 – 4, 2016" in your calendar and come forward with appropriate contributions including early registration.

With the rainfall playing truant, and with water scarcity and deprivation threatening a large part of our country, it is imminent to plan varied strategies if we want sustainability in this context. Water will be one of the major topics for this conference and we wish to discuss different aspects, problems and possible solutions. We look forward to active participation from all members.

It is very encouraging to note that there is renewed vigour in IWSA activities since New Year and we need to maintain it most enthusiastically.

With Best Wishes,

Dr. Devaki Ramanathan
President, IWSA
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Cancer Detection Camp:

A free cancer detection camp was organized by IWSA on 23rd Jan. 2016 in association with Indian Cancer Society, Mumbai. The camp was sponsored by the family of our former Trustee and senior member of IWSA, late Dr. (Mrs) Jayashree Nadkarni to commemorate her memory and her wishes for the Association. The camp offered a chest X-ray, blood check, Head and Neck examination, prostrate evaluation for men and breast and cervical examination for women. Eighty three participants were screened during the camp.

Report on Science Academies Lecture Workshop on Bioinformatics

Indian Women Scientists' Association (IWSA) conducted a two-day workshop on "Bioinformatics' in collaboration with Karmaveer Bhaurao Patil College (KBP) in Vashi, Navi Mumbai on 6th and 7th of February, 2016. The workshop was sponsored by the Indian Academy of Sciences, Bangalore, Indian National Science Academy and National Academy of Sciences, India.

Fifty-three participants were selected from 110 applicants – most of whom were students with a background in life sciences from different colleges in Mumbai and Navi Mumbai. The program was held at IWSA on 6th February and at KBP College on 7th February and the participants had opportunity to have hands on experience on bioinformatics both at IWSA and KBP College, besides lectures by eminent scientists.

The inauguration of the workshop was held at ICICI Multipurpose Hall of IWSA on 6th February morning. Dr. Devaki Ramanathan, President, IWSA welcomed the participants and spoke about the various activities of IWSA. Dr. A. P. Thakare, Vice principal of KBP College gave a brief introduction of Rayat Sikshan Sanstha and KBP college. Dr. Tarala Nandedkar, Convener of the workshop gave an overview of the different educational programs by the Science Academies. Dr. Rita Mukhopadhyay, Co-ordinator of the workshop gave the outline of the lectures and practical sessions. Dr. K. V. R. Chary, Department of Chemical Sciences TIFR, Mumbai delivered the keynote address and spoke on NMR Spectroscopy and the use of bioinformatics for interpretation of NMR data and structure determination. Dr. Surekha Zingde, Vice President, IWSA acknolwledged the participation of the resource persons, the students and all those who have helped in the organization of the program.

The workshop had four sessions: (i) Use of bioinformatics for X-ray crystallography, (ii) Mass spectroscopy for protein identification and structure determination, (iii) Applications of gene sequences and (iv) From protein sequences to functional analysis. The resource persons included Dr. Ashok Varma, Dr. Rukmini Govekar, Dr. Geetanjali Sachdeva and Dr. Rita Mukhopadhyay.

On the first day, a two hour hands on session was held at the Computer Centre, IWSA and on the second day at KBP College. Each participant used personal terminals to design primers and for multiple sequence alignment. The participants also learnt about down loading protein sequences, matching sequences and structure determination.

The valedictory function was held at KBP College and Dr. A. P. Thakare, Vice Principal of KBP College presided over the function. There was a feed-back session wherein students expressed their satisfaction with the course and expressed the desire for more such courses.

IWSA and KBP College express their thanks to the three Science Academies for supporting the workshop.

BRNS sponsored IWSA Popular Science Lectures

In the past four months IWSA conducted five BRNS sponsored lectures in Mumbai and Navi Mumbai to reach out to college students and to inculcate scientific temper in them.

Popular Science Lecture at SIES College, Sion on 20th February, 2016

A popular science lecture was conducted on Saturday, the 20th February, 2016 at 14.00 hrs. at SIES College of Arts, Science and Commerce, Sion, Mumbai. Dr. Dimple Dutta, Senior Scientist, Chemistry Division, BARC delivered a lecture on "Crystal Field Theory".

The nature of the bonding in transition metal complexes has fascinated chemists and physicists for centuries. In 1893, Werner was the first to propose correct structures for coordination compounds containing complex ions, in which a central transition metal atom is surrounded by neutral or anionic ligands. However, the first attempt at explaining the nature of bonding in complex ions was through the Valence Bond Theory (VBT) suggested by Linus Pauling. This was based on the Heitler-London model of covalent bonds which was proposed in 1927. The VB approach concentrates on forming bonds in localized orbitals between pairs of atoms, and hence retains the simple idea of Lewis structures and electron pairs. The valence bond theory was fairly successful in explaining qualitatively the geometry and to some extent, the magnetic behaviour of the complexes. However, the major shortcoming was the inability to explain the origin of color in transition metal complexes. Crystal Field Theory (CFT) was proposed by the physicist Hans Bethe in 1929 by applying group theory and quantum mechanics to electrostatic theory. The name crystal field arose because the theory was first developed to explain the properties of solid, crystalline materials, such as ruby. Subsequent modifications to accommodate some co-valency in the interactions were added by J. H. Van Vleck in 1935.

Crystal Field Theory is based upon the effect of a perturbation of the d-orbitals consisting of electronic interaction between the cation nucleus and the negatively charged electrons of the ligands wherein the metal-ligand interactions are considered to be solely electrostatic in nature. In this lecture, Dr. Dutta discussed in detail about how Crystal Field Theory successfully accounts for some magnetic properties, hydration enthalpies and spinel structures of transition metal complexes.The lecture was attended by about 100 students and was well appreciated.

Popular Science Lecture at Vivekananda Education Society's College of Arts, Science and Commerce, Chembur, on 23rd February, 2016

Another IWSA-BRNS popular science lecture on "Proteomics Today" was delivered by Dr. Surekha Zingde, Vice President, IWSA at Swami Vivekananda Education Society's College of Arts, Science and Commerce, Chembur on 23rd February, 2016.

The Human genome sequence was completed in 2003 and since then the number of genes in the human genome has been continuously revised and the latest figure stands at around 20,000 protein coding genes. We are now aware that each gene is transcribed into RNA and there are several post transcriptional processes leading to differentially spliced RNA from the same gene. The next step, which is translation into protein is followed by several post translational modifications which results in many more proteins than the genes on the genome. It is obvious that Proteomics is as if not more complex than genomics.

The Human Proteomics Project of the Human Proteome Organization has undertaken to characterize all the proteins of the genome, through its chromosome centric (C-HPP) and Biology /disease based (B/D_HPP) approaches. It will generate a map of the protein based molecular architecture of the human body and become a resource to help elucidate biological and molecular function and advance diagnosis and treatment of diseases.

Another interesting and complex approach to characterize proteins is the Human Protein Atlas. This is a publicly available data base with millions of high-resolution images showing the spatial distribution of proteins in normal and cancer tissues and different human cell lines. The database is gene-centric and the website permits complex queries regarding protein expression profiles, protein classes and chromosome location.

Each of these Proteomics initiatives is supported by technological developments in mass spectrometry, use of mass spectrometry for the identification, quantitative assessment of proteins and their post translational modifications. The expression level of several proteins and protein-protein interactions have been possible using high through put arrays. These technologies are being used to answer both basic and translational queries in biosciences.

Proteomics in India, has grown immensely over the last twelve years. Proteomics is used to address a spectrum of biological queries in academia and industry. The contributions from India and its participation in the HUPO initiatives are receiving worldwide attention. India has representatives on the councils of the international proteomics organizations. There are major programs for promoting proteomics among the students, teachers and new researchers. It is apparent that Proteomics has come of age in India and its future is definitely very promising, Dr. Zingde opined.The lecture was attended by about 100 students and teaching community.

Popular Science Lecture at Padmashree Dr. D. Y. Patil University, Navi Mumbai on 9th March, 2016.

A third Popular Science Lecture was arranged at Padmashree Dr. D. Y. Patil University, Navi Mumbai on 9th March, 2016. In this lecture, Dr. P. K. Gupta, Associate Director, RRCAT, Indore discussed at length on "Photonics for Health Care Applications".

The versatility of Lasers, combined with the large information processing capability of present day computers have made high resolution imaging and diagnosis using light scattered from tissues possible. This non-invasive technique for detection of cancer at early stages and provides new modalities to treat it with high selectivity. Photonics has also provided means to optically manipulate, in a minimally invasive manner, single cells or sub-cellular objects and measure their mechanical or spectroscopic properties which can in turn provide important diagnostic information.

In the above talk, Dr. Gupta presented a brief overview of the current status of the developments made in some of these areas by his group at RRCAT. He briefly touched upon the work carried out on the use of optical spectroscopy for the screening of the cancer of oral cavity. The use of optical coherence tomography set ups and their functional extensions developed for biomedical imaging applications, in particular for non-invasive monitoring of the healing of wounds, was discussed next. Some aspects of the work being carried out on the use of photodynamic therapy for treatment of tumor in hamster cheek pouch and for antimicrobial and wound healing applications was also presented. Finally, he described a few representative studies on optically trapped red blood cells and the diagnostic information that these blood cells could provide.

About 125 students, doctors and professors attended the program and there was an interactive session which evoked lot of interest in the subject.

Popular Science Lecture on 13th March, 2016 at IWSA Complex

Dr. Snehal Deshpande, a well-known Physiotherapist attached to several hospitals of Mumbai and Director of SNEH, a rehabilitation Research Centre delivered a popular science lecture on "Wellness for Women" on 13th March, 2016 at IWSA's ICICI Multipurpose Hall, Vashi, Navi Mumbai. This lecture was held in collaboration with Rotary Club of Satellite City Navi Mumbai. In her, talk, Dr. Deshpande focused on the overall wellness of women of all ages. She covered several problems encountered by women at various stages, such as childhood, adolescence, youth, middle age and advanced age.

She started on a light note by engaging audience in a stimulating game displaying quick responses and reflexes. Then she spoke on the nutritional requirements of women at various stages. The lack of awareness of perfect nutrition could lead to several ailments later on, which can be avoided, she said. Good nutrition backed by exercises to strengthen the different parts of the body is extremely important.Several simple exercises were demonstrated for pre-natal, post- natal and different age groups of men and women. She was helped in her talk by her nutritionist and assistant physiotherapist.

The lecture was attended by 73 participants, which included students from neighbouring colleges, IWSA members and members of the Rotary Club of Satellite City Navi Mumbai.

Popular Science Lecture in the IWSA Complex on 28th April, 2016.

A popular science lecture entitled "Swami Vivekananda and the Tatas – A blessed combination which came as a boon to Indian scientific scenario" by Mataji Rev. Pravrajika Amalaprana, General Secretary, Sri Sarada Math and Ramakrishna Sarada Mission, Kolkata was held on 28th April 2016 at IWSA's ICICI Multipurpose Hall at 4.30 pm. There was an exhibition depicting Swami Vivekananda's influence on Indian science and industry. This was a historical exposition through photographs from the 1900s. The exhibition was inaugurated by Mataji at 4.00 pm on the same day. The exhibition was kept open to the public up to 30th April, 2016. More than ninety people attended the lecture and also visited the exhibition.

Conclusion of the Science Nurture Programme 2015-2016

Science Nurture Programme is the hands-on-experiment project run for a few students of VII and VIII grades from Sainath School of Sector 10, Vashi. These students come once every week for 2 hour's laboratory practice at IWSA in batches. Our Resource teachers (volunteers from IWSA) give them experimental practice based on their science courses at school. The experiments are developed as tools of fun, but they exemplify the underlying scientific concepts.

This year the programme started in August, 2015 and ended by February, 2016. There were no lab sessions in November as the school was closed for Diwali vacation. The concluding program was held on February 26, 2016 at 1.30 p.m. Both the batches were combined for this purpose. Two teachers from Sainath School who handle their science subjects were invited to attend. Resource teachers, Dr. Bakhtaver Mahajan, Dr. Devaki Ramanathan, Ms. Malati Rao, Ms. Tripta Tiwari and Ms. VijayalakshmiTilak were present. Dr. Devaki Ramanathan spoke about the National Science Day, its significance, about Sir C.V. Raman and his research work and the importance of the celebration of the National Science Day. Ms. Tripta Tiwari demonstrated a simple, but effective experiment to show how air contained in a balloon expands and contracts when immersed in water baths of different temperatures.

Ms. Malati Rao encouraged the students to talk about the experiments they had performed in a mock test at IWSA. All students gave the feedback that they enjoyed doing the experiments better than the theory. Dr. Bakhtaver Mahajan explained to the students the efforts that are put in to run this programme.

Dr. V. Sudha Rao, Trustee and past President of IWSA, was invited to distribute certificates of participation and a gift-book from IWSA to each student. The teachers expressed appreciation of IWSAs efforts as there was no provision for doing experiments at school at these levels. The students showed their gratitude with a loud applause.

Rainbow - 2016 (3rd and 4th March 2016)

This year's Rainbow – (Teaching Aids exhibition) theme was Science, Maths and Nature.

In the Maths corner, there were six games, namely Shape Bingo, Elephants' face, Maths in Market and Find the way home. Children enjoyed playing these games. Games helped them to develop concepts on shapes, number, time, opposites, currency, counting etc.

In the Science corner, a water saving game, wonder maze using magnets, Dolphin to find its way back home, play with helicopter, flying fish, Dr. Fix it (body parts), Khana Khajana (filling food pyramid), Rangoka Mela, Magic flying magnet to find animals and their young ones were kept.

Through all these games children (from 2-6 year group) not only enjoyed, but also explored the nature and world of science and maths. They also had hands on experience at an early age. This helps them to develop scientific temper since 80% of brain development takes place in early childhood.

There was a Moppet show on "What happens when Ryan's Crayons go on a strike", which enthralled about 2000 children who listened to the story of crayons'.

A workshop was conducted by Ms Shweta Naik of HBSCE on "Mathemagica". Simple mistakes made by students were narrated and corrected by conducting activities involving different games.

Amit Modi of Techshiksha conducted a workshop "Science is Fantastic" for about 100 NMMC students and teachers. Do-it-ourself kits were used to build a glider, a balloon powered car and a rubber band roller. By making these items Newton's three laws were explained in a very simple manner.

There were two very interesting demonstrations with flowers. Ms. Zarin Parikh showed six flower arrangements including Ikabana and Ms. Sulabba Sagwekar demonstrated how to make photo frames and greetings cards using dry flowers, leaves and how to make best use of waste.

Mr. Jayant Joshi demonstrated and sold kitchen compost baskets where in you can make manure by using kitchen waste in 20 days.

Ms. Rupali Madan gave a fantastic experience to children as well as mothers by making pots on a potter's wheel. Toys and books by Comet media and Navneet were also appreciated by parents and teachers.

The program was conducted in association with Chetan Memorial Trust. Our teachers Ms. Shaheena Shaikh, Ms. Snehalata Bhavsar, Ms. Rekha Pradhan and all trainees from this year's batch put in their best efforts to make Rainbow a grand success.

Sports Day Celebration

Sports Day was held on 6th February 2016 on the IWSA ground. All the children from Nursery and Day Care Centre participated in Sports Day Celebration. Parents of the children were also invited for the program.

Parents and children enjoyed and had fun.They celebrated Sports Day with full enthusiasm. Sports Day celebration began with exercise session followed by different games according to the age group of children.

Udaan

A skill development training workshop was conducted for 20 teachers of CORP (Community Outreach programme) at IWSA. CORP has been working with underprivileged communities. It was a unique and holistic programme aimed at developing attitude, skills and knowledge, which is necessary while you work with young children as well as to update and upgrade to modern improved teaching methods.

Visit to Anisha Global School, Hingewadi, Pune, on 12th March 2016

Accepting the invitation extended by Mr. Manoj Singh, Director, Anisha Global School (AGS), 6 members of IWSA & Amit Mody made a long trip to AGS. They were: Devaki R, Lalitha D. Malati Rao, Madhu Pawha, Vijayalakshmi Tilak and Vijaya Charkravarthy. At the School, Mr. Manoj Singh & Ms. Shraddha (PR) welcomed and introduced them to Ms. Ankita Patil Lunkad, Managing Trustee and Mr. Leo Png, advisor to AGS & Chief Executive Officer of CEOlution, a training programme company. Mr. Manoj Singh showed the IWSA members the whole school. After lunch the members gave a brief interview to a TOI journalist to whom they spoke in detail about all programmes of IWSA and their impression of AGS. Thereafter, Mr. Manoj Singh showed them the school's organic farm. AGS is located in an area of 7 acres – a lot of open space that includes space for sports activities & sustainable organic agriculture nurtured by the school children (under supervision). The agricultural plants and products : tomatoes / capsicum / melons / methi / broccoli / cabbage/ lettuce are grown using different farming techniques : hydro culture, fog ponies, vertical gardening etc. There were a number of spice plants, variety of apple trees & mango trees. All this was very impressive and exiting.

In the school, the members went around all the class rooms as the students were show casing their lessons through active demos using models, drama techniques, and speech: It was interesting to see the tiny tots of KG class & above give speeches on Bhagavad Gita, Roman Empire, the Indus valley civilization, historical Jalianwala bagh incident etc.

This was followed by a tour around the Physics & Chemistry labs of secondary classes. The visit to the Electronics lab where Wyse Biometries, Pune had supplied a number of kits to learn functioning of primary devices like Decode, transistor, circuits to measure voltage, frequency, inductance, resistance, capacitance etc was the most impressive.

The SPACE lab was the next stop where Smt. Sunita Patil, Centre for Art & Craft Enrichment promotes & develops artistic talent in students with choices from painting, wood working, glass art, metal craft & pottery. The SPICES lab – society for the promotion of Innovations & Creative Excellence in Schools, is a Dr. Vijay Bhatkar's initiative, adopted by AGS which extends Real-time collaborative technologies / cluster-based learning strategies and Inter & Intra schools knowledge transfers. AGS adopts education based on Future Schools of Singapore. There is no attendance register but a Biometric sensing system in each class. Students are taught holistically to pursue many subjects by their choice:- Music/Sanskrit/Latin/Art & Crafts/Farming/Dancing/Sports etc. The school is completely covered by Internet. The students have a lot of freedom to roam within the campus and wherever they are, can be tracked and the teachers can find out what the student is working on-all with the help of sensors, their tablets and internet. Innovative equipment from Heulab Pvt. Ltd., Singapore, help these students to access easy-to-use & interactive learning techniques.

AGS also teaches horology – the art of watch making and its intricacies – to the students. At the entrance of the school there is a TIME SQUARE – where 12 clocks surrounded a central big clock showing India time. The 12 clocks show times on other 8 countries including Indonesia, Bhutan, Canada, USA etc.

Evening of 12th March was the Annual day celebration for AGS. They had arranged variety entertainment and prize distribution for students. All parents and guests were present. Some prizes were given to innovative students who had given designs for future cycles. The IWSA members who were present, were felicitated on the stage, and given a glass trophy carrying the emblem of AGS. The visit was a good educative experience for all.

Felicitation of IWSA Members

Two members from IWSA, Dr.Sudha Padhye and Dr. Devaki Ramanathan were felicitated as women achievers from different areas by Evolve Business School, Sector 19, Vashi, on 15th March, 2016. The occasion was Women's day celebration of the school at Maratha Sahitya Mandir, Sector 6, Vashi. Ms. Vidya Randive and her daughter, Dr. Niyati Bhattacharya, Dr. Sudha Rao, Ms. Bhuvana R., Ms. Madhu Pahwa, Ms. Malati Rao & Ms. Vijayalakshmi Tilak attended the function from IWSA. Dr. Kiran Bedi joined the function to deliver a talk on women leadership.

Donations for Various Areas of the Hostel Building

Vijaya Mookambika Wings; Dr. M. A. Vijayalakshmi, Director, Centre for Bioseparation Technologies, VIT, Vellore, had given donations for the 3rd floor wings of the Hostel building. The naming of the wings took place on the 17th March, 2016 in the presence of IWSA members and the Hostel staff.

IWSA's Hostel Office: Dr Sunita Mahajan had given donations to IWSA for the hostel office in the memory of her late husband Mr. Madhusudhan D. Mahajan. The naming ceremony was held on 19th March, 2016 in the presence of IWSA members and hostel staff.

IWSA's Trustee Room: Mrs. Chayya Kelkar had given donation to IWSA for the Trustees' Room in the memory of her late father Prof. G.S. Gokhale. The naming ceremony was on 19th March, 2016 in the presence of IWSA members and the Kelkar family.

Report from Baroda Branch of IWSA

Lectures Conducted by the Branch

Indian Women Scientists' Association (Baroda Branch) has conducted many training workshops and seminars during last year. Recently the association has conducted two talks on "Conscious Living: A Need for Students" and "Literary Touch (Poetry) in Science for Positive Pathway".

These lectures were organized in association with Botany Alumni Association, at the Department of Botany, Faculty of Science, The Maharaja Sayajirao University of Baroda, Vadodara on 25th August, 2015. These have been conducted by considering the stress level of the students, especially the research students.

This report summarizes key points of the two lectures which focused on the students and their living with emphasis on the positive attitude towards their life. The aim of these talks was to highlight the best possible methods/techniques to minimize the stress level experienced by the students of the science field and how they can take each and every challenge in a positive way and live their life happily. The talks were given by the women scientists who are also experts in the field of stress management. One of them was Prof. Nalini Purohit and the other speaker was Dr. Jessica Karia. Prof. Purohit is a Professor in the Department of Chemistry, a renowned Hindi poetess and an active member of IWSA, Baroda Branch, while Dr. Jessica is a Consultant in the field of Remote sensing & GIS and she is also the alumni member of the Department of Botany. The talks were attended by many undergraduates and Post graduate students as well as research students from various departments of the Science Faculty, majority of them being girls. The first talk was given by Dr. Jessica and she highlighted how students can increase their concentration by different activities and if they become conscious about their life, it will directly influence their student life also. Later on Prof. Nalini Purohit spoke on how various scientific concepts are linked with literature. She explained to the students that by understanding this connection, they can change their negativity towards different challenges they face during their life. In this way the student community can be benefitted and they can increase their potential level during their student life. Highlights of these talks are as given below:

The objectives:

1. To understand the actual meaning of conscious living and why there is a need for students to live their life consciously.
2. To understand how science and literature are interlinked and how this connection is beneficial for building a positive attitude.

Evaluation of the Programme by Participants:

At the end, the participants actively participated in the discussion. They discussed various issues related to the subjects. In their feedback all of them highly appreciated the programme and they also gave some useful suggestions. Both the talks were highly appreciated.

Report on National Workshop on "Hyperspectral Remote Sensing of Natural Resources".

National Workshop on "Hyperspectral Remote Sensing of Natural Resources" was organized by ISG Vadodara Chapter in association with Department of Botany, Faculty of Science, The M.S.University of Baroda, Indian Women Scientist's Association and ISCA (Vadodara Chapter) during 7th to 13th September, 2015. This workshop was tailor made for practicing remote sensing scientists/engineer, policy makers, academicians and students working in the fields of Botany, Geology, Geography, Planetary Sciences and Life sciences. Seven experts from reputed institutes like MSU, ISRO, IIT Bombay, BHU, JNTU and other institutes of National repute were invited to delivers lectures. For this workshop, an engineer from Electrotek International Inc., Chennai was also invited. Twelve candidates from different universities/institutes participated in the workshop.This report summarizes key points from 7 days' schedule which focused on the Hyperspectral remote sensing with emphasis on natural resources. Weightage was also given to ground based hyperspectral remote sensing viz. Spectroradiometer. The workshop also identified some potential areas of collaboration between the MSU and other institutions like SAC-ISRO, IIT, BHU etc. Highlights of this workshop are as given below:

1. To understand physics and technology of hyperspectral remote sensing.
2. To understand techniques for hyperspectral ground truth data collection.
3. To understand the analysis, processing and interpretation of hyperspectral data of space.

The workshop covered Hyperspectral Remote Sensing Technology and Application addressing:

- Principles of Hyperspectral Remote Sensing.
- Hyperspectral Sensors and Data Characteristics.

This workshop also included instruction and laboratory/field demonstration of the basic operating features of an ASD spectrometer with an emphasis on:

- ASD instrument design, characteristics and performance parameters.
- ASD instrument setup and radiometric measurements.
- Use of RS3™ and ViewSpec™ Pro software to collect and post process spectra.
- Ground Truth Data Collection and Field Experiments.
- Incorporation of ASD spectra into programs such as ENVI®.
- Discussion of specific application considerations and case studies.

Evaluation of the Workshop by Participants:

At the end of workshop, participants were asked to evaluate the programme. In their feedback all of them highly appreciated the programme and they also gave some useful suggestions. Lectures by all the speakers were highly appreciated. Further, they felt that they now had a complete understanding of this advanced remote sensing technique although duration of the workshop was short.

List of the speakers and topic on which lecture was delivered:

Sr. No.	Name of Speaker	Topic
1	Shri. Purshotaman, Electrotek International Inc, Chennai	Use of Ground Truth Hyperspectral Spectroradiometer.
2	Prof. G. Sandhya Kiran, Head, Department of Botany, Faculty of Science, The M.S.University of Baroda, Vadodara	Concepts of Hyperspectral Remote Sensing.
3	Dr. S. S. Manjul Ex-Scientist, SAC-ISRO, Ahemdabad	Overview Of Hyperspectral Remote Sensing:Hyperspectral Imaging Systems.
4	Prof. I V. Murali Krishna, Former Professor and Head, Spatial Information Tech. & Director [R&D], JN Technological University, Hyderabad.	Hyperspectral Data Processing and Analysis.
5	Prof. D. Ramakrishnan, Professor, Department of Earth Sciences, I.I.T. Bombay	Processing and Analyses of Hyper-spectral Data for Geo-Exploration.
6	Dr. K. R. Manjunath, Space Applications Centre, ISRO Ahmedabad	Hyperspectral Data Applications for Vegetation Studies.
7	Dr. P. N. Shah, Former Director, RSAC-UP, Lucknow, Uttar Pradesh	Multispectral and Hyperspectral Remote Sensing Data Analysis For Natural Resources.

Dr. G. Sandhya Kiran
Convener, IWSA's Baroda Branch
Head and Professor, Department of Botany

Plutonium- an Unique Element

Abstract

Plutonium -more specifically the important isotope Pu-239- was isolated and identified on February 23, 1941, exactly 75 years ago. The discovery of plutonium has made a great impact on mankind, in more ways than one. The common man remembers plutonium as a dangerous and toxic element used in nuclear weapons. Those who belong to nuclear fraternity, however, recognize that it is an element with unique and interesting properties, and an element with great potential to provide clean energy to the world. This article provides an account of the discovery of plutonium and developments related to its production and utilization. Considering that this year is a landmark year for Pu discovery, the emphasis is more on historical rather than technical aspects.

Plutonium- a Special Element

Of all elements known to mankind, plutonium is indeed an unique element. It is the first man made element to be made in "visible" quantities, and the only man made element to be produced in tonne scale. It has unusual physical and chemical properties. It is one of the most dangerous materials to be handled by man in large quantities. To quote Seaborg [1], "Plutonium is so unusual as to approach the unbelievable. Under some conditions, it can be nearly as hard and brittle as glass; under others, as soft and plastic as lead. It will burn and crumble quickly to powder when heated in air, or slowly disintegrate when kept at room temperature. It undergoes no less than five phase transitions between room and temperature and its melting point. Strangely enough, in two of its phases, plutonium actually contracts as it is being heated. It also has no less than four oxidation states. It is unique among all the chemical elements; and it is fiendishly toxic, even in small amounts". It is important also to note that the early studies on plutonium had to be carried out under conditions of great secrecy and urgency.

Discovery of Plutonium

Soon after the discovery of artificial radioactivity by Joliot and Irene Curie, attempts began to create new elements / isotopes by bombarding different nuclides with projectiles. Fermi and Szilard recognized the possibility of "activating" stable elements by irradiating them with thermalized neutrons. Fermi and his group irradiated a large number of elements with neutrons and observed that out of 63 elements investigated, 37 showed an easily detectable activity. Fermi also explored the possibility of formation of trans-uranium elements by bombarding thorium and uranium with neutrons. During such studies, many new radioactive nuclides were observed, and Fermi in fact, concluded that some of the radioactive species were isotopes of elements 93 and 94.

The Nobel Prize in Physics 1938 was awarded to Enrico Fermi "for his demonstrations of the existence of new radioactive elements produced by neutron irradiation, and for his related discovery of nuclear reactions brought about by slow neutrons". In his Nobel lecture, Fermi stated "Both elements (thorium and uranium) show a rather strong, induced activity when bombarded with neutrons; and in both cases the decay curve of the induced activity shows that several active bodies with different mean lives are produced. We attempted, since the spring of 1934, to isolate chemically the carriers of these activities, with the result that the carriers of some of the activities of uranium are neither isotopes of uranium itself, nor of the elements lighter than uranium down to the atomic number 86. We concluded that the carriers were one or more elements of atomic number larger than 92; we, in Rome, use to call the elements 93 and 94 Ausenium and Hesperium respectively".

Fermi's conclusion, however, was not based on rigorous chemical identification. Ida Noddack [2] was quick to point out that Fermi's conclusions may not be valid. In fact, she stated that "when heavy nuclei are bombarded by neutrons, it would be reasonable to conceive that they break down into numerous large fragments which are isotopes of known elements but are not neighbours of the bombarded elements", which was indeed a clear prediction of the process of nuclear fission.

Systematic efforts to synthesise trans-uranics continued elsewhere. Mc Millan at University of California, Berkeley, irradiated thin films of uranium compounds to neutrons produced by the bombardment of beryllium target by 8 MeV deuteron beams in the 37 inch cyclotron. He observed that while fission products were ejected from the foil, a strong activity with 25 minute half-life remained in the foil. This was attributed by him to U-239, as also observed earlier by Hahn, Meitner and Strassman [3]. Mc Millan also observed the growth of a 2.3 d half-life beta emitter. His simple physical means of removal of fission product elements from irradiated uranium by exploiting the process of recoil of the fission products greatly enabled the study of the trans-uranium elements, which grew from the decay of uranium-239 retained in the foil. Emilio Segre further studied this phenomenon, and noted that the chemical behavior of the 2.3 d half-life isotope was more like a rare earth and not like rhenium whose properties the element 93 was expected to resemble. Segre's paper on this subject was published in 1939 [4].

Mc Millan however, found it difficult to believe that the new activity could be attributed to a rare earth. He decided to pursue further studies on this subject by using the 60 inch cyclotron that had been newly commissioned, and which could produce 16 MeV deuteron beams. He observed that the 2.3 d activity did not always behave like a rare earth. He was joined by Philip Ableson from Carnegie institute of Washington, who came to Berkeley on a short vacation. Abelson collaborated with Mcmillan and conducted more careful chemical speciation studies that conclusively showed that the isotope was indeed unique in its chemical properties. For example, its oxidized form in solution did not precipitate along with rare earth fluorides. Mc Millan and Abelson proved the genetic relationship between the 23 min (U-239) activity with the 2.3 d activity which proved that the 2.3 d isotope was that of element 93 [5]. They also tried to look for the alpha active daughter product of the element 93 (which should be element 94) but were not successful.

After Abelson returned to Washington, Mc Millan continued to refine the experiments to look for the alpha activity due to element 94, formed due to beta decay of element 93. He tried bombarding uranium directly with 16 MeV deuterons produced in the 60 inch cyclotron and found that significant alpha activity could be detected. However, Mc Millan could not continue the experimentation because he had to depart from Berkeley to take part in the development of radar for national defence. Seaborg wrote to Mc Millan and obtained his consent to continue the studies. He continued the work by involving A.C.Wahl, a graduate student and J.W. Kennedy, an instructor in the Department of Chemistry in the University of California. December 1940 saw the irradiation of uranium oxide with 16 MeV deuterons from the cyclotron, and the chemically separated 93 fraction had alpha activity growing in it, which could be clearly attributed to element 94 after the new element was separated from other elements by exploiting its redox behaviour. The key to the separation of pure form of Pu present in sub-ppm levels in a matrix of uranium containing highly radioactive fission products, was in fact, the discovery by Seaborg and Wahl that plutonium is carried by rare earth fluoride precipitates only when it is present in trivalent form, and it is not carried when it is present in hexavalent form. Experiments also showed that element 94 was more difficult to oxidize to its hexavalent state than element 93, and needed more powerful oxidizing agents. The isotope of plutonium thus identified was Pu-238, formed by the nuclear reactions:

$$^{238}_{92}U + ^{2}_{1}D \longrightarrow ^{238}_{93}Np + 2\,^{1}_{0}n \quad ; \quad ^{238}_{93}Np \xrightarrow[2.117\,d]{\beta^-} ^{238}_{94}Pu$$

On Jan. 28, 1941, the Seaborg team submitted a brief paper on the formation of radioactive element 94 from bombardment of deuterons on uranium to the journal "Physical Review", but the paper was withheld voluntarily until after the end of world war. The paper was then published in 1946 [6].

For the next year and half, detailed chemistry experiments were carried out to have a positive identification of plutonium and delineate its chemical properties. The element plutonium was positively identified on the night of Feb 23-24, 1941. The search for Pu-239 was simultaneously continued, with the involvement of Emilio Segre. The isotope Pu-239 was finally prepared by reaction of uranium with neutrons obtained through the bombardment of beryllium with 12 MeV deuterons, as per following nuclear reactions:

$$^{238}_{92}U + ^{1}_{0}n \longrightarrow ^{239}_{92}U \xrightarrow[23.5\,min]{\beta^-} ^{239}_{93}Np \xrightarrow[2.3565\,d]{\beta^-} ^{239}_{94}Pu$$

A secret report on the chemical properties of element 93 and 94 was sent to the Uranium Committee formed by President of USA, on March 1942, and the same was published with slight modifications in 1948 [7]. The first isolation of plutonium was described in a paper by Cunnigham and Werner as late as 1949 [8].

Soon after the isolation of Pu-239, a measurement of its neutron cross section, using a sample of a few micrograms of the isotope, revealed that it was more fissile than U-235. This was communicated to the journal "Physical Review" in 1941 as a letter, but this was also voluntarily withheld from publication until the end of the second world war [9]. It is interesting to note that even before its isolation and identification, in 1940, Louis Turner, from Princeton University, predicted [10] that the neutron capture in U-238 would lead to formation of new isotopes, among which Eka Osmium (referring to plutonium, whose properties were expected to be similar to that of Osmium at that point of time) might be expected to have a large fission cross section.

Naming of Element 94

As the element 92 (uranium) was named after the planet Uranus and the element 93 (neptunium) was named after the planet Neptune, element 94 got its name "plutonium" after the plant Pluto. However, the name plutonium was held a secret and the new element was referred to as "element 94" or even "element 49" (4 standing for atomic number 94 and 9 standing for mass number 239) until after the war. In Seaborg's words, "following the discovery in February 1941 and well into 1942, we continued to use only the name 'element 94' among ourselves and the other few people who knew of the element's existence. But we needed a code name to be used when we might be overheard. Someone suggested "silver" as a code name for element 93, and we decided to use "copper" for element 94. This worked just fine until, for some reason I cannot recall now, it became necessary to use real copper in our work. Since we continued to call element 94 'copper,' on occasion we had to refer to the real thing as 'honest-to-God copper.'

Microchemistry

The compulsion to make intricate measurements on very small samples of plutonium led to the development of unique techniques in microchemistry. Initial experiments on the properties of plutonium in solution were carried out in beakers and test tubes made of capillary tubing and under a microscope, using micromanipulators. Typically, the reactions were carried out in capillary cones about 1mm in diameter, 3-4 mm in length and a capacity of approx. 1 microlitre. Because of the cone size, reagents were transferred using handmade micropipettes with tip volumes as small as 0.01 microlitre. To make weight measurements on plutonium samples, Cunningham devised a quartz fiber microbalance that was calibrated in three different ways to a precision of a hundredth of a microgram [1].

The first time man could "see" a synthetic element - plutonium was on August 18, 1942. A few micrograms of plutonium were separated from several milligrams of rare earths, from a sample of uranium irradiated in the 60 inch cyclotron at Berkeley [1] by B.B. Cunningham and L.B. Werner. Subsequently, hundreds of pounds of uranium were irradiated with neutrons produced by the cyclotrons at Washington and Berkeley, and the irradiated uranium was shipped to Chicago. A team of chemists succeeded in separating around 100 micrograms of Pu along with after a few milligrams of rare earths. Cunningham and his team obtained Pu through several steps of further purification, and finally, a sample of 2.77 microgram of Pu in the form of oxide was for the first time weighed on Sep. 10, 1942, using the balance built by Cunningham [1].

Separations Chemistry

It can be seen from the above that the development of plutonium chemistry also fawned the development of separations science. Following the development of the techniques for separation of Pu from irradiated uranium targets, a decision was taken to set up a plant at Hanford based on co-precipitation with bismuth phosphate. This process was patented in 1957 (S.G.Thompson et. al., US patent no. 2785951 dt. Mar.19, 1957). Today, world over, plutonium is separated in a pure form from irradiated uranium based fuels or MOX (U,Pu) fuels by the Purex process. This process essentially exploits the relative ease in reduction of plutonium to its trivalent state in solution, while uranium is retained unaffected in its hexavalent state in the reduction step. Tri-n-butyl phosphate dissolved in aliphatic diluents is used as the extractant to separate uranium and plutonium from irradiated fuel. This process was patented in 1960 by Anderson et al (US Patent no. 2924506 dt. Feb 9, 1960).

Plutonium in Metal Form

Once the techniques for separation of plutonium from irradiated uranium and preparation of its compounds were established, efforts began to obtain plutonium metal. Magel and Dallas designed and built a unique centrifuge, in which high temperature reduction of plutonium compounds could be carried out along with simultaneous centrifugation. The design enabled collection of very small globules of plutonium metal at the bottom of the graphite crucible placed in the centrifuge. Using this centrifuge, the first pure metal was prepared in Nov. 1943 by the reduction of 35 mg of PuF_4 by barium at 1400o C, and a one gram of plutonium metal specimen was produced on March 23, 1944 [11].

The measurement of the density of plutonium metal produced in various runs gave a clear indication of the allotropism in plutonium metal, because the density values varied very significantly [12]. The first conclusive evidence of the allotropism was provided by careful dilatometric experiments carried out by Schnettler in June 1944 (for an excellent account of plutonium crystallography, please see Ref.13). As a sample of plutonium metal was heated from ambient temperature, the thermal expansion behavior was seen to be unusual, with some phases exhibiting positive and some negative thermal expansion. Alpha plutonium was hard and brittle, and was unsuitable for fabrication into shapes required for the weapons. A systematic and thorough search into effect of alloying elements was initiated, and finally it was concluded that alloying with gallium could stabilize the plutonium in delta phase, with desirable properties. It is however, significant to note that the Pu-Ga phase diagram arrived at by American and Russian scientists differed significantly, and only after over 50 years, the differences could be reconciled! [14]. This goes to show the uniqueness of plutonium as a complex element for human investigation, both in solution and solid forms.

Manhattan Project

The recovery of large quantities of plutonium, its conversion to metal and the fabrication of the atomic bomb were all part of a unique and ultra-secret mega project, the Manhattan Project, the like of which perhaps has not been known in science history. It was led by Major General Leslie Groves of the U.S. Army corps of engineers; physicist J. Robert Oppenheimer was the Director of Los Alamos National Laboratory that developed the bombs. At the peak of the project, it has nearly 130000 employees, and cost nearly 2 billion USD at 1945 value [15]. This project finally led to the Trinity Nuclear Test, and subsequently, the end of the world war through the dropping of bomb over Nagasaki.

Actinide Hypothesis

Today, we understand that the element actinium and the 14 elements following it, including plutonium constitute the "Actinide Series", much like the Lanthanide series starting from Lanthanum. However, this concept was not known at the time of discovery of neptunium or plutonium. It was presumed that the elements 90-94 would occupy positions below elements 72-76 (Hf to Os). Thus, uranium was presumed to belong to same group as molybdenum, and plutonium would resemble osmium. However, careful and detailed investigations on the chemical properties of elements 90-94 showed that although the first members (Th,Pa) of this group show a great resemblance in chemical properties to the first members (Hf, Ta) in the 5d transition series and to the first members (Zr,Nb) in the 4d transition series, the later members (Np, Pu) have unique chemical behaviour not seen with Re and Os and to Tc and Ru. Seaborg therefore advanced a hypothesis of actinide series, in which the 5f shell gets filled [16]. An excellent account of the evolution of the concept and its basis is available in Ref. 17.

When Seaborg advanced this hypothesis, there were few takers! In the words of Seaborg, "When I broached the idea at the upper level Met-Lab meetings, it went over like the proverbial lead balloon. I remember that at one meeting, the head of the chemistry division said that even if the concept was correct, he doubted it would be of much use. Latimer (Wendell Latimer, a senior chemist and a Dean at Berkeley), told me that such an outlandish proposal would ruin my scientific reputation. Fortunately, that was no deterrent because at the time I had no scientific reputation to lose" (see Ref.18).

Unique Properties

Plutonium metal has many unique and unusual properties [19]. The allotropism observed in Pu metal, and its unusual thermal expansion behaviour were discussed above. Plutonium has six allotropic modifications at atmospheric pressure, and a seventh one at higher pressures. Interestingly, the crystal structures of the allotropes closest to room temperature are of low symmetry. Among the six allotropes, the phase with fcc structure, which is a close packed atomic arrangement, is least dense. Unlike most metals, plutonium contracts on melting. The surface tension of liquid plutonium is very large, and plutonium has the highest viscosity among metals, at temperatures near its melting point [20]. The electrical resistivity of plutonium metal is very high as compared to most other metals, and increases as the temperature is lowered to 100 K.

In solution, plutonium can exist in oxidation states from +3 to +7 under various conditions. In fact, the oxidation potentials of plutonium ions are so close that under certain conditions, as many as four oxidation states can coexist in solution. The absorption spectrum of plutonium ions exhibit several bands in visible wavelength region, with the result that solutions of plutonium are coloured, and in fact provide a visual clue to the presence of specific oxidation states.

Plutonium as Fuel

The first fast neutron reactor Clementine used plutonium metal as the fuel. The reactor attained criticality in 1946, and operated till 1952. Plutonium in the form of mixed oxide with uranium, was introduced in a thermal reactor for the first time in 1963, and in a commercial reactor in Germany in 1972. Today, the uranium, plutonium mixed oxide (MOX) is used as fuel in a number of reactors in Europe and Japan. Plutonium has also been deployed in various other chemical forms of fuel, viz., carbide, nitride and metal alloys.

Indian Experience

Naturally occurring uranium has only 0.72 % of U-235, and the isotope U-238 accounts for nearly 99.27 %. While U-235 is fissile, U-238 is not fissile but fertile, i.e., it can be converted to a fissile isotope. U-238 can absorb neutrons in a reactor, and get converted to Pu-239 through the nuclear reactions indicated earlier. Pu-239 being fissile, this conversion of U-238 is a unique route to efficient utilisation of the natural uranium. India has from the inception of its nuclear programme, enunciated and followed a policy that would allow it to exploit its modest natural uranium resources to the fullest possible extent. This philosophy, termed the three stage program, essentially involves use of natural uranium in PHWRs in the first stage, use of Pu generated in the first stage, along with the depleted uranium, in fast reactors to enhance uranium utilisation and produce U-233 from thorium, and ultimately exploiting the large thorium resources in the third stage. This three stage programme, enunciated by Dr. H.J. Bhabha, has continued to be the basic tenet of the DAE's policy with regard to nuclear energy production.

Plutonium separation from irradiated uranium in India on a pilot plant scale started with the setting up of the Plutonium Plant (called "Project Phoenix" at that time) at Trombay. The plant was commissioned on March 31, 1964. Based on the successful operation of this plant and using the experience gained from this plant, India commissioned additional reprocessing plants at Tarapur and Kalpakkam, which continue to separate plutonium from irradiated thermal power reactor fuels. The plutonium recovered from these plants has been used to fabricate fuel charge for the Purnima reactor at Trombay, Pu-Al alloy fuel for KAMINI reactor at Kalpakkam, MOX fuel for thermal reactors and the Pu-rich, unique Pu,U mixed carbide fuel for the Fast Breeder Test Reactor (FBTR) at Kalpakkam. The plants were also the source for the plutonium used in fabrication of the MOX fuel at the Advanced Fuel Fabrication Facility at Tarapur, Maharashtra, for use in the 500 MWe Prototype Fast Breeder Reactor built at Kalpakkam. India has thus has rich experience in fabricating a variety of Pu based fuels.

The first reactor in India to use plutonium fuel was the Purnima reactor, a critical facility at Trombay. Purnima-I attained its first criticality in May 1972, and the experiments in Purnima reactor gave valuable inputs on fast reactor neutronics. The first irradiation experiments with MOX fuel pins in the CIRUS reactor were conducted in 1975. With the decision to use a unique Pu rich U,Pu mixed carbide as driver fuel for the FBTR at Kalpakkam, India carried out extensive developmental studies on this hitherto unexplored fuel. The fabrication of the carbide fuel for FBTR is carried out at the Radio-metallurgy Laboratory at BARC, Trombay. The reactor attained criticality in 1985, and has been operating successfully for the last over 30 years. The Pu based carbide fuel has reached record levels of burn-up (around 160 GWd/t); over 1500 pins have crossed 150 GWd/t and only one fuel pin failure has been reported so far. The MOX fuel test subassembly with PFBR fuel composition (with 30 % PuO2) was irradiated at FBTR to a burn-up of over 100 GWd/t.

The Pu-rich mixed carbide fuel from FBTR, discharged at burn-up levels exceeding 150 GWd/t, has been reprocessed at the CORAL facility at Kalpakkam successfully, and the Pu recovered has in fact, been used to fabricate fuel for FBTR, thus demonstrating closure of FBTR fuel cycle. It should be noted that there was no prior experience in the reprocessing of such Pu rich carbide fuel by any country. Actions are now under way to establish a fuel cycle facility at Kalpakkam to close the fuel cycle of PFBR, by reprocessing its MOX fuel and re-fabrication. When operational, it would be one of the most unique plutonium facilities in the world, a, comprehensive fuel cycle facility co-located with the reactors that it would serve, and carry out reprocessing and refabricating Pu based oxide fuels on a large scale.

In future, the Department of Atomic Energy has plans to establish fast reactors based on metal alloy fuels based on plutonium, to exploit their high breeding potential with other simultaneous advantages. Towards this, sodium bonded U-Pu-Zr fuel pins have been fabricated and test pins are undergoing irradiation in FBTR. The development of pyro-processing route for Pu based metal alloy fuels is also under way.

It is thus obvious that plutonium would continue to play a central role in the Indian nuclear power programme, and this approach would enable India to enhance its nuclear energy growth in a sustainable manner. For India, plutonium represents a great potential for production of clean energy through nuclear fission, and we can expect that in the next few decades, plutonium utilization to expand nuclear energy growth would be a central theme of our programmes.

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Plutonium - 75 Years and Beyond

Introduction

Nuclear power plays a very important role in meeting the growing need for energy of the World. As on March 2016, 422 nuclear reactors are operating all over the World, with an installed capacity of 384.116 GWe energy [1]. Around 66 nuclear reactors are under construction in various countries. In India, during the year 2015, 21 are operational with an installed capacity of 5780 MWe [2]. In the year 2015, the electricity production due to nuclear power was 34.6 TW.h, contributing to about 3.5 % of the total energy produced in India. Around 6 reactors are under construction at various locations in the country.

The element plutonium has a unique role in the history of various fields of science and technology, which include chemistry, physics, nuclear technology, and strangely even in international relations. The immense interest in plutonium is due to its unique nature of playing a dual role, use as nuclear fuel for power production and in nuclear weapons, making it both a friend and foe depending on which side of the story is looked upon. Notwithstanding the derogatory reference to Pu as a " Bargain with the Devil", Pu plays and would continue to play an important role to meet the energy starved world.

Plutonium is one of the most complex and fascinating elements present in the periodic table. The metal exhibits six solid allotropes at ambient pressure and its phases are extremely unstable – changing with change in temperature, pressure, chemical additions, and time (due to its unique property of self-irradiation damage) associated with a change in its density by as much as 25%. The metallurgical properties vary for each of these allotropes - from brittle to malleable. It has six chemical oxidation states (including the metal state), possible to change from one oxidation state to other, thus making it possible to form innumerable complexes in environment – an attractive candidate for study by chemists.

The element Pu was discovered over 75 years ago and an attempt has been made in this article to introduce to the readers about how the discovery of Pu was made and also give a concise review of the nuclear energy program in India for the utilisation of Pu for the peaceful purposes.

Historical Perspective of Plutonium

The isotope of plutonium (238Pu) was first produced in late 1940 by bombarding uranium with deuterons [3] by the reactions below.

$$^{238}U + {}^{2}H \longrightarrow {}^{238}Np + 2\,{}^{1}n$$
$$^{238}Np \longrightarrow {}^{238}Pu + {}^{-1}e\ (T_{1/2}\ \text{of}\ {}^{238}Np = 2.1\ \text{days}) \quad \text{..............................(1)}$$

The isotope ^{239}Pu, which is of great importance to the nuclear technology was discovered in 1941 by the following reactions.

$$^{238}U + {}^{1}n \xrightarrow{(n,\gamma)} {}^{239}U \xrightarrow[23.5\ \text{min}]{\beta^-} {}^{239}Np \xrightarrow[2.36\ \text{days}]{\beta^-} {}^{239}Pu \quad \text{..............................(2)}$$

The ability of 239Pu to fission with slow neutrons was established in 1941, which paved the way for its use as a nuclear energy source. In March 1942, the element 94 was christened as 'plutonium' with the chemical symbol of 'Pu'. Plutonium was named after the planet Pluto, following the pattern used in naming neptunium and uranium.

In August 1942, in the wartime Metallurgical Laboratory at the University of Chicago, about 1μg of 239Pu was isolated from 90 kg of uranyl nitrate which was irradiated in a cyclotron [4]. This experiment made plutonium the first man made element to be obtained (as Pu(IV) iodate) in a substantial quantity. Plutonium is now produced in much larger quantities than any other synthetic element in the world from reprocessing of the irradiated nuclear fuels by PUREX process which is discussed in this article subsequently.

Following these initial experiments, a large number of isotopes of Pu were synthesized from different reactions, all of which are radioactive in nature. The data on various quantities such as nuclear masses, decay schemes, alpha/beta and gamma energies etc. can be obtained from different data sources [5,6].

Traces of plutonium are found all over the world, which predominantly is 'manmade' plutonium - due to the atmospheric testing of nuclear weapons during the 1950s. The two isotopes of plutonium (namely 239Pu and 244Pu) are also found which are 'natural' in origin. 239Pu can be produced in nature by nuclear processes occurring in uranium ore bodies (by reaction 2 due to the neutrons emitted by spontaneous fission of 238U) Minute traces of 244Pu exist in nature as remnants of primordial stellar nucleosynthesis. Alpha spectrometry and high resolution and high sensitive mass spectrometry techniques have been employed for determination and characterisation of isotopic composition of plutonium in environmental samples.

Production and Uses of Pu Isotopes

Of the different Pu isotopes, the isotopes ^{238}Pu, $^{239-244}Pu$ have been produced in sufficient quantities from nuclear reactors, for various applications. The production and application of a few of these isotopes of Pu are given below.

^{238}Pu

Large amounts of ^{238}Pu can be produced by neutron irradiation of ^{237}Np followed by chemical separation using ion exchange techniques. Isotopically pure ^{238}Pu can be obtained by separating it from ^{242}Cm. Due to its short half-life (87.7 years), it has a large power density of about 6.8 to 7.3 W cm^{-3} (Specific Power of 0.57 W g^{-1}). Hence, the decay heat of ^{238}Pu can be utilised by a suitable energy conversion system to partially transform into electricity.

Based on this process, ^{238}Pu powered nuclear pacemaker was first implemented in France on April 27, 1970. Subsequently, nuclear pacemakers powered by ^{238}Pu have been implanted in a number of patients and were found to be successful. Subsequent to advances in electronics, ^{238}Pu powered nuclear pacemakers have been discontinued.

For space exploration, $^{238}PuO_2$ have been employed as power sources for instrument packages on the five Apollo missions to the Moon, the Viking unmanned Mars Lander, and the Pioneer and Voyager probes to the outer planets (Jupiter, Saturn, Uranus, Neptune and beyond). Several General Purpose Heat Source Radioisotope Thermoelectric Generators (GPHS-RTGs) have been flown on Galileo, Ulysses, and Cassini spacecrafts. Several Smaller Light Weight Radioisotope Heater Units (LWRHUs) have also been used to maintain spacecraft equipment within their normal operating temperature ranges, which is important in space exploration [7]. These smaller heater units have been employed on the Pioneer 10 and 11, Galileo, Mars Pathfinder, Mars Exploration Rovers (Spirit and Opportunity), and Cassini spacecraft, and are planned for use in many future missions.

^{239}Pu

^{239}Pu is the most important isotope of plutonium. It has a long half-life of 24,110 years [5,6]. The cross section of ^{239}Pu for fission with thermal neutrons is high (748 barns) and hence it is useful as nuclear fuel for both nuclear power reactors as well as nuclear weapons. The second nuclear weapon used on Nagasaki during the Second World War was the one based on ^{239}Pu. Most of the studies on the chemical and physical properties of plutonium have been done using ^{239}Pu. The specific power of ^{239}Pu is 2.2 x 10^{-3} W g^{-1}. It has high alpha specific activity. Due to the high fission cross-section, one also has to take precautions regarding the criticality hazard when handling large amounts of ^{239}Pu which can be addressed by limiting the mass of Pu handled as solid, its concentration in a solution and geometry of the system employed. In addition to criticality, due to its high alpha specific activity, the neutron dose due to the (α,n) reactions with low Z materials cause another issue for handling ^{239}Pu.

Production of Higher Isotopes of Pu

The higher plutonium isotopes are formed due to the successive neutron capture as per the following equation. This can be possible either in a high flux nuclear reactor or in a nuclear device (where a copious amount of neutron is present for the reaction to proceed.)

$$^{239}Pu \xrightarrow{(n,\gamma)} {}^{240}Pu \xrightarrow{(n,\gamma)} {}^{241}Pu \xrightarrow{(n,\gamma)} {}^{242}Pu \ldots\ldots\ldots\ldots\ldots(3)$$

The heavier isotopes of Pu (244Pu, 245Pu, and 246Pu) were discovered in the coral debris of the Mike thermonuclear test conducted in 1952, due to the extremely high neutron fluxes of the event.

Properties of Pu

Plutonium sits near the middle of the actinoid series marking the emergence of 5f electrons in the valence shell. Elements that are in the left of Pu (Pa, U and Np) have delocalized (bonding) electrons exhibiting multiple oxidation states. The elements to the right of Pu (Am and above) exhibit more localized (nonbonding) character and have predominantly one oxidation state (III). For Pu, poised in the middle of the actinoid series, the electrons seem to be in a unique blend, having both these characters, a property that leads to novel electronic interactions and unusual physical and chemical behaviour. When the unique nuclear properties are also considered, the study of plutonium is inherently multidisciplinary in nature.

The solution chemistry of Pu is also unique due to its ability of existence in different oxidation states in combination of its property of disproportionation (i.e. conversion from one oxidation state to another). The interactions of Pu with various environmental ligands are interesting to study and several theoretical investigations have also been performed for understanding the behaviour of Pu in environment.

A large amount of work has been performed over the years regarding the different Pu compounds and the interaction of Pu with various ligands, which have led to many doctoral thesis in India and Worldwide. Due to paucity of space, the same is not discussed in detail in this article. The readers may refer to books and the references thereof for understanding the scientific research regarding Pu and its isotopes [8].

Production of Pu in the Nuclear Fuel Cycle

Pu can be produced in larger quantities by reprocessing of irradiated fuels from Nuclear reactors. Pu is produced in the 235U based nuclear reactors by the process explained by equation 2 earlier. PUREX process is usually employed for the reprocessing of the irradiated nuclear fuels. The schematic diagram of the PUREX Process is shown below.

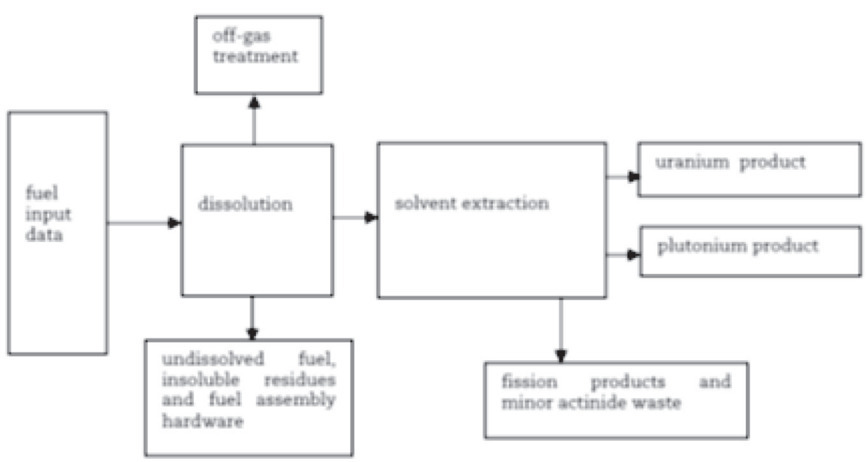

Figure 1. Schematic diagram of the PUREX flow sheet for the Reprocessing of Spent Fuel for obtaining U and Pu [11].

PUREX Process

30% v/v Tributyl Phosphate with n-dodecane as diluent is used as an extractant in the PUREX process. The different steps in the PUREX process are (i) decladding or dejacketing (i.e removal of the fuel sheath either mechanically by shearing into small pieces or chemically by dissolution) (ii) Dissolution in Nitric acid (iii) Feed conditioning (iv) Co-decontamination of U and Pu from Fission products (v) Uranium and Plutonium Partitioning - separate the U and Pu into two separate streams for further processing (vi) uranium and plutonium purification cycles (vii) Conversion to respective oxides. The details of the PUREX process can be obtained from various reports and the references thereof [9, 10, 11].

Nuclear Reactor

The nuclear reactors are devices designed to maintain a chain reaction producing a steady flow of neutrons generated by the fission of heavy nuclei. In these reactors, the fission of heavy atomic nuclei, the most common of which is ^{235}U, produces heat that is transferred to a fluid which acts as a coolant. This heat energy is used for converting water into steam which runs a turbine for the conversion to electricity. The details of different types of reactors can be obtained from various books and reports [12].

The only natural element currently used for nuclear fission in reactors is uranium. Naturally occurring uranium comprises, almost entirely, two isotopes: ^{238}U (99.283%) and ^{235}U (0.711%) (a very small amount of ^{234}U (0.005%). The former is not fissionable while the latter can be fissioned by thermal neutrons. As the neutrons emitted in a fission reaction are fast, in reactors using ^{235}U as fuel the neutrons are slowed down by "Moderator" before they escape from the fuel for furthering the nuclear fission reaction. A fraction of the neutrons are captured by ^{238}U producing ^{239}Pu (Reaction 2). The ^{239}Pu formed can also undergo fission and also form higher isotopes of Pu in the reactor (Reaction 3). The isotopic composition of Pu produced in a reactor will depend on the various parameters. The formation of the different Pu isotopes will be dependent on many factors such as (i) Initial Enrichment of ^{235}U in the fuel (ii) Type of moderator used (iii) Neutron energy spectrum in the reactor (iv) Design features of the reactor such as control rods (v) Burn-up etc. and is useful for identification of the source of Pu. The production of ^{239}Pu by the thermal reactors is not very efficient and hence the concept of breeder reactors was introduced.

Concept of Breeder Reactors

In thermal reactors, with increase of the neutron energy, the fission cross-section increases and the capture cross-section also increases at almost the same rate. The number of neutrons emitted when one neutron is absorbed in the nucleus expressed in equation (1) below

$$\eta = \nu \{\sigma f / (\sigma f + \sigma c)\} \qquad (1)$$

where σ_f and σ_c are the cross-sections for fission and capture, respectively, and ν is the average number of emitted neutrons per nuclear fission. The value η depends on the energy of the colliding neutrons, and is shown in the Fig-2. For thermal neutrons, η is about 2, however, when the energy is more than 0.1 MeV, η increases rapidly. If many neutrons are generated in this way, not only can a chain reaction be maintained, but it may also be possible that there will be excess neutrons. If ^{238}U absorb these neutrons, ^{239}Pu can be produced (Reaction 2). Fissile material can be produced at the same time as fissile material is consumed for power production. The number of newly generated fissile atoms per consumed fissile atom is called the conversion ratio. If the value η is sufficiently larger than 2, it is possible to obtain a conversion ratio larger than 1. Thus, it is possible to generate more fissile material than is consumed. This is called breeding, and the conversion ratio in this case is often called the breeding ratio and this type of reactor is called a breeder reactor. In other words, fissile material can be bred using fast neutrons in a fast breeder reactor.

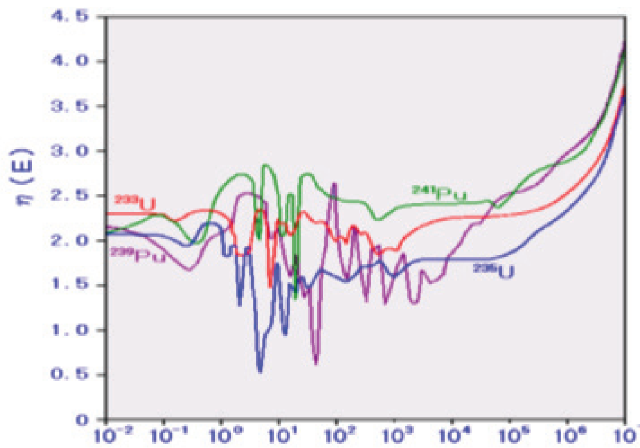

Figure 2. Variation in the effective number of Neutron emitted per fission with Neutron energy [13].

Three Stage Nuclear Power Program of India

Plutonium, along with uranium and thorium (Th), plays a major role in the three stage Indian Nuclear program. Dr. Homi Bhabha devised India's three-stage nuclear power program in 1954. The Indian nuclear power program is envisaged in three stages focusing on the judicious utilisation of our Indian Nuclear fuel resources, especially the vast thorium reserves to ensure long-term energy sustenance. India has only about 2% of the global uranium reserves but 25% of the world's thorium reserves [14]. The multifaceted research activities have also been widened for ensuring a synchronous advancement from one stage to another in a seamless manner.

The three stages are [15]:

1. Natural uranium fuelled Pressurized Heavy Water Reactors (PWHR)
2. Fast Breeder Reactors (FBRs) utilizing plutonium based fuel
3. Advanced nuclear power systems for utilization of thorium

Stage 1

The first stage involved using natural uranium to fuel Pressurized Heavy Water Reactors to produce electricity and producing ^{239}Pu as a by-product. Using Pressurized Heavy Water Reactors rather than Light Water Reactors was the best choice for India due to its limited U resources. While Pressurized Heavy Water Reactors used natural uranium, Light Water Reactors required enriched uranium. India has mastered the first stage of the program, where all the components of PWHR are indigenously manufactured in India. The ^{239}Pu produced would be used in the second stage.

Stage 2

The second stage involves using ^{239}Pu to produce mixed-oxide (MOX) fuel, which would be used in Fast Breeder Reactors. These reactors have two purposes (i) ^{239}Pu undergoes fission to produce energy (ii) ^{238}U in MOX can produce more ^{239}Pu. Furthermore, ^{232}Th will be used in the reactor, to produce ^{233}U (Reaction 4). This uranium isotope is crucial for the third stage.

$$^{232}\mathrm{Th} \xrightarrow{(n,\gamma)} {}^{233}\mathrm{Th} \xrightarrow[21.8\ \mathrm{min}]{\beta^-} {}^{233}\mathrm{Pa} \xrightarrow[27.0\ \mathrm{days}]{\beta^-} {}^{233}\mathrm{U} \text{..............................(4)}$$

Pu-rich carbide based, sodium cooled test reactor namely the Fast Breeder Test Reactor (FBTR) has been in operation for over 25 years at IGCAR, Kalpakkam. The operation of FBTR has provided valuable experience in the various stages of nuclear fuel cycle especially for fast reactor fuels – production of Pu based fuel of required characteristics, operational experience including the handling of Liquid Na as coolant and also for the reprocessing of the fast reactor based fuels. Based on this experience, the Prototype Fast Breeder Reactor (PFBR) is being developed to demonstrate the techno-economic viability of Fast Breeder Reactor technology.

Stage 3

The main purpose of stage-3 is to achieve a sustainable nuclear fuel cycle. The advanced nuclear system would use a combination of 233U and Th. Thus India's vast thorium reserves could be utilized, using a thermal breeder reactor. India is also looking forward to simultaneously use its thorium in other technologies. The options include Accelerator Driven Systems (ADS), Advanced Heavy Water Reactor (AHWR) [16] and Compact High Temperature Reactor (CHTR) [17].

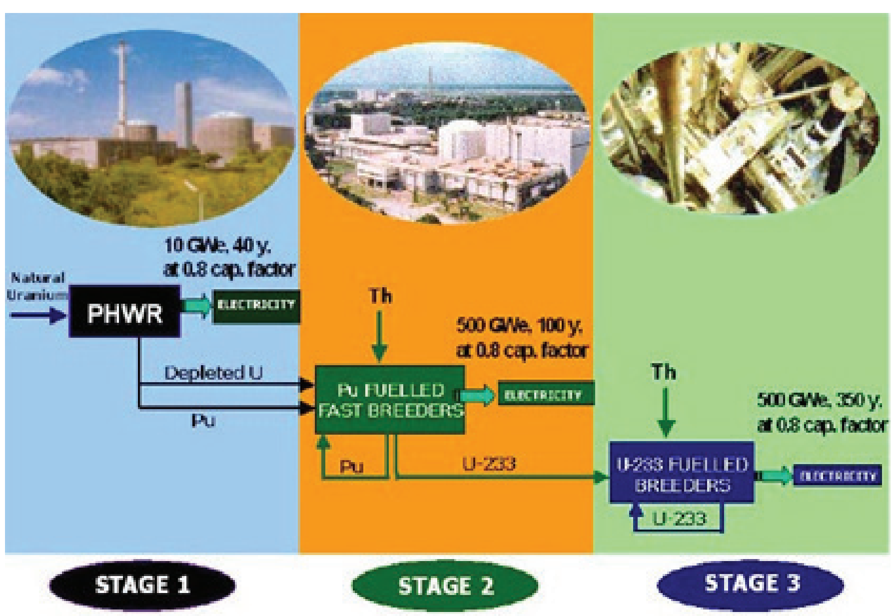

Figure 3. Three Stage Nuclear Power program of India [18].

Conclusions

As India is set for a period of rapid economic growth; increase in energy production would be necessary for sustenance of this rapid growth. India's power system needs to almost quadruple in size by 2040 to catch up and keep pace with electricity demand that increases at almost 5% per year. Energy use in industry is the largest among the end-use sectors, its share in final consumption rising above 50% by 2040. Industrial energy use is buoyed by substantial growth in output of steel, cement, bricks and other building materials, and by the expansion of domestic manufacturing encouraged by the "Make in India" initiative of the Government of India. Putting manufacturing at the heart of India's growth model means a large rise in the energy needed to fuel India's development. The Indian government also has a goal of providing round-the-clock electricity access for all households [19].

Coal-fired power plants – half of which have entered into service during the last ten years remain the backbone of the Indian power system. A large expansion of coal output makes India the second-largest coal producer in the world, but rising demand for electricity and industrial requirement also means that India becomes, before 2020, the world's largest coal importer, overtaking Japan, the European Union and China, making it vulnerable to international price shocks as well as international conflicts.

A large addition of coal based plants also raises the issue of Global warming, which was the topic of the Paris Climate Change Conference - November 2015. Nuclear energy has an important role to play in providing clean energy for meeting the energy demand in the future. To address the issues of the safety of the nuclear plants as well as the safety of the fissile materials, a large amount of work is being undertaken worldwide. India is one of the countries of the Generation-IV International forum [20]. The main aim of this forum is to develop reactor technologies that are clean, safe and cost-effective means for meeting increased energy demands on a sustainable basis, while being resistant to diversion of materials for weapons proliferation and secure from terrorist attacks.

Pu is 75 years young and is still playing a major role in the world energy scenario and would continue to play a significant role in the years to come.

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The focus of the conference will be the three sustainability goals: **water, food/agriculture and energy.** The conference will attempt to highlight the strong linkages of S & T to sustainable development. Participants will immediately note the close inter-linkages and overlaps among these and other SD goals. The last day of the conference will also have a special session dedicated to the work of different NGOs contributing to preserving our ecosystems, which is the key to sustainable development.

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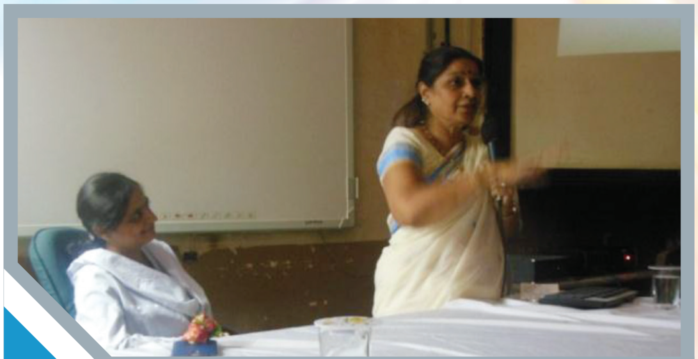

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