A Ganguly

ANIL KUMAR GANGULY

(1918-1988)

Elected Fellow 1979

BIRTH, CHILDHOOD AND EDUCATION

Born on November 1, 1918 at Faridpur now in Bangladesh, young ANIL KUMAR GANGULY passed his years of childhood and early adulthood in a large joint family in his home-town. He recalled shortly before his death that he was introduced to the Bengali alphabet through the primer "Varan Parichay" written by Ishwar Chandra Vidyasagar. He chose to attend a morning pre-primary school run by the Corporation (बिनावेतन no fees) because he got the impression that in this school they will not use a cane (बेंत) as he was afraid of being beaten in the class. Recollecting his early childhood, he said that Sarda Mohan Sircar, Head Master of the School was so impressed by him because he could spell p-o-t 'pot' and c-a-t 'cat' that he took him straight into Class III.

One event which Anil Kumar recalled recently was about a pilgrimage to Puri with his parents. On his return after an absence of about two weeks the Head Master questioned him. His replies were very straight forward and truthful. He was asked by the Head Master whether there was water in Puri and if so how deep it was. With all innocence the child replied that there was lot of water and as for the depth it was allways more than the length of his legs.

From the sixth standard he came to Baghbazar High School and then three years later joined the Madaripur High School. At the Madaripur High School his elder brother, Kanhailal, was also a student and a top ranker. Everyone therefore referred to young Anil Kumar as Kanhailal's brother, which he did not very much enjoy. He wanted to be known on his own performance rather than ride on the shoulders of his brother.

In 1932, when Anil Kumar was in the ninth class his elder brother died. This was a big shock to the young boy. He neglected studies in Sanskrit for which he was punished and he decided that Sanskrit was not for him. In later years he used to say that he regretted this decision now.

Anil Kumar passed High School in 1934 and joined the Scottish Church College in Calcutta on a merit scholarship as he had three distinctions at the High School. Here he came under the influence of the then Principal of the College, Arkward, who impressed him as a devoted and dedicated teacher and treated the college like his own baby. Other professors who influenced young Ganguly were Prof Ravi Chatterjee, who taught him chemistry, and later Prof PC Mitra who taught him organic chemistry in the University.

For the MSc, Ganguly joined the University College of Science where he came in contact with stalwarts like Professor Meghnath Saha and Jnan Mukherjee who left their mark on him. He particularly recalled the phenomenal memory of Meghnasd Saha who remembered the name of every one of his students and rarely referred to telephone directory or diary to recall a telephone number. Anil Kumar Ganguly himself had developed an excellent memory for facts and figures. This was perhaps due to his very poor eye-sight because of which he found it difficult to refer to books and journals, especially if they happened to be in fine print. He allways used to say that 'we do not make use of our brain to its full capacity- the more we use it the sharper it becomes'.

CAREER

After a brilliant career at the Calcutta University from where Anil Kumar Ganguly passed his BSc Honours and MSc in pure chemistry he became a Lecturer in Chemistry at the Scottish Church College, Calcutta, where he taught from 1941 to 1949 and later at the Calcutta Universsity where he taught until 1951. For his MSc desertation he worked under Dr SK Mukherjee, then a senior research worker in the University Chemistry Department, on some aspects of ion exchange characteristics of silicate minerals. Even as a post graduate student Anil showed his ability to go deep into fundamentals of a subject, a quality which he sustained throughout his life. During his MSc work he raised many unanswered points which he examined systematically and answered decisively in his DSc work on base exchange capacity of homoionic and heteroionic clays. The degree was awarded to him by Calcutta University in 1949. Part of the work on the clay minerals has been published in the *Journal of physical and colloidal chemistry* and has been referred to in various reviews and books. The young student and the young guide also developed during this period a fondness and regard for each other. Shortly before his death, Ganguly mentioned to the author of this memoir that he is yet to meet as perfect a gentleman as his teacher and friend Sushil Mukherjee.

For a brief period of two years Ganguly left the University to join as a Physical Chemist with the Bengal Immunity Research Institute where he developed methods for the analysis of certain drugs and pharmaceuticals. In 1953 he got an offer of a Post-Doctoral Research Associateship at the Radiation laboratory of the University of Notre Dame (USA). It was here that Ganguly carried out work in theoretical radiation chemistry and published the now well-known paper "*Radical Reaction Mechanism in the Tracks of Ionising Radiation*". The paper in collaboration with Prof Magee in the *Journal of Chemical Physics* (1953) is now internationally recognised as one of the oustanding contributions in the field of radiation chemistry and is quoted in all books and reviews.

It was here in 1954 that I the author of these memoir first met Ganguly. While on a visit to the United States I had also been asked to be on the look out for a suitable

Indian who could organise "Health Physics" and "Waste Disposal Groups" in the Indian Atomic Energy Commission. After spending the day at the Notre Dame University Radiation Laboratory, shortly before leaving back for Chicago, I casually enquired of the Director whether there were any Indians working in the University. He replied that there was one engaged in some theoretical radiation chemistry studies, and asked me whether I would like to meet him. I just had about ten minutes to spare before reaching the station to catch the train to Chicago, and so I decided to meet and say "hellow" to my fello-countrymen. I was led to the basement where we found Ganguly bent over some books and papers (because of his poor eye-sight). After introductions, I enquired how long he had been there and what he had done before coming to the States. When I was told that his earlier work was in the field of base exchange capacity of clay minerals and that he was doing radiation chemistry then, it flashed through my mind that he might be a suitable person for organising health physics and waste management. So I asked Ganguly whether he had a job in India and on his replying that he had to resign before coming to Notre Dame I asked him whether he would be interested in joining the Atomic Energy Commission. On his giving a reply in the affirmative I invited him to come with me to Chicago, about an hour's journey by train. We had dinner together and he returned to his University later in the night. We had an extremely fruitful discussion during the journey and later during dinner at my hotel. Ganguly at once impressed me with his deep knowledge of the subjects in which he had worked and by his simplicity and integrity and there on the spot I offered him a position of Jr Research Officer, the starting salary to be fixed later after an interview in India. He readily accepted and it was arranged that befgore leaving the United States for home, he would write to me so that I could arrange his formal interview soon after he landed in India. This he did. He was interviewed the day he arrived and in view of the excellent work which he had done both in India and abroad, the Committee decided to offer him the position of a senior Research Officer (instead of the tentative offer of Junior Research Officer). Thus started a new career and our new collaboration and friendship which continued not only for the time that we were in service but even in later years after our formal retirement from the Atomic Energy Commission.

Amongst the foreign scientists Ganguly met, he once recalled he was most impressed by Debye. In spite of the fact that Debye was already internationally known for his contributions, what most impressed Ganguly was the humility of the great scientist. Ganguly also mentioned that Debye whom he met at the home of Magee, told him that his well- known theory of strong electrolytes was built on the work of Prof JC Ghosh of India.

Soon after he joined the Atomic Energy Establishment Trombay, as BARC was then known, he was made Head of a newly created Radiation Hazards Control Section where he later became the head of the Health Physics Division and shortly before his retirement, Director of the Chemical Group of what later came to be known as Bhabha Atomic Research Centre. During this period Dr Ganguly concerned himself with problems connected with health and safety including siting of nuclear power reactors. For each site selected for the power reator Ganguly collected base data which included analysis of soils, surface and ground waters, air, vegetables, fruits etc. in an area encompassing approximately 5 miles from the reactor site. He also organised at each site a laboratory to continuously monitor the environment in that area on a regular basis throughout the life of the reactor. He has written extensively on these subjects including systematics of nuclear reactor siting. As some of the power reactors in India are located close to the sea, Ganguly has also carried out stúdies on marine pollution. He has established a good school on this subject in BARC. In this area of work Ganguly during his life time was accepted as an international authority. He has also contributed to diffusion chemistry in view of the fact that this plays a very important role both in marine pollution and in disposal of nuclear wastes.

Thus, among Ganguly's scientific works were diverse topics he dealt with, some by choice and others due to professional necessity. They covered a wide spectrum of scientific disciplines such as soil chemistry, radiation chemistry, geochemistry, meteorology, oceanography, environmental chemistry, radiation metrology, nuclear and radiation safety, radiation physics and fission physics, radiation dosimetry and some other related fields.

Radioactivity building-up in Nuclear Reactors

Since Dr Ganguly was in charge of Radioactive Waste Disposal in the fifties, one of his initial interests was the radioactivity buildup in nuclear reactors, part of what is now called as 'Source term' evaluation. The objective was to estimate the buildup of activation products in the APSARA reactor in its time dependent operations. While 'rough estimates' with adequate 'safety factors' were considered sufficient for health physics purposes, it was Ganguly's accent on exactness that led to the rigorous derivation of serveral new expressions for activity buildup in time-dependent nuclear operations. Looking back at it now, that work appears to be quite superfluous, thanks to the availability of the modern computers. But in those precomputer days (at least in India), it provided a strong tool in generating valuable data which very soon gained international acceptance. As a natural sequel, Ganguly developed stronger interests in fission product generation and behaviour and this led to fruitful research in the area of statistical model of fission.

Nuclear Fission

One of the many problems which tickled Ganguly's interest was the fission phenomenon. Since his early days in the BARC, the phenomenon of asymmetry in fission interested him very much. He developed a theoretical model for the fission process based on the statistical process of order- disorder phenomenon applied to systems in chemical thermodynamics. The model has for its basis the systematics found in the stability of nuclides and the fact that fission fragments are confined to nuetron rich regions. It envisaged a two step process for fission : An early charge polarisation in the fissioning nucleus followed by a statistical random distribution of the balance neutrons as in order-disorder processes between two impending fragments. The model intrinsically provided an explanation for the asymmetry in fission such that the empirical parameter of "balance neutrons", i.e. neutrons left after the charge polarization in the first step, conceived in the model bore a distinct correlation with asymmetry. It implied that mass division was only consequential and charge polarization was more fundamental in nature which decided the asymmetric division of the fissioning nuclide. The first paper on the model appeared in the *Physical Review* in 1971 and was followed by a series of important publications during the period 1971-81. The basic model and its extended applications explained the various aspects of the fission process such as asymmetric division, charge distribution and connected parameters, odd-even effects, neutron evaporation and related energy release, disappearance of asymmetry with increasing mass of the fissile nuclide and prediction of predominantly symmetric division in the superheavy nuclide region.

Radiation Metrology

Dr Ganguly had an innate interest in Radiation Metrology. He actively participated in the development of gas flow counters for low level counting. Using simple equipment he developed methods for estimating U^{235} content in uranium samples. Dr Ganguly showed keen interest in the study of shortlived radioactivity (both beta and gamma) in fission products. Some of the early exotic ideas of his were put into practice by him and his students at Cirus and Apsara reactors at a time when sophisticated instrumentation was not available. These techniques included fast pneumatic transfers, choppers and cine-photographing the dekatron scaler sequence. Among other results, this led to the establishment of a method for determining very short beta decay halflives in fission products, of the order of 0.2 sec. This topic is of great importance from the point of view of early period of fission product heating in reactors. The short lived gamma measurements were later developed for estimation of fissile materials in U samples.

Ganguly very early realised the importance of non-destructive assay methods for nuclear materials, even before this was initiated by the International Atomic Energy Agency. As an application of the studies on short lived fission products, methods to estimate and characterise fissile and fertile materials were developed by his group. Later this led to a wider spectrum of activities incorporating passive methods. The need for on-line processing of data demanded by systems based on these investigations in turn led to development of microprocessor based systems for various assay applications.

Criticality Parameters Of Fissile Systems

Around 1963 the Department got interested in the criticality parameters of condensed fissile systems. Being new to this field and therefore unbiased by the earlier work turned out to be an advantage because of Dr Ganguly's innate ability to look at a problem in the most basic way. It was the time when Sn technique was gaining importance. Monte Carlo methods were being considered as the 'Cure-all' and adopted indiscriminately. Dr Ganguly could clearly see that Monte Carlo techniques were not really called for to handle one-dimensional systems and that one can obtain all their advantages by tracking an average particle in criticality calculations. This led to the development of Source-Collision Iteration Technique (SCIT), an extremely accurate and fast method for obtaining criticality parameters. That was also the beginning of a decade of very fruitful work in radiation transport. Subsequently the SCIT was extended to anisotropic systems and extensive data on the gamma ray and neutron transport generated.

Thermoluminescence And Radiation Dosimetry

Dr Ganguly and his associates have carried out considerable amount of work on thermoluminescence (TL) of several materials, in particular lithium fluoride, mineral fluorite, calcium sulphate, quartz etc. Lithium fluoride is one of the most popular thermoluminescent materials used in radiation dosimetry because of its approximate tissue equivalence and its satisfying other requirements of a good dosimeter. From a solid state view point, however, the behaviour of thermoluminescent LiF, is rather complex. It is affected by moderately high doses of radiation in a manner which to-date is an enigma, and by thermal treatment and mechanical stress. The irradiated phosphor is also influenced by ultraviolet light. Magnesium is the major dopant : about 100-200 ppm. There is also some other minor dopant widely believed to be about 10ppm titanium. Magnesium enters the lattice as Mg^{2+} replacing Li^{+} and a vacancy is created for charge compensation. Mg impurity - vacancy (I-V) form a dipole. These dipoles and modifications of dipoles and dipole aggregates - dimers and trimers are some of the defect centres envisaged as the trapping entities (TC) in LiF. The luminescent centres (LC) are related to Ti. In addition F centre electrons and V_3 centre holes are involved. V_3 are twohole centres stable at room temperature. As the temperature is raised an electron from the impurity-F-Centre complex is released and recombines via the conduction band at a V_3 and releases a one hole centre V_k which is unstable at that temperature. V_k and an electron tunneling from the F centre combines at the activator site to give luminescence.

Dr Ganguly initiated studies on the heat treatment to LiF crystals and its consequences on I-V dipoles, their aggregation and dispersion, impurity movement, etc. He showed that the dipoles, dimers and trimers are responsible for the TL peaks but direct correlation was not possible. However, changes in the response of different peaks are clearly observed. Luminescence centres are not affected.

The response of LiF is linear for doses upto about a few hundred rads (5-10 Gy) above which it becomes supralinear, saturates and then decreases showing damage effects. The physics behind this radiation induced enhancement and decrease of response are still an enigma. Several models have been proposed. To explain the supralinearity of response a model, which Dr Ganguly christened TC-LC in the fully annealed (400^0 C 1 h)LiF; Mg, Ti phosphor. In crystal as grown these complexes are not present. An absorption band at 137 nm is presumed to be associated with these centres. Upon irradiation TC-LC breaks-up into TC and LC. The addition of LC's leads to supralinearity and the creation of TC's thus gives rise to a peak at 395^0 C. The decrease in response is attributed to damage to the LC's. Absorption studies and thermal effects were used in support.

Dr Ganguly and colleagues carried out spectral measurements and phototransfer studies on mineral fluorite, quartz and $CaSO_4$. A high temperature peak (650^0 C) was discovered in fluorite. Dr Ganguly and co-workers also proposed an explanation for the TL in the rare-earth (RE) doped $CaSO_4$. $CaSO_4$: RE is easily made in the laboratory and differently doped samples were prepared and their characteristics studied to arrive at an explanation of the TL. The phenomenon is essentially redox reactions in the RE^{3+} ions.

Miscellaneous

It was during the CIRUS construction period that Dr Ganguly got interested in radiation shielding problems. In those days "Reactor Shielding" by Rockwell used to be the bible and Dr Ganguly very soon noticed that we could do far better than the prescriptions of Rockwell. This resulted in significant developmental work in radiation shielding and set his "Point Kernel Method" on a firm footing.

A problem which fascinated Dr Ganguly till the end was in the area of low energy background radiation. The fact that the bulk of high energy radiation ends up as thermal energy of the medium is obvious. Starting from MeV region, the behaviour of gamma rays down to several tens of KeV has been well studied experimentally and theoretically. Dr Ganguly strongly believed that an area which still remained fertile for investigation, both from the basic understanding and applications point of view, was the passage of radiation from tens of KeV to thermal energies. He was constantly beseeching his younger colleagues to intensify work in this area. The little work that was done was quite rewarding in providing a physical basis for broad hump around 80 KeV observed in the natural background radiation.

While there are many other areas of radiation physics, such as thermoluminescent dosimetry, radiation spectrometry etc., where Dr Ganguly was responsible for pioneering work, probably his most significant contribution to radiation physics was to give it a form as a viable scientific discipline. By mid sixties, while the chemical and biological aspects of interaction of radiation with matter had already developed as independent and active disciplines of Radiation Chemistry and Radiation Biology, the study of its physical aspects was quite diffused. Different topics of radiation physics such as basic interactions, radiation transport, shielding, spectrometry and dosimetry, radiation instrumentation etc. were being studied as supports to various other disciplines. Right within the establishment, he observed that different divisions and groups were working on different aspects of radiation physics in isolation, utilizing nearly the same techniques and methods. Dr Ganguly could clearly discern the need and immense potential of radiation physics as a distinct discipline and his initiatives in this direction led to the organisation of the first National Symposium on Radiation Physics in 1970 at Bombay and the first International Symposium on Radiation Physics in 1974 at Calcutta. His relentless efforts finally resulted in the formation of the Indian Society for Radiation Physics in 1976. Subsequently, the message transcended national boundaries and led to the formation of International Radiation Physics Society in 1985 at Ferrara, Italy. That these national and international societies are quite active now and radiation physics has come to be accepted as a distinct subject of much scientific and social relevance, is a standing monument to Ganguly's vision and foresight.

It is not in the context of radiation physics alone that he was a pioneer. At the time when reactor safety research was just an appendage to reactor engineering, he recognised the importance of safety research and set the trend by establishing Safety Research Laboratory at Kalpakkam entirely devoted to fast reactor safety problems. Again, long before the environmental issues became a band wagon, he showed immense concern for the environment and way back in 1956-58 established the practice of setting up environmental survey laboratories at all nuclear power stations.

Ganguly was a gifted teacher. It is not that he was always solving his students' problems; he was more interested in developing in them an ability to solve problems. What endeared him most to his colleagues was that they could completely share their excitement or concern however trivial it was. He would listen to them with genuine interest, discern the little substance amidst a lot of chaff and nurture the substance. And yet it is not often one finds him as a co-author. Notwithstanding the ideas and guidance provided by him he was against being a co-author unless he had soiled his hands with the details of the work.

There was never a dull moment with Ganguly around. Whatever may be the activity with which he was associated, his involvement was complete and whatever may be the subject for discussion, his participation was total. But the spirited discussions with him never left any rancour. In the final analysis a question stands out; what made Dr Ganguly what he was? In the words of one of his students and colleagues "Dr Ganguly was living on two different planes. Outwardly he was in complete resonance with the surroundings, sharing its excitement, joy and anxiety. But deep inside, there was the person with scientific objectivity, detachment and totally devoid of ego."

In the areas of health, safety and preservation of the environment, Ganguly was an outstanding scientist, recognised as such, nationally and internationally. On many occasions he was invited by the International Atomic Energy Agency (IAEA) to go abroad to advise the Atomic Energy Commissions of several countries on setting up facilities for health and safety.

After his retirement from the BARC, he was selected as National Environmental Fellow by the Department of Science & Technology (DST), Govt of India for two years. In January 1981, he was appointed as visiting Professor at the BARC for two years. He was honoured by the award of Padmashri in 1974. Several State Governments used to invite him to advise on problems of environment related to the setting up of chemical industries. His criteria that within a radius of 1.6km of a nuclear reactor there should be no population, which upto a radius of 8km, called the sterile zone, there should be thin population, held good for chemical industries dealing with hazardous & toxic chemicals. These guidelines are a landmark and are strictly followed in selecting sites for nuclear reactors and should be followed for chemical and fertilizer plants.

Dr Anil Kumar Ganguly left for his heavenly home on January 17, 1988. India lost a dedicated scientist by his death. A scientist who devoted a greater part of his scientific career in the area of health, safety and preservation of natural environment. May his soul rest in peace.

JAGDISH SHANKAR

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