



## Adsorption of crude oil from aqueous solution: A review

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### ABSTRACT

Crude oil provides a significant contribution to a country's economy, resulting in a diverse range of petroleum products that can be used to create significant income. However, the major disadvantage of using crude oil is that it depletes world water resources. This has led to a large amount of literature being cleaned out every year on ways of mitigating crude oil spills, particularly by adsorption. In this study, the different types of adsorbents that have been employed in the sorption of crude oil in recent times were reviewed in order to identify the best class of adsorbents needed for successful clean-up and draw conclusions from the findings. The adsorbents were grouped into seven different classes, namely: biosorbents, activated carbons, biochars, polymers and resins, clays and minerals, nanoparticles, and composites. Biosorbents were found to be the most commonly used (43.8 %) due to their abundance and ease of preparation, while activated carbon and clays and minerals (4.2 % each) were the least frequently used. The majority of adsorbents had excellent adsorption capacity and removal efficiency (> 85 %). The adsorption process for all the adsorbents mainly followed the Langmuir isotherm model and correlated well with the pseudo-second order kinetic model. Sorption occurs primarily through intra-particle diffusion, film diffusion, and ion exchange. Other adsorption processes, such as the effects of operating parameters, thermodynamic studies, and adsorbent regeneration and reuse, were also discussed and recommendations outlined for futuristic studies.

### 1. Introduction

Crude oil exploration processes contribute notably to a country's economy, resulting in the wide range of applications of petroleum products that may be employed to generate substantial revenue [1]. However, as a result of the rise in the use of petroleum products as well as the building of refineries near cities and populated areas, the contamination of surface and subsurface waters has increased [2]. For example, within a span of 36 years (1962–1997), a total of 826 oil spill cases were recorded in the United States of America's marine waters alone, which amounted to a loss of  $1.02 \times 10^6$  kg of crude oil [3]. According to the data recorded by the International Federation of Cruise Ship Pollution, large-scale oil spills occurred 53 times between 2010 and 2017, with about 47,000 tons of crude oil discharged into the sea, whereby a

ton of spill leaves a 12 km<sup>2</sup> film of oil on the water's surface, causing significant harm to marine species and general health in the water near shore [4]. Overtime, the increase in the production and evolution of oil and gas technology is associated with risks that occur as a result of the uncontrolled introduction of crude oil and its fractions to marine and water bodies. This is often caused by human error and carelessness in the transportation and distribution of crude oil [5], pipeline vandalism [6], earthquakes and natural disasters [7,8], among others, which allow the oil to seep into the oceans. The environmental consequences of an oil spill are significant, and the impacts are felt on the ecosystem as it causes physical and ecological changes as well as chemical toxicity. The severity of these effects is determined by the extent of pollution, the physical and chemical properties of the spilled oil, the ambient environmental conditions, the sensitivity of marine life, and external factors

Abbreviations: AC, activated carbon; NP, nanoparticle; MWCNT, multi-wall carbon nanotube; PUF, polyurethane foam; PFO, pseudo-first order; PSO, pseudo-second order; RE, removal efficiency;  $q_{max}$ , maximum capacity

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# Adsorption From Aqueous Solution

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## **Adsorption From Aqueous Solution:**

**Adsorption From Aqueous Solutions** P.H. Tewari,2012-12-06 Adsorption from aqueous solutions is important in many technological areas like water purification mineral beneficiation soil conservation detergency and many areas of biology Recently adsorption of radionuclides from aqueous solutions has become the focus of attention in assessing the movement of radionuclides through a geologic medium from underground radioactive waste repositories This volume provides a multidisciplinary overview of current work in the area of adsorption from aqueous solutions and reviews the progress that has been made in the theoretical models for assessing adsorption Adsorption of heavy metal ions and the effect of complex formation is treated extensively as are the effects of surface chemical properties of the adsorbent solution pH and thermodynamic parameters important in the adsorption process Adsorption of pesticides and organic polymeric species on different adsorbents are included and implications of adsorption of ions on dental materials are discussed Also included are studies of the adsorption of radionuclides by geologic media under environmental conditions The study of the chemical nature of the adsorbed species at the surface by X ray photoelectron spectroscopy which often provides mechanistic information for the adsorption process is included for adsorbed metal ions on clay and mineral surfaces

**Adsorption from Aqueous Solution** ,1968 *Adsorption from aqueous solutions* P. H. Tewari,1965 **Adsorption from aqueous solution** ,1968 **Adsorption from Aqueous Solution** ,1968 **Adsorption from Aqueous Solution** American Chemical Society Staff,1968-01-01 **Adsorption from Aqueous Solution: a Symposium... at the 154th Meeting of the American Chemical Society, Chicago, Illinois, Sept. 14-15, 1967** American Chemical Society,1968 **Kinetics of Metal Ion Adsorption from Aqueous Solutions** Sotira Yiacomou,Chi Tien,2013-11-27 This monograph is intended to provide a systematic presentation of theories concerning the adsorption of metal ions from aqueous solutions onto surfaces of natural and synthetic substances and to outline methods and procedures to estimate the extent and progress of adsorption As heavy metals and the problems associated with their transport and distribution are of serious concern to human health and the environment the materials presented in this volume have both theoretical and practical significance In writing this monograph one of our goals was to prepare a book useful to environmental workers and practicing engineers For this reason our presentation relies heavily on concepts commonly used in the environmental engineering literature In fact the volume was prepared for readers with a basic understanding of environmental engineering principles and some knowledge of adsorption processes No prior familiarity with the ionic solute adsorption at solid solution interfaces is assumed Instead introduction of the necessary background information was included Generally speaking metal ion adsorption may be studied in terms of three distinct but interrelated phenomena surface ionization complex formation and the formation and presence of an electrostatic double layer adjacent to adsorbent surfaces Analyses of these phenomena with various degrees of sophistication are xviii ADSORPTION OF METAL IONS FROM AQUEOUS SOLUTIONS presented and their various

combinations yield different models that describe metal ion adsorption

**Adsorption from Aqueous Solution. A Symposium Co-sponsored by the Division of Water, Air, and Waste Chemistry and the Division of Colloid and Surface Chemistry at the 154th Meeting of the American Chemical Society. Chicago, Ill. 1967** American chemical society. Division of water, air, and waste chemistry, American chemical society. Division of colloid and surface chemistry, ACS., 1968

**Adsorption from Aqueous Solution** Walter J. Weber, P. J. Usinowics, 1974

**Cr(VI) Adsorption from Aqueous Solution Using Agricultural Wastes** Suhad Yasin, Tariq Najim, 2012 This work presents the results of a detailed study of the adsorption process that removed Cr VI ions from aqueous solution using a common naturally occurring materials MPPG, FMPGP and PF were suitable for the removal of Cr VI Operational parameters such as the amount of adsorbent, contact time, initial concentration of Cr VI and solution pH all clearly affected the removal efficiency The different operating conditions that would be required for efficient removal of Cr VI from aqueous solution D R isotherm could be used to model isothermal sorption of Cr VI onto MPPG, FMPGP and PF The kinetics data were best modeled by a pseudo second order kinetics equation It was obvious that the mechanism of adsorption on all adsorbents was physisorption The adsorption process was also thermodynamically spontaneous under natural conditions

Adsorption from Solutions of Non-Electrolytes J. J. Kipling, 2013-10-22 Adsorption from Solutions of Non Electrolytes provides a general discussion of the subject which has so far been given little or no attention in current textbooks of physical chemistry A general view of the subject is particularly needed at a time when we wish to see how far it will be possible to use theories of solutions to explain the phenomena of adsorption The book opens with an introductory chapter on the types of interface aspects of adsorption from solution types of adsorption and classification of systems This is followed by separate chapters on experimental methods adsorption at the liquid solid interface adsorption from completely miscible and partially liquids adsorption of gases and solids from solution adsorption of polymers and adsorption in multicomponent systems Subsequent chapters deal with factors influencing competitive adsorption at the liquid solid interface adsorption at the liquid vapor and liquid liquid interface kinetics and thermodynamics of adsorption from the liquid phase the use of columns in adsorption and use of adsorption from solution to measure surface area

**Advanced Water Treatment** Mika Sillanpää, 2020-01-08 Advanced Water Treatment Adsorption discusses the application of adsorption in water purification The book reviews research findings on the preparation of five different nano microcellulose based adsorbents their characterization the study of adsorption kinetics and isotherms the determination of adsorption mechanisms and an evaluation of adsorbents regeneration properties The book describes modification microfibrillated cellulose MFC the use of succinic anhydride modified mercerized nanocellulose and aminosilane and hydroxyapatite modified nanostructured MFC for the removal of heavy metals from aqueous solutions Final sections describe the use of aminosilane epoxy and hydroxyapatite modified MFC as a promising alternative for H<sub>2</sub>S removal from aqueous solutions along with new findings on the adsorption properties of carbonated hydroxyapatite modified MFC as

multifunctional adsorbent for the removal of both cations and anions ions from water Includes the most recent research on advanced water treatment by adsorption Provides the latest updates on novel absorbents for water purification Describes REE removal using various absorbents Covers a wide range of methods and their integration **Aqueous Phase**

**Adsorption** Jayant K Singh, Nishith Verma, 2018-10-25 This book covers theoretical aspects of adsorption followed by an introduction to molecular simulations and other numerical techniques that have become extremely useful as an engineering tool in recent times to understand the interplay of different mechanistic steps of adsorption Further the book provides brief experimental methodologies to use test and evaluate different types of adsorbents for water pollutants Through different chapters contributed by accomplished researchers working in the broad area of adsorption this book provides the necessary fundamental background required for an academician industrial scientist or engineer to initiate studies in this area Key Features Explores fundamentals of adsorption based separation Provides physical insight into aqueous phase adsorption Includes theory molecular and mesoscopic level simulation techniques and experiments Describes molecular simulations and lattice Boltzmann method based models for aqueous phase adsorption Presents state of art experimental works particularly addressing removal of emerging pollutants from aqueous phase *Adsorption from Solution at the Solid/Liquid Interface* G. D. Parfitt, Colin H. Rochester, 1983 Non electrolytes Adsorption of small molecules Adsorption from mixtures of miscible liquids Adsorption of nonionic surfactants Adsorption of polymers Electrolytes Adsorption of small ions Adsorption of ionic surfactants Adsorption of dyes Adsorption of polyelectrolytes from dilute solution *Adsorption at the Mercury-aqueous Solution Electrical Double Layer* Alan Roy Sears, 1971 *New Advances on Disease Biomarkers and Molecular Targets in Biomedicine* Nikki P. Lee, C.Y. Cheng, John M. Luk, 2013-06-22 Rising occurrences of various diseases and epidemics have pressurized the already burdened health system across the globe and this imposes an unprecedented challenge on our current research in identifying disease specific biomarkers and molecular targets in particular for cancers neurological disorders and unexplained infertility Despite decades of efforts in deciphering the fundamental biology underlying various diseases at discrete levels using an array of advanced technologies attempts to identify reliable and disease indicating markers for detection and biomolecules or cellular structures for targeting are still in vain This monograph describes and discusses the updated findings in this field with a specific aim to compile prior and recent literature and from there to acquire some insights to facilitate future research to expand options of understanding detecting and treating diseases Among the many possible areas of biomedical research this content comprises two themes disease biomarkers and molecular targets The book also covers topics that are more advanced in development to emerging scientific discoveries In particular this monograph includes concepts on the renovated use of oncofetal molecules in cancer prediction and treatment the evolving development in cancer biology at the cellular and molecular levels and the recent involvement on new classes of molecules in diseases This book renews established concepts in the field and at the same time leads to important insights for research and

development of drugs diagnostics and interventions for managing diseases of unmet medical needs      Encyclopedia of Surface and Colloid Science - Arthur T. Hubbard,2002-07-18 This comprehensive reference collects fundamental theories and recent research from a wide range of fields including biology biochemistry physics applied mathematics and computer materials surface and colloid science providing key references tools and analytical techniques for practical applications in industrial agricultural and forensic processes as well as in the production of natural and synthetic compounds such as foods minerals paints proteins pharmaceuticals polymers and soaps      *Encyclopedia of Microfluidics and Nanofluidics* Dongqing Li,2008-08-06 Covering all aspects of transport phenomena on the nano and micro scale this encyclopedia features over 750 entries in three alphabetically arranged volumes including the most up to date research insights and applied techniques across all areas Coverage includes electrical double layers optofluidics DNC lab on a chip nanosensors and more      Journal of the Chemical Society Chemical Society (Great Britain),1921

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