SUSHIL KUMAR MUKHERJEE

(01 January 1914 – 18 November 2006)

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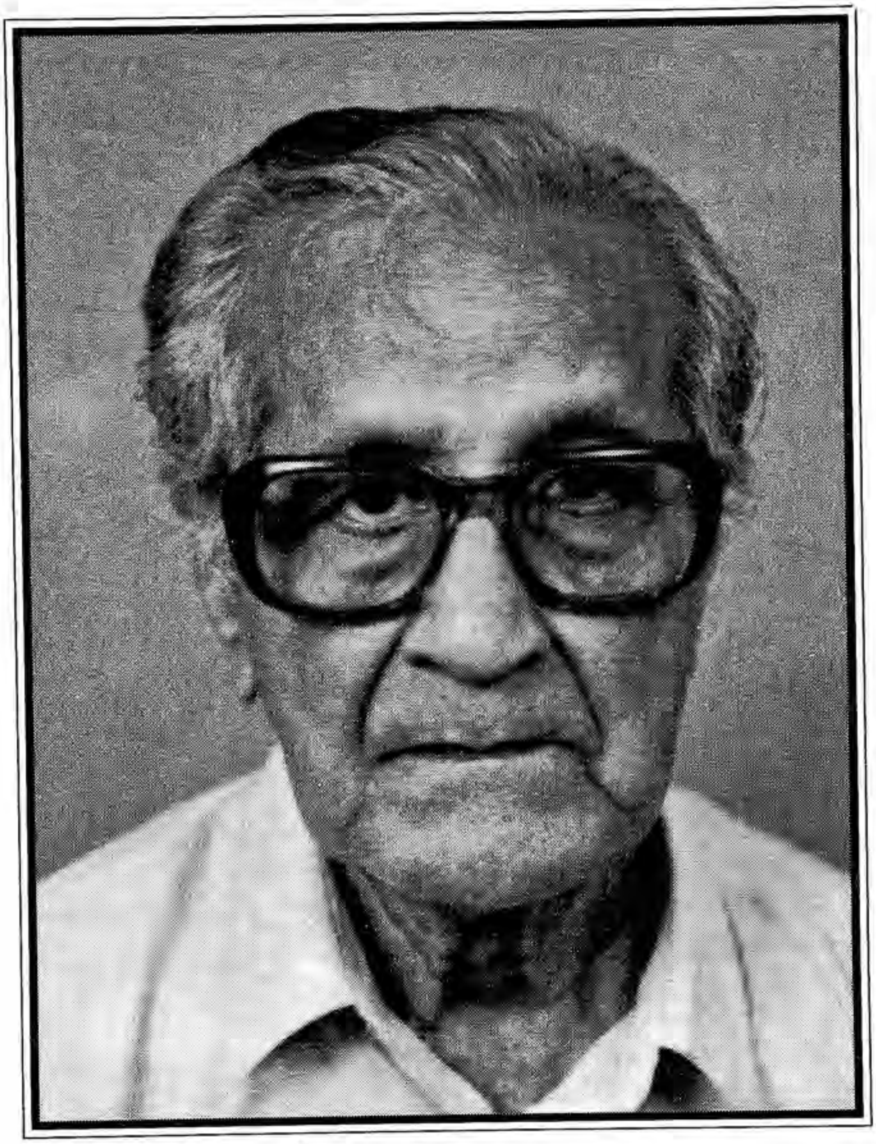

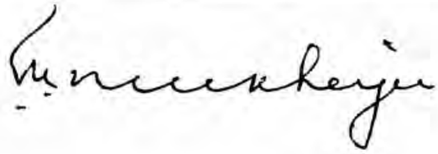

SUSHIL KUMAR MUKHERJEE

(1914 – 2006)

(Elected Fellow 1977)

FAMILY BACKGROUND AND EDUCATION

PROFESSOR SUSHIL KUMAR MUKHERJEE, who epitomized Indian intellectualism at its very best, breathed his last on 18 November 2006 at his residence in Kolkata.

Professor Mukherjee was born on 13th October 1914 in a small village in Barisal, undivided Bengal on the full moon night of *Lakshmi Pooja*. Professor Mukherjee epitomized Indian intellectualism at its very best. He was underage at the time of his Matriculation examination, so his official age had to be increased by almost one year. Late Bhagwati Charan Mukherjee, his father, was deeply involved in *Swadeshi*, from handloom to homeopathy, through which making money was inconceivable even though the family was never well off.

After early schooling in his village, Professor Mukherjee came to Kolkata to complete his education. Following High School, he did his college education all along from Calcutta University, with BSc (Honours in Chemistry) and finally MSc in Chemistry (in 1936) standing First in Physical Chemistry (he was assessed by doyens like Professor NR Dhar, Sir JC Ghosh and Dr SS Bhatnagar). Thereafter, he joined research at Calcutta University under Professor JN Mukherjee. His senior and junior collaborators include Professors SP Ray Chaudhuri, RP Mitra, B Chatterjee, NP Datta, SC Das and TD Biswas. One of the greatest contributions of Professor JN Mukherjee was to motivate the best students of the University to get involved into agricultural research, something unheard of at that time. Professor Mukherjee became so indoctrinated in this mission that he completed the Associateship course of Imperial (now Indian) Agricultural Research Institute in 1938.

PROFESSIONAL CAREER

In 1943, a National Project commenced under Professor JN Mukherjee to make an inventory of soil resources with one Soil Survey Officer and four Assistant Soil Survey Officers on regional basis; Professor Mukherjee was In-charge of Eastern India. This was the beginning of soil survey, genesis and classification at the national level. During this period, Professor Mukherjee worked extensively all over Eastern India including the hills of Assam, jungles of Orissa and inaccessible coastal regions of East Bengal, often living in country boats for weeks.

In 1945, D.Sc. degree of Calcutta University was conferred on him for his work on electrochemistry of clays. Soon he joined the Chemistry Department of Calcutta University as a Lecturer and within a year, moved to the Applied Chemistry Department. From 1948 to 1950, he worked with Professor CE Marshall at the University of Missouri, Columbia, USA as the prestigious Ghosh Travelling Fellow of Calcutta University. There, Professors SA Barber and AH Beavers were his colleagues while EO McLean was a doctoral student.

The years from his return to Calcutta University in 1950 to his leaving for Indonesia in 1957 were the most fascinating period of his life. As a student, Professor Mukherjee came under the direct influence of *Acharya* PC Ray - Father of Indian Chemistry and Indian Chemical Industry, who also motivated him into social service and the spirit of nationalism. Professor Mukherjee, like his *Guru*, lived in the laboratory, waking up very early, working throughout the day and finally sleeping after midnight on a wooden table without a pillow or mattress. About twenty doctoral students were always working with him on various problems of Soil Science, Physical Chemistry and Chemical Technology. However, he meticulously struck off his name from the publications and many of them were registered for their PhD under someone else. Some like late Professor DP Burma, FNA submitted their thesis independently. During this period, he conceived the necessity of an organisation for University Teachers and founded the Calcutta University Teachers Association. Also, he accepted the responsibility of running the Research Workers Association of India from none other than *Acharya* MN Saha.

In Indonesia, Professor Mukherjee worked as an UNESCO Professor of Chemistry from 1957 to 1960. Personally, he was greatly influenced by *Acharya* SN Bose, especially the idea of science education through mother tongue. This he put into action. A linguist by nature with an excellent command over German, French and Russian, he also learnt both Dutch and Indonesian. Later, he not only taught in Indonesian, but also finding no proper book available in that language, wrote monographs in Indonesian on Chemistry, Physics and Mathematics.

As instructed by *Acharya* Bose, he returned to Kolkata and joined as Professor of Macromolecules at the Indian Association for the Cultivation of Science, Kolkata and within a year moved to a newly formed Kalyani University as Professor and Head of the Chemistry Department and Dean, Faculty of Science. He also regularly taught at the Agriculture Faculty. During this period, through the initiative of *Acharya* PC Mahalanobis, a Joint Research Project with far reaching consequences of origin of life on earth, was conducted at the Indian Statistical Institute by Professor Mukherjee and the renowned British Biochemist, Dr RL Synge, Nobel Laureate.

In 1965, he was invited by his *alma mater* to chair as the first incumbent to the post of *Acharya* PC Ray Professor of Agricultural Chemistry. Subsequently, in 1968, he became the Vice-Chancellor of Kalyani University (present day Bidhan Chandra

Krishi Vishwavidyalaya, Uttar Banga Krishi Vishwavidyalaya and University of Animal Science and Fisheries were all within it). In the same year, he became a Member of Committee on Science and Technology, Government of India.

In 1970, he was invited to be one of the three full-time Members of the National Commission on Agriculture. This was only the second such Commission in India and the first one since independence. The voluminous reports of this Commission are testimony to his painstaking work and far-sighted concepts. Professor Mukherjee returned to Kolkata in 1976 as Director, Bose Institute and within a few months, he became Vice-Chancellor of Calcutta University wherefrom he finally retired on December 31, 1978.

During his professional career, Professor Mukherjee was a vastly travelled man; some trips he made, however, are of particular interest. In 1965, he had been to USSR under the auspices of the Indo-Soviet Friendship, and again in 1978 to attend the Congress of the World Federation of Scientific Workers. In 1986, Professor Mukherjee visited Montpellier in France as a Member of the Indian delegation to participate in discussion related to rural development programmes in France. In 1984, Professor Mukherjee went to Vietnam on an international delegation of scientists to gather *in situ* evidence for the extensive pollution of soil, water, aquatic life as well as human deformations resulting from war in Vietnam during 1965-1975.

The students of Professor Mukherjee in India and abroad, became Ministers and MPs, Chairman and Managing Directors of both public and private sectors, Government Secretaries, Director Generals (including the first Indian DG in North America), Vice-Chancellors, Directors, FNAs, etc. Incidentally, his first doctoral student was late Dr Anil Kumar Ganguly, DSc, FNA of BARC, Trombay, and the author is not the last but the youngest.

RESEARCH WORKS

Professor Mukherjee's research *forte* was Soil Science and Physical Chemistry, but he was at ease from Physics to Philosophy and Social Sciences. Whenever any one was in trouble with his research, whatever the subject, they sought his suggestions and surprisingly he had the solution in most of the cases. During the last couple of years of his life, he studied more *Sanskrit* than any other subject and deeply delved into the concept of consciousness; a few articles and lectures bear testimony to these remarkable deliberations.

In his initial years, Professor Mukherjee's research emphasis was on clay mineralogy while later on shifted to soil organic matter. Like his teacher's (JN Mukherjee's) "Calcutta School" pertaining to Clay Mineralogy, he established a School of Humus Research that is till today the most recognized Indian centre at the international level.

Professor Mukherjee's DSc thesis was on Electrochemical Properties of Hydrogen Clays. Normally, exchange of cations from clays follows the lyotrope series though deviations have also been reported. Observations by him regarding pH effects on cation exchange in clays, could satisfactorily account for such deviations in the lyotrope series. Symmetry values of a number of clay salts against various electrolytes were measured with and without adjustment of pH of the system. When a constant pH was not maintained, deviations from the normal lyotrope series often occurred. These deviations disappeared when the symmetry values measured at a constant pH ranging from 6.0 to 7.0 were compared. At a constant pH between 3.0 and 5.0, the various cations examined gave the same symmetry value and the cation effect as envisaged in the lyotrope series altogether disappeared.

Subsequent to this phase, he extensively studied soils in the field all over Eastern India. He particularly studied their mineralogy, genesis and transformation. He also studied clay pans in South Bengal basin.

In USA with Professor CE Marshall, Professor Mukherjee worked on thermodynamics of ion-exchange reactions and on ion-activity measurements by membrane electrodes. By controlling the orientation of clay particles, he developed a membrane having semi-conductor properties, a juvenile subject in those days. This work greatly impressed none other than Professor Linus Pauling, Nobel Laureate, who made a personal visit to see the material and there started a life long association.

During his early years of research guidance, Professor Mukherjee concentrated on the electrochemical properties of clay minerals. Clays in suspension may be regarded as macromolecular, negatively-charged ions that are surrounded by fixed- and a diffuse-layer of counter ions in solution. Depending on their distance from the charged surface, the counter ions have different levels of affinity for the clay. This confers on the clay suspension, certain peculiar properties that are most evident in its acid-base behaviour. Thus, titration curves of H-clays with different bases show differences not only in their features but also in the total acidity. Also, in the presence of neutral salts, H-clays show strong acid behaviour. The explanation is that, as the H^+ ions are held to the clay with increasing affinity on nearing the surface, all H^+ ions are not immediately available to the OH^- for neutralization; the extent of neutralisation (hence, observed total acidity) depends on the extent to which the accompanying cation can exchange positions with the H^+ ions and thus make it available for neutralisation.

The properties of clay acids are further complicated by the presence of exchangeable aluminium ions on the surface. The aluminium ions are a result of "aging" of the clay suspensions by exchange of H^+ ions in solution with Al^{3+} ions in octahedral positions. Salt treatment also causes liberation of H^+, Al^{3+} and $Fe^{3+/2+}$ from clays; with successive treatments, the ratio of Al^{3+} released to H^+ released becomes very large. If the aluminium ions are removed by quick exchange with H-resins and immediately titrated, the features of the titration curves are modified and by repetition of the process of desaturation and neutralisation, the clays show signs of degradation. Calculation of lattice charge distributions after corrections for free oxides, indicated that considerable amounts of octahedral cations are removed from the lattices followed by a redistribution of electrical charges in the tetrahedral and octahedral layers. Titration curves exhibit gradual changes from weak acid to strong acid character with increase in cation exchange capacity. Potentiometric and conductometric titration curves of H-clays normally show four inflexions. The first two are due to H^+ and Al^{3+} ions. The remaining weak acid is due to ruptured Si-O-Al and Al-OH-Al bonds on the lateral surface.

Ion exchange in soils and clays is defined in terms of its exchange capacity for cations and anions, the intensity of retention, and the selectivity of exchange for different ions. Many methods have been proposed to determine the exchange capacity of clays. Since results vary with the concentration of ions used for exchange and the pH, lack of agreement in results is often noted. Professor Mukherjee studied the causes of the differences and formulated conditions under which fairly reliable results might be obtained. He developed the KCl-KOH method which gives rapid, reliable results. He also suggested potentiometric titration of clays with tetramethylammonium hydroxide in the presence of its salts.

In order to predict ion-distribution in a soil/clay system that is in equilibrium with more than one cation, ion exchange formulae have been derived. Ideally, equations derived from the laws of mass action should suffice. In reality, the validity of the equations are, however, limited. This is because of (i) preferential adsorption of certain ions over others depending on ion valence, hydrated volume and geometric-fit, polarisability and polarising power, and (ii) non-equivalence of binding sites as proposed by Professor Mukherjee; thus it was shown that in a bi-ionic kaolinite, the exchange sites up to 50 percent saturation are of a different bonding energy from those above the saturation. Professor Mukherjee studied ion exchange and calculated thermodynamic quantities of exchange reactions utilising ion activity measurements by membrane electrodes. He applied in a novel way the Donnan membrane equilibrium concept for the determination of ion activity in colloidal clays.

Nature of exchange and exchangeability of various metal ions were also studied by Professor Mukherjee. Electrometric measurements of exchange in Ag-clays using Ag-AgCl electrode and potassium, barium and thorium nitrates as exchangers were carried out and the results were analysed with the help of four rearranged mathematical formulations, viz. of Wiegner and Jenny, Renold, Jenny and Bray. It was found that in most cases, the expected straight-line relationship held good, up to a certain concentration above which the points lay on another straight line having an altogether different slope. The equation of Bray fitted the best. Professor Mukherjee suggested that exchange probably took place discontinuously and at stages, which are characterized by different equilibrium constants. He also reported that the metal ions exchanged followed the order: Cu^{2+} > Mn^{2+} > Zn^{2+}. Fixation of the exchanged metal ions was in the order: Cr^{2+} > Ni^{2+} > Mn^{2+} > Cu^{2+}. In certain instances, exchange of ions of small radius may proceed further, with migration of these ions into the octahedral 'holes' causing a total negative charge reduction. Such behaviour has been observed with montmorillonite, especially using Li^+ or Zn^{2+}. The products are termed as reduced charge montmorillonites (RCM). The aforesaid behaviour was also observed by Professor Mukherjee using Cu^{2+}, Zn^{2+} and Mn^{2+}.

Adsorption properties of clays for organic molecules have found a variety of uses ranging from calculation of surface area to catalysis and gastro-intestinal remedies. Such investigations are, therefore, of interest to a number of scientific disciplines. Professor Mukherjee studied the adsorption characteristics of proteins, sugars, alkaloids, krilium, urea, cetyltrimethyl ammonium bromide and humic acids on smectite and showed that non-ionic organic molecules of polar character could be adsorbed on its basal plane surfaces. He investigated the adsorption of quaternary ammonium compounds on different clay minerals and their mixtures. The results are of much interest for the identification and separation of component clay minerals from mixtures. Organic derivatives of clays show pronounced change in physical characteristics such as water-repellency. He also studied the sorption characteristics of cationic dyes such as methylene blue, crystal violet, malachite green, etc. Results were used for determining orientation of these molecules at the surface as well as surface area of the clay. The disadvantages of using methylene blue for determining surface area of clays were simultaneously examined. The sorption characteristics of $Co(NH_3)_6^{3+}$, $Co(pm)_3^{3+}$ and other dyes on clay surfaces were studied and a correlation between adsorption-desorption and shape, size and charge of the dye ions was observed.

Viscosity against pH-curves for H-clays is a simple and elegant method that can not only enable identification of a clay mineral but also enable estimations of their relative proportions especially in binary mixtures. Professor Mukherjee demonstrated the usefulness of viscosity measurements in estimation of the predominant clay mineral in artificial mixtures or in soils. Sedimentation volumes, measured with pH, zeta potential and viscosity, in clay suspensions containing quaternary ammonium compounds showed charge reduction, charge reversal and differences in adsorption of the cations. Based on the differences in sedimentation volume or zeta potential, components of binary mixtures were separated.

An interesting development resulting from ion exchange studies of clays is the clay membrane electrodes, which could be used to measure the activities of cations in 10^{-3} – 10^{-5} molar concentration range not only in pure solutions but also in colloidal suspensions of clays. This technique has been extended to synthetic resin membrane electrodes and to electrodes prepared in a variety of ways, in order to obtain selective electrodes. The membrane electrodes have been used successfully to understand many of the finer features of exchange equilibria, in addition to supplementing information obtained on such equilibria, through chemical analytical procedures. Because of the possibility of measuring the activities of the interacting ions, it has been possible to determine more accurately the equilibrium constants of exchange reactions. From the data at various temperatures, the thermodynamic properties of the exchange systems were evaluated.

In the concluding part of his research career, as a visionary, Professor Mukherjee directed his efforts to the study of soil organic matter. The macromolecular character of soil humus and its various fractions were systematically and thoroughly studied by taking recourse to electrometric, viscometric, osmometric, diffusion, light scattering and spectral measurements, not only with the naturally occurring humus materials but also with synthetic preparation simulating the natural ones. Three significant contributions deserve mention (i) Identifying humic substances by a single method eluded researchers. Professor Mukherjee, by utilising fluorescence excitation spectroscopy, established that all humic fractions exhibited a peak at 465 nm, (ii) Tropical soils are poor in productivity because of low humus content. Inputs are there, but they decompose quickly. If such decomposition can be arrested, humus is stabilised. Professor Mukherjee demonstrated that clay bound, humus is much more resistant to microbial attack than humus alone, (iii) Finally, research work on physical chemistry of humus as carried by Professor Mukherjee over three decades laid the foundation for the development of macromolecular structures of humic substances. Nowadays, all their properties and characteristics are explained through these molecular models. Such studies have greatly helped to elucidate the complex nature of humus, and the part it plays in improving the physical, chemical and biological properties of the soil.

AWARD AND HONOURS

1. Silver Medal, University of Calcutta
2. Nagarjuna Gold Medal in Chemistry, University of Calcutta
3. DSc (*Honoris causa*), University of Kalyani and Burdwan University
4. Honorary Member, International Society of Soil Science (now International Union of Soil Science)
5. JC Ghosh Memorial Medal, Indian Chemical Society
6. Golden Jubilee Award, Indian Society of Soil Science

7. Platinum Jubilee Distinguished Service Award, Indian Science Congress Association

POSITIONS

1. Assistant Soil Survey Officer, Imperial (now Indian) Agricultural Research Institute, New Delhi
2. Lecturer, Department of Chemistry, University of Calcutta, Calcutta
3. Lecturer (and then Reader), Department of Applied Chemistry, University of Calcutta, Calcutta
4. UNESCO Professor of Chemistry, Indonesia
5. Professor, Department of Macromolecules, Indian Association for the Cultivation of Science, Calcutta
6. Professor and Head, Department of Chemistry, Dean, Faculty of Science, University of Kalyani, Kalyani
7. Acharya PC Ray Professor of Agricultural Chemistry (first incumbent), University of Calcutta, Calcutta
8. Vice-Chancellor, University of Kalyani, Kalyani
9. Member, National Commission on Agriculture, New Delhi
10. Director, Bose Institute, Calcutta
11. Vice-Chancellor, University of Calcutta, Calcutta

Throughout his life, Professor Mukherjee was involved in innumerable activities. To name a few, Secretary, Editor and President, Indian Society of Soil Science; Secretary and Editor, Indian Chemical Society; Editor, Indian Journal of History of Science; Editor-in-Chief, Everyman's Science; Secretary and Editor, Research Workers Association of India; Founder Secretary, Calcutta University Teachers Association; Founder President, Scientific Research Workers Association; Founder President, West Bengal Academy of Science and Technology; Founder President, Clay Minerals Society of India; Founder President, Raman Centre for Applied and Interdisciplinary Sciences; President, Indian Association for the Cultivation of Science; Chairman, Ramakrishna Mission Seva Pratisthan; Vice-President, Asiatic Society; Vice-Chairman, Commission on Compilation of History of Science in India; President, CRESSIDA; President, *Rabibasar* (an elite literary society). Last but not the least, he was the first Indian to be an Honorary Member of the International Society of Soil Science (now International Union of Soil Science). His great intellect and knowledge in diverse fields made him a natural choice for presidentship of a variety of scientific and social organisations.

Professor Mukherjee co-authored "Textbook of Soil Science" with Professor TD Biswas, the first book on Soil Science based on Indian data. He has written a few books in Bengali also. The brilliant editorials he had drafted for *Everyman's Science*, along with his other articles published elsewhere, are in the process of compilation now.

AS A PERSON

Professor Mukherjee's greatest contribution was his service to humanity. He was a soft-spoken gentleman to the core. His first doctoral student, late Dr AK Ganguly, mentioned to Professor Jagdish Shankar "he is yet to meet as perfect a gentleman as his teacher and friend Sushil Mukherjee" (INSA Biographical Memoir on Dr Anil Kumar Ganguly by Dr Jagdish Shankar). At the same time, he never wavered from his ideology and commitments. He invariably rose to the occasion and provided leadership when situation demanded. He was never shy of criticising anything unjust, whoever may be involved or however much price to be paid for that. For this reason, he was revered by every one cutting across all the barriers. He was also one of not too many scientists, who meticulously followed science in daily life till the end. To any one acquainted with him, Professor Mukherjee was a sage who commanded infinite gratitude, respect and admiration.

Professor Mukherjee is survived by his wife, Professor KK Rohatgi-Mukherjee, D.Phil. (Oxon), FNA, a distinguished Physical Chemist, past President of the Indian Chemical Society and first Asian woman to be the General President of the *Association Internationale de Photobiologie.*

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