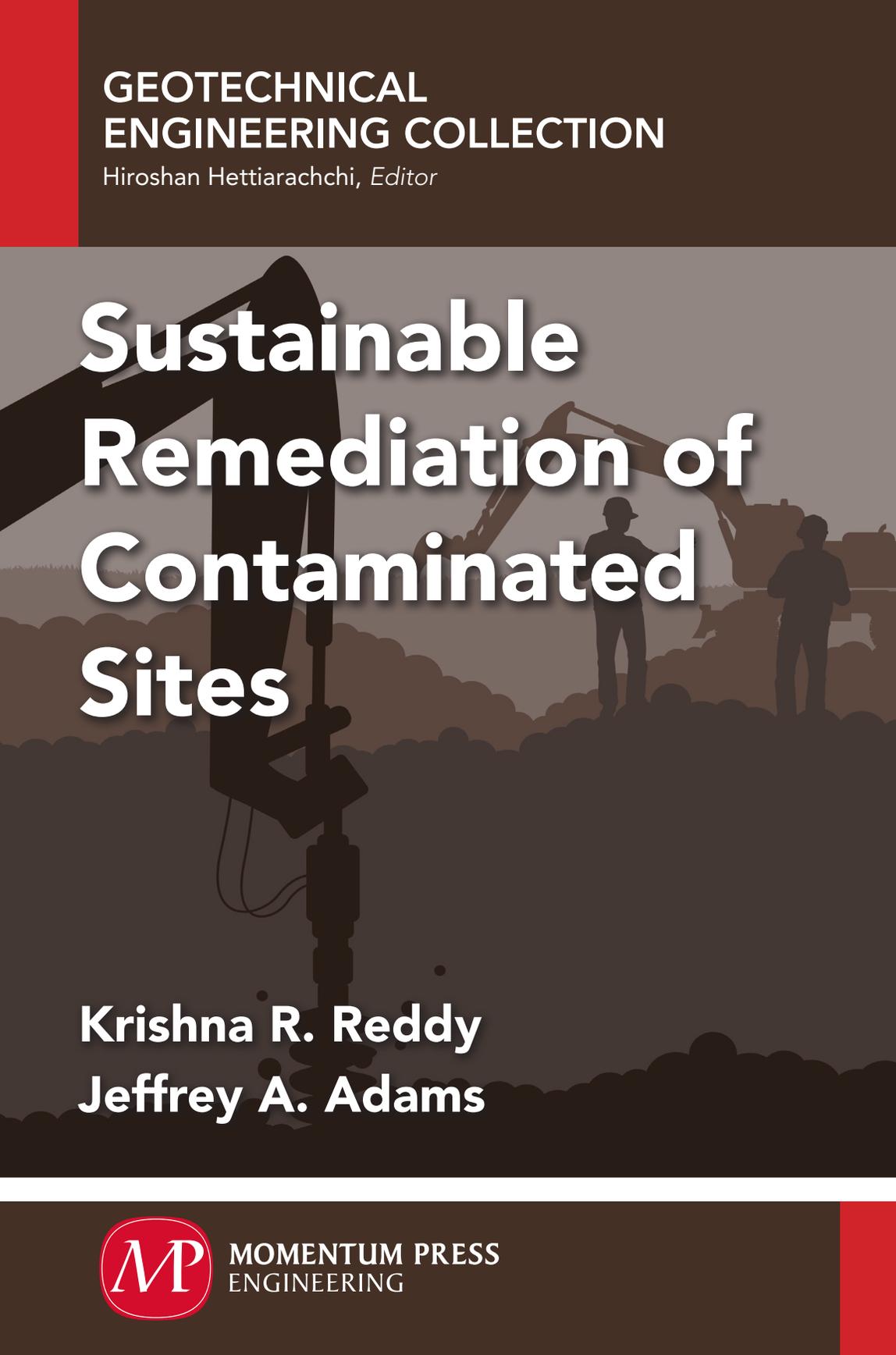


**GEOTECHNICAL
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Hiroshan Hettiarachchi, *Editor*

The background of the cover features a dark, monochromatic silhouette of a remediation site. In the foreground, a large vertical drilling rig is prominent. In the background, several workers wearing hard hats are visible, along with other pieces of heavy machinery like excavators. The overall scene is set against a dark, textured ground surface.

Sustainable Remediation of Contaminated Sites

**Krishna R. Reddy
Jeffrey A. Adams**



**MOMENTUM PRESS
ENGINEERING**

**SUSTAINABLE
REMEDICATION OF
CONTAMINATED
SITES**

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**KRISHNA R. REDDY
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ABSTRACT

Traditional site remediation approaches typically focus on the reduction of contaminant concentrations to meet cleanup goals or risk-based corrective levels, with a primary emphasis on remediation program cost and time-frame. Such an approach, however, may result in ancillary impacts to the environment that, when considered in totality with the remediation activity, result in a net negative impact to the environment. In contrast to a traditional remediation approach, this book presents a holistic approach to remediation that considers ancillary environmental impacts and aims to optimize net effects to the environment. It addresses a broad range of environmental, social, and economic impacts during all remediation phases, and achieves remedial goals through more efficient, sustainable strategies that conserve resources and protect air, water, and soil quality through reduced emissions and other waste burdens. Inside, the authors simultaneously encourage the reuse of remediated land and enhanced long-term financial returns for investments. Though the potential benefits are enormous, many environmental professionals and project stakeholders do not utilize green and sustainable technologies because they are unaware of the methods for selection and implementation. This book describes the decision framework, presents qualitative and quantitative assessment tools, including multidisciplinary metrics, to assess sustainability, and reviews potential new technologies. It presents several case studies that include sustainable remediation solutions, and will also highlight the challenges in promoting this practice.

KEY WORDS

brownfields, environment, land contamination, life cycle assessment (LCA), remediation, remediation technologies, sustainability, sustainability development, sustainability framework, sustainability metrics, sustainability tools

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CHAPTER 1

INTRODUCTION

1.1 EMERGENCE OF ENVIRONMENTAL CONCERNS

From the 1940s through the 1960s, very little if any collective energy was focused on environmental issues. The U.S. economy and population were both growing at an unprecedented pace, and individual, private sector, and public sector goals and initiatives were directed toward providing housing, consumer, and durable goods to growing families within an expanding middle class. Additionally, the United States was engaged in an expanding Cold War and space race with the Soviet Union. Americans were aware of the environment; however, the slogan “dilution is the solution to pollution” indicated where environmental issues registered within the American psyche.

During this time, disposal practices of liquids and solids were quite rudimentary. Solids and liquids were often placed in uncontrolled dumps without any provisions for secondary containment, or in many cases, primary containment. Liquid wastes and solid wastes were also dumped into waterways without regard for chemical or thermal effects to the receiving waters. Despite some initial evolving legislation in the 1950s, air emissions from point or mobile sources were often unregulated or unchecked. As a result, the rapidly increasing pollutant loads to air, water, and soil were overwhelming the environment’s ability to absorb these releases without manifested side effects. Additionally, numerous chemicals released to the environment could not be degraded through natural processes within a reasonable amount of time.

Air pollution was becoming increasingly prevalent, and notable smog outbreaks in Donora, Pennsylvania (1948), London, UK (1952), New York (1953), and Los Angeles (1954) resulted in appreciable loss of life and significant disruptions to daily activities. In response, the Air Pollution Control Act was passed in 1955. This initial legislation acknowledged that

air pollution was a growing hazard to public health; however, it deferred the responsibility of combating air pollution to the individual states and did not contain enforcement provisions to sanction or hold air polluters responsible for their actions.

Water pollution was gaining notoriety with spectacular images and events. In 1969, the Cuyahoga River in Cleveland caught on fire. In fact, the river had reportedly caught fire several times prior to the 1969 event. Further, studies of the river had reported extensive visible observations of oily sheens and the absence of animal life and most other forms of aquatic life. Downstream from the Cuyahoga River, its receiving water, Lake Erie, was declared biologically dead in the 1960s. Yet, Ohio was by far not the only source of impacted water bodies—they were found in every state, and the impacts were increasing.

Buffalo, New York, exhibited significant water pollution (Niagara River, Lake Erie); however, it became even more synonymous with soil pollution. A previously abandoned canal in Niagara Falls, New York, was used as a dumping ground for thousands of tons of waste from the Hooker Chemical Company. Once the canal had been filled with waste, it was reportedly capped with clay and *closed*. Over time, a neighborhood was built over the canal (Love Canal). The resulting development and infrastructure construction pierced the clay-lined canal. Later, in the early 1950s, the local Board of Education constructed an elementary school on the canal. Over time, noxious odors were observed, and significant acute and chronic health problems were reported by the citizens. Eventually, follow-up testing and analysis determined the presence of widespread soil and groundwater contamination, and the U.S. federal government paid for the relocation of hundreds from the Love Canal area.

Several other notable environmental impacts entered the public consciousness. Among several large-scale oil platform and tanker disasters, in 1969, an offshore well accident resulted in crude oil washing ashore onto beaches along the Santa Barbara Channel in California. Additionally, nuclear fallout from above-ground nuclear weapons testing, first in the deserts of the western United States, and later in the Pacific Ocean, results in health impacts among those exposed.

These high-profile events as well as the everyday observations of *ordinary* citizens in their lives gave rise to a *grass-roots* environmental movement. Of the milestone occurrences associated with this movement, the first has been traditionally credited to the publishing of Rachel Carson's *Silent Spring* in late 1962. Ms. Carson's book observed the death of song birds, ostensibly from the uncontrolled use of pesticides for vector abatement, most notably mosquitoes. Other evidence of

dichlorodiphenyltrichloroethane (DDT) use and its deleterious impact on the environment began to emerge—declining bald eagle populations in the United States were attributed to bioaccumulation of DDT, resulting in adverse effects to their eggs. Public outrage increased, and eventually DDT use was banned in the United States in 1972.

The 1969 Santa Barbara Channel oil spill also helped inspire the first observance of Earth Day in April 1970. Following the spill and federal government inaction, leaders of the political, business, and activist worlds conceived of an environmental *teach-in* to raise environmental awareness. The idea was well received by a wide range of audiences and interest groups, and millions took part in seminars, conferences, rallies, and demonstrations. Earth Day continues to this day and is celebrated in an ever-increasing number of countries by hundreds of millions of people.

Not to be discounted, the space race and the resulting ambitious scientific and engineering programs sometimes linked to environmental impacts actually inspired a growing environmental consciousness. In December 1968, while in lunar orbit, the Apollo 8 command module broadcast live images of an *earthrise* to a worldwide television audience. Given the unprecedented distance that the Apollo 8 mission traveled and the equally unprecedented images transmitted back to an enthralled audience, the images of the *blue marble* earth against the black emptiness of deep space and the starkness of the lunar surface inspired millions to realize that the earth is a fragile, discrete world worthy of protection in ways that had not been communicated or possible before the mission. Subsequent images generated during lunar missions, space station visits, and spacewalks have enforced these feelings with equally powerful images.

1.2 EMERGENCE OF ENVIRONMENTAL REGULATIONS

The major environmental events as well as the evolving public interest in environmental protection began to coalesce in the 1960s and 1970s, and the federal government began to take notice. Beginning in the 1960s and well into the 1970s, the federal government began to enact legislation designed to protect the environment. Some of these legislative acts and regulations include the following (Sharma and Reddy 2004):

- Solid Waste Disposal Act (SWDA) (1965, 1970)—the first federal legislation attempting to regulate municipal solid waste. Provisions of the law included:

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- An emphasis on the reduction of solid waste volumes to protect human health and the environment.
- An emphasis on the improvement of waste disposal practices.
- Provisions of funds to individual states to better manage their solid wastes.
- Amendments in 1970 encouraged further waste reduction and waste recovery as well as the creation of a system of national disposal sites for hazardous wastes.
- National Environmental Policy Act (NEPA) (1969)—major legislation affirming the U.S. commitment to protect and maintain environmental quality. Provisions of the law included:
 - The creation of the Council of Environmental Quality, a new executive branch agency. Eventually, the Environmental Protection Agency (EPA) was created through a subsequent presidential action.
 - Requirement of the preparation of an Environmental Impact Statement (EIS) for any federal project that may have a *significant* effect on the environment. An EIS is a comprehensive document that assesses a wide range of potential impacts to the environment as well as social and economic impacts.
- Marine Protection, Research and Sanctuaries Act (MPRSA) (1972)—this law was passed to limit ocean dumping of wastes that would affect human health or the marine environment. Provisions of the law included:
 - Regulation of runoff, including those from rivers, streams, atmospheric fallout, point-source discharges, dredged materials, discharges from ships and offshore platforms, and accidental spills.
 - Prohibition of dumping of certain wastes, including high-level radioactive wastes, biological, chemical, or radiological warfare materials, and persistent inert materials that float or are suspended in the water column.
 - Permitting for all wastes to be dumped at sea.
 - Prohibition of states from enacting regulations relating to the marine environment as covered under MPRSA.
- Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) (1972, 1982, and 1988)—the law was created to regulate the storage and disposal of these products. Provisions of the law included:
 - Labeling requirements for these products.
 - Registration and demonstration of usage proficiency by users of these products.

-
- Registration of all pesticides with the U.S. EPA to confirm appropriate labeling and that the materials will not harm the environment.
 - Specific tolerance levels to prevent unreasonable hazards.
 - Clean Air Act (CAA) (1970, 1977, and 1990)—following previous attempts at air pollution-related legislation, the CAA represented the first comprehensive law that regulated air emissions from area, stationary, and mobile sources. Provisions of the law included:
 - The establishment of National Ambient Air Quality Standards (NAAQSs) for criteria pollutants.
 - Development of standards for other hazardous air pollutants, including asbestos, volatile compounds, metals, and radionuclides where NAAQSs have not been specified.
 - Establishment of air quality regions within the United States for the purposes of regional monitoring toward the attainment or nonattainment of quality goals.
 - Later amendments established a comprehensive permitting system for various emission sources toward the regulation of several common pollutants.
 - Clean Water Act (CWA) (1977, 1981, and 1987)—this law established a basic structure for the regulation of discharge of pollutants into U.S. waters. Provisions of the law included:
 - A total of 129 priority pollutants were identified as hazardous wastes.
 - Wastewater discharge treatment requirements mandating best available technologies.
 - Prohibition of discharge from point sources unless a National Pollutant Discharge Elimination System (NPDES) has been obtained.
 - Discharge of dredged material into U.S. waters is only allowed if a permit has been obtained.
 - Discharges from Publicly Owned Treatment Works (POTWs) must meet pretreatment standards.
 - Safe Drinking Water Act (SDWA) (1974, 1977, and 1986)—the act was passed to protect the quality of drinking water in the United States, whether obtained from above-ground or groundwater sources. Provisions of the law included:
 - Establishment of drinking water standards, including maximum contaminant levels, primary goals, and secondary goals that provide protection of health and aesthetic standards.
 - Protection of groundwater through the regulation of hazardous waste injections.
 - Designation and protection of aquifers.