

biotechnological interest ever since Gary Strobel and his team described a functionalized diterpenoid and the famed anticancer agent paclitaxel, from species of *Taxus* across the globe⁹⁻¹¹. A novel fungus *Taxomyces andreanae* was recovered from *Taxus brevifolia*, which also produced paclitaxel. With these beginnings, endophytic, bacterial and fungal diversity has been extensively screened for antibiotics, antivirals and anticancer agents, as antioxidants, anti-insecticidal activity, and antidiabetic and anti-immunosuppressive compounds, etc.^{12,13}.

While antimicrobial and anticancerous searches continue with renewed vigour, novel technologies based on endophytic bacteria have recently emerged on the scene. Barc *et al.*¹⁴ have utilized genetically engineered endophytic bacterium, *Burkholderia cepacia* for phytoremediation of water-soluble and volatile organic pollutants such as toluene. This was achieved through the introduction pTOM plasmid of *B. cepacia* G4 into the natural bacterial endophyte of the yellow lupine (*B. cepacia* L. S. 2.4), and introduction of the modified strain (*B. cepacia* VM 1330) into surface-sterilized seeds. Besides considerable degradation of toluene which resulted in marked reduction of phyto-

toxicity, there was 50–70% reduction in transpiration through the leaves. Endophytic colonization strategy had earlier been attempted with the biocontrol bacterium *Bacillus subtilis* BB for vegetable brassicas following seed inoculation¹⁵.

Endophytic habitat appears to provide a protective environment that helps a potentially exploitable bacterium with reduced competition from the indigenous microbial populations. In view of their widespread application in plant and human health and environment, concerted efforts at endophytic diversity searches coupled with exploitation are necessary in the country on account of the varied and rich plant diversity.

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Indo-US nuclear agreement: expectations and concerns

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The Indo-US Agreement of 18 July 2005 and the subsequent agreement of 2 March 2006, following the visit of President Bush to India, have been discussed extensively in the Indian and US media for the past ten months. At present, the US Congress is holding hearings on the proposed legislation to enable the US to enter into civil nuclear energy cooperation with India and to allow the US administration to approach the nuclear suppliers' group to adjust its policies to make an exception in the case of India. We shall certainly be hearing of both support and opposition from various Senators and Congressmen. As of now it is not clear if the US Congress will accord its approval before the June or July deadline. There will be a recess thereafter and on reconvening, the US Congress is expected to be busy with new elections. There is also a possibility that the US Congress, even if it were to

approve the legislation, may include some additional conditions that India would have to accept. The Indian Government's position is that it stands by the agreements of 18 July 2005 and 2 March 2006 and that no new conditions would be acceptable to the Government.

To understand the whole gamut of issues involved, it is important to recall the background to the 18 July 2005 agreement. This agreement itself sought to redress the anomalous situation India enjoyed in the global non-proliferation regime. India refused to join the nuclear non-proliferation treaty (NPT), which came into being in 1968, at the initiative of USA, USSR and the UK. The NPT defined a cut-off date of 1 January 1967 and recognized those countries which had carried out a nuclear test prior to that date as nuclear weapon states (NWS), and all other countries as non-nuclear weapon states

(NNWS). Initially, the NPT was conceived to deny the countries that launched the second world war, namely Germany, Japan and Italy permanently of the ability to make nuclear weapons. As it turned out, the NPT legitimized USA, USSR, the UK, France and China as NWS (incidentally, the same five states are also the five permanent members of the United Nations Security Council with veto powers) and required other states to give up their rights to acquire nuclear weapons for all times.

India termed the NPT discriminatory and refused to join it from the very beginning. Pakistan, although receiving substantial military and economic assistance from USA, also refused to join the NPT, on the ground that India had chosen to keep itself out of it. Israel also kept itself out of the NPT and managed to build up a nuclear weapon capability during

the 1970s and 1980s. Israel did receive assistance from France, Britain and USA in its nuclear weapons programme. USA and many countries of the world have accepted the Israel argument that its nuclear deterrent is an existential necessity, as it is surrounded by a number of countries who are not reconciled to its very existence.

India built its first research reactor Apsara, pretty much on its own in 1956. It was the first research reactor in Asia outside the Soviet Union. India started its first heavy-water production facility at Nangal in 1962 and its first plutonium separation plant in Trombay in 1965. At the Second United Nations Conference on the peaceful uses of atomic energy held in Geneva in 1958, Bhabha outlined India's three-stage nuclear power programme – the first stage consisting of natural uranium-fuelled heavy water-moderated reactors, to be followed by fast reactors using plutonium from the spent fuel of the first-stage reactors, producing more plutonium from uranium-238 or uranium-233 from thorium. In the third stage, either thermal or fast reactors would operate on the uranium-233–thorium cycle. The logic for this approach was the rather limited resource base of uranium in India (recognized even at that point of time) and the large reserves of thorium in the country. The importance of developing capability of producing heavy water on the one hand and separating plutonium from spent fuel was obvious. India also undertook all activities to exercise full control over the entire fuel cycle. Mining for uranium commenced in the 1960s, though earlier to this, uranium was extracted from the monazite sands. Fuel fabrication for the research reactor CIRUS was taken up in the early sixties, followed by fuel required for the pressurized heavy-water reactors. During the same period, plants were set up to produce nuclear-grade zirconium and zirconium alloys required for fuel assemblies. A plant for vitrification of long-lived nuclear waste coming out of the spent fuel reprocessing facility was also built.

With regard to nuclear power plants, the first twin-reactor unit at Tarapur, incorporating boiling-water reactors, was commissioned in 1969 using the US reactor technology. At about the same time, a twin-unit pressurized heavy-water reactor using Canadian technology was built in Rajasthan. The third nuclear power station at Kalpakkam was designed and built as a total Indian venture. India undertook

the Peaceful Nuclear Experiment (PNE) in 1974 and in its wake both the US and Canada imposed embargoes on nuclear commerce with India. The US, which had contracted to supply low enriched uranium fuel for Tarapur, told India that it could not supply the fuel due its domestic laws under the nuclear non-proliferation act. In undertaking the PNE, India had violated no agreements with USA or Canada. Plutonium produced in the Canadian-supplied CIRUS reactor was used for the PNE, but at that time both USA and USSR were themselves carrying out nuclear explosions for peaceful purposes. The nuclear embargoes certainly affected adversely the execution of the Indian nuclear power projects. They were all delayed considerably as a whole new nuclear industrial infrastructure had to be built up in the country. During the same period, USA working with its allies and partners, set up the nuclear suppliers group and the restrictive supply regimes known as 'Wassenaar' and 'Energy'. Many research institutions and industrial establishments in India came under the 'Entities list' of the US Department of Commerce.

In spite of the impediments posed by nuclear isolation, India made steady progress in building nuclear power plants, heavy-water production plants, fuel fabrication facilities and reprocessing facilities, in addition to wide-ranging research and development across the entire spectrum of nuclear sciences. In parallel, radiation technologies and isotopes were used extensively in the fields of health, industry and agriculture. In the 1980s, intelligence information revealed that Pakistan had advanced a great deal in setting up a centrifuge uranium-enrichment plant. By the end of the decade of 1980, A. Q. Khan had boasted to a few Indian journalists that Pakistan had some nuclear weapons in its basement. The strong and on-going collaboration between China and Pakistan in nuclear matters was an open secret. This situation required India to respond appropriately to secure its national interests. It was under these circumstances that India began its programme of weaponization. However, Prime Minister Rajiv Gandhi proposed to the special session on disarmament of the United Nations that the NWS agree to a time-bound programme on universal nuclear disarmament. A timetable of fifteen years was suggested. While this proposal was welcomed by President Gorbachev of the USSR, USA rejected this proposal outright. It then became clear to policy makers in

India that it had no option but to embark on a nuclear weapons programme, given the China–Pakistan nuclear axis. There was an attempt to conduct a weapons test in the mid-nineties, when Narasimha Rao was the Prime Minister. But this decision appears to have been countermanded reportedly under US pressure. It was in May 1998 that India carried out its tests under the leadership of Prime Minister Atal Behari Vajpayee. Later that month, Pakistan also carried out its tests. India also announced its policy of building a credible minimum deterrent, of no first use and a voluntary moratorium on further tests. Predictably, sanctions followed at the initiative of the US. But it was found that the Indian economy had become sufficiently robust and could survive the sanctions without any discomfort.

Contrary to the expectation that with India going overtly nuclear, Indo-US relations would be damaged severely, after the lapse of a short interregnum, Indo-US relations entered a more mature phase based on pragmatic considerations. During the Clinton administration, Strobe Talbott and Jaswant Singh met in a number of places around the world to work out a new architecture of Indo-US relations, including the nuclear area. India repeatedly pointed out about the need to enlarge its nuclear electric capacity and how it was constrained by the denial of civilian nuclear technology. The situation from the Indian perspective appeared unfair when China, once considered by the US as an adversary, could access civilian nuclear technology from the West and Russia. The legal argument that it had signed the NPT, although as a NWS, was simply a fig leaf, in India's view. In the Talbott–Singh negotiations, according to reports, US insisted on India putting all its civilian nuclear facilities under IAEA safeguards as a precondition for resuming civilian nuclear energy cooperation.

The visit of President Clinton to India was a big publicity event with his address to the joint session of Parliament being a crowning event, when Clinton was mobbed by our parliamentarians. However, there were no substantive agreements that were then signed and certainly no narrowing of the US–India nuclear differences.

It was in this background that discussions on the nuclear issue between India and the US were resumed under the leadership of President Bush and Prime Minister Manmohan Singh. There were some impressive achievements in the nuclear field in India that preceded these discus-

sions. In the period 2000–05, the nuclear power units began to operate with high capacity factors, one of them even creating an international record. The heavy-water plants and nuclear fuel facilities were turning in excellent performance. The fast breeder test reactor using Indian-developed mixed carbide fuel operated well, giving confidence to launch the construction of the 500 MW prototype fast breeder reactor in 2004. In March 2005, unit no. 4 of the Tarapur atomic power station, India's largest reactor and largest single-unit-generating-plant attained criticality. The time was appropriate to launch a much larger nuclear power programme. However, there were some constraints. The first related to availability of uranium in the country. As of now, India possesses only relatively low-grade uranium ores which cost some four or five times the international price to extract. The total quantity available is also limited. The internationally accepted nuclear power units have a capacity of 1000 MW or more and employ low enriched uranium – an option barred to India due to the extant rules governing nuclear export. Thirdly, there is an inevitable time lag before thorium can be used as a source of energy, as a sufficient capacity of fast reactors using the plutonium–uranium cycle have to be built before thorium can be utilized.

A parallel development at a political level was the initiative of President George Bush to change the relationship between USA and India into a strategic one, recognizing the commitment to democracy in India and its continuing economic growth at 7 to 8% per annum. In this context, the role of making adequate quantities of energy, alternative to hydrocarbons, was recognized as urgent and important. The 18 July 2005 agreement noted that India was a responsible country with an advanced nuclear programme and had an impeccable non-proliferation record. The US undertook to change its laws to permit full civil nuclear cooperation with India and to work with its friends and allies in the nuclear suppliers group to make an exception in the case of India, to allow its members to engage in nuclear trade with India. As a reciprocal measure, India agreed to separate its civilian and military facilities in a phased manner and to place the civilian facilities under IAEA safeguards. For this purpose, India would negotiate an additional protocol with the IAEA. In the agreement reached on 2 March 2006 in Delhi between India and USA, India agreed to put fourteen of

the twenty-two reactors, now in operation and under construction, under IAEA safeguards, retaining eight reactors outside the civilian safeguarded regime. India also kept the fast-breeder test reactor and the prototype fast-breeder reactor outside the safeguards regime. The fourteen reactors would be brought under safeguards progressively by 2014. Future civilian reactors, including the breeder-type, will be placed under IAEA safeguards. The agreement recognizes India's right to build new facilities committed to its security requirements. The agreement also provides for application of IAEA safeguards on the upstream and downstream facilities like fuel fabrication and reprocessing facilities when handling safeguarded fuels. India has also declared nine research facilities as civilian.

The Indo-US agreement, as negotiated on 18 July 2005 and 2 March 2006, has drawn a wide spectrum of responses both in India and USA. We shall discuss the reactions in India first. A number of persons who have been a part of the nuclear establishment have taken great interest in this matter. This is to be welcomed, as these pioneers have formulated the past policies and worked on its implementation. They have built up a strong nuclear technology base under difficult conditions. Naturally, the entire nuclear community wants to ensure that the gains made against formidable odds are not frittered away now. One set of these critics feel that the earlier situation of total independence of the programme must be preserved at all costs into the indefinite future. They are prepared for a slow growth of nuclear power for the next two or three decades and an acceleration later, based largely on fast breeder reactors and thorium-based systems. In this view, the freedom of the country with respect to the size and diversity of the nuclear deterrent would be maintained fully. It is not adequately appreciated that a small nuclear power programme continuing for another two or three decades may well result in a loss of interest and an eventual abandonment of the programme. It could be argued that deploying the cream of India's S&T manpower on a programme of limited near-term impact was simply not in the country's interest. On the other hand, India's energy appetite is growing amidst many supply-side constraints. First, the pressure on hydrocarbons is growing globally and India has had to depend heavily on the politically volatile Middle East. Indian coal has high ash content and new mine

locations are mostly in areas classified as reserve forests, thus creating a conflict situation in land use. Moreover, increasing dependence on fossil fuels is adding to the greenhouse problem. So India has to use more of nuclear energy, hydroelectric energy and non-conventional sources of energy to reduce greenhouse gas emissions. The mandate of the Department of Atomic Energy is to produce increasing quantities of nuclear energy to power the Indian economy. Thus an important section of the nuclear community favours civil nuclear co-operation with other nuclear advanced countries so long as India's credible minimum nuclear deterrent is protected fully.

In his *suo motu* statement of 7 March 2006, Prime Minister Manmohan Singh stated that: 'I might mention: (i) that the separation plan will not adversely affect our strategic programme. There will be no capping of our strategic programme and the separation plan ensures adequacy of fissile material and other inputs to meet the current and future requirements of our strategic programme, based on our assessment of the threat scenarios. No constraint has been placed on our right to construct new facilities for strategic purposes. The integrity of our nuclear doctrine and our ability to sustain a minimum credible nuclear deterrent is adequately protected. Our nuclear policy will continue to be guided by the principles of restraint and responsibility; (ii) the separation plan does not come in the way of the integrity of our three-stage nuclear programme, including the future use of our thorium reserves. The autonomy of our research and development activities in the nuclear field will remain unaffected. The fast-breeder test reactor and the prototype fast-breeder reactor remain outside safeguards. We have agreed, however, that future civilian thermal power reactors and civilian fast-breeder reactors would be placed under safeguards, but the determination of what is civilian is solely an Indian decision'.

In an article in *The Asian Age* of 15 April 2006, P. K. Iyengar (former Chairman, Atomic Energy Commission) and M. Gupta have taken strong objection to putting a number of research facilities, including the Tata Institute of Fundamental Research, Variable Energy Cyclotron Centre, Saha Institute of Nuclear Physics and the Institute of Plasma Research under the civilian list. They have gone on to say: 'An international "license-permit raj" on Indian scientific creativity will be

here to stay and the army of IAEA inspectors will invade all related public and private sector entities, sometimes even without prior intimation. At the very least, it would guarantee that scientists and engineers would be endlessly tied up in bureaucratic red-tape so as to satisfy an infinite number of queries so that very little constructive work is actually achieved'.

It is necessary to recall that the research facilities identified as civilian now, have in fact figured in the 'Entities lists' of the US Department of Commerce and are unable to obtain dual use equipment, except on a case-to-case clearance basis. These restrictions are also imposed by other supplier nations under the 'Wassenaar' and 'Energy' guidelines. By declaring them as civilian facilities, these restrictions will not apply; nor is there any bar on these facilities collaborating freely with institutions in other parts of the world in an unfettered manner. The question of IAEA inspection arises only if fissile materials, namely uranium-235, plutonium-239 or uranium-233 are in use in significant quantities or if work is in progress on uranium enrichment or on spent fuel-reprocessing or if activities involving weapons research are undertaken. None of the nine listed facilities have been involved in these activities in the past nor will they be so involved in the future. Bhabha Atomic Research Centre, Indira Gandhi Centre for Atomic Research, Raja Ramanna Centre for Advanced Technology and other strategic facilities are outside the list of facilities accessible to IAEA inspection. While in the early stages of the programme, the civilian and strategic activities were taken up in the same premises, this is no longer the situation. Also using dedicated S&T personnel and technicians for strategic activities is a reality now and does not in any way weaken this effort. So the concerns expressed by Iyengar are grossly exaggerated and do not have any basis in reality.

So far as the strategic community is concerned, the response indeed covers a wide spectrum. A number of them with a strong media presence, have stressed the importance of an emerging strategic relationship between India and USA. They have been critical and impatient about the rigidity of the nuclear establishment during the negotiations and have, unfairly in my view, accused the latter of derailing the agreement. There is another segment of the strategic community at the

other end, which wants the present totally autonomous, some say, autarchic position on independence of India's nuclear policy to continue. They would pitch for a large nuclear arsenal and matching missile capabilities. The sober middle ground finds a larger measure of support. They agree that it is good for India to end nuclear isolation and use civil nuclear cooperation with other advanced countries to rapidly increase nuclear power capacity, without compromising on the nuclear deterrence or the freedom to pursue the three-stage programme, including thorium utilization.

US Secretary of State Condoleezza Rice in her testimony to the US Congress on 5 April 2006, has strongly supported this agreement and urged the support of the United States Senate. Rice has argued that the agreement is good for America as also for India. President Bush said in New Delhi: 'India in the 21st Century is a natural partner of the United States because we are partners in the cause of human liberty'. Rice elaborated this point and said, 'It (India) is a vibrant, multi-ethnic, multi-religious democracy characterized by individual freedom, the rule of law, and a constitutional government that owes its power to free and fair elections'. She also went on to recognize that India is a rising global power and a pillar of stability in a rapidly changing Asia. She forecasted that by 2025, India will most likely rank among the world's five largest economies. Since a large part of India's civil nuclear facilities will be open to IAEA inspection, the agreement is seen as a gain to the pursuit of non-proliferation, with India becoming a full partner in achieving this objective. Rice stressed that the nuclear agreement was a key element of the growing strategic partnership between the US and India and that the two countries would cooperate in many areas to mutual benefit. She opined that if the agreement did not go through, all the hostility and suspicions would be doubled. India and the US would then continue to be 'estranged democracies'. In the testimony, India's needs for energy to sustain high rates of economic growth have been noted and the importance of measures to reduce dependence on hydrocarbons (especially from volatile regions of the world) and equally to reduce greenhouse gases has been stressed.

Certain suggestions made from the US in the past few weeks, however, have caused concern in India. There has been

a suggestion that India define the size of its credible minimum deterrent. India has rightly refused to do so, as none of the other nuclear weapon powers have done so.

Moreover, the Indian Parliament itself is fiercely protecting the pursuit of economic development and is not known to support jingoistic proposals for acquisition of military might for its own sake. A second suggestion has been made to include a provision for fore-swearing future nuclear weapon tests in the bilateral agreement between India and the US. This suggestion is also not acceptable to India, which has reiterated its voluntary moratorium on future tests. However, a new situation would arise if some other states, especially in India's neighbourhood were to undertake a test in future. Regarding the fissile material cut-off treaty, India has stated that it will join negotiations with other countries, in good faith, in the conference on disarmament; however, this matter was not a bilateral issue between India and the US. India continues to support universal nuclear disarmament, whenever the global community is ready for it. As Rice told the US Senate, the agreement in its present form should go through, as renegotiation would just not be possible.

As of the time of writing (May 2006), it is not clear when and in what manner the US Congress will approve the agreement. If it is approved in its present form, India will benefit from civil nuclear cooperation and expand the nuclear energy base rapidly. Isolation in the nuclear field, imposed on India in unnatural circumstances, will end. India can then participate fully in international developments leading to global energy security. If the initiative were to fail because of unacceptable conditions that the US Congress may impose, then India will continue its autonomous nuclear energy programme, even if in the near term, the growth of nuclear energy may be slow. The relationship between India and the US may grow in other areas but it is unlikely that a fully grown, mature relationship will emerge. So the stakes are high both for India and the US, and it is hoped that the US Congress will take a balanced and mature view.

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