



# ELECTROKINETICS

for Petroleum  
and  
Environmental  
Engineers

George V. Chilingar  
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# **Electrokinetics for Petroleum and Environmental Engineers**

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# Electrokinetics for Petroleum and Environmental Engineers



# Dedication

*This book is also dedicated to the memory of the founding father of the U.A.E., H.H. Sheikh Zayed bin Sultan Al Nahyan, whose leadership and vision have been instrumental in driving his ambitious dreams into reality.*

*The authors would also like to dedicate this book to:*

*H. H. Sheikh Khalifa bin Zayed Al Nahyan, the president of the U.A.E., who has guided this wisdom into all disciplines of our society, making the U.A.E. a world class major educational hub for nurturing our young talent into experts that support the needs of the economy.*

*H.H. Sheikh Mohamed bin Zayed Al Nahyan, the Crown Prince of Abu Dhabi and Deputy Supreme Commander of the UAE Armed Forces, for his genuine support for the advancement of science and technology, through his endeavors in education and nation building.*



# Dedication

*To Dr. and Mrs. Henry Chuang whose contributions were invaluable in writing this book. Dr. Chuang Yueheng (Henry) is Executive Chairman of the Board of Willie International Holdings Limited. As my former star graduate student and teaching assistant, he was very active in the USC Electrokinetics Laboratory. His contributions for advanced scholarship are helping USC students in Petroleum Engineering. He reflects great honor upon himself and the petroleum industry. We are proud of You!*

*The principal author dedicates this book to Dr. John Mork, President and Chief Executive of Energy Corporation of America (ECA), who's passion for academic excellence is witnessed by his generous contributions promoting advanced scholarship here at USC in the area of Petroleum Engineering. As one of my former stellar graduate students at USC he shined and now is a recognized pioneer and giant in the petroleum industry. We are proud of You!*

*The principal author is pleased to dedicate this book to Dr. Erle C. Donaldson with whom he has enjoyed many professional adventures (trips to conferences in foreign lands) and endeavors that have culminated in the birth of the "Journal of Petroleum Science and Engineering" and books on unique topics such as microbial enhanced oil recovery, subsidence, and petrophysics.*





# Foreword

I am pleased to write the foreword to the book by Dr. G. V. Chilingar, and Dr. M. Haroun. *Electrokinetics for Petroleum and Environmental Engineers* addresses the advances made in the science of electrokinetics (EK) as it applies to environmental and petroleum engineering. What was once a technology for dewatering clays and soils is now being positioned for use in environmental remediation and enhanced oil recovery. This reference book includes chapters by the foremost researchers in the world conducting research in the area. Top academic researchers from USC, Lehigh University, the University of Vermont and the Petroleum Institute of Abu Dhabi contributed to the book. You will learn about the most recent advances for the use of EK to assist in the cleanup of contamination in soil and ground water. You will also learn about the application of the EK technology for extracting oil as an innovative Enhanced Oil Recovery (EOR) Process.

Electrokinetics was introduced to the US by Leo Casagrande, of Harvard University, in the 1950s. He had used the technology extensively in Europe, for construction site soils stabilization, prior to, and during World War II. In the 1950s, Dr. G. V. Chilingar, and his students at USC conducted a series of laboratory experiments, which suggested that electrokinetics could be utilized to increase flow in permeable formations and for Enhanced Oil Recovery (EOR). About the same time, researchers at a General Electric (GE) facility were conducting field investigation, which indicated that electrokinetics could be an effective and efficient EOR technology. Later, some of these researchers left GE, taking the EK technology with them, founded Electro-Petroleum, Inc. (EPI), and have continued to develop an understanding of EK field implementation.

Electrokinetics is a simple concept to move fluids through rocks and soil under a unidirectional electrical current flow. Current research has extended this technology to move contaminants and oil under the same

stressors. The application of Electrokinetics commercially, to date, has been limited to the soil dewatering and soil stabilization and should be extended by those who read this book. Previous field studies have suffered from a lack of knowledge relating to issues which are being defined and addressed in the chapters in this book. The understanding of the transport of heavy metals having different oxidation states and mobility and organic molecules having different adsorbent coefficients are elucidated in the chapters. The volume of research from laboratory studies is large and the hundreds of research papers published in the scientific literature were reviewed to understand the issues surrounding the complexity of EK technology. This basic understanding of the variables surrounding the technology field can be used to design meaningful field tests.

By reading this book you will learn about the most recent laboratory results for the transport of contaminants in soil and ground water, be exposed to research in the use of EK for oil recovery in the previously unexplored use in carbonate rocks. In Chapter three, Dr. D. G. Hill evaluates the use of the EK process in the oilfield showing the potential of the process for releasing previously unrecoverable oil resources around the world.

Finally great strides are being made in the transferring of the laboratory results into a series of models which can be used to predict the transport phenomena in all types of substrates.

The simple and straight forward style of this book will be of use to the academic researcher following EK technology development, the environmental remediation engineer looking for a state of the art technology for cleaning up contaminated sites and the petroleum executive looking at the next breakthrough in Enhanced Oil Recovery.

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