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ISBN: 978-81-322-0850-1 ISBN: 978-81-322-0851-8 (eBook)
DOI: 10.1007/978-81-322-0851-8
Springer New Delhi Heidelberg New York Dordrecht London

Library of Congress Control Number: 2012954478

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Foreword

Indian economy has grown at a CAGR of 7.6% in the first decade of the twenty-first century, and the coal industry has played a very important role in sustaining this economic growth. Coal is the most important mineral mined in the country and accounts for 52% of its commercial energy consumption.

Indian government is giving a major thrust for development of the power sector as electrical energy is a key input for economic growth. The installed capacity for generation of electricity has gone up from 101.6 GW in 2000–2001 to 200 GW in 2011–2012 (CAGR 6.3%). In the XII Five-Year Plan, another 90 GW generation capacity is planned to be installed. As approximately 70% of the power generated in the country is coming from coal-fired power stations, such major expansion of the power sector requires commensurate expansion of the coal mining sector. Along with the power sector, the steel and cement sectors in the country are also undergoing expansion at a rapid rate adding to the increasing coal demand in the country. Indian coal production was 322.7 Mt in 2000–2001 and reached a level of 534.5 Mt in 2011–2012 registering a compounded annual growth rate of 4.7%. The XII Five-Year Plan now under formulation stage has projected an expansion of the coal mining sector at a higher rate of 8.2% for coal production to reach 795 Mt in 2016–2017. The demand for coal is so high that even with the projected rate of expansion of indigenous production, the country will need to import approximately 200 Mt of coal in 2016–2017.

Most of the coal deposits in India occur in forested tracts with many mine leaseholds containing large patches of forest land. These days, almost 90% of coal produced in India comes from opencast mines. Large mechanised opencast mines with high-stripping ratios exceeding 1 in 4 and in some cases even 1 in 6 or 1 in 7 and going to great depths inevitably cause large-scale deforestation and loss of soil cover over large areas and creation of huge external overburden dumps.

The total land requirement in India for mine operation, waste dumps and mine infrastructures is projected to increase from the level of 1,470 km^2 (including a forest area of 730 km^2) in 2006–2007 to 2,925 km^2 (including a forest area of 730 km^2 in 2025) as per 'Vision Coal-2025' document. The technology of opencast mining inevitably leads to complete degradation of land, destruction of forest ecosystem and fragmentation of wildlife habitat, and magnitude of devastation is so massive that entire landscape of the area is changed. The only saving grace is that unlike other industries, mining is a temporary user of land and with proper scientific restoration, a functioning ecosystem can be restored, and in some cases even a better landscape can be created. Several organisations are concerned about the problem and are actively involved in carrying out scientific restoration work in mined out areas. The universities and other organisations teaching mining course have incorporated the subject of mine closure and ecorestoration in the mining environment syllabus. One constraint faced by the students as well as practising engineers of the subject is the lack of availability of books dealing specifically with restoration of mine degraded land in India. Dr. Subodh Kumar Maiti has been working in the Centre of Mining Environment, Indian School of Mines, Dhanbad, for more than two decades and has been teaching and conducting research on the subject.

In this book, Dr. Maiti has discussed the scientific basis of ecorestoration, the different ways one can achieve the goals, and explains how the ecorestoration can be made self-sustainable. This book is presented in two parts: Part I dealing with different aspects of ecorestoration and Part II dealing with sampling, laboratory analysis and evaluation of overburden materials, soils and plants.

Public opposition to mining is increasing in most parts of the world. General public has become more aware of the importance of preserving the environment and ecorestoration of mine degraded lands. The social licence for mining, given by the Ministry of Environment in the form of environmental clearance for a project, generally requires the mine management to carry out systematic reclamation of degraded mined-out land. I hope this book by Dr. Maiti will be useful for the environmental professionals in the mining industry, students of mining engineering course, mine planners as well as the general public.

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S.P. Banerjee

Preface

India is essentially a land-short economy. Its demand for usable land is growing at an exponential rate. Mining of minerals is put into the category of 'temporary use of land'. Centuries of mining have resulted in many mining land beyond any commercial, recreational or social use. It is now important to restore such land for fruitful use and also to plan the future mining in a way so that the used land can be reused in the future.

Coal mining industry in India plays a very important role in country's economy—more than 70% of the total power generated in the country is from coal. India's coal consumption ranks third in the world, and the country's demand for coal continues to grow much faster than the world average. Coal deposits are mainly found under the forest cover and are confined to eastern and south central parts of the country. Indian coal sector is poised to grow at a very fast rate in the near future due to steep increase in coal demand for providing power to all by 2012. Total indigenous coal production is expected to grow from the current level of around 540 Mt (2011–2012) to around 1,086 Mt by 2024 and 2,037 Mt by 2031–2032 as per the draft Coal Vision document, and more than 90% will be produced by opencast mining.

The quantum jump in coal production from opencast operation and consequent overburden removal will put significant stress on the environment due to total destruction of the vegetation and soil cover, formation of waste dumps, depletion of water tables, increase in dust pollution and deterioration of landscape and aesthetics of the area. The total land requirement for mine operation, waste dumps and mine infrastructures is projected to increase from the level of 1,470 km^2 (including a forest area of 730 km^2) in 2006–2007 to 2,925 km^2 (including a forest area of 730 km^2 in 2025) as per 'Vision Coal-2025' document.

In India, majority of the new and unmined mineral and coal deposits is under forest cover; thus, complete degradation of land, destruction of forest ecosystem and fragmentation of habitat are inevitable, and magnitude is so massive that entire landscape is changed. Fortunately, unlike other industries, mining is very temporary user of land, and proper scientific ecorestoration can restore the functioning of ecosystem and may bring better landscape. There is a growing concern to make the land useful yet again. Several organisations are concerned about these aspects and are actively involved to carry out restoration work, but no book as guide is available until date to deal with restoration of degraded land. After working more than two decades in Centre of Mining Environment, Indian School of Mines, Dhanbad, which is known as the Mining Capital of India, I feel a book in this line is overdue.

The purpose of this book is to discuss the scientific basis of ecorestoration and in what different ways one can achieve the goals and how to ensure that the ecorestoration is self-sustainable. This book is presented in two parts: Part I contains different aspects of ecorestoration, and Part II contains laboratory analysis and evaluation of overburden materials, soils and plants.

This book is presented as follows:

Part I

Chapter 1 provides an introduction to the importance of coal mining in India and relevant environmental issue, principles and components of ecorestoration, issues related to restoration, legal and statutory framework of ecorestoration.

Chapter 2 gives the basic concepts of ecology and functioning of ecosystem in mine degraded areas.

Chapter 3 discusses the importance of physical reclamation for ecorestoration process, estimation of sediment loss from bare areas, design of diversion ditches and sediment pond.

Chapter 4 reviews the important properties of minesoil that is going to affect the plant establishment and growth in mine degraded lands.

Chapter 5 stresses the importance of topsoil management, which includes removal, storage and redistribution of topsoil.

Chapter 6 discusses the methods of vegetation cover development, selection of plant species and case studies related to the existing tree covers in different dumps.

Chapter 7 introduces the importance of seeding for ecorestoration, its collection, preservation and breaking of dormancy.

Chapter 8 provides the details of nursery raising of forest tree species for the ecorestoration purposes.

Chapter 9 introduces the techniques of the establishment of grass and legume cover.

Chapter 10 introduces importance of mulching, geotextile and organic amendments.

Chapter 11 discusses the importance of bio-fertiliser technology for ecorestoration.

Chapter 12 introduces the importance of biodiversity, causes of biodiversity erosion and its methods of conservation.

Chapter 13 highlights the importance of monitoring and aftercare of ecorestored sites for the development of self-sustaining vegetation cover.

Chapter 14 discusses the criteria for the evaluation of ecorestoration success and indicators.

Chapter 15 provides the important forest and wildlife conservation acts.

Chapter 16 discusses the ecological impact assessment procedure for surface mining projects.
Chapter 17 highlights the importance of mine closure, objectives, issues, planning, activity, cost, mine closure guidelines in India and preparation of closure plan report.

Part II

Chapter 18 introduces the sampling and processing of soil and mine spoils for laboratory analysis, onsite test and description of parameters.
Chapter 19 provides detail laboratory analysis procedure of physical parameters like texture, bulk density, moisture content, infiltration test, rooting depth etc. and the interpretation of test results.
Chapter 20 provides detail analysis of chemical and nutritional parameters.
Chapter 21 contains laboratory procedure of analysis of soil microbiological parameters.
Chapter 22 provides detail of vegetation sampling procedure, plant nutrient analysis, pot and field trial experiments and analysis of plant growth parameters.

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About the Author

Dr. Subodh Kumar Maiti (b. 25-04-1960) is a professor in the Department of Environmental Science and Engineering, Centre of Mining Environment, Indian School of Mines, Dhanbad. He did B.Sc. (Hons) and M.Sc. in Botany from Calcutta University in 1984, M.Tech. (Environmental Science and Engineering) from IIT Mumbai in 1986 and worked as senior environmental engineer in Kirloskar Consultancy Division, Pune, until 1987. In 1988, he joined as lecturer in ISM, Dhanbad, and earned his Ph.D. in Environmental Science and Engineering in ecological aspects of reclamation of coal mine degraded lands. He underwent 3-month training on EIA and auditing at University of Bradford, UK, in 1996 and 1-month advanced training on mining and environment at University of Lulea, Sweden, under SIDA in 2001. He served as guest faculty in University of Technology, Papua New Guinea in the year 2008. He is teaching ecology, environmental microbiology and land reclamation in B.Tech. and M.Tech. levels and has guided several research students.

He has been working in the biological aspects of reclamation of mine degraded lands for more than two decades. He has published over 60 papers in international and national journals, - has presented over 120 papers in international and national seminars. He has attended International Conference organized by Society of Ecorestoration International (Perth, Western Australia) in 2009; 2nd International Conference on Constructed Environment (Chicago, USA) in 2011 and visited many more countries. He has also published two books" Handbook of Methods in Environmental Analysis Vol I

(Water and Wastewater analysis) and Vol II (Air, Noise, soil and overburden analysis). He has completed several R&D and consultancy projects on biological reclamation, biodiversity assessment and design and development of green belts in mining areas. He is life member of IAEM, IASWC, *Mycorrhiza News*, MGMI and *The Indian Mining & Engineering Journal* (IME). He was also selected as Fellow National Environmentalist Association (FNAE), Member SERI (Australia) and IPS (USA).

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Part I

Ecorestoration of Coalmine Degraded Lands

1 Introduction

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1.1 Importance of Coal Mining in India

Coal mining industry in India plays a very important role in the country's economy—more than 70% of the total power generated in the country is from coal, and considering the total energy requirement, coal contributes more than half. India's coal consumption ranks third in the world, and the country's demand for coal continues to grow much faster than the world average. The estimated recoverable reserve of coal and lignite is 101.9 billion tonnes (Bt), which is about 10% of the total world reserves (Table 1.1). As of 31.03.10, the estimated reserves of coal were around 277 Bt, an addition of 10 Bt over the last year. Coal deposits are mainly confined to eastern and south central parts of the country. The states of Jharkhand, Orissa, Chhattisgarh, West Bengal, Andhra Pradesh, Maharashtra and Madhya Pradesh account for more than 99% of the total coal reserves in the country. If India has to sustain an 8–10% economic growth rate, over the next 25 years, to eradicate poverty and meet its human development goals, an increase in its primary energy supply by 3–4 times compared to the level of 2003–2004 is required.

The Integrated Energy Policy (IEP 2006) document formulated by Planning Commission (August 2006) has presented several alternative scenarios of energy mix to sustain a GDP growth

S.K. Maiti, *Ecorestoration of the Coalmine Degraded Lands*,
DOI 10.1007/978-81-322-0851-8_1, © Springer India 2013

Table 1.1 World recoverable coal reserves (billion tonnes) (IEH 2011)

Region/country	Coal	Lignite	Total
World total	827.4	173.4	1,000.8
United States	234.7	36	270.7
Russia	161.6	11.5	173.1
China	89.1	20.5	109.6
India	99.3[a]	2.6	101.9

Source: Expert Committee on Coal Reforms
[a]Total proved 'in place' reserves instead of recoverable reserves relevant for other countries

Table 1.2 Coal demand projections (million tonnes)

Plan period	Power	Non-power	Total
XI 2011/2012	436	164	627
XII 2016/2017	603	221	824
XIII 2021/2022	832	299	1,131
XIV 2026/2027	1,109	408	1,517
XV 2031/2032	1,475	562	2,037

Source: Integrated Energy Policy (2006), Planning Commission

at 8% until 2031–2032. The requirement of coal demand has been projected to 2,037 Mt (2031–2032) against the 627 Mt projected for the end of 2011–2012 (XI plan) (Table 1.2). However, the requirement of coal-based energy has been projected to vary from 1,022 Mtoe (2,555 Mt) for a coal-dominant scenario to 632 Mtoe (1,540 Mt) in the scenario considering utilisation of full potential of nuclear, hydro and renewable resources along with all energy conservation measures. Therefore, coal will remain a dominant source of energy in India up to 2031–2032 and possibly beyond (Chaudhuri 2008).

Share of coal production from surface mines was increased from less than 20% in 1973–1974 to a level of more than 80% during 2001–2002. As of 31.12.2010, there are 717 mining projects of CIL and 140 mining projects in SCCL. Of these, a few mines are of large planned capacities—such as Gevra (20 Mt), Jayant (10 Mt), Nigahi (14 Mt), Dadhichua (10 Mt) and Rajmahal (10.5 Mt). Unfortunately, a large number of small-capacity surface mines (producing 0.1–0.3 Mt per annum) are spread over in old coalfields posing a higher threat to the environment if proper corrective/controlling measures are not taken. However, for these smaller mines, effective environmental protection measures could not be adopted due to limited resources and other various reasons resulting in formation of large overburden (OB) dumps and huge voids at mining sites left as orphan land. Virtually all surface mining methods produce dramatic change in landscape due to large Indian coal sector poised to grow at a very fast rate in the near future due to steep increase in coal demand for the major reason of providing power to all by 2012. Total indigenous coal production is expected to grow from the current level of around 407 Mt (2005–2006) to around 1,086 Mt by 2024 as per the draft Coal Vision document.

The share of opencast production has increased from 26% (20.77 Mt) in 1974–1975 to 84.95% (345.79 Mt) in 2005–2006, whereas total underground production has declined from 74% (58.22 Mt) to 15.05% (61.25 Mt) in the same period. In the years 2006–2007, coal production was 430.83 Mt (terminal year of XI plan), out of which opencast contributed to around 373 Mt (87%) with an estimated overburden removal of 600 million m^3. A long-term perspective of coal production and OB removal presented in the 'Coal Vision 2025' document of Ministry of Coal indicates a coal production 1,086 Mt of which 900 Mt will be from opencast operation. The corresponding OB removal figure is estimated at 2,700 Mm^3. In 2009–2010, coal production was 533 Mt as compared to 493 Mt during 2008–2009, registering a growth of 8%. Even in the past 10 years, production figures indicate that OC production continues to rise year after year. It is estimated that at the end of terminal year of the 11th Five-Year Plan (2011–2012), the coal demand would be about 713 Mt, whereas the indigenous availability would be about 630 Mt. Therefore, there is likely to be a gap of 83 Mt, which is required to be met through imports (MOC 2011). Table 1.3 shows the technology-wise coal production since 1951.