Atomic Energy in India – 50 Years. C. V. Sundaram, L. V. Krishnan and T. S. Iyengar. Department of Atomic Energy, Government of India. 1998. 277 pp. Price not stated.

Long before India became independent, Meghnad Saha and Homi Jehangir Bhabha, doyens of science in India, recognized the potential use of nuclear fission as a source of energy. In a seminal lecture[1] delivered before the Indian Physical Society as early as March 1941, Saha concluded with the remarkably prescient observation, 'the above process (chain reaction), if it can ever be perfected, can give us an enormous amount of heat. This should not be allowed to occur with explosive violence but should be sufficiently slowed down. After these problems are solved and we get a steady supply of heat, we could utilize it to feed our machinery for the conversion of heat to electrical energy .... It is also possible that a process may be discovered which would render the reactions to proceed with explosive violence .... The idea that a tablet of Ur-235, not more than a homoeopathic globule in size, may blow off a Super-Dreadnought – a feat which can at the present time be performed only by a torpedo carrying several tons of explosives in its head – cannot but be an exciting one'. Bhabha, on the other hand, observed in his appeal in March 1944 to the Sir Dorabji Tata Trust for funding an institute of fundamental research (TIFR) that 'when nuclear energy has been successfully applied for power production, in say a couple of decades from now, India will not have to look abroad for its experts but will find them ready at home'.

Thus, when the Atomic Energy Committee was constituted with Bhabha as Chairman and Saha as a member, its mandate was to devise ways and means to harness raw materials for production of atomic energy. In its recommendations as to how the goal is to be approached the Committee underscored the role of universities and research institutes:

(i) the universities should be encouraged to impart elementary instructions in the theory and experimental techniques of atomic physics,

(ii) the existing centres of atomic research, namely the Palit Laboratory of the University College of Science, Calcutta, the Bose Research Institute, Calcutta, and TIFR, Bombay should be strengthened, and

(iii) TIFR should be made the main centre for all larger programmes of atomic research, until the stage is reached for a full scale programme on atomic energy development.

The emergence of the Atomic Energy Committee from an embryonic state within the CSIR, to its incarnation after independence as the Atomic Energy Commission (AEC) in the Ministry of Atomic Energy in 1948 under the direct charge of the Prime Minister marked two significant changes. First, Saha was replaced by K. S. Krishnan, then Director of NPL. The second change, perhaps a sequel to the first, dispensed with the earlier recommendations on the involvement of universities and research institutes in the atomic energy programmes. All activities, research and development, related to the original mandate of generating atomic energy, were brought under the roof of the Department of Atomic Energy (DAE), its own personnel, laboratories, and establishments.

The Atomic Energy Act of 1948 clamped secrecy on the entire atomic energy programme of the country. This secrecy came under relentless criticism in articles authored by Saha and in his speeches. He emphasized[2] that in France, progress in the atomic energy programme, despite American obstructions, was in a large measure due to the open disavowal of secrecy. The programme there made 'a great national effort in which the knowledge and skill of all available scientists of the country, physicists, chemists, geologists, technologists, and engineers were utilized for the objective'. Even in USA, he pointed out, only procurement of minerals, production of fissile materials, and weapons development were entirely under the AEC. The programme of generating power from nuclear reactors was pursued in collaboration with industrial firms, whereas programmes related to peaceful use of atomic energy, basic research, and development of machinery and instruments were carried out in collaboration with associations of universities and research organizations[2]. During the debate[3] in the Lok Sabha on Peaceful Uses of Atomic Energy on 10 May 1954, Saha made an impassioned appeal, 'First of all there should be no secrecy. If you read out Atomic Energy Act you find that it does not tell us what to do but it simply tells us what is not be done .... I would ask our honourable friends on the Treasury Bench to read the Atomic Energy Acts of England and America and see how broad based they are. They, of course, have secrecy but the Act deals with how work has to be organized properly and how the money which will be devoted for this purpose has to be spent judiciously, how the efforts of the scientific talents of the country have to be harnessed in one scientific effort'. The response[3] of the Prime Minister had an apologetic overtone. He said, 'I entirely agree with him and so far as we are concerned, we want no secrecy. Our difficulty has been that when we deal with another country, whether it is France or England, when they give us any process or any information, they insist on secrecy for their part and we have to agree because it is their custom'.

Denied of access to key information and knowledge in chemical and technological operations by 'external secrecy', and windows closed for inputs and feedbacks from universities, research institutes, IITs, IISc, etc., thanks to 'internal secrecy' clamped by the Atomic Energy Act, the atomic energy programme in India sailed on an uncertain lonely course in uncharted waters to reach the distant goal of generation of nuclear power. The entire programme starting right from the first step of 'growing science', as Bhabha used to call it, by giving appropriate training to graduates in physical and biological sciences and technologies, to the final step of delivering electrical power from nuclear reactors was brought under one government department, the DAE, and implemented by its numerous establishments and facilities. From the Nuclear Research Laboratory at Srinagar in the north to the Minerals Separation Plant at Manavalkuruchi in the south, and the Heavy Water Plant at Hazira in the west to the Radio-Immunoassay Centre at Dibrugarh in the east, DAE units span the entire length and breadth of the country.

The book *Atomic Energy in India – 50 Years* by C. V. Sundaram, L. V. Krishnan, and T. S. Iyengar, all senior ex-employees of DAE establishments provides a guided tour of the vast DAE empire along with the history and the role played by numerous establishments. The honour of the jewel in the crown clearly belongs to the Bhabha Atomic Research Centre (BARC). Home of five research reactors and the mother of all research and developmental activities in the atomic energy programme, BARC, with well above 10,000 scientific and technical personnel on its payroll, is the largest science and technology centre in the country. The book tells us about the units with specific mission orientation that BARC spawned in different parts of our country over the years. Notable among these are the Electronic Corporation of India at Hyderabad, the Centre for Advanced Technology at Indore, the Variable Energy Cyclotron Centre at Calcutta, and the Indira Gandhi Centre for Atomic Research (IGCAR) at Kalpakkam. Exploration, mining, and extraction of atomic minerals are carried out by two DAE organizations, the Atomic Minerals Division and the Indian Rare Earths Ltd. India has proven uranium reserves of 86,000 tonnes of uranium oxide while thorium reserves, mainly in Kerala, are much larger at around 360,000 tonnes. To exploit the large reserve of thorium and the naturally occurring isotope of uranium Ur-238 as nuclear fuel in power reactors one needs to develop the fast breeder reactor technology. This technology is still at a developmental stage. A fast breeder test reactor in IGCAR became critical in 1985. Operation, management, and construction of nuclear power reactors were brought under the aegis of the Government owned Nuclear Power Corporation in 1987, while earlier in 1983 the Atomic Energy Regulatory Board was put in place to oversee and carry out regulatory and safety measures in all nuclear installations. The place of pride in the book is given to the successful nuclear explosions in Pokaran I and Pokaran II. For the benefit of readers the book presents a long interview on the subject with the present Chairman of AEC, R. Chidambaram, who has seen both.

Generation of electrical energy from nuclear reactors for industrial use is the touchstone of success of any civilian atomic energy programme. Precisely this has been the Achilles' heel of the DAE. By the end of 1997 the share of nuclear power in the total electricity output in the country is a paltry 2.2% (ref. 4), and that too at an enormous cost. Out of the ten power reactors in the country, the two oldest in Tarapur, obtained on a turnkey basis from General Electric, have been relatively trouble free. Commissioned in 1969, these two boiling water reactors (BWR), each designed to generate 210 MWe (later downrated to 160 MWe) have been in operation for more than 29 years. Subsequently, DAE adopted the policy of building pressurized heavy water reactors (PHWR) for the production of electricity and plutonium. Among the eight PHWRs commissioned to date, the two oldest near Kota in Rajasthan were designed and supplied by Canada. The remaining six, two near Chennai, two at Narora in UP, and two at Kakrapur in Gujrat were designed and built indigenously. Remarkably prone to accidents, the Indian PHWRs have been plagued by time and cost overruns right from the beginning. Designed for installed capacity of 235 MWe each, the units have been downrated to 220 MWe or lower. If one leaves out Pakistan, the average load factor at 50% of the eight Indian PHWRs is the lowest in the world[4]. The corresponding figure for the Chinese reactors is 72.56%. In his lecture in January 1966, reproduced in the book, Bhabha observed with a sense of pride that the research reactor *Apsara*, designed and built indigenously, was already two years in operation before China had its first reactor in place, designed and built by the Soviet Union. The advantage that India had in the atomic energy programme initially has slipped away in the last four decades, perhaps irretrievably. Successful explosions in Pokaran I and II have apparently brought some cheer to this dismal scenario but they are diversions into military use of the atomic energy.

Underperformance of the PHWRs and the cost and time overruns in installing them have been the underlying reasons for the decision to purchase two Russian reactors of 1000 MWe each. In fifty years, the principle of self reliance, the cornerstone of the Indian atomic energy programme, has become the casualty. All these years, scientists and technologists of the country at large could contribute very little in this great national effort and were kept waiting with muted expectations outside the wall of secrecy which Saha tried so hard to demolish.

1. Saha, M. N., *Sci. Cult.*, 1941, **6**, 694. Reprinted in *Collected Works of Meghnad Saha* (ed. Chatterjee, S.), Saha Institute of Nuclear Physics, Calcutta, 1982, vol. 1, p. 361.
2. Saha, M. N., *Sci. Cult.*, 1954, **19**, 368. Reprinted in *Collected Works of Meghnad Saha* (ed. Chatterjee, S.), Saha Institute of Nuclear Physics, Calcutta, 1982, vol. 1, p. 470.
3. *Meghnad Saha in Parliament* (eds Chatterjee, S. and Gupta, J.), Asiatic Society, Calcutta, 1993, pp. 169–206.
4. *Nuclear News Digest* compiled by Kalyane, V. L., Library and Information Services, BARC, Mumbai, 1998, vol. 11.

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Classical and Spatial Stochastic Processes. Rinaldo B. Schinazi. Birkhäuser Verlag AG, P.O. Box 133, CM-4010, Basel, Switzerland. 1999. 192 pp. Price: SFr 98/DM 118.

Undergraduate or post-graduate courses in stochastic processes are generally centered around Markov processes and Brownian motion. Most reference books, written for undergraduate/post-graduate readers, also emphasize these two aspects of the topic at the exclusion of a wide range of spatial stochastic processes. This book however, presents topics on spatial processes which could be introduced at an undergraduate or post-graduate level to initiate students to the exciting developments that have taken place in these subjects over the last three decades.

The first three chapters of the book deal with Markov chains, both discrete and continuous time. These chapters cover the standard results on classification of states, recurrence and transience, existence of stationary distributions, renewal theorem, passage times, etc. An interesting feature of the treatment of these topics here is that unlike in classical books[1,2], many of the proofs employ Doeblin's coupling technique, thereby simplying the proofs and also making them more intuitively appealing.

The remaining four chapters are on spatial processes, viz. percolation theory, cellular automaton, continuous time branching random walk and contact processes. A lot of work has been done in recent years by mathematicians and physicists on these topics and these chapters provide a nice introduction to them.