
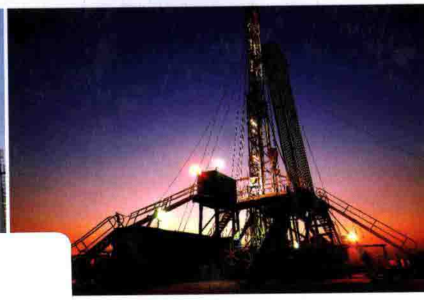


Waste Management

in the Chemical and Petroleum Industries

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Dedicated to the loving memory of my Parents, grandparents, and to all who contributed so much to my work over the years.

Preface

Oil and gas are major sources of energy and revenue for many countries today – their production has been described as one of the most important industrial activities in the twenty-first century – and obviously waste treatment and disposal assume a greater degree of importance in the petroleum, chemical processing, and unconventional oil and gas industries.

Wastewater quality and the quantity produced determine the means of disposal and the costs of disposal. Suspended solids, total dissolved solids, and oxygen demand of produced waters have the most impact on wastewater treatment.

Wastewater is a complex mixture of organic and inorganic compounds and the largest byproduct by volume generated during chemical processing and both conventional and unconventional oil and gas recovery operations. The potential of oilfield-produced water to be a source of freshwater for water-stressed oil-producing countries and increasing environmental concerns, in addition to stringent legislations on produced water discharge into the environment, have made produced water management a significant part of the oil and gas business.

In marginally economic coal bed projects, the water disposal costs and attendant environmental accounting are critical factors in the investment decision; water disposal costs can economically make or break a marginal project.

Before investing in a coal bed methane (CBM) process, multiple questions need to be answered concerning the water to be produced – questions concerning quantity, flow-rates, chemical content, disposal means, monitoring, and environmental regulations. Perhaps no other factor affects the economics and feasibility of CBM projects as much as water removal and disposal.

In heavy oil production, between 2 to 4.5 volume units of water are used to produce each volume unit of synthetic crude oil in an ex situ mining operation. Despite recycling, almost all of it ends up in tailings ponds. However, in Steam Assisted Gravity Drainage (SAGD) operations, 90–95% of the water is recycled and about 0.2 volume units of water is used per volume unit of bitumen produced.

A major hindrance to the monitoring of oil sands-produced waters has been the lack of identification of individual compounds present. By better understanding the nature of the highly complex mixture of compounds, including naphthenic acids, it may be possible to monitor rivers for leachate and also to remove toxic components. Such identification of individual acids has for many years proved impossible, but a recent breakthrough in analysis has begun to reveal what is in the oil sands-produced waters.

The extraction and use of shale gas can affect the environment through the leaking of extraction chemicals and waste into water supplies, the leaking of greenhouse gasses during extraction, and the pollution caused by the improper processing of natural gas.

A challenge to preventing pollution is that shale gas extractions vary widely in this regard, even between different wells in the same project; the processes that reduce pollution sufficiently in one extraction may not be enough in another.

Chemicals are added to the water to facilitate the underground fracturing process that releases natural gas. Fracturing fluid is primarily water and approximately 0.5% chemical additives (friction reducer, agents countering rust, agents to kill microorganisms). Since (depending on the size of the area) millions of liters of water are used, this means that hundreds of thousands of liters of chemicals are often injected into the soil.

Only about 50 to 70% of the resulting volume of contaminated water is recovered and stored in above-ground ponds to await removal by tanker. The remaining "produced water" is left in the earth where it can lead to contamination of groundwater aquifers, though the industry deems this "highly unlikely." However, the wastewater from such operations often leads to foul-smelling odors and heavy metals contaminating the local water supply above-ground.

This book unravels the essential requirements for the process design and engineering of the equipment and facilities pertaining to the wastewater treatment units, solid waste disposal, and wastewater sewer systems of oil and gas refineries, chemical plants, oil terminals, petrochemical plants, unconventional oil and gas industries (coal seam gas or coal bed methane, shale gas and oil sands production), and other facilities as required. Included within the scope are:

- Liquid and solid disposal systems.
- Primary oil/solids removal facilities.
- Further oil and suspended solids removal (secondary oil/solids removal), such as dissolved air flotation units.
- Granular media filters and chemical flocculation units.
- Chemical addition systems.
- Biological treatments.
- Filtration and/or other final polishing.
- Sewage systems handling domestic and medical sanitary appliances of buildings.
- Drainage systems carrying surface and rainwater.
- Wastewater gathering systems.
- Clean water drainage, e.g., from buildings and paved areas.
- Evaporation ponds and disposal by natural percolation into the subsoil in permeable ground.
- Sanitary sewage treatment.
- Sludge handling and treatment.

It is obvious that the aim of any drainage/effluent disposal system should be to segregate uncontaminated water from contaminated water or effluents and to segregate different types of effluents in order to reduce the size, complexity, and costs of any treatment units that may be required for handling the contaminated water and effluents before they are discharged from a unit.

All wastewater effluents from industry that are discharged to public and/or natural water sources or directed for recycling purposes inside the industry, and that may contain a wide variety of matters in solution or suspension, should be controlled according to the requirements imposed by the final destination. However, in any case, elimination of the waste or the hazard potential of the waste should be the ultimate goal in the management.

Under no circumstances should effluent water cause oil traces on the surface or embankments of the receiving water, or affect the natural self-purification capacity of the receiving water to such an extent that it would cause hindrance to other users.

Under no conditions should polluted streams be combined with unpolluted streams if the resultant stream will then require purification. In general, the main sewer systems in the industry will be segregated according to the following categories:

- Stormwater sewer systems.
- Oily water sewer systems.
- Non-oily water sewer systems.
- Chemical sewer systems.
- Sanitary sewer systems.
- Special sewer systems.

In all areas, including process, offsite, and utility units, provisions should be made to anticipate any of the above mentioned sewer systems as required.

The treatment of wastewaters involves a sequence of treatment steps. Each wastewater treatment process involves the separation of solids from water in at least some part of the operation and the removal of biochemical oxygen demand (BOD) to some extent.

The end of pipe treatment sequence can be divided into the following elements: primary or pre-treatment, intermediate treatment, secondary treatment and tertiary treatment plus ancillary, sludge dewatering, and disposal operations.

The key to optimizing the treatment sequence for provision of maximum water treatment at minimum cost is to identify the rule of each unit operation and optimize that operation. Optimizing the performance of specific unit operations, such as API separators, dissolved air flotation, biological treatment, etc., can best be achieved if:

1. The properties of influent streams are considered.
2. The chemical principles that are used in solids pre-treatment are understood.
3. The variety of chemicals available for solids treatment is recognized.
4. The properties of effluent water are established based on the local environmental regulations and final disposal.
5. The protocols for quantifying results are identified.

In general, most industries require water for processing or other purposes; much of this water after use is discharged either to public and/or natural water sources or directed for recycling purposes inside the industry.

Such discharge, which may contain a wide variety of matter in solution or suspension, should be controlled according to the requirements imposed by the final destination and/or environmental regulations.

Moreover, according to the type of plant and the method of plant operation, the sources of solids in a wastewater treatment plant can be uncovered. Solids may also be formed by interaction of waste streams in the sewer.

Wastewaters contain metal ions, such as iron, aluminium, copper, magnesium, and so on, from corrosion of the process equipment, chemicals used in treating cooling water, salts in the water intake, and chemicals used in processing.

Insoluble metal hydroxide floc may be formed when alkaline wastes are discharged and raise the pH of wastewater above neutral. The wastes, containing considerable concentrations of phenols, sulfides, emulsifying agents, and alkalines, should be segregated. In general, discharging any material to the oily sewer system or other drainage system should be investigated in line with the final waste treatment and disposal targets.

In view of the above, this book will unravel the fundamental engineering for waste recovery, treatment, and disposal systems in the petroleum, chemical, and unconventional oil and gas processing industries. These new fundamental discoveries will enable the development of practical solutions to these pressing environmental issues.

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Biography

Alireza Bahadori, PhD is a research staff member in the School of Environment, Science & Engineering at Southern Cross University, Lismore, NSW, Australia. He received his PhD from Curtin University, Western Australia. For the better part of 20 years, Dr Bahadori had held various process engineering positions and involved in many large-scale projects at NIOC, Petroleum Development Oman (PDO), and Clough AMEC PTY LTD.

He is the author of over 200 articles and 6 books. His books have been accepted/published by prestigious publishers such as John Wiley & Sons, Springer, Taylor & Francis and Elsevier. Dr Bahadori is the recipient of highly competitive and prestigious Australian Government's Endeavour International Postgraduate Research award as part of his research in oil and gas area. He also received top-up award from State Government of Western Australia through Western Australia Energy research Alliance (WA:ERA) in 2009. Dr Bahadori Serves as a member of editorial board for a number of journals such as *Journal of Sustainable Energy Engineering* which is published by Wiley-Scrivener.

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