Water Science and Technology Library

Vijay P. Singh
Shalini Yadav
Ram Narayan Yadava *Editors*

Environmental Pollution

Select Proceedings of ICWEES-2016

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Water Science and Technology Library

Volume 77

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Preface

Fundamental to sustainable economic development, functioning of healthy ecosystems, reliable agricultural productivity, dependable power generation, maintenance of desirable environmental quality, continuing industrial growth, enjoyment of quality lifestyle, and renewal of land and air resources is water. With growing population, demands for water for agriculture and industry are skyrocketing. On the other hand, freshwater resources per capita are decreasing. There is therefore a need for effective water resources management strategies. These strategies must also consider the nexus between water, energy, environment, food, and society. With these considerations in mind, the International Conference on Water, Environment, Energy and Society (WEES-2016) was organized at AISECT University in Bhopal, MP, India, during March 15–18, 2016. The conference was fifth in the series and had several objectives.

The first objective was to provide a forum to not only engineers, scientists, and researchers, but also practitioners, planners, managers, administrators, and policy-makers from around the world for discussion of problems pertaining to water, environment, and energy that are vital for the sustenance and development of society.

Second, the Government of India has embarked upon two large projects: one on cleaning of River Ganga and the other on cleaning River Yamuna. Further, it is allocating large funds for irrigation projects with the aim to bring sufficient good-quality water to all farmers. These are huge ambitious projects and require consideration of all aspects of water, environment, and energy as well as society, including economics, culture, religion, politics, administration, law, and so on.

Third, when water resources projects are developed, it is important to ensure that these projects achieve their intended objectives without causing deleterious environmental consequences, such as water logging, salinization, loss of wetlands, sedimentation of reservoirs, loss of biodiversity, etc.

Fourth, the combination of rising demand for water and increasing concern for environmental quality compels that water resources projects are planned, designed, executed and managed, keeping changing conditions in mind, especially climate change and social and economic changes.

Fifth, water resources projects are investment intensive and it is therefore important to take a stock of how the built projects have fared and the lessons that can be learnt so that future projects are even better. This requires an open and frank discussion among all sectors and stakeholders.

Sixth, we wanted to reinforce that water, environment, energy, and society constitute a continuum and water is central to this continuum. Water resources projects are therefore inherently interdisciplinary and must be so dealt with.

Seventh, a conference like this offers an opportunity to renew old friendships and make new ones, exchange ideas and experiences, develop collaborations, and enrich ourselves both socially and intellectually. We have much to learn from each other.

Now the question may be: Why India and why Bhopal? India has had a long tradition of excellence spanning several millennia in the construction of water resources projects. Because of her vast size, high climatic variability encompassing six seasons, extreme landscape variability from flat plains to the highest mountains in the world, and large river systems, India offers a rich natural laboratory for water resources investigations.

India is a vast country, full of contrasts. She is diverse yet harmonious, mysterious yet charming, old yet beautiful, ancient yet modern. Nowhere we can find mountains as high as the snow-capped Himalayas in the north, the confluence of three seas and large temples in the south, long and fine sand beaches in the east as well as architectural gems in the west. The entire country is dotted with unsurpassable monuments, temples, mosques, palaces, and forts and fortresses that offer a glimpse of India's past and present.

Bhopal is located in almost the center of India and is situated between Narmada River and Betwa River. It is a capital of Madhya Pradesh and has a rich, several century-long history. It is a fascinating amalgam of scenic beauty, old historic city, and modern urban planning. All things considered, the venue of the conference could not have been better.

We received an overwhelming response to our call for papers. The number of abstracts received exceeded 450. Each abstract was reviewed and about two thirds of them, deemed appropriate to the theme of the conference, were selected. This led to the submission of about 300 full-length papers. The subject matter of the papers was divided into more than 40 topics, encompassing virtually all major aspects of water and environment as well energy. Each topic comprised a number of contributed papers and in some cases state-of-the-art papers. These papers provided a natural blend to reflect a coherent body of knowledge on that topic.

The papers contained in this volume, "Environmental Pollution," represent one part of the conference proceedings. The other parts are embodied in six companion volumes entitled, "Hydrologic Modelling," "Groundwater," "Energy and Environment," "Water Quality Management," "Climate Change Impacts," and "Water Resources Management." Arrangement of contributions in these seven books was a natural consequence of the diversity of papers presented at the conference and the topics covered. These books can be treated almost independently, although significant interconnectedness exists among them.

This volume contains five parts. Part I containing seven papers deals with some aspects of environmental pollution. Part II discusses pollution indicators. Part III focuses on generation of pollution as described in nine papers. Water quality assessment is described in Part IV containing 11 papers. Part V contains four papers that present water quality modelling.

The book will be of interest to researchers and practitioners in the field of water resources, hydrology, environmental resources, agricultural engineering, watershed management, earth sciences, as well as those engaged in natural resources planning and management. Graduate students and those wishing to conduct further research in water and environment and their development and management may find the book to be of value.

WEES-16 attracted a large number of nationally and internationally well-known people who have long been at the forefront of environmental and water resources education, research, teaching, planning, development, management, and practice. It is hoped that long and productive personal associations and friendships will be developed as a result of this conference.

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We express our sincere gratitude to Shri Santosh Choubey, Chancellor, and Dr. V.K. Verma, Vice Chancellor, Board of Governing Body, and Board of Management of the AISECT University, Bhopal, India, for providing their continuous guidance and full organizational support in successfully organizing this international conference on Water, Environment, Energy and Society on the AISECT University campus in Bhopal, India.

We are also grateful to the Department of Biological and Agricultural Engineering, and Zachry Department of Civil Engineering, Texas A&M University, College Station, Texas, U.S.A., and International Centre of Excellence in Water Management (ICE WaRM), Australia, for their institutional cooperation and support in organizing the ICWEES-2016.

We wish to take this opportunity to express our sincere appreciation to all the members of the Local Organization Committee for helping with transportation, lodging, food, and a whole host of other logistics. We must express our appreciation to the Members of Advisory Committee, Members of the National and International Technical Committees for sharing their pearls of wisdom with us during the course of the Conference.

Numerous other people contributed to the conference in one way or another, and lack of space does not allow us to list all of them here. We are also immensely grateful to all the invited Keynote Speakers, and Directors/Heads of Institutions for supporting and permitting research scholars, scientists and faculty members from their organizations for delivering keynote lectures and participating in the conference, submitting and presenting technical papers. The success of the conference is the direct result of their collective efforts. The session chairmen and co-chairmen administered the sessions in a positive, constructive and professional manner. We owe our deep gratitude to all of these individuals and their organizations.

We are thankful to Shri Amitabh Saxena, Pro-Vice Chancellor, Dr. Vijay Singh, Registrar, and Dr. Basant Singh, School of Engineering and Technology, AISECT University, who provided expertise that greatly helped with the conference organization. We are also thankful to all the Heads of other Schools, Faculty Members

and Staff of the AISECT University for the highly appreciable assistance in different organizing committees of the conference. We also express our sincere thanks to all the reviewers at national and international levels who reviewed and moderated the papers submitted to the conference. Their constructive evaluation and suggestions improved the manuscripts significantly.

Sponsors and Co-sponsors

The International Conference on Water, Environment, Energy and Society was Jointly organized by the AISECT University, Bhopal (MP), India and Texas A&M University, Texas, USA in association with ICE WaRM, Adelaide, Australia. It was partially supported by the International Atomic Energy Agency (IAEA), Vienna, Austria; AISECT University, Bhopal; M.P. Council of Science and Technology (MPCOST); Environmental Planning and Coordination Organization (EPCO), Government of Madhya Pradesh; National Bank for Agriculture and Rural Development (NABARD), Mumbai; Maulana Azad National Institute of Technology (MANIT), Bhopal; and National Thermal Power Corporation (NTPC), Noida, India. We are grateful to all these sponsors for their cooperation and providing partial financial support that led to the grand success to the ICWEES-2016.

Contents

About the Editors

Prof. Vijay P. Singh is **University Distinguished Professor, Regents Professor,** and the inaugural holder of the **Caroline and William N. Lehrer Distinguished Chair in Water Engineering** in the Department of Biological and Agricultural Engineering and Zachry Department of Civil Engineering at Texas A&M University. He received his B.S., M.S., Ph.D., and D.Sc. degrees in engineering. He is a registered professional engineer, a registered professional hydrologist, and an Honorary Diplomate of American Academy of Water Resources Engineers.

Professor Singh has extensively published the results of an extraordinary range of his scientific pursuits. He has published more than **900** journal articles; **25** textbooks; **60** edited reference books, including the massive **Encyclopedia of Snow, Ice and Glaciers and Handbook of Applied Hydrology**; 104 book chapters; 314 conference papers; and **72** technical reports in the areas of hydrology, ground water, hydraulics, irrigation engineering, environmental engineering, and water resources.

For his scientific contributions to the development and management of water resources and promoting the cause of their conservation and sustainable use, he has received more than 90 national and international awards and numerous honors, including the **Arid Lands Hydraulic Engineering Award, Ven Te Chow Award, Richard R. Torrens Award**, **Norman Medal**, and **EWRI Lifetime Achievement Award**, all given by American Society of Civil Engineers; **Ray K. Linsley Award and Founder's Award**, given by American Institute of Hydrology; **Crystal Drop Award**, given by International Water Resources Association; and **Outstanding Distinguished Scientist Award** given by Sigma Xi, among others. He has received **three honorary doctorates**. He is a **Distinguished Member** of **ASCE**, and a fellow of **EWRI**, **AWRA**, **IWRS**, **ISAE**, **IASWC**, and **IE** and holds membership in 16 additional professional associations. He is a fellow/member of 10 international science/engineering academies. He has served as **President** and **Senior Vice President** of the **American Institute of Hydrology** (AIH). Currently he is editor-in-chief of two book series and three journals and serves on editorial boards of 20 other journals.

Professor Singh has visited and delivered invited lectures in all most all parts of the world but just a sample: Switzerland, the Czech Republic, Hungary, Austria, India, Italy, France, England, China, Singapore, Brazil, and Australia.

Prof. Shalini Yadav is Professor and Head of the Department of Civil Engineering, AISECT University, Bhopal, India. Her research interests include solid and hazardous waste management, construction management, environmental quality and water resources. She has executed a variety of research projects/ consultancy in Environmental and Water Science and Technology and has got rich experience in Planning, formulating, organizing, executing and management of R&D programs, seminars, and conferences at national and international levels. She has got to her credit guiding an appreciable number of M.Tech. and Ph.D. students. She has published more than 10 journal articles and 30 technical reports. Dr. Shalini has also visited and delivered invited lectures at different institutes/universities in India and abroad, such as Australia, South Korea, and Kenya.

Professor Shalini Yadav graduated with a B.Sc. in Science from the Bhopal University. She earned her M.Sc. in Applied Chemistry with a specialization in Environmental Science from Bhopal University and M.Tech. in Civil Engineering with a specialization in Environmental Engineering from Malaviya National Institute of Technology, Jaipur, India in 2000. Then she pursued the degree of Ph. D. in Civil Engineering from Rajiv Gandhi Technical University, Bhopal, India in 2011. Also, she is a recipient of national fellowships and awards. She is a reviewer for many international journals. She has been recognized for one and half decades of leadership in research, teaching, and service to the Environmental Engineering Profession.

Dr. Ram Narayan Yadava holds the position of Vice Chancellor of the AISECT University, Hazaribag, Jharkhand. His research interests include solid mechanics, environmental quality and water resources, hydrologic modeling, environmental sciences and R&D planning and management. Yadava has executed a variety of research/consultancy projects in the area of water resources planning and management, environment, remote sensing, mathematical modeling, technology forecasting, etc.

He has got adequate experience in establishing institutes/organizations, planning, formulating, organizing, executing and management of R&D programs, seminars, symposia, conferences at national and international level. He has got to his credit guiding a number of M.Tech. and Ph.D. students in the area of mathematical sciences and Earth sciences. Dr. Yadava has visited and delivered invited lectures at different institutes/universities in India and abroad, such as USA, Canada, United Kingdom, Thailand, Germany, South Korea, Malaysia, Singapore, South Africa, Costa Rica, and Australia.

He earned an M.Sc. in Mathematics with a specialization in Special Functions and Relativity from Banaras Hindu University, India in 1970 and a Ph.D. in Mathematics with specialization in Fracture Mechanics from Indian Institute of Technology, Bombay, India, in 1975. Also, he is a recipient of Raman Research Fellowship and other awards. Dr. Yadava has been recognized for three and half

decades of leadership in research and service to the hydrologic and water resources profession. Dr. Yadava's contribution to the state of the art has been significant in many different specialty areas, including water resources management, environmental sciences, irrigation science, soil and water conservation engineering, and mathematical modeling. He has published more than 90 journal articles; 4 textbooks; 7 edited reference books.

Part I
Environmental Pollution

Socioeconomic Environment Assessment for Sustainable Development

Atul Kumar Rahul, Shaktibala, Bhartesh and Renu Powels

Abstract Sand mining is proposed at Alappad, Panmana, and Ayanivelikulangara of Kollam District within an area of 180 ha because of which nearly 550 families are being exposed to the impact of this mining. Families suffer from various problems associated with the mining activity, which includes environmental, social, and economical health. In addition, they have to be rehabilitated to other acceptable areas. The Resettlement & Rehabilitation (R&R) plans are an integral part of this EIA (Environmental Impact Assessment) study. Hence, this issue needs to be carefully studied and solved in an amicable manner. The objective of the present study is to ascertain the socioeconomic and other impacts on the people and on the area of operation and preparation of R&R plan for the project-affected families in the 180 ha mine lease area in line with Indian Rare Earth's (IRE's) R&R plans. We need to identify reasons of various social–political driving forces causing complaints and obstruction of existing in proposed mining and work out mechanisms for consultation with all stakeholders and influential forces in order to address issues related to mining.

Keywords EIA (Environmental impact assessment) · R&R (Research & development) and IRE · Social-economical · Mining activities · Sand mining Kollam district

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Introduction

Kerala is known for its 570-km-long coastline as one of world's most potential fishing grounds with unique biodiversity and as the abundant source of some of the rarest minerals in the globe, especially its southern coast. It is one of the ten 'Paradises Found' by the National Geographic Traveler, for its diverse geography and overwhelming greenery, in which, fall some of the sandy beaches and back-waters. It is situated on the southwest coast of Kerala between 9° 28′ and 8° 45′ latitude and 76° 28′ 77° 17′ north longitude. Kollam District is bounded on the north by Alappey and du, South by Trivandrum District and west by Lakshadweep Sea. South to Ernakulam is the commercial capital of the State. Kollam is connected to Ernakulum, by both road and rail. Indiscrete disposal of industrial waste leads to several geoenvironmental disasters on land and it has huge socioeconomic effects on the population residing in the impacted area, especially in terms of livelihood and health. Once this happens, it becomes a news item and comes into focus for geoenvironmental evaluation. Mining and processing of heavy and rare-earth minerals inevitably involves distress of the land environment, the magnitude and intensity of which depends on the type of chemicals, and processes used, the efforts taken in the management of waste as well as on environmental fragility of location.

Central Government laid strict mining rules and regulations (Atomic Energy Act, 1962), which prohibited individuals or private enterprises from undertaking such mining activity. The Policy Statement also allows selective entry of the private sector. Sandy beaches rank among the most intensively used coastal ecosystems by man (Schlacher et al. 2006). In many jurisdictions around the world, beach management has almost exclusively focused on maintaining and restoring sand budgets, with very little consideration for ecological dimensions (Nordstrom 2000; Wong 2003; Schlacher and Thompson 2007; Aarninkhof et al. 2010). A framework for integrated impact assessment of chemicals was proposed by Briggs (2008) with regard to integrated environmental health impact assessment, whereas Crane (2010) reported on approaches for converting environmental risk assessment outputs into socioeconomic impact assessment. The adoption of EIA procedure, in fact, with due differences, encompasses developed, developing, and transitional countries (Lee and George 2000). That means sustainable development should meet the needs of present generations while preserving the natural environment in its undisturbed state. Economic development must not compromise environmental integrity (Hilson and Murck 2000). Improper management of the industrial waste from the titanium dioxide (TiO_2) pigment producing industry is a cause for concern. The Census of Marine Life indicates that a number of marine biological resources have been depleted. Due to overfishing, stocks of species such as tunas, sharks, and sea turtles have declined sharply in the past decade, some even reduced by 90–95% (Ausubel et al. 2010; Hilson et al. 2011). People of the area live under the constant threat and fury of nature. Studies show that coastal erosion is prevalent in the coastal strip proposed for mining. As a study indicates 'towards south of Palakkad from Thrikkunnapuzha to Thottapally, a zone of 4.3 km is under moderate erosion'

(Seakale et al. 1997). Kerala has a history of environmental social movements, which has won victories many a time, environmental activists had been supporting the anti-beach sand mining movement scientifically and intellectually right from the initial stages onward. In the present, study the seriousness of the social, environmental, and health hazards that might result from the indiscriminate mining activity by a profit-oriented company. A statement validity analysis is also conducted in order to summarize the findings of the study. Shoreline changes of Kerala coast every year (Sreekala et al. 1998).

Objectives

- To assess the extent of socioeconomic impact and preparation of R&R for the project-affected families in line with IRE R&R in the areas of Alappad, Panmana, and Ayanivelikulangara of Kollam district.
- To ascertain the reasons and various social and political driving forces causing complaints and obstruction of existing and proposed mining.
- To work out mechanisms through consultation with all stakeholders and influential forces in order to address issues relating to mining.
- To make creative recommendations for getting the cooperation of local communities

Methodology

Description of the Study Area

The Kollam coast in *Kerala* is a blessed coastal belt with the best mineral sand deposit of the country. This belt commonly known as the *Chavara* deposit, after the main locality, is 22 km (14 mi) in length and about 8 km (5.0 mi) wide in the north and 6 km (3.7 mi) in the south. Around 60% of the Chavara barrier beach portion is composed of heavy minerals. *Indian Rare Earths Limited* (*IREL*) is a government-owned ISO 9002 Certified corporation in *India*. One of the four production plants of *IREL* is situated near *Chavara*, in the suburbs of Kollam city. The plant operates on a mining area containing as high as 40% heavy minerals and extending over a length of 23 km in the *Chavara* belt. Figure 1 shows the present annual production capacity of *Chavara* unit engaged in dry as well as wet (dredging) mining and mineral separation stands.

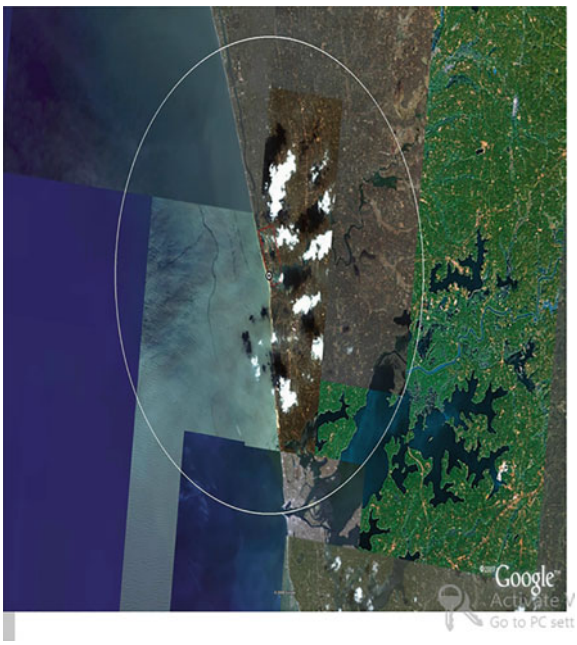

Fig. 1 Chavara unit mining and mineral site

Types of Data Collected

The following types of data were collected for the study:

- Documentary evidence mainly from records and published materials available in various related departments.
- Interview data from the families of the project-affected areas of Alappad, Panmana, and Ayanivelikulangara of Kollam district.
- Field notes by the researcher through observation and discussion with the knowledgeable persons, local leaders, and other resource persons.
- Focus group discussions with the stakeholders.

Tools of Data Collection

Data for the empirical study were collected mainly through interview schedules and focus group discussions. The schedule-elicited information on areas required for getting the information given in the objectives. Wherever possible the responses in the schedule were pre-coded to facilitate easy tabulation and analysis. Most of the questions had distinct options for answers and only a few qualitative parameters were elicited through open-ended questions.

Data Collection Analysis

Quantitative analysis rests judgmental conclusion based purely on data. Qualitative assumptions are about how the world works, what are suitable categories for data. Figure 2 describes what constitute good data, and the validity of scientific procedures to explain the descriptive and inferential statistics. For future projections, the role of qualitative assumptions is significant.

Personal Profile

The socioeconomic and demographic profiles of the respondents are given which covers detailed information on the various dimensions of the families in the project-affected areas of Alappad, Panmana, and Ayanivelikulangara of Kollam district. The personal information gives a benchmark data of the families in these areas, which will be useful to understand the general characteristics of the areas under study.

Fig. 2 Quantitive assumption of Chavara site

Age

Maturity is an index to understand the issues of the sand mining in an intelligent way. The age-wise classification of the occupants of the mining lease area is given in Table 1.

Sex

Male-to-female ratio in these three villages are given in Table 2. It is clear from the table that men are more exposed to the issues of the sand mining, as they are more in touch with many people in the areas (Fig. 3).

Table 1 Age analysis

Age group (years)	Frequency	Percentage
15–25	14	2.6
26–35	53	9.9
36–45	127	23.8
46–55	159	29.9
56–65	110	20.6
66–75	52	9.8
Above 75	18	3.4
Total	533	100

Table 2 Sex analysis

Sex	Frequency	Percentage
Male	393	73.7
Female	140	26.3
Total	533	100

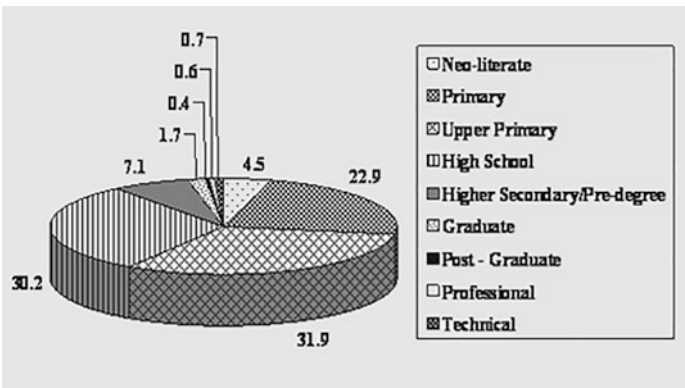

Fig. 3 Education analysis

Table 3 Matrital status analysis

Marital status	Frequency	Percentage
Unmarried	4	0.8
Married	473	88.7
Widow	49	9.2
Widower	1	0.2
Separated	6	1.1
Divorced	0	0
Total	533	100

Marital Status

Generally, married persons are more responsible in decision-making process concerning family and connected important affairs, as they understand the issues that affected the family and society in a broad and in-depth manner (Table 3).

Literacy

Literacy plays a key role in determining factors of decision-making process. Education contributes significantly to one's ability to change attitudes and modify behavior pattern. Highly educated persons are more flexible and susceptible to changes than less educated. This is mainly because education provides scope for broadmindedness and thinking capacity.

Occupation

The main occupation of the people in this area is fishing and other allied minor activities as they reside near the coastal areas of the sea. Table 4 clearly shows that the majority (34%) of them are engaged in fishing followed by other (22.7%) type of work like agriculture, commercial contracts or contract laborer of IRE, working outside the lease area, transport section, etc.

Assessment and Mitigation

Impact Assessment

The identified impacts due to mining and associated activities have been studied in relation to the following areas.

Table 4 Occupation analysis

Occupation	Frequency	Percentage
Unemployed	77	14.4
Employed in Govt/Pvt	35	6.6
Business	43	8.1
Farmer	5	0.9
Daily-waged	45	8.4
Student	2	0.4
Retired	24	4.5
Fishing	181	34.0
Others (specify)	121	22.7
Total	533	100

Topography and Land Use

Original topography of the beach sand mining extension area will change due to future mining operations. As the backfilling system is integrated into the mining process, the excavated land will be subsequently reclaimed and the ground surface of the reclaimed land will be brought back to the contours matching with surrounding topography. Excavation and backfilling will take place simultaneously so that the affected land can be made ready for further use without any appreciable loss of time. The ground elevation of the beach zone is at 2–4 MRL (Mean reduce level) which very gently rises to about 7–8 MRL toward the east to places which are relatively far away from backwaters. There will be some interim impact on topography and landform due to the destruction of original landform. Overall landscape shall improve in a phased manner when greenbelt development/plantation shall cover stretches subsequent to backfilling.

Drainage

The deposit is totally isolated from the landside by T.S canal. Seasonal/perennial streams join T.S canal at places instead of directly discharging into the sea. The canal is connected with the sea at two ends of the deposits. In certain parts, dredging will be carried out for the sand deposits underlying T.S canal. Floating of the dredge on the canal water or sand extraction at the canal bed for some period will not have any appreciable impact on drainage. Thus, beach sand mining will not have any impact on the network of backwater bodies including T.S canal.

Air Environment

Due to beach sand extraction, primary concentration, and backfilling, there will not be an appreciable rise in gaseous or particulate pollution level in ambient and work zone environment. Sand extraction process (dredging) is a wet primary process and backfilled mass is a moist in form which does not release dry dust in the mining area. Therefore, in the proposed area, pollution will be insignificant. At stack at MSP-monitored particulate matter, SO_2 and CO values, in general, are within permissible limits. Monitored SPM, SO_2, NO_x, and CO values at AAQ stations and at work zone are also well within respective permissible limits. The predictions of ground level concentration of pollution from the two stacks of 30 t/day FBD and 3 t/day FBD have been carried out with the help of air quality simulation model ISCST3, released by USEPA. At the present EIA study, GLCs (Ground level concentration) are predicted for 24 h for SO_2 and SPM. As a first step, actual monitored site meteorological data for winter season have been considered. The meteorological data were generated near plant site for a 1-month period on an hourly basis. Stabilities have been determined with the monitored data by using Turner method (insulation-based classification). Up to a height of 30 m, SO_2 and NO_x values will remain stable. The maximum height at Cochin has been taken as a reference for the present study. The locations are located with respect to 16 radial wind directions (N to NNW) and the radial distances have been fixed based on physical stack height, as the major stack height is 30 m, the receptors in each of the radial directions were fixed at 75, 150, 300, 600, 825, 900, 975, 1050, 1200, 1350, 1650, 2100, 2700, 3300, 4200, and 5000 m (Table 5).

Water Environment

Water from T.S Canal is utilized for supplying makeup water to dredge pond. Water is utilized for primary concentration at MRP. In CUP (and BWP) the pumped out water from T.S canal is circulated in gravity spirals. Freshwater drawn from bore wells is used for washing the CUP concentrate. At present 30 m^3/h of bore water is drawn from the bore wells. After expansion, 60 m^3/h of freshwater shall be required. No trace of saline water ingress has been noted because groundwater is drawn from a depth of 230 m only. Entire mining lease on a narrow strip of sandy

Table 5 Predicted GLC results

Description	Height (m)	Flow rate (nm^3/h)	Top dim (m)	SPM		SO_2		Temp (°c)	Location	
				mg/Nm^3	kg/h	mg/Nm^3	kg/h		*X*	*Y*
30 t/day FBD	30	12,400	0.5 dia.	150	1.8	363	4.5	80	0	0
3 t/day FBD	12	1250	0.3 * 0.3	150	0.1°	363	0.45	80	92	2

formation being surrounded by saline water on either side and freshwater has been very thin in the locality.

Impacts of Ecology

The existing and proposed core zones are the sea beach and inland areas close to the beach. The inland areas are covered by coconut groves and backwaters. In addition, coconut trees are present at the edges of the beach. In order to carry out mining, the coconut trees will have to be cut down. The herbs and shrubs growing on the beach and inland will also have to be removed. Due to mining the beach fauna (consisting of crabs, mole crabs, bivalves, and small gastropods) will perish. Similarly, the benthic flora and fauna in mining areas in the backwaters will also perish due to mining. However, the effects of mining will be temporary. The coconut trees which will be cut down will be replaced by new saplings after backfilling the mined out areas. Ipomoea pes-caprae and spinifexsps, which are the main plants growing on the sand, will be planted soon after backfilling to stabilize the sand. Seeds of other plants are airborne and will recolonise the backfilled areas within a few months. Larval forms of the beach fauna are present in the sea water and will start recolonising the backfilled areas within a few days after completion of mining. The air pollutants released by diesel powered machinery will be of very small quantity and will be easily diluted and will have no impacts on the ecosystems.

Impacts on Soil and Agriculture

The core zone soil is basically sandy soil. The mining will involve extraction of this sandy soil, and dumping back the tailings in the mined out areas. Since the heavy mineral extraction is a simple physical process, the sand which is dumped back will not differ chemically from the pre-mining sand except that the heavy minerals are no longer present. The physical changes which will occur will be minor and will have no lasting impacts. Mining will involve cutting down of coconut trees leading to loss in coconut production. But these trees will be placed by new saplings of improved variety which will actually improve the agricultural yield. The emission from MSP is also too less to have any impact on the soil or agriculture production in the study area.

Land Use

Excavated land will be subsequently reclaimed by backfilling with reject tailings. Backfilling is integrated into operating system. Land areas under the four blocks are