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Radioactive Ion beam Facility

Radioactive Ion Beam Line at the Variable Energy Cyclotron Centre, Kolkata

To understand the synthesis of elements in stellar cores, studies of nuclear reactions involving short lived radioactive nuclei are required. Radioactive Ion Beam (RIB) is an accelerator tool to study such nuclei. Using this facility, the conditions inside a star or a supernova explosions can be created, though for a very brief moment, and studied. For such studies, a Radioactive Ion Beam facility is being set up at the Variable Energy Cyclotron Centre, Kolkata.

Radioactive Ion beam Facility

To understand the world around us, be it the galaxies and stars in the night sky, or life itself, physicists aim to study the nature and interplay of the four fundamental forces that govern the universe, namely gravitational, strong, weak and electromagnetic interactions. Particle accelerators are the tools that help scientists understand the fundamental forces and their manifestations.

Atom is the basic building block of matter. It contains a positively charged massive core called the nucleus. Negatively charged electrons revolve around the core. The nucleus at the core of the atom contains positively charged protons, and neutral particles called neutrons. Nuclear research is all about understanding the properties of the nucleus as well as the nature of forces that bind the nuclear particles.

The nucleus of a Radioactive Isotope transforms to another nucleus, having a lower energy state. This transformation is called Beta-decay and accompanies emission of positrons or electrons, also called Beta-particles and neutrinos or antineutrinos.

Radioactive isotopes are extremely useful. Be it imaging of human body for diagnosis of cancer, or determining the age of earth. These radioactive isotopes, barring a few such as Uranium which are found in mines, are not available in nature and have to be synthesized in laboratory using accelerators. Short lived radioactive nuclei are also being continuously created and annihilated in the deep interiors of stars in the universe, a phenomenon that is keeping the stars, like our own Sun and other stellar objects burning due to nuclear reactions.

To unravel the mysteries of the universe, specifically the synthesis of elements like oxygen, nitrogen, carbon, uranium and other about 112 elements in the stellar cores, one needs to study nuclear reactions involving these short-lived radioactive nuclei. One accelerator tool to study such nuclei is the Radioactive Ion Beams or RIB. Using RIB one can recreate in the laboratory, the conditions inside a star or a supernova explosion, for a very brief moment, and, study the phenomena happening right now, in the universe.

This is the main motivation behind constructing a Radioactive Ion Beam (i.e., RIB) facility that the Variable Energy Cyclotron Centre has started developing for last few years.

A schematic layout of the RIB facility is shown in Fig. 1. Fig. 2 shows the Electron Cyclotorn Resonance (ECR) Ion Source for Radioactive Ion Beam. The radioactive atoms will be produced in a Thick Target using the light-ion beams (proton and alpha-particles) from the VEC cyclotron. The

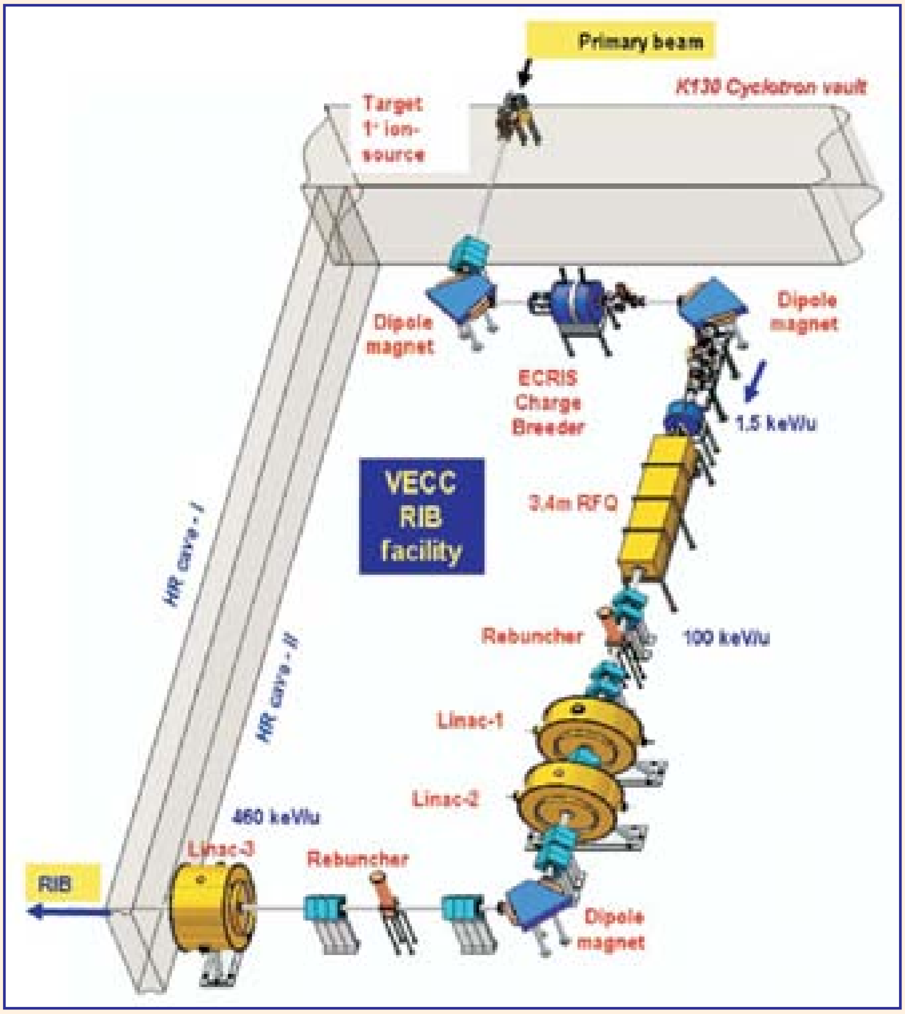


Fig. 1. Schematic layout of RIB facility

photo-fission route for production of RIB using an electron Linac is also being explored. After diffusion the atoms will be ionised in a two ion-source Charge Breeder. Thereafter the ions of interest will be selected in an analysing section consisting of a dipole magnet and a few other focusing elements. The selected ion beam after the analyzer magnet comprises what is known as a low energy RI Beam that can be used for experiments of interest to condensed matter physics and biology. For nuclear physics and nuclear-astrophysics experiments, the low energy Radioactive Ion (RI) Beam needs further acceleration. This will be done in Radio Frequency Quadrupole (RFQ) (Fig. 3 and 4) and Linac (Fig. 5) post-accelerators. The low energy RIB will be first accelerated to about 100 keV/u in an RFQ and then in stages to 460 keV/u in three IH-Linac tanks. The facility is being planned in such a way that physics can be done at each stage of development.

At the moment 29 keV/u beta-stable Oxygen (O2+, O3+, O4+), Nitrogen (N3+, N4+) and Argon (Ar4+) beams are available from the facility and are being used for material science studies. A photograph of the RIB facility as on today is shown below.

The new 100 keV/u RFQ and the first Linac tank will be installed shortly. A number of thick-targets have been developed and an integrated thick-target 1+ ion-source is being developed.

Fig. 2. ECR Ion Source for Radioactive Ion Beam

Fig. 3. 1.7 m long Radio Frequency Quadrupole accelerator during assembly

Fig. 4. 3.4 m long Radio Frequency Quadrupole accelerator during assembly

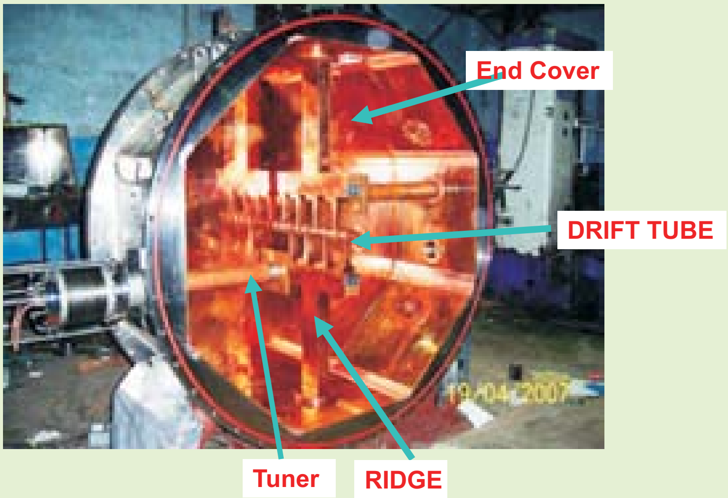


Fig. 5. LINAC during assembly

Managing New Nuclear Power Paradigm

(Excerpts from transcript of the speech by Dr. Anil Kakodkar, Chairman, AEC at the Indian Atomic Industrial Forum (IAIF), on 14th August, 2008, Anushakti Nagar, Mumbai)

First of all, let me say that, this is an opportunity for me to be able to talk to all of you. We need to prepare ourselves for the next era in the development of Atomic Energy in India and I am sure, all of you are looking forward to new opportunities.

We have still several steps to negotiate and there are hurdles at each step. So, at this moment we are talking on the basis of an assumption that we will be able to negotiate those steps in a manner that is consistent with our interest and that we are in a position to realize the full benefit and expectations of this new era. There is always a possibility of slip between the cup and the lip. All what I am saying is therefore subject to realization of the assumption that everything will go in accordance with what we expect. I think we should however prepare ourselves. I am sure you are all already on this track for some time. My talking to you would only help you to fine tune your strategies hoping that we will be able to get into this new era which we are all looking forward to.

Let me begin first by saying that we have come to this point in the history of development of Atomic Energy in India because of several decades of concerted cooperative working between Nuclear Power Corporation, other entities in the Department of Atomic Energy and the Industry. We are very conscious of the great efforts that have been put in, by all of you in terms of realization of several new technologies over a period of time. Today I don't have to tell you that the achievements of all of you together has created a distinguished status for India and that is embedded in the description of India as a country with advanced nuclear technology. This phrase creates a distinctive classification for India and based on this classification we expect several things to happen. World today knows that India builds PHWRs which are of global standards.

Dr. Anil Kakodkar, Chairman, AEC

One can construct them at a cost much cheaper than the per mega watt cost of other nuclear power alternatives. India today is a leading country in Fast Breeder Reactor technology. India is the second country next only to Russia which will have that big a fast reactor. There were countries - France for example, that had built a bigger reactor but they have been shutdown and so it will take quite sometime before these countries get into this size or larger size FBR capacities. So we have a pre-eminent position. The point I wish to make is that this is something which the world recognizes. Earlier also they would recognize this to be a fact in our private conversation. Today they recognize in a formal manner. There are of course several reasons why this change towards us has taken place. But I must put it to you that the achievements in the Atomic Energy programme in the country, which has happened as a result of collective effort of all of us together, has an important role to play in creating this new situation. The industrial participation or involvement in Atomic Energy programme has gone through a qualitative change. I myself remember the days and I am sure this is true for most of us, when once a contract is made for making a new equipment for the first time, the barriers between the purchaser and vendor vanished, and everybody worked together. I think that has been a great learning experience. From there we have graduated to a phase where now we benefit from several new innovations that take place in the industry, several new management innovations that take place in industry, so on and so forth. So there is a certain degree of national competence which is a source of great strength.

I am saying all this because it is absolutely important that in the new emerging domain, we make sure that, this strength is preserved and of course not just preserved but we build on it, strengthen it even further. If we don't organize ourselves well in protecting and building on our self made strength, I put it to you that we could subject ourselves to a great threat. I want to deal with this as I go along. But remember this point that it is important for us to preserve and build further on the national capability that we have built in the nuclear technology. We are all familiar with embargos. They don't threaten us any more.

In spite of the embargos all this has been achieved. We have a capability of overcoming the denial regime and carry forward. They say that development in isolation is a problem. Our answer to that has been - there is no question of isolation of one sixth of humanity. That is what India is. You can isolate a small domain. How can you isolate a universe? If we are talking about a big domain, isolation is not a big problem and that is what has been the case. In fact overcoming denial regime in an environment of isolation I think is relatively easy, compared to withstanding the denial regime in an open environment. This is a new scenario that we need to understand. As you move to this new open environment there are all kinds of possibilities. For example, today our industries have been making the nuclear equipment; we have our own products which we use in our power stations. With this change it is also possible that we have the opportunity to get newer technologies for similar products as also technologies for different kind of products which may be required for the new technology reactors like Light Water Reactors (LWRs) or build components or equipment for export markets. Such possibilities could open and that is going to be a big advantage to us. At the same time we are also talking about fairly sizeable Atomic Energy programme that is not in the civilian domain. It is to be remembered that the programme which is not in the civilian domain will be still subjected to the denial regime. It is important for us to be able to organize ourselves in a manner that we are able to cater to both the domains. The programme which is not a part of the civilian domain and that programme is not going to be small. That programme is going to be large because the ultimate energy independence for the country would come about through the three stage nuclear power programme. This programme has to be autonomous since there is no parallel elsewhere and there is no other solution either. Thus while we have identified some PHWRs to be put in civilian domain, some are not. These would feed the subsequent development, the fast reactors, the interconnecting fuel cycle, that means the reprocessing plants and then when you go to the third stage the thorium reactors and the related fuel cycle.

This is still a technology in evolution and because we want to evolve the technology to a level of commercial robustness of global competitive level, we want to be able to do this on our own and so we need to protect this development from external vulnerabilities and so it is outside the civilian domain. We are talking about four more FBRs to follow immediately after PFBR. We are talking about a fast breeder programme which may well be 30-40 times larger than PHWR programme and a good part of that we would have to keep outside the civil domain till we are sure about a synchronized working of the reprocessing plant and the reactor plant with commercial efficiency and assurance. In PHWR you get the fuel, you put it in the reactor, you produce electricity and keep the spent fuel in the storage bay and you can carry on. You have time of the order of 10 years, 20 years to worry about what to do with this spent fuel. That is not the case with fast reactors. In the fast reactors, we have to recycle the fuel let us say within a matter of 18 months - 24 months and because fast reactor has to work on its own fuel. It does not need fuel from outside and so if the reprocessing does not work with the required level of commercial performance, it will have an impact, adverse impact on the capacity factor of the reactor plant and vice versa. Remember we are taking about a programme which may be 30 times or even larger than the PHWR programme We need to move forward on this larger programme as a national effort along with the growth of the civilian programme that we visualize both in terms of PHWRs as well as in terms of LWRs which we hope to import. This is of crucial importance for our long term energy independence.

This is important from yet another angle which I think is even more important. Let us say we get certain capacity of LWRs 20,000 MWe, 30,000 MWe, or 400,000 MWe. We want to be able to extract more energy from the spent fuel that will arise from these LWRs in just the same way as we are doing with the indigenous three stage nuclear power programme. For example if you set up 40,000 MWe Light Water capacity, using the spent fuel and using the fast breeder technology we should be in a position to further augment electricity generating capacity without the need of additional external fuel input to the tune of 10 times larger. 40,000 MWe LWRs capacity can lead to 400,000 MWe of fast breeder capacity. Now this second part is not going to come from anybody else because they don't know as much of fast breeder technology as we know. So again our effort, which I have mentioned in terms of running the three stage nuclear power development, will come in handy in terms of deriving much larger benefit out of the external acquisition in terms of light water reactors and their associated fuel. But this is possible only if we don't loose the technological capability that we have built and as I said not loose but also build on that as we go along.

I have come here to specifically emphasize that the motto of selfreliance is not just a slogan. I think it is an important element of our technological march and our ambition to in fact lead the world. From the position that we are in, it is quite possible for us today to take India to a leading position globally. I think DAE and Indian industry working together, we can realize that objective. We have gone on the nuclear power programme in a particular way because we have limited uranium and we have lots of thorium resource. Take it from me that 50 years down the line that is gong to be the situation world over. Ten years ago the world was seeing plenty of uranium and that was because the nuclear power technology was a preserve of a few industrially advanced countries. In these countries their energy requirement is at a saturated level because per capita energy consumption is high and their population is stable. Today things are changing. Today there is a much larger segment of global population which is on a rapid economic growth path. India, China and several countries in Asia, and I have no doubt, tomorrow same thing will happen in Africa. This is already happening in South America. So the larger part of the humanity is getting empowered to fulfill its own developmental aspirations, whatever energy crisis we are seeing in India today I think world is also witnessing . They have become conscious of this fact and they will feel it in an acute manner, as we are feeling it today. Once that happens you will find the global uranium is also in short supply. Just as today the global hydro carbon is under great stress. When that happens the world would have to move towards fast reactors. World will move also towards thorium. We have evolved ourselves into this technology out of our necessity. We thus have an opportunity to take India to a position where Indian experience, India's capability is something the whole world will be seeking after. This is the big opportunity that I think is there before us and we should not loose sight of that opportunity.

Let me now come to the threats which I mentioned earlier. We are now expecting opening of civil nuclear cooperation with other countries. We look forward to getting external inputs as additionality to domestic programme. People question me what is this word additionality? But I insist on using the word additionality, the way it is. We are all quite positive about seeking these additionalities but as we move forward in terms of getting more PWRs from, call it France, call it Russia, call it United States or call it wherever, one condition everybody has to fulfill. That it should produce electricity at a rate which is competitive or comparable with the other alternative electricity producing options at that location; whether it is coal, whether it is oil, gas, hydro whatever because without competitive electricity production the utility cannot do business and I have made it clear and I think most of the people recognize if that has to happen they have to ensure a much large part of the supply chain to be met from within India. If they make their equipment abroad and bring it here, I think there is no way we can produce electricity at the rate which is competitive with other supply options. And so I am also aware of the fact that several of these foreign entities are talking to many of you. We want such collaborations, partnerships, it may take various forms, This is crucial and this is bound to happen. Without such domestic supply chain they cannot set up nuclear power plants with Nuclear Power Corporation which could compete on the Indian electricity market. This is where I have a few words to tell to all of you. I think you must take advantage of this. But I also want to point out a few pitfalls that you must protect yourself.

So far you have been making equipment quite a good number of them, there are exceptions, but a good number of them on a kind of, arrangement in which I should say, you get engineering specifications, the design requirements and then convert into a product, fabricate or manufacture and supply. You are essentially doing the equipment manufacture to the design of Nuclear Power Corporation of India Ltd., (NPCIL). In the new dispensation it would become necessary for you to manufacture equipment to the design or engineering specifications of a supplier, architect engineer and supply the equipment to the NPCIL. There is a difference between the two. In the first case so far NPCIL has been the technology holder. In the case of reactor acquisition from abroad just as it was the case with Tarapur reactor the supplier vendor companies would be the technology holder so in your dialogue on working arrangements with these companies it is natural that there will be issues related to technology transfer, there will issues related to IPR and so on and so forth. Now in setting up your arrangements it is my strong suggestion to all of you that you must ensure that you don't compromise your independence. While there are no difficulties in protecting the Intellectual Property Rights (IPR) or protecting the technology which you acquire from wherever but in the process you should not surrender the technology that you already have. You don't surrender the IPR you already have or for that matter you don't surrender the NPCIL technology or NPCIL IPR and I think this is a matter of crucial importance otherwise tomorrow there is every chance of you and us being blamed of not adhering to the so called ' quote unquote technology transfer agreement or IPR agreement and I have been talking about this even to the entities abroad. You should well define your pre-existing technological capabilities and background IPR. While there should be no difficulty in protecting acquired technology and its use, your right to use your own pre-existing technology and your building on it on your own strength should be fully preserved and exercised. You should carefully avoid any situation in which this right gets compromised as otherwise we may face a situation like - 'I showed you my pump and we discussed about that pump and you cannot make any pump on your own without me as it is my technology' can come about. You must make sure that you don't get into that kind of a situation.

At this stage I should also clarify the legal position. So far everything was being done as per DAE or NPCIL specifications and Technology. So there was no issue. A quick reading of Atomic Energy Act, and related rules would tell you that, all these equipment and technologies come under what is known as prescribed equipment, prescribed material, prescribed technology and we have a national system of legislation where the government is required to control this technology. We have to control this technology to ensure its use for the welfare of India which also includes preventing it from getting into wrong hands both within the country and outside. There is a full control list and all items on that list need prior government approval for activities concerning them. Opening of civil nuclear cooperation is on the basis of our credible track record in this matter and our commitment to sustain these controls consistent with the international practice. I am sure you would have heard all this in the context of NSG related debate. Thus if you have a foreign partner, as far as the foreign partner is concerned he is subject to controls of his Government on these controlled items and the Indian entities are subject to controls by the Indian rules and legislation on these items and I think you should be very clear and careful about these requirements in designing your linkages.

The second element for example, today you get an order from NPCIL, you can build equipment, you get an order from BHAVINI, you can build an equipment. But if you have to build an equipment for AREVA or Atomstroyexport or General Electric or Westinghouse, you must make sure that in dealing with one your choice of doing business with other foreign or Indian entities is not scuttled. This is another care I would suggest you must take in terms of working out your arrangements. I think redundancy is important, multiple technology acquisition is important and ultimately I think it is important that we create a brand India. I must also inform you that we already have a significant technological capability in PWRs and NPCIL has worked out an Indian PWR design afront and I think we are going to put it on table soon.

So the idea is that we should have an Indian LWR just as there is Chinese PWR design, there is a Korean PWR design, there was a Japanese PWR & BWR design and they are all emerged from Westinghouse and GE and others. So it is important that we will have an Indian PWR which becomes a Brand India PWR along with of course brand India PHWRs which already exists, brand India Fast Breeder Reactor, which already exists. But I think we need to create this and as I said, since we are looking forward to India leading the global table of nuclear technology we must conduct business in a manner that does not constrain us from getting into top position as otherwise we simply become the so called fabricators or service providers fabricating something for x's orders, y's orders and z's orders etc. You keep doing that you don't take yourself to a position where you are in a position to make global impact.

The third point is with regard to the so called controlling technology proliferation. World is moving to cooperate with us because now world knows that India has already learned this technology and perhaps much better than others. So there is in fact no risk and it make business sense to deal with India. But with this change we are going to get a new added responsibility. We don't want to get into any situation the way Mr. A.Q. Khan has taken his country into. So we need to control the technology because all said and done, this is a very sensitive business. Reactors are themselves very sensitive but the fuel cycle work is even more sensitive. In the international literature you would find the term ENR - Enrichment Reprocessing technology being considered extremely sensitive. They will do nuclear trade but not in ENR technology and as I told you earlier, as part of the development of three stage programme ENR technologies are very crucial for us. We are already working, there are lots of you who are working with our reprocessing plants and other facilities so we would be working on such programmes but then it is absolutely important for us to make sure that we maintain our own technology control regime and make sure that nothing goes out of the country without a proper authorization and certainly nothing of this can fall into wrong hands. This is another domain where I think we will have to work together as Government and the industry.

Let me now move onto other areas. The policy that we would like to follow is to maximize the value addition within the country and of course as far as indigenous designs are concerned we are talking about 100 per cent or near 100% value addition within the country. But even with imported reactors, we are talking about maximizing the value addition within the country for the supply chain and that makes sense because otherwise I don't see how the nuclear power stations can be made competitive under Indian conditions. On the other hand, it is clear that running nuclear utility is a very different ball game as compared to running a conventional utility and certainly far different from running any other business entity.

A nuclear reactor once you start, you have to keep its safety systems running and the plant always manned. Once you have started the nuclear reactor there is no way you can decide that the reactor plant is closed and say “let us lock up the door and all of us can go home”, - no way. Whether the reactor is producing electricity or not you have to keep a minimum complement of people for various activities like shut down system, cooling, radiation surveillance, physical protection, house keeping and so on and so forth. This is an exclusive characteristic of a nuclear utility. In other power plants, whether it is gas plant, oil plant, hydro, coal you can decide to shut down and go home. Come back after some time and restart. There may be some issues but not as unforgiving as in a nuclear plant. For example if there is an Enron like episode in nuclear, while Enron itself was a major shock, but it was in terms of economics and finance. They closed it down and went home, somebody else again started. Lots of components were found defective, they were repaired but then finally they could do it. At what cost is another matter. Imagine if the same thing were to happen in a nuclear utility. You will immediately have a major safety issue of national dimension on your hand. Because we would be faced with question like what is going to happen to the fuel, if there is cooling crisis, temperature would rise, there could be failures, if the chemistry is not maintained, you could have corrosion failure and so on. If there is no proper and responsible approach not withstanding the financial viability issue then we have a major safety problem. So the point is that we can't allow this to happen. In fact if such things were to happen it could become a criminal offence and people have to go to jail. What I am telling you is one dimension. There are other dimensions which relates to safety regulation.

Following regulatory requirements not just in letter but in spirit. Just getting a license is not enough. Safety regulation is a continuous process. Safety regulation in India has its own unique feature and all plant operators have to abide by it. This requires prior experience under Indian Conditions. We would want the utility business in the hands of only those who already have prior experience under Indian conditions. It cannot go in the hands of anybody unless there is prior experience. You will say this is an egg and chicken problem, unless you work with it how do you have prior experience. I think the way to deal with this issue is to get the requisite prior experience by partnering with Nuclear Power Corporation which has vast experience in this area. So I think, any interested entity has to work with Nuclear Power Corporation as a junior partner, learn the ropes of nuclear utility management and only after you accumulate experience which qualifies you for such activity can one think of moving further. I think this should be very clear. I thought I should mention this here because you would realize, this is a matter of crucial importance from point of view of protecting the public, protecting the environment and of course protecting the investments.

Then there are issues that relates to fuel. It is our policy that spent fuel cannot be disposed off as spent fuel quite unlike the policies in other countries. In US you can dispose of spent fuel as waste. In India you cannot. For us spent fuel is an energy resource. Further there are issues of long term waste management, environment protection and security. You thus have to reprocess to separate the fissile and fertile materials and recycle them. Only the fission fragment and such other things can be immobilized and then disposed of. So our policy has been that of closed fuel cycle, right from day one. As I told you earlier this is a part of sensitive nuclear technology which is much more strictly controlled world wide. In India too, while we have this technology developed indigenously, as responsible nuclear power, we would control this technology in a rigorous manner.

Thus while we are extremely positive and encouraging both the Indian industry as well as the foreign vendors to maximize the value addition in the country for the supply chain items as far as the utility business is concerned, one can get into that only on the basis of prior experience. I think this would be a more organized way of developing the programme further. We should recognize that dimension of this programme is very large. We are talking about reaching something like 200,000 to 2,50,000 MWe based on the indigenous programme, the indigenous three stage programme with PHWR, Fast Breeder and thorium utilization. We could have another 400,000 MWe on the basis of the multiplier to the imported acquisition ie LWRs through Fast Breeder Reactors. Thus we are talking of about 500,000 to 600,000 MWe over the next 50 years or so. Then there are opportunities in the markets abroad. So we are talking about very large business. Whether it will be realized or not time only will tell. I certainly don't want to raise another slogan like 10,000 MWe by 2020. Rather, we should talk about creating an enabling environment. I think it is doable. I think even the investment will come through. It will require government investment wherever it is a question of demonstrating indigenous development. For the commercial part of the programme, I think investments have to be self generated and also attracted on the basis of good financial performance.

Let me now come to fuel linkage. Although we are talking about building the programme on the basis of uranium that we know is existing in the country and also on the basis of the possibility of external acquisitions as additionalities, we are also pursuing an equally aggressive programme of exploration. We are investing, a few thousand crores in exploration, mining and milling programmes in the country. This is a major effort. While exploration is a business of probability, we do hope that it would be successful and if hit a jackpot then we can think of new scenarios . Since Indian energy requirement is expected to grow to a very large level, availability of uranium, whether from within the country or from outside, would be a single most important rate determinator for such growth. In this context I am also encouraging people to also start looking at uranium assets abroad.

So that is roughly all that I wished to say. For the 10,000 MWe PHWR programme, all we need to do over and above the reactors and projects that are already in place is to build eight 700 MWe units. I think we should be in a position to launch construction of four out of the 8 units in a matter of few months from now. Because I think we will be able to establish the necessary fuel linkages by that time. If things go on well it should be possible to also decide on the remaining four 700 MWe units may be next year or there about. That would tie up 10,000 MWe programme completely. If you get more uranium then it is going to be competition between PHWR and LWR and I believe that for sometime till the PWRs settle themselves in Indian industrial environment PHWRs particularly those running on the enriched uranium may remain a more competitive option and if that happen then Indian industry on the basis of Indian technology and design we can also give a tough competition to imported design and technology both in India as well as abroad This is important because if you want to keep the unit electricity cost from PWRs low, you must have a competitive alternative available here and I want PHWR to provide that alternative. That allows you to do a hard bargain with the imported technology proposals.

Let me close with a word on the export market. I think opening of civil nuclear cooperation is not just about our ability to get things from outside but it is also about ability to export. I have been carrying forward this battle for you. I am sure atleast some of you are aware that this also has been a problem, It has started opening a little bit. I won't be surprised if that opens up earlier than things coming from outside into India, simply because the Indian industry can provide things with great competitive advantage. So all in all, I would say we are looking forward to this new era and if you want to realize the maximum advantage of this new era then I think the industry and the DAE will have to work together and work together with a degree of maturity and responsibility and a collective action and I think we can do things in a manner where atleast it could be one area where the world recognizes that India is a major player. I look forward to that day.

Radioactive Waste Management in India

Introduction

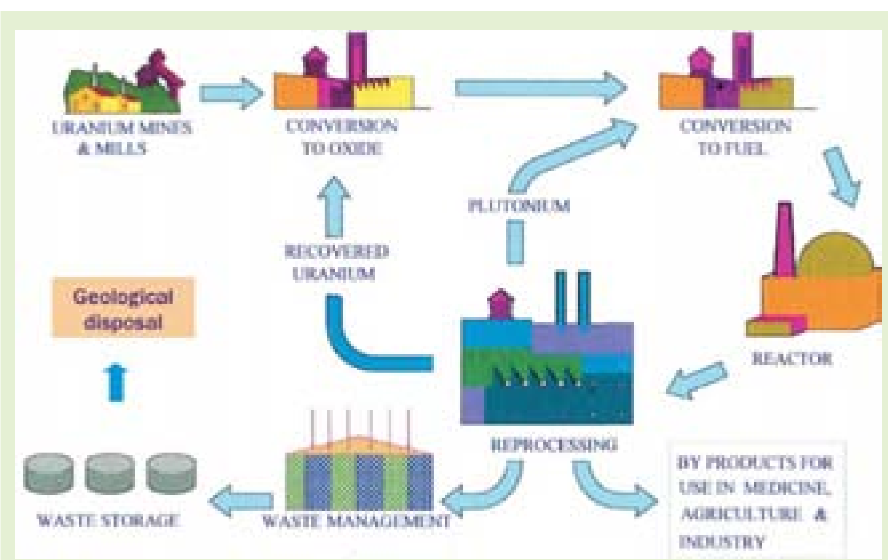
Nuclear technologies are used for generation of electricity and for production of a wide range of radionuclides for use in research and development, healthcare and industry. One of the special features of nuclear industry is that it uses nuclear fission as source of energy. As a result, a large amount of energy is available from relatively small amount of fuel. For example, a nuclear power station uses only one ton of natural uranium, to produce as much electricity as 25,000 tons of coal will produce in a conventional thermal power station. Naturally, the resultant quantities of waste are relatively very small in case of nuclear power. In India, "close fuel cycle" has been adopted treating spent nuclear fuel as a source of useful materials. The close fuel cycle aims at recovery and recycle of U and Pu, separation of useful isotopes of Cs and Sr for use in healthcare and industry. This finally leads to a very small percentage of material present in spent nuclear fuel requiring management as radioactive waste. Another special feature of the Indian Atomic Energy Programme is the attention paid from the very beginning to the safe management of radioactive waste.

Sources and classification of radioactive waste

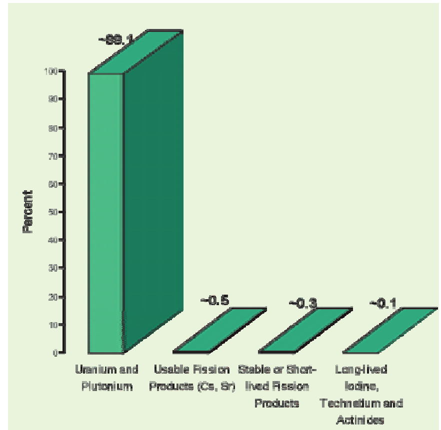
Radioactive wastes arise at various stages of nuclear fuel cycle. In addition, radioactive wastes are also generated in nuclear research facilities and in use of radioisotopes. Radioactive waste streams are commonly classified as low level waste (LLW), intermediate level waste (ILW) and high level waste (HLW). Solid radioactive wastes are also classified as compressible or non-compressible and combustible or non-combustible depending upon the corresponding physical nature.

Policy and implementation

The basic philosophy in the management of radioactive wastes is to concentrate and confine as much radioactivity as possible within



Indian nuclear closed fuel cycle



Constituents of spent nuclear fuel

practical means and to adopt only such practices which lead to the protection of health of present and future generations. In order to achieve this objective, a set of basic principles are followed at all stages of radioactive waste management.

Basic Principles

- Minimization of generation of waste by suitable design and operation features
- Adoption of safe operation practices in radioactive waste management plants/facilities
- Controlling of radioactive discharges to the minimum so as to preserve the quality of the environment

Process and technology

The expertise obtained during last four in the indigenous development of process, technology, equipment and assemblies so far has led to the standardization in design of radioactive waste management systems. Various process and technologies used in radioactive waste management are as follows.

Chemical treatment : Low level

Low level waste treatment by chemical precipitation at Centralised Waste Management Facility, Kalpakkam

liquid wastes containing less than 1% of total radioactivity originated from nuclear power station and other nuclear facilities are treated for removal of radionulcides using chemicals like barium chloride, sodium sulphate, potassium ferrocyanide, copper sulphate, ferric nitrate, etc.

Ion exchange: Naturally occurring ion exchangers like vermiculite and bentonite are used mostly in site specific operations. Synthetic ion exchangers such as resorcinol formaldehyde polycondensate resin and ammonium molybdophosphate, due to their regenerative nature and high exchange capacities, are being extensively used in India for treatment of liquid waste from spent fuel storage pools and reprocessing plants.

Evaporation: Evaporation based on steam heating is used for waste of low volume and high activity whereas solar evaporation is a preferred mode of evaporation for larger volumes of waste with low activity.

Membrane processes: Membrane based processes like reverse osmosis and ultra filtration are used essentially for treatment of low level liquid waste.

Cementation: Cement and cement composites are extensively used for immobilization of relatively low level radioactive concentrates, chemical sludges, etc, Cementation process has universal application due to low cost and operational simplicity.

Polymerization: Various types of polymeric materials like polyester styrene are being used for immobilization of spent ion-exchange resin from the nuclear power stations and other facilities.

Cementation of sludges using cone mixer assembly at Waste Immobilisation Plant, Trombay

A three–step strategy has been adopted for management of high-level waste:

- Immobilization of waste oxides in stable and inert solid matrices
- Interim retrievable storage of the conditioned waste under continuous cooling
- Disposal in deep geological formations

Immobilisation: High level radioactive liquid waste (HLW) containing more than 99% of total radioactivity procedure in the nuclear reactor, is generated during reprocessing of spent nuclear fuel.

Table : Waste Management Facilities in India

Site	Year of Commissioning	Nuclear Facility
Coastal		
Trombay	1956	Research reactors, fuel fabrication plant, fuel reprocessing plant, research laboratories, isotope production, waste immobilization plant (WIP)
Tarapur	1969	Boiling Water Reactors (2x160 MWe), fuel reprocessing plant, fuel fabrication plant, WIP
Kalpakkam	1984	Pressurised Heavy Water Reactors (2x220 MWe), fuel reprocessing plant, research laboratories, research reactor (FBTR), WIP under construction
Inland		
Rajasthan	1972	PHWR (1x100; 1x200; 2x220MWe), Isotope facility
Narora	1989	PHWR (2x220MWe)
Kakrapar	1993	PHWR (2x220MWe)
Kaiga	2000	PHWR (2x220MWe)

After the decay of short-lived radio nuclides, HLW is converted into the solid form. Different vitreous matrices have been developed for immobilization of HLW. Borosilicate glass has been selected for industrial scale immobilization in India. Vitrified Waste Product (VWP) has desired characteristics like very high radiation resistance; excellent thermal stability and low leachability. After successful development and establishment of vitrification technology using induction heated metallic melter, this has been deployed on industrial scale in Waste Immobilisation Plant (WIP) at Trombay. The first Advanced Vitrification System based on Joule Heated Ceramic Melter (JHCM), has also been developed and made operational at the Solid Storage Surveillance Facility (SSSF), Tarapur.

Waste Immobilisation Plant, Trombay.
Inset showing pouring & welding of vitrified waste product canister

Interim storage: Solidified high-level radioactive, waste is associated with high decay heat. Hence, it is necessary to store these wastes for an interim period of 25-30 years during which time decay heat would reduce to almost half the original value. Natural convection air cooled vault has been selected in India. This system is self-regulating and can compensate for changes in heat load or weather conditions.

Interim Storage facility for Vitrified Waste at SSSF, Tarapur

Geological disposal: The final step in the management of solidified high level radioactive waste is the deep geological disposal. A programme to investigate host rock characteristics for waste repository in homogeneous granites has been in progress in phased manner for the last two decade, based on certain selection parameters and criteria. A depth of 500 - 600 meter is being considered for the placement of solidified high level waste in specially constructed underground chambers, adopting multi-barrier system. After placement of waste using remotised equipments, the chambers will be back-filled using naturally occurring clays and minerals which arrest/retard movement of radionuclides. In view of very low waste volume associated with nuclear power programme, the need for a deep repository will arise after several decades.

Radioactive gaseous waste

Safety of working staff in nuclear installations is ensured by maintaining the necessary air flow pattern and rate inside the facility. Though this air is normally free of radioactivity, as an abundant precaution, it is treated before discharge. Similarly, vapours and gases generated during operation of nuclear facilities like fuel reprocessing and vitrification, are also treated by suitable techniques before discharge. The techniques used for treatment of gaseous wastes are: condensation, scrubbing, adsorption, filtration, etc. Commonly used filters are: high efficiency particulate air (HEPA) filter and combined particulate and iodine filters (CPIF).

Spent radiation sources

The radiation sources of various types and strengths are used in healthcare, industries and research institutes. Since all radiation sources decay with time, they are either re-used for alternate applications or treated as waste after their strength declines. Strength of spent radiation sources varies from milli curie to thousands of curies depending upon their area of application.

Spent radiation sources are returned after use to Bhabha Atomic Research Centre (BARC) from users all over the country. Spent sources are first conditioned to make them suitable for disposal. They are then disposed/stored in either reinforced concrete trenches or tile holes. Waste Management Division of BARC uses its facilities located at Trombay and Kalpakkam as the nodal centers for storage/disposal of spent radiation sources.

Radioactive solid waste

Nuclear operations generate a variety of primary solid waste comprising of tissue materials, glassware, plastics, protective rubber-wears, used components like filters, piping, structural items, unserviceable equipment, etc. This type of solid waste is generally associated with low and intermediate level of beta and gamma radiation and, in some cases, by low levels of alpha contamination. Following processes are used for treatment of solid radioactive waste.

Decontamination: Decontamination process aims at removal of radioactivity from the material. A wide variety of processes are used for this purpose like sand- blasting, electro-polishing, chemical complexing and ultrasonic decontamination.

Joule Heated Ceramic Melter at Advanced Vitrification System, Tarapur

Volume reduction: Solid radioactive wastes are first segregated in two groups based on their compressibility and combustibility. Compressible wastes of low and intermediate level activity are volume reduced by baling and compaction under controlled conditions. Solid waste associated with high level of radiation dose is handled remotely. Melt densification technique is used for volume reduction of polymeric material.

Incineration: Specially designed incinerators are in use for low-level solid radioactive waste. A typical incinerator consists of furnace, cyclone separator, cooler, bag-filter and high efficiency particulate air filters. The ash residue left after incineration is further immobilised in cement matrix.

Siting and surveillance

Siting and design of near surface disposal facility involves characterization of soil and ground water, development of underground and above ground engineering structures for placement of waste, evaluation of materials used for packaging of waste product. Based on the results of safety assessment of a given site for locating a disposal facility, type of disposal module is selected. Suitable back-fill materials are used to enhance the retention capability of the disposal system as a whole. Performance of the containment is monitored by regular sampling of ground water from monitoring bore-wells located at various distance from the waste disposal system and in the down flow direction of ground water.

Storage and disposal

Solid radioactive wastes are collected and transported to storage

Tile holes

and disposal sites following requisite safety procedures for protection of personnel involved in handling and transportation.

Trenches and Tile holes: Solid radioactive waste is disposed in underground reinforced concrete vaults called 'trenches'. All the interspatial gaps are back-filled with natural ion-exchangers like vermiculite and bentonite. After filling, these are covered with pre-cast concrete slabs which provide shielding. Finally, the trenches are given a special water-proofing treatment for sealing the disposal module. Relatively higher active solid wastes are placed in deep circular underground vaults known as 'tile-holes'. These vaults are 4 - 5 meters deep steel-pipes lined with concrete and externally water proofed surfaces.

Human resource development

During last five decades, the Department of Atomic Energy has nurtured and developed expertise in the fields of design, development, construction and operation of waste management systems. The personnel engaged in these activities are trained and retrained to keep pace with the developments globally. The training is imparted at all levels, for example, to graduate/postgraduates in engineering and science, in design and development. Similarly, training is given to diploma holders in engineering, in the construction, operation and maintenance and to technicians in fabrication, operation and maintenance of equipment and assemblies used in waste management facilities. The training programme covers both class room lectures as well as hands-on training. The infrastructure developed for in-house training in India is used for extending similar training in various aspects of radioactive waste management to trainees from other countries under the auspices of International Atomic Energy Agency (IAEA). Indian professionals regularly serve as experts in radioactive waste management in different capacities with IAEA.

In view of the wide experience and the depth of human resources developed within the country, India is considered as one of the developed countries in the field of radioactive waste management. Further, research and development work is continued to explore ways to maximize recycle with economic gains and minimization of waste that needs disposal. Developments in the area of selective separation of radioactive species, partitioning and transmutation of long-lived actinides, use of thorium in fuel cycle with much lower arising of actinides, etc. are some examples of thrust in this direction.

In-situ solidification in Reinforced Concrete Trenches

Nisargruna Project: Present And Future

S. P. Kale, Nuclear Agriculture and Biotechnology Division
Bhabha Atomic Research Centre, Mumbai - 400085

The fertile Indian soils have fed millions and millions of people since time immemorial. India is also blessed with a good amount of forest cover. Yet all is not well in this prime discipline which faithfully continues to serve us. A quote of Dr. Carver tells us that the future of the country is safe only if the top soil layer is safe. A continuous exploitation of our soils over several thousands of years has caused depletion of organic carbon. Organic carbon is the soul of fertile soil. The chemical fertilizers can only supplement the soil; they can not build the soil. Excessive and untimely applications of such fertilizers have proved detrimental in many areas and the top soil layer has been irreversibly damaged. Excessive irrigation has also significantly contributed to this loss. Such soils will be sick and will not be able to provide any protection to the standing crops. In the present time, when already large population is becoming larger every day, this is a cause of serious concern. The only solution is replacement of this soil layer by the organic matter. Organic matter can build our soils in a sustained fashion.

The question is from where to get the enormous quantities of organic matter? We can produce these large quantities in our own country using only indigenous resources. The concept of bioenergy can provide us both energy and valuable manure. Nature has shown us an excellent way of harvesting solar energy through biological route. Every living cell is an energy power house. Directly or indirectly it uses solar energy. Every biomolecule is loaded with energy. We use this energy to drive our lives. When plants make food for us either through their grain or fruit, they also generate a large quantum of energy in paraphernalia like leaves, fruit skins etc. These paraphernalia if handled properly can provide us a viable option of harvesting that energy. This route of harvesting energy through NISARGRUNA concept (Please see the box) also ensures that we get an energy rich soil conditioner. This will help in replenishing the depleting top soil layer providing us sustainable and dynamic soil matrix to fulfill our food demand. The route also ensures the continuation of biogeochemical cycles of various elements. Indian farmland extends to about 142 million hectares. Each hectare needs about 2-3 MT of good quality organic manure per year. If we are able to provide organic manure in such large quantities, we can all eat organic food. This will also help to reduce substantially the use of chemical fertilizers. The effects will be long lasting. We can also harvest huge energy from such Nisargruna biogas plants. A rough estimate to produce such a large quantity of organic manure is to set about 300,000 Nisargruna plants of 50 MT/day. These plants will produce about 100,000 MW decentralized energy which is equivalent to almost 70% of the country's energy needs. The biomass required to run these large number of plants can come from sparing about 15-20% of the cultivable land for this purpose only, in addition to available agro residues. The overall increase in yields of all crops due to good quality of organic manure would compensate easily for this land use. These plants would generate a large number of employment opportunities.

While generating such a large energy using biological resources, we can earn carbon credits by adopting following two ways:

1. Avoiding methane release in the environment due to decomposition of biodegradable waste materials
2. Saving equivalent quantities of fossil fuels by effectively using liberated biogas

An organized Nisargruna industry can make these carbon credits possible thereby adding valuable foreign exchange to our reserves. Moreover we shall be happy that we could play our role in saving the environment from release of green house gases like methane. Methane is the most damaging green house effect.

Almost one crore people are likely to be employed on these Nisargruna plants. A large number of indigenous industries will get benefited by large scale implementation of decentralized Nisargruna project. These plants will process the entire biodegradable waste of the country adding advantages in health sector. Our country bears the brunt of infectious diseases mainly because solid waste management is handled very carelessly. The general health of the country and specifically aesthetics will improve making our country clean. What we need at this juncture is political and administrative will to identify our strength and take some bold decisions to implement the bioenergy concept. Except for metro cities, we have enough land sites available to put up these projects. Even in metro cities, careful allocation of space in existing sewage treating plants, crematoria, big residential colonies etc. is possible to raise these plants.

We need energy for industrial and civil security. We need organic manure for food security. Bioenergy offers an excellent gateway for obtaining both at reasonably good price and in perfectly ecofriendly manner. Nisargruna technology offers a good route to harvest this dual option.

How The BARC-Nisargruna Technology Differs From Conventional Anaerobic Digester Technology

Nisargruna technology developed for processing of biodegradable solid waste materials generated in kitchens, vegetable market, slaughter houses and animal stables is based on aerobic-anaerobic sequential processes. It offers an excellent alternative for decentralized processing of solid biodegradable waste and avoids the contamination of land-fill sites. It differs from the classical anaerobic digesters in the following aspects.

1. Nisargruna plant has a broader scope to accept a variety of raw materials mentioned above while the anaerobic system developed in our country is mainly used for processing animal dung.

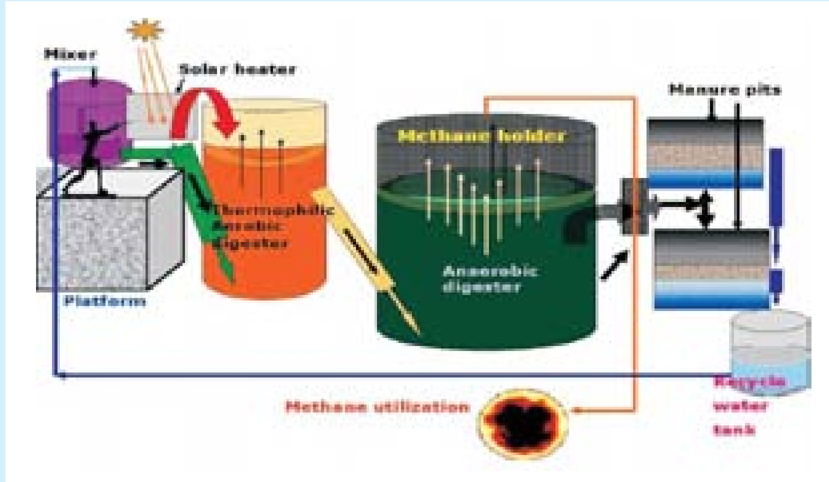
2. Nisargruna technology is a high rate bio-methanation process. It uses a mixer to homogenize the biodegradable waste with water into free flowing slurry.

3. Nisargruna process involves pre-treatment of the homogenized biodegradable waste slurry in an aerobic digester for a limited period (about 3-4 days). This process is accentuated by aeration and higher temperature. The temperature is maintained between 45-50°C using solar energy. The hydrolysis and acidification stages are carried out in this phase.

4. Aerobic phase helps in removing scum forming protein materials. This is a major achievement as scum formation can terminate the entire process.

5. It helps in oxidation of sulphur compounds. Formation of hydrogen sulphide is thereby avoided in anaerobic process and biogas formed is free of this corrosive gas.

6. The temperature in this range (45-50oC) helps in hygienization of the waste. All coli-form bacteria are eliminated due to higher temperature



What is Nisargruna technology?

The biodegradable waste generated in kitchen in the form of vegetable refuge, stale cooked and uncooked food, extracted tea powder, waste milk and milk products can all be processed in Nisargruna plant. A 3-5 HP mixer is used to process the waste before putting it into predigester tank. The waste is converted in slurry by mixing with water (1:1) in this mixer. Usually this is the failure point as solid waste is difficult to get digested and can easily clog the system. If we can pulverise the waste in a paste, the digestion is assured. There will be no scum formation and no clogging. The other important thing is use of thermophilic microbes for faster degradation of the waste. The growth of thermophiles in the predigester tank is assured by mixing the waste with hot water and maintaining the temperature in the range of 45-50°C. (The hot water supply is from a solar heater. Even few hours' sunlight is sufficient per day to meet the needs of hot water. Alternately, part of biogas generated in the system can be used for getting hot water). Their main role is to digest proteins and low molecular weight carbohydrates to produce volatile fatty acids.

Ideally there would be two pre-digesters which will receive the waste on alternate days so that undisturbed digestion for about 48 hours will be possible, giving desirable results. The same result can be achieved by providing a baffle wall in single predigester. It is mandatory that the effective volume in either case be the same. The pH of the slurry drops to 4 - 6 due to accumulation of volatile fatty acids. The total soluble solids reduce from 23-25% to 13-15% in this tank.

The retention time is between 72 to 96 hours. More retention in predigester than this period would result in loss of biogas and manure in the second phase. Pre-digestion is extremely important for following reasons:

- Hydrolysis of the waste
- Acidification and formation of volatile fatty acids
- Removal of scum forming components
- Removal of sulphur in the form of sulphur dioxide
- Formation of uniformly flowable slurry to ensure smooth digestion in anaerobic digester

After the predigester tank the slurry enters the main tank where it undergoes mainly anaerobic degradation by a consortium of archaebacteria belonging to Methanococcus group. These bacteria are naturally present in the alimentary canal of ruminant animals (cattle). They produce mainly methane from the cellulosic materials in the slurry. As the gas is generated in the main tank, the dome is slowly lifted up. The design of the dome, which floats on a water seal, is such that there is no direct contact between the slurry and the dome. It reaches a maximum height of 4 feet holding biogas. The biogas is a mixture of methane (55-75%), carbon dioxide (40-15%) and water vapour (5-10%). It is taken through GI pipeline to the lamp-posts. Drains for condensed water vapour are provided on line. This gas burns with a blue flame and can be used for cooking as well. The excess gas is liberated in the atmosphere after the dome reaches maximum height. The utilization of gas should be spaced in such a manner that this release of excess gas is avoided. The main component in biogas is methane (green house gas) and it has a very high negative impact on the environment. The pressure in the dome is between 100 to 200mm of water column. The pressure is sufficient to take this gas to a distance of about 200-300m without any loss of efficiency. The pressure can be increased by putting additional weight in the form of MS discs or any other suitable and aesthetically acceptable alternative.

The gas generated in this plant can be used for gas lights fitted around the plant. The potential use of this gas would be thermal applications like cooking purposes. It can also be used to produce electricity. The undigested lignocellulosic and hemicelluloses materials then are passed on in the settling tank in the form of finely divided powder. After about a month high quality manure can be dug out from the settling tanks. There is no odour to the manure at all. The organic contents are high and this can improve the quality of humus in soil, which in turn is responsible for the fertility. The manure can be used for nurseries and fields. The manure pits are provided with filtration system that can separate out the water in an underground tank. This water can be reused in the system. The BOD of this water is less than 100-150 which is quite acceptable for reuse in the Nisargruna system. The bucket centrifuge can do the job faster.

It must be noted that BARC NISARGRUNA plant is suitable as a community plant rather than for individual dwellings. City corporations, big hotels, government establishments, housing colonies, residential schools and colleges, hospitals, power plants, Agricultural Produce Market Committees and large factories can easily set up such plants and process their wastes in most environment friendly way.

There are thirty-seven Nisargruna plants presently operating and some more plants are getting ready in the next 2-3 months.

and acidic conditions.

7. There are several structural changes made in anaerobic digester. These changes are intended for smoother particle movement and enrichment of biogas with respect to methane value.

8. The dome structure has been changed to avoid its contact with slurry (which used to be the case in gobar gas technology) thereby ensuring proper entrapment of the biogas.

9. The water coming out of the anaerobic slurry is allowed to settle in settling tanks where filtration is used to remove manure and recycle the water.

10. Thus the plant achieves the dream of “Zero garbage, Zero effluent and Zero energy process” as more energy is generated in the form of biogas than energy spent in the operation of the plant.

11. It has a good potential to generate the employment opportunities in lower strata of the society. The NGOs of such dedicated persons can help in achieving this target.

12. The manure generated in the process is weed-free and rich in organic carbon contents. Hence it will be a better soil conditioner than any other organic manure.

13. The biogas has better fuel value. It can be used for thermal purpose or can be used to generate electricity.

14. The technology can be upgraded as per user's requirement. This is especially useful in urban area where large quantities of wastes are generated in relatively smaller places.

Advantages of Nisargruna Technology

1. Environmental friendly processing of biodegradable waste is achieved. This waste is completely zeroed and by-products are generated.

2. The elemental cycles like nitrogen, carbon, hydrogen, oxygen etc. cycles expect that the biodegradable waste has to go through microbial route for ensuring their availability for future life. Nisargruna achieves this objective fully.

3. The processing cost of biodegradable waste is far lesser as compared to any other foreign technology.

4. Decentralized handling of the waste will reduce the transportation costs, dumping yard needs and assured processing. In the long run, it means that dumping yards could be totally eliminated. If proper segregation occurs at the source, then the requirement of land-fill sites can be reduced by 60-70%.

5. Transportation of this waste through crowded areas could easily be avoided if decentralized Nisargruna plants are made available.

6. By-products like biogas and manure can make the process economically attractive.

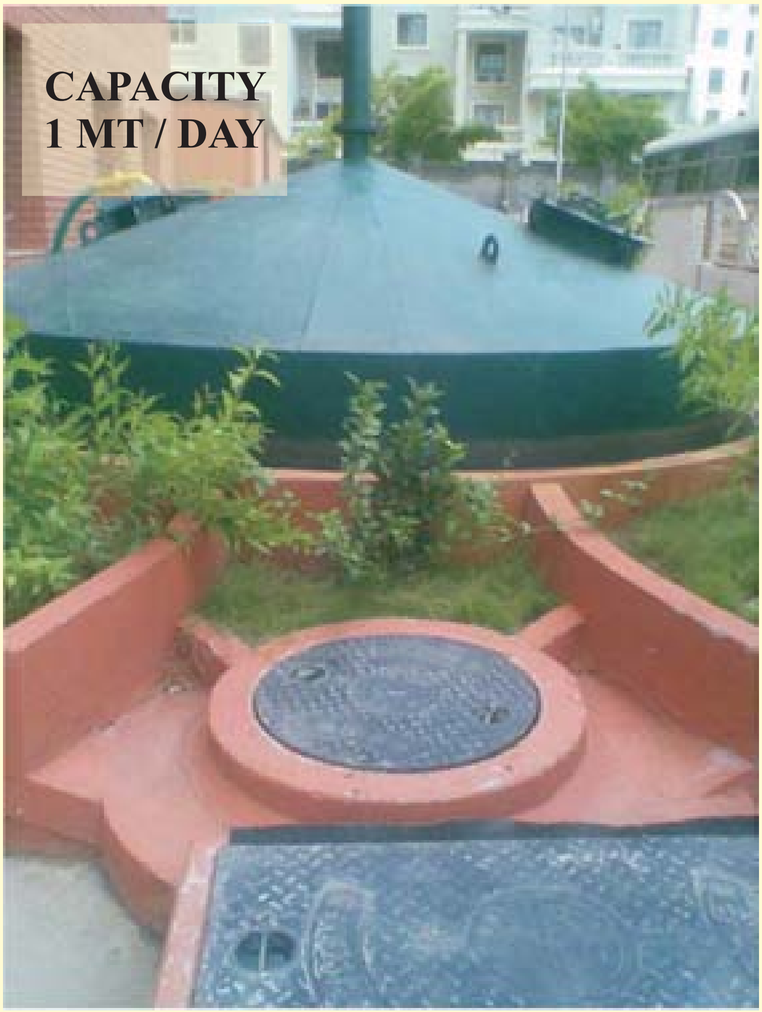
7. Processing of solid biodegradable waste in this manner would ensure that this material won't be carried to dumping yards and release methane there, in slow and unplanned composting. Since the biogas is trapped to burn, the contamination of environment with a vast quantity of methane will be completely avoided. This would earn carbon credit.

8. The use of biogas as fuel will save the classical fuel consumption including petrol, LPG and diesel. This is another reason which will ensure the carbon credit for the process.

9. In rural areas where biomass can be made available to run these plants, energy-freedom can easily be achieved. The stand-alone Nisargruna plants can be rural power houses.

10. In rural areas it will reduce the use of wood as fuel thereby helping indirectly in afforestation.

11. The aesthetic looks of the



Nisargruna Plant at Symbiosis, Pune

Nisargruna Plant at Tata Consultancy Services, Thane

country can be changed using Nisargruna technology.

12. It offers a long-life methodology to treat the biodegradable waste in a very limited space. The continuity of the process makes it possible to treat a large quantity of waste at a single site without any need of adjoining areas.

13. The technology is relatively simple and does not involve any imports. The plants can be operated by unskilled workers after training them initially for about 3-4 weeks. It is developed keeping in mind local environment and the types of wastes.

14. The manure generated in the process will help in rejuvenating the depleting organic carbon contents in our agricultural soils.

15. The processing of biodegradable waste and making it zero would tremendously improve the hygiene of the country, reduce the epidemics and make people in general healthy. The substantial reduction in health bills is a distinct possibility. It would also influence the human efficiency.

The Nisargruna technology has generated considerable interest in urban local bodies and many of these bodies all over the country are actively discussing its implementation for handling the biodegradable waste in their regions. A rough estimate is that the existing plants have processed about 18,000 MT of biodegradable waste so far. Many Municipal Councils in Maharashtra have passed resolution for implementing this technology. Governments of Karnataka, Kerala and Gujarat have shown interest in implementation of this technology. A large number of private entrepreneurs have shown keen interest in buying this technology and propagating it throughout the country. There are at present 63 technology holders and many of them are busy in implementation aspects. The technology is evolving too. The gas utilization for electricity generation has been successfully tried out. Some of the Nisargruna plants [Matheran, Symbiosis (Pune), Tata Consultancy Services (Thane)] have attracted a large number of visitors so far.

An Exposition on Multidisciplinary Development & Technologies

DAE participated in the Exhibition cum Conference & Fair on Multidisciplinary Development & Technologies held at Hodal, Haryana during July 19-21, 2008. The exhibition was inaugurated by Shri Chandraban, Member, Legislative Assembly, Haryana, from Hodal. The activities of the Department in the areas of nuclear power, healthcare, agriculture, food, industry and advanced technologies were exhibited through picture panels, samples etc. Several farmers visited the pavilion and showed keen interest in the Department's work in the area of agriculture and food security. High school students and teachers from over twenty schools found the exhibition immensely informative and the students particularly interacted very enthusiastically with the officials from DAE.

Department of Space and Defense Research and Development Organisation (DRDO) were among the other government departments that participated.

Shri Chandrabhan, MLA, Hodal, Haryana visiting the DAE pavilion

Brisk interaction with students

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www.plasma.ernet.in
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Those Years... These Months...

A compilation of important events during these months in the history of DAE

Ravi Shankar, Hd AVORP, PAD, DAE

August 10, 1948

Atomic Energy Commission is constituted.

July 29,1949

Rare Minerals Survey Unit is brought under the Atomic Energy Commission and named as 'Raw Materials Division' (RMD), with Headquarters at New Delhi. In 1958, this unit becomes Atomic Minerals Division (AMD). In 1974, it is shifted to Hyderabad. On July 29, 1998, it is renamed as Atomic Minerals Directorate for Exploration and Research (AMD).

August 18, 1950

Indian Rare Earths Limited (IRE), owned by the Government of India and Government of Travancore, Cochin, is set up for recovering minerals, processing of rare earths compounds and Thorium - Uranium concentrates. In 1963, IRE becomes a full-fledged government undertaking of DAE.

August 03, 1954

Department of Atomic Energy is created.

August 01, 1955

Thorium Plant at Trombay goes into production. (Plant is now closed).

1956

AMD discovers uranium mineralisation at Umra, Rajasthan.

August 04, 1956

APSARA - first research reactor in Asia, attains criticality at Trombay, Mumbai.

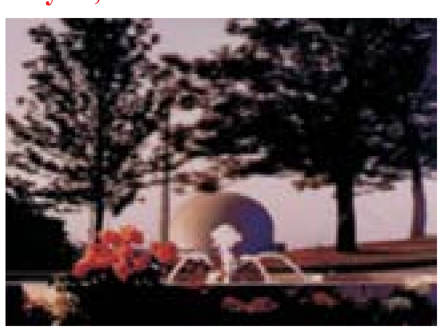
August 19, 1957

AEET Training School starts functioning at Trombay.

1959

The International Mathematics Olympiad is introduced in India. This is followed by International Chemistry Olympiad in 1969, International Physics Olympiad in 1970, International Biology Olympiad in 1990, and International Astronomy Olympiad in 1996. India hosted the 37th International Mathematical Olympiad in 1996 and the 33rd International Chemistry Olympiad during 6-15 July, 2001.

July 10, 1960



CIRUS - the 40 MWt research reactor, attains criticality. (The plant has been refurbished recently.)

July 1977

Heavy Water Plant, Baroda, Gujarat is commissioned.

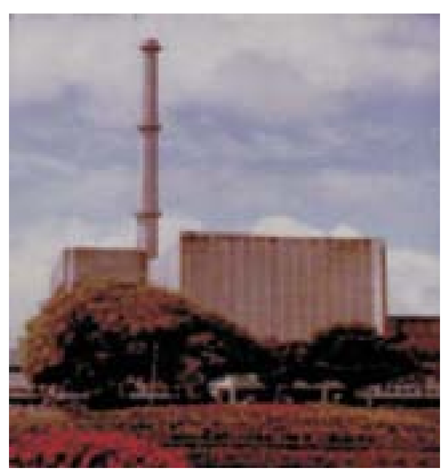
July 1978

Heavy Water Plant, Tuticorin, Tamil Nadu is commissioned.

1979

AMD hands over Bhatin and Turamdih (East) uranium deposits (now in Jharkhand State) to UCIL.

August 08, 1985



Research Reactor DHRUVA (100 MWt) attains criticality. It attains full power on January 17, 1988.

August 10, 1998

The 500 keV industrial electron accelerator developed indigenously by BARC is commissioned for its first phase of operation.

Ammonium diuranate production commences at Rare Earths Division of IRE, at Alwaye, Kerala.

1999

AMD's discovery of Gogi uranium occurrence in Gulbarga district, Karnataka.

July 1999

Solid Storage and Surveillance Facility (S3F) is commissioned at Tarapur.

August 27, 2005

The 450 MeV electron beam injected in the Storage Ring of Indus-2 completes full four rounds. Later, on December 2, 2005, first synchrotron light from Indus-2 is recorded. On December 17, 2005, this 2.5 GeV synchrotron radiation source is dedicated to the nation. The Centre for Advanced Technology at Indore, Madhya Pradesh, is also named as Raja Ramanna Centre for Advanced Technology.

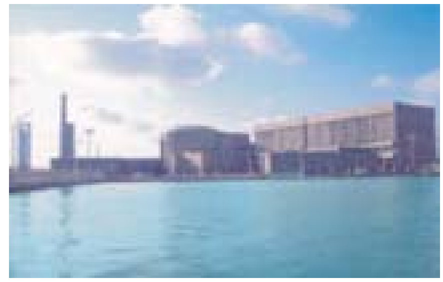
2005

BARC develops indigenous teletherapy machine Bhabhatron that uses Cobalt-60 as radiation source. The machine is commissioned at ACTREC.

August 4, 2006

Apsara the first nuclear research reactor in the whole of Asia completes 50 years.

August 18, 2006



TAPP-3 goes commercial.

August 2007

The BARC Training School completes 50 years. The setting up of the Training School in 1957 has provided almost the entire human reources for the nuclear programme in India.

August 31, 2007

Units 3&4 of the Tarapur Atomic Power Station dedicated to the Nation.

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